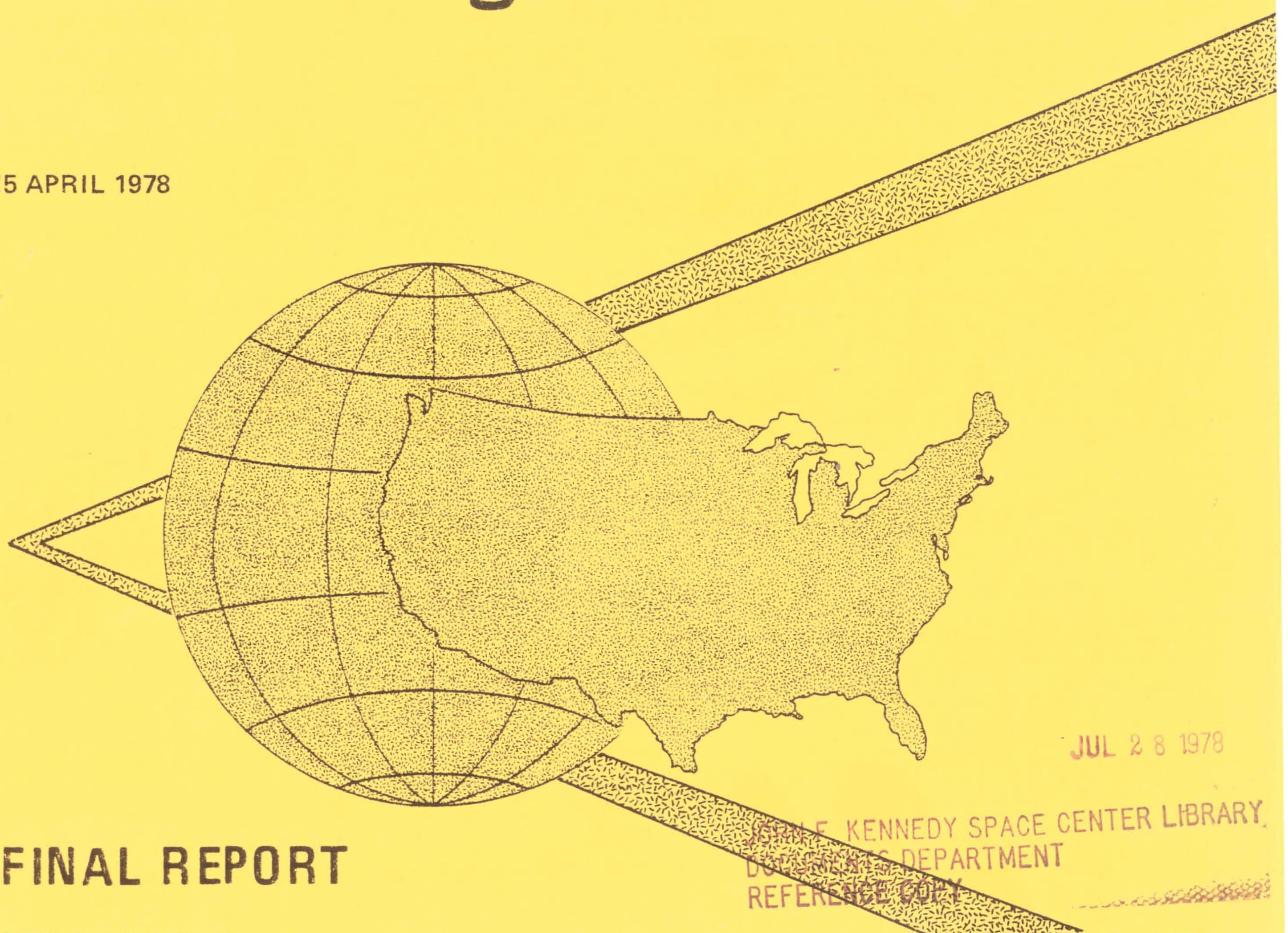
SAI-79-603-HU

Space Industrialization

Opportunities, Markets and Programs

15 APRIL 1978



FINAL REPORT

VOLUME 2

SPACE INDUSTRIALIZATION
SCIENCE APPLICATIONS, INC.

SAI-79-603-HU

SPACE INDUSTRIALIZATION STUDY

FINAL REPORT - VOL 2

SPACE INDUSTRIALIZATION

-OPPORTUNITIES, MARKETS AND PROGRAMS

April 15, 1978

PREPARED UNDER NASA CONTRACT NAS8-32197

SCIENCE APPLICATIONS, INC.
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FOREWORD

This $198,962.00 Space Industrialization Study was performed under NASA Contract NAS8-32197 for Marshall Space Flight Center from September 1976 through April 1978. The study was in two parts: Part 1 identified the future opportunities for space industrialization, quantified the potential benefits and developed and analyzed evolutionary program options required to take advantage of these opportunities; Part 2 defined the framework of international governmental, industrial, legal and economic constraints within which space industrialization (SI) must evolve. Step-by-step guidelines to implementation of programs to capitalize on the SI opportunities were formulated using information from Part 1 and Part 2. The study results are documented in four volumes:

1. SPACE INDUSTRIALIZATION - AN OVERVIEW
2. SPACE INDUSTRIALIZATION - OPPORTUNITIES, MARKETS AND PROGRAMS
3. SPACE INDUSTRIALIZATION - WORLD AND DOMESTIC IMPLICATIONS
4. APPENDICES

Part 1 of the study was managed by Dr. Ralph Sklarew and Part 2 by Mr. Gerald W. Driggers. Other key SAI participants were Mr. E. Battison, Mr. D. Davis, Mr. Sam Gibson, Mr. Mark Klan and Mr. Gordon Collyer. A large portion of the work reported here was accomplished by consultants who occupied roles as principal investigators. The key consultants were:

- Mr. Robert Salkeld - System Planning and Programmatics
- Mr. G. Harry Stine - Industrial Planning and Marketing
- Mr. Paul Siegler - Market Assessment and Economic Analysis
- Dr. J. Peter Vajk - World Dynamics and Futures Assessment

A subcontract to Southern Research Institute (SoRI) in Birmingham, Alabama, was managed by Mr. Driggers during Part 1 of the study, prior to his joining SAI. Key participants at SoRI were Mr. S. J. Causey and Mr. R. Monroe.

Certain individuals within, and with no affiliation to SAI, provided valuable informal data, comments and guidance during the study. The following are recognized for their special contributions.

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The study was performed under the technical direction of Mr. Rodney Bradford (Part 1) and Mr. Georg von Tiesenhausen (Part 2), Marshall Space Flight Center. Mr. J. von Puttkamer was the program manager for NASA Headquarters, Office of Space Transportation Systems.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

Section | Page

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

1. INTRODUCTION

This is Volume 2 in a four volume series that is the Final Report on the Space Industrialization Study conducted by Science Applications Incorporated (SAI) for the National Aeronautics and Space Administration (NASA) as discussed in the Preface.

The data presented in this volume were derived to provide initial ("first cut") answers to three questions.

- What is Space Industrialization (SI)?
- Why industrialize space?
- When can increases in space industry activities be anticipated?

The approach taken was one of hanging a variety of backdrops (Future Scenarios) against which SI could evolve; cataloging the various initiatives (Industrial Opportunities) that might constitute that evolution; qualitatively and quantitatively assessing and meshing the drivers and sustainers (Needs and Markets,) of industry activities; and deriving and analyzing the various hardware requirements vs. time (Space Industry Programs) as SI evolves.

The philosophy and methods of derivation of each of these elements is explained in this Volume. The implications of the results of this assessment to the United States and the World are provided in Volume 3.

As evidenced by the material in this document, strong emphasis was placed by SAI on derivation of quantitative information rather than purely subjective assessment. The purpose was to provide a data base for opening of horizons beyond the 1980s and identification of key near term stepping stones. Subjective assessment could never provide the insight into the Space Industrialization needs and promise of the 1990s and beyond that is contained here. There is subjectivity here in the basic assumptions which underpin the calculations, and debate is anticipated. The debate will not substantially change the scale or timing of things in the aggregate, and at the present stage of SI understanding and planning that is a substantial contribution. Data to intrigue, stimulate and provide a departure point are provided here.

2. THE TERRESTRIAL BACKGROUND FOR SPACE INDUSTRIALIZATION 1980 - 2010

During the next few decades, space technology (developed for purely scientific reasons, for political and prestige reasons, or to serve specific military needs) can be adapted, extended, and expanded to use the new environment and nearly limitless resources of outer space for the benefit of humanity in an economically profitable manner. Space Industrialization will then grow from a handful of commercially operated communications satellites into a highly diversified and expanding sector of the human socioeconomic system. In the first few decades, however, it will necessarily depend for its very existence on the conventional segments of the socioeconomic system to provide the technology, the original investment capital, and the markets for its goods and services. Thus it is essential to explore the nature and shape of the socioeconomic system as it may evolve in the next few decades before we can realistically examine just what may constitute Space Industrialization, and how, why, and when portions of the new space industries may arise.

This examination of the terrestrial background has been done in two parts. First, basic macroeconomic projections were made to examine the needs of the human socioeconomic system during the coming decades with respect to basic materials: energy fuels, minerals, and basic agricultural commodities. If the "limits to growth" hypothesis should prove to be correct, then perhaps Space Industrialization could provide some of the very basic needs of the industrialized societies of the world. Second, a variety of alternative futures were examined to examine how Space Industrialization would be shaped by events and developments in the rest of the system. The economic profitability, political viability, and social desirability of specific space industrial activities can only be defined in the context of general social, political, economic, and technological factors characterizing an alternative future. These alternative future scenarios also provide some basis for contingency planning and for identifying stepping stones in space technology which are most likely to be useful in any future space programs or activities.

The results of these two parts of our examination of the terrestrial background provided some of the basis for considering the market potentials of various possible space industries and much of the foundation for developing specific examples of possible programs of Space Industrialization during the next few decades. The necessity for continuous planning of intermediate and long range programs became quite clear from this work. Just as buggywhip manufacturers who did not foresee that self-propelled trucks would make the horse-drawn milkwagon obsolete were soon reduced to financial ruin, proponents of specific possibilities for industries in space may find themselves stranded by changes in the terrestrial background due to new economic, political, social, or technological factors unless they continually dedicate some effort to planning their programs in relation to current developments and trends on Earth.

2.1 ASSESSMENT OF TERRESTRIAL RESOURCES: SPACE INDUSTRIALIZATION AND THE 'LIMITS TO GROWTH' DEBATE

Why should we industrialize space? What human needs can Space Industrialization satisfy? Is Space Industrialization essential to the survival of the socioeconomic system?

In order to address these questions, it is necessary to examine the question of resource demand and supply here on Earth during the period of interest in this study, 1980 to 2010. Before presenting the projections we have made on the basis of available data and other studies, we will present a broad review of the basic issues at stake in the recent debates concerning the "limits to growth."

During the last two decades or so, many have argued that the resources of this finite planet are being depleted at an alarming rate and that the rate of increase of the planet's human population is dangerously high. An extreme form of this argument was presented in the bestselling report *The Limits to Growth,*[1] a popularly written book describing a study performed by the Systems Dynamics Group at M.I.T. under the encouragement of the Club of Rome. Using a highly aggregated computer model of the global socioeconomic system which incorporated a number of severe neo-Malthusian

(1)D. H. Meadows, D. L. Meadows, Jr. Randers, and W. W. Behrens III, *The Limits to Growth,* Universe Books, New York, 1972.

assumptions, the M.I.T. group projected a massive collapse of industrial civilization early in the twenty-first century. The primary cause of the collapse was the assumption that the costs of nonrenewable natural resources would soar rapidly because of exhaustion of economically recoverable ores within just a few more decades. Secondary factors contributing to the collapse included insufficient agricultural land to support a rapidly growing population and rising death rates due to ever increasing pollutant levels in the environment as industrial output expands around the world.

But the material and energy resources of the solar system are clearly many orders of magnitude greater than those of just Earth itself. If the costs of extracting essential minerals from progressively lower-grade ores were to rise dramatically, as the neo-Malthusian school has argued, then at some point the decreasing costs of access to space resulting from continued advances in technology would permit any given mineral to be obtained from space at a lower price so that the expanding demand of a growing industrialized terrestrial population could be met for many centuries to come. If the "limits to growth" arguments were correct, they would provide a strong and natural justification for a massive publicly-funded program to industrialize space at an early date.

The opposite pole in the debate, the "technological optimist" point of view, has argued that technological advances have always been stimulated by rising costs of extracting minerals from lower grade ores. As the costs per ton of product rise while the technology remains fixed, the economic incentive to develop a new, less costly technology increases until the breakthrough is made which permits the lower grade ores (or a substitute material) to be produced at costs comparable to, or frequently lower than, the older technology. This pattern has, in fact, held for the minerals industries in the United States throughout the period 1870 to 1957 (at least).(2)

The technological optimist has also argued that, although certain materials we presently use are indeed in short supply on Earth, technology can devise substitutes based on abundant materials. For sound environmental reasons, substitutes have been found for most of the applications of

(2) Harold J. Barnett and Chandler Morse, *Scarcity and Growth: The Economics of Natural Resource Availability*, Resources for the Future and Johns Hopkins University Press, Baltimore, 1963.

mercury in industry as little as twenty years ago. Goeller and Weinberg have argued this point most strongly,[(3)] suggesting that a technological, industrialized society with a population several times greater than the Earth's present population could enjoy a North American material standard of living indefinitely far into the future--at least a few million years--by technological substitutions of abundant materials for scarce materials. Society would then be based on wood, plastics, glass, cement, stone, iron, aluminum, and magnesium.

Of course, it is necessary to examine these issues on a case-by-case basis because of the possibility that certain critical materials may have unduly large leverage on the economy. Photographs and radiographs, for example, are of critical importance in some industries, even if their costs represent only a miniscule fraction of the total cash flow for such an industry. Should silver suddenly become unavailable or severely rationed, some industries might conceivably be disrupted, with far-ranging consequences ricocheting through the rest of the economy with effects far exceeding the value of all the silver consumed each year in the United States.

Notwithstanding the importance of such case-by-case consideration, it is still useful to consider the average cost of minerals used in the socioeconomic system as a whole. In 1968, the total sales price of minerals consumed in the United States (including fossil fuels) amounted to less than 5% of the Gross National Product. Worldwide, total minerals consumed were valued at less than 8% of Gross World Product. (The higher figure for the global average reflects the relatively higher prices of basic structural materials in Third World countries where the economic infrastructure is poorly developed.)

Neo-Malthusian arguments have held that the costs for extraction of minerals will soon begin to climb steeply. But if these costs presently amount to only 5 to 8% of GNP (or GWP), a five- or even ten-fold increase in costs of minerals could be tolerated without collapse of the socioeconomic system, provided only that the rise were sufficiently gradual (as, indeed, it is in the computer projections presented in *The Limits to Growth*). The three-fold increase in world petroleum prices, to be sure, produced economic

(3) H. E.Goeller and A. M. Weinberg, "The Age of Substitutability", Science 191, 683 (1976).

dislocations, but despite its extreme abruptness, even such a steep rise did not produce collapse of the global socioeconomic system. The highly aggregated computer model used by the M.I.T. group thus appears most unrealistic in its assumptions about non-renewable resources.

The more detailed assessment (case-by-case) of natural resource availability described above has been made for 18 minerals selected either because of their large volume (such as iron) or because of critical importance to important industrial processes or agriculture (such as phosphate). Fossil fuels were also examined in assessing likely sources of energy in the next three decades. But to assess supply and demand for such commodities, it was necessary to project population growth and trends in basic economic indicators such as GNP and personal incomes. In addition, we have examined the outlook for a number of basic agricultural commodities, albeit in the somewhat simplistic manner. The following sections summarize the results of these assessments.

2.1.1 Basic Demographic and Economic Data and Projections

2.1.1.1 Population Projections

The basic data from which world population figures were projected were obtained from the *United Nations Statistical Yearbook (1974)*. More recent data have been published since our projections were made, suggesting that the projections given here are too high. Several important points should be mentioned, however, which cast serious doubts on the validity of most population projections. In most of the less developed countries, not only is the economy poorly developed but so are the means for gathering vital statistics. All the U.N. data is based on reports provided by the governments for the individual nations involved; the U.N. has no facilities for critical review or evaluation of these data. In many cases, the data provided to the U.N. amount to little more than estimates by the central government.

During the 1950's and 1960's, national prestige was often identified with vigorous growth in all national statistics, including population, and population size and growth rates may in some cases have been exaggerated. More recently, many of the industrialized countries have exerted pressure on the less developed countries to reduce their birth rates. It is possible that some of the more recent statistical reports from some of these countries may have changed in response to this political pressure, with little relationship to actual statistics.

Finally, among those countries in which vital statistics are collected in a reliable manner, reported birth rates may differ in meaning because of differing statutory definitions. In the United States, for example, a premature infant which succumbs an hour after delivery is counted as a "live birth" and included in the birth-rate statistics. In some countries where high infant mortality is the rule, birth rates are computed on the basis of children who survive to age one, excluding all those who died weeks or months after delivery.

For the purposes of this study, populations were projected in four separate groups of nations:

(a) the industrially developed free-market nations (28);
(b) the industrially developed socialist nations (9);
(c) the emerging nations (35); and
(d) all the rest, including the "underdeveloped" nations.

For each group, a population-weighted average of the population increase rates for each country was calculated and applied to the 1970 or 1973 population levels to obtain projected levels. The socialist states showed a growth rate of 6.22 per 1000 population per year; the industrialized free-market states had a weighted growth rate of 8 per 1000; the emerging countries showed a growth rate of 24.24 per 1000; and the remaining underdeveloped nations had a combined rate of 26.42 per 1000.

The results of these projections are shown in Figure 2-1. The underdeveloped nations and the emerging nations would double their populations from 1975 to 2010. In contrast the industrial socialist countries (excluding China) will increase by only 32% and the free-market industrial countries by only 24% in the same 35 year span. According to these projections, the total world population will increase from about 4.05 billion in 1975 to about 7.5 billion in 2010.

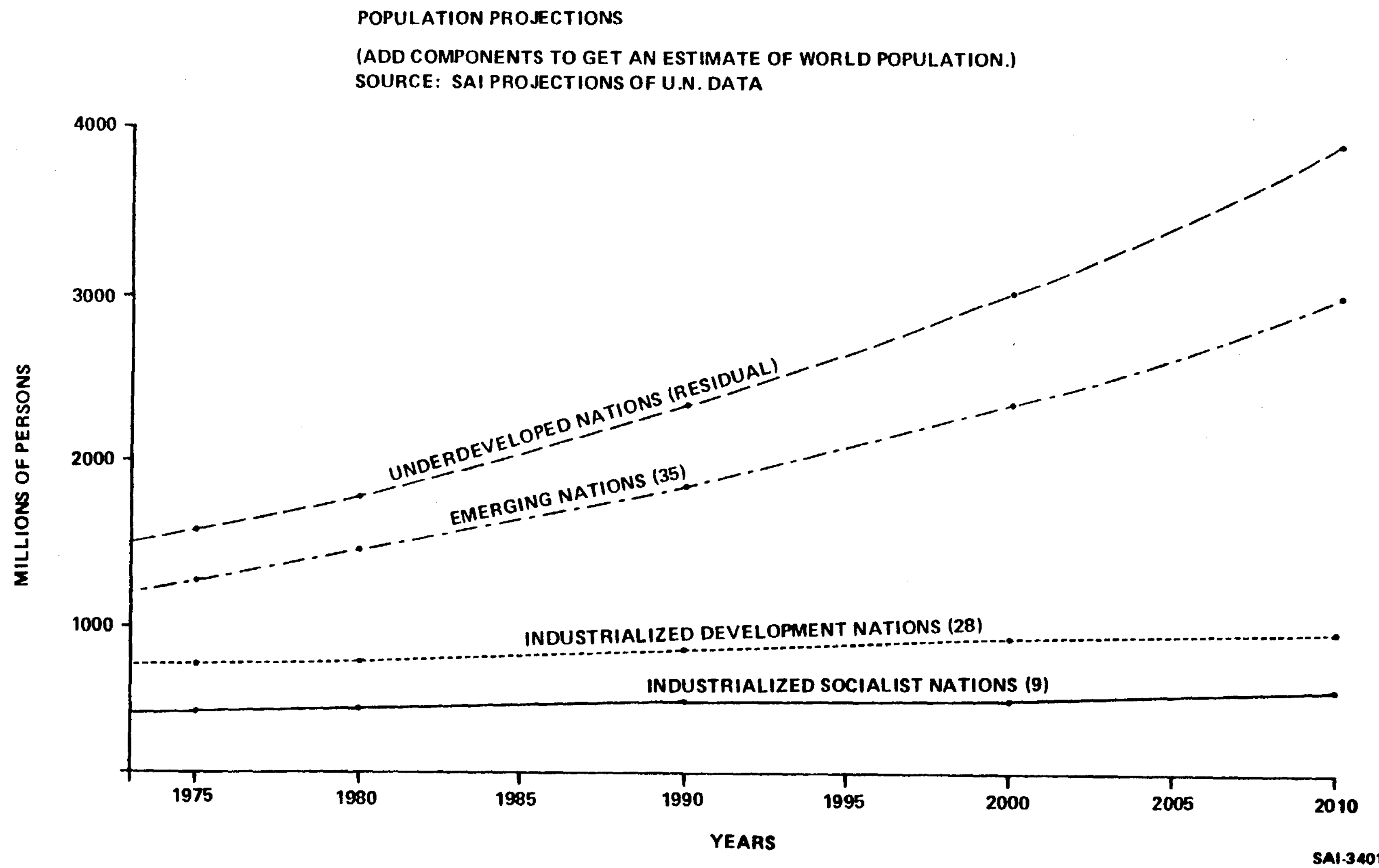

POPULATION PROJECTIONS
(ADD COMPONENTS TO GET AN ESTIMATE OF WORLD POPULATION.)
SOURCE: SAI PROJECTIONS OF U.N. DATA
MILLIONS OF PERSONS
4000
3000
2000
1000
UNDERDEVELOPED NATIONS (RESIDUAL)
EMERGING NATIONS (35)
INDUSTRIALIZED DEVELOPMENT NATIONS (28)
INDUSTRIALIZED SOCIALIST NATIONS (9)
1975
1980
1985
1990
1995
2000
2005
2010
YEARS
SAI-3401

Figure 2-1.

It must again be emphasized that more recent data suggest lower growth rates and that these projections have made no allowances for significant decreases in birth rates in the emerging and underdeveloped nations; these changes can be very rapid. In Sri Lanka (formerly Ceylon), birth rates fell by half in the space of two years due to a government program which provided one kilogram of rice per person per week, free, to every man, woman, and child, with a second kilogram made available at a price substantially below the normal market price. The reduced birth rate was the direct result of the rapid improvement in infant survival: parents felt less need to have many children in order to guarantee that at least one or two would survive to support their parents in their old age.

2.1.1.2 U.S. Population Projections

Population projections for the United States were adopted from the Bureau of Census projections presented in *Current Populations Report*. The Series II projection was used, which assumes that fertility will rise from the present value of less than 1800 lifetime births per 1000 women to normal replacement level of about 2100 per 1000 women by 1990 and remain at that level throughout the period. Little evidence, however, is available to suggest that fertility will rise much above the present levels. Figure 2-2 shows this projection and also shows the contribution of net immigration to population growth.

2.1.1.3 Gross National Product and Per Capita Income

The GNP and the per capita personal income (PCI) for the United States are shown in Figure2-3,based on data from the *U. S. Survey of Current Business* and *Statistical Abstract of the U.S.* To make time streams easily comparable, all dollars were translated into constant 1976 dollar values for both past levels and future estimates, using Department of Commerce data on the Implicit Price Deflator and the Consumer Price Index.

Figure 3 presents alternative maximum and minimum projections. One simple trend analysis for GNP would be a combination of the Bureau of Labor Statistics projection and compound growth at 4.3% per year. The United States GNP would then be about \$2.5 trillion in 1985; about \$3.6 trillion in 1995; and about \$6.4 trillion in 2010. A linear increase, however, would result in a GNP of only \$4.7 trillion in 2010.

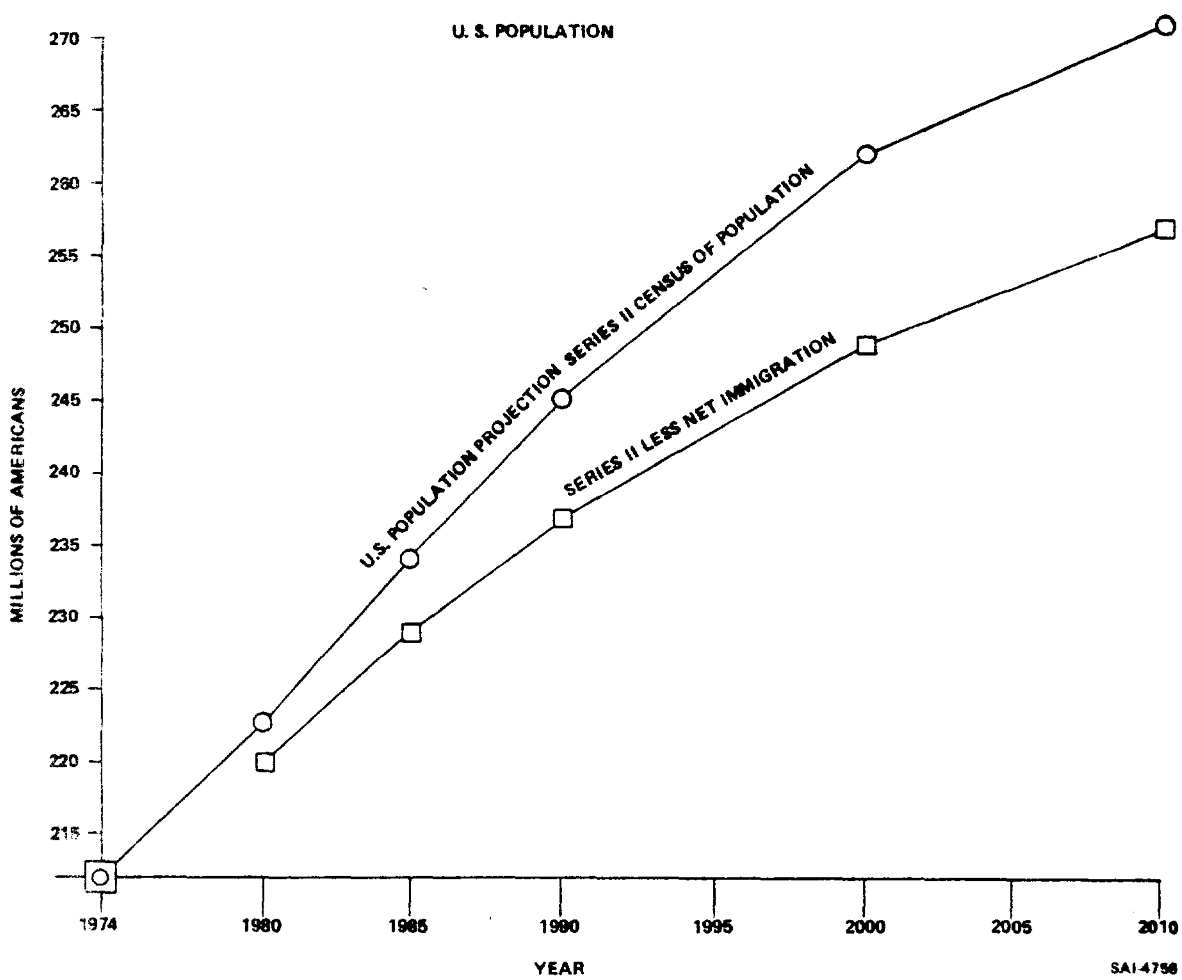
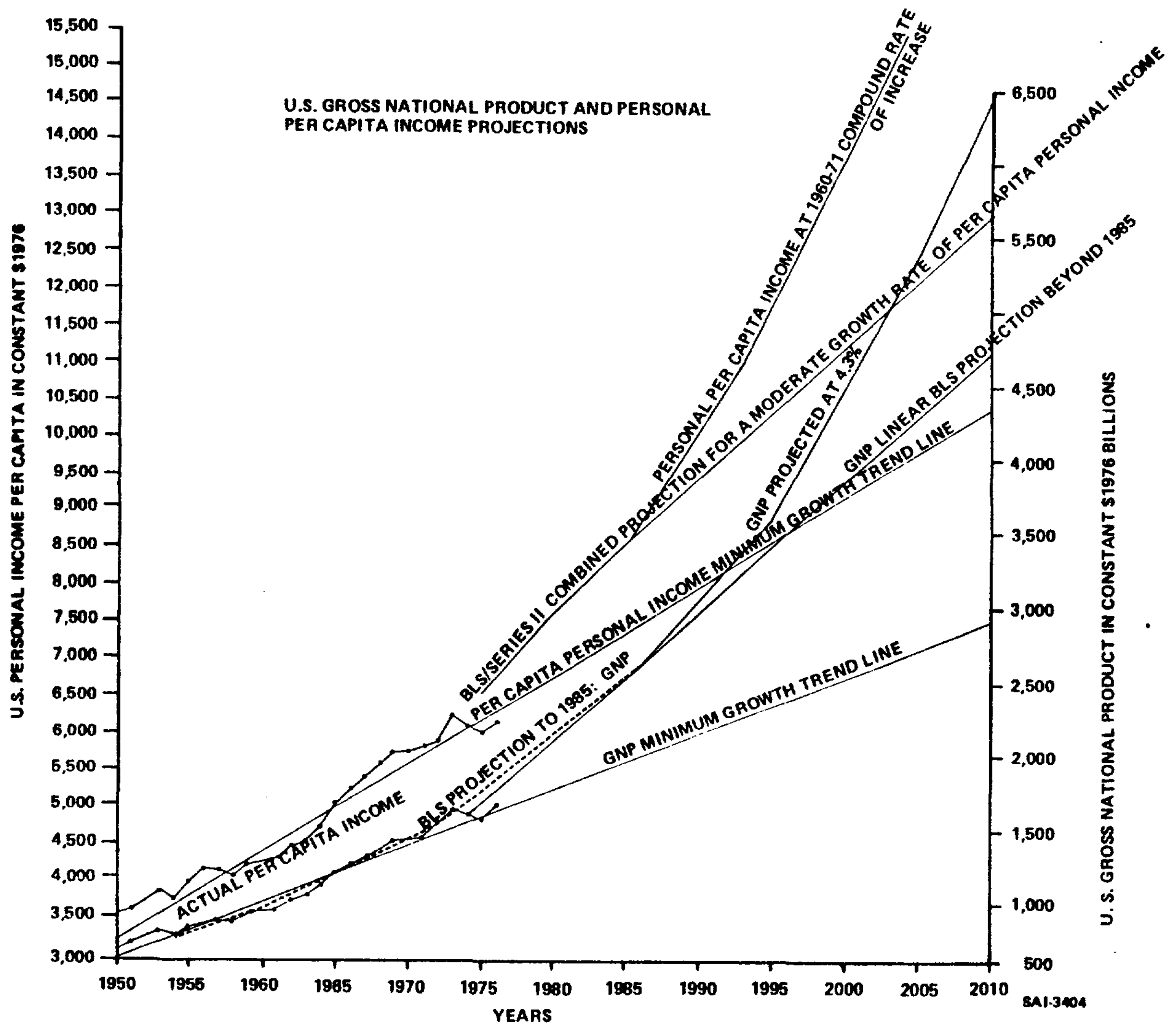


Figure 2-2. U.S. Population


U.S. GROSS NATIONAL PRODUCT AND PERSONAL PER CAPITA INCOME PROJECTIONS
U.S. PERSONAL INCOME PER CAPITA IN CONSTANT $1976
U. S. GROSS NATIONAL PRODUCT IN CONSTANT $1976 BILLIONS
YEARS
PERSONAL PER CAPITA INCOME AT 1960-71 COMPOUND RATE OF INCREASE
BLS/SERIES II COMBINED PROJECTION FOR A MODERATE GROWTH RATE OF PER CAPITA PERSONAL INCOME
GNP PROJECTED AT 4.3%
GNP LINEAR BLS PROJECTION BEYOND 1985
PER CAPITA PERSONAL INCOME MINIMUM GROWTH TREND LINE
BLS PROJECTION TO 1985: GNP
GNP MINIMUM GROWTH TREND LINE
ACTUAL PER CAPITA INCOME
15,500
15,000
14,500
14,000
13,500
13,000
12,500
12,000
11,500
11,000
10,500
10,000
9,500
9,000
8,500
8,000
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3,500
3,000
6,500
5,500
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
SAI-3404

Figure 2-3.

Several possible trends are shown for per capita personal income for the United States. An extension of the Bureau of Labor Statistics personal income trend divided by the Series II population projection to 1985 results in a logical but very moderate rate of growth. This trend projects a rise in per capita personal income from $6305 in 1975 to $7688 in 1980; $8543 in 1985; $11,600 in 2000; and perhaps $13,600 in 2010. Compounding per capita personal income at a growth rate equal to that in the period 1960 to 1971 results in a much higher projection. (In fact, using such compound growth results in higher-than-expected levels for both the United States and the developed nations.)

Figure 2-4 shows the high and low projections for U.S. per capita personal income (from Figure 2-3) together with projections for per capita disposable income for the industrially developed free market nations, the emerging nations, and the underdeveloped nations. Linear trends for the United States and for the industrialized countries appear more likely than compound growth because of Third World industrialization and because of the policies of the emerging nations to raise prices for raw material and fuel resources through the formation of cartels and by threats of embargoes to obtain greater economic strength.

Because of growing prosperity in the 1960's and 1970's, the trend in per capita disposable income for the 37 emerging nations appears as a rapidly increasing growth curve. The underdeveloped nations, however, show little indication of an upward trend in per capita income until after the turn of the century because their present economic base is so poor.

2.1.1.4 Composition of the U.S. GNP

Table 2-1 shows the projected composition of the U.S. GNP (based on the demand concept) according to major components in dollars, in percent distribution, and in annual (average) rate of change. (This projection is based on Table 2-5 of *The U.S. Economy in 1985*, Bureau of Labor Statistics Bulletin 1809.) Sectors of the economy generating prime economic activity in the years ahead are suggested by Table 2-2 which projects GNP distribution by 2-digit Standard Industrial Classification (SIC) codes. This table is based on Table 2-6 of Bulletin 1809, with the figures for 1975 added.

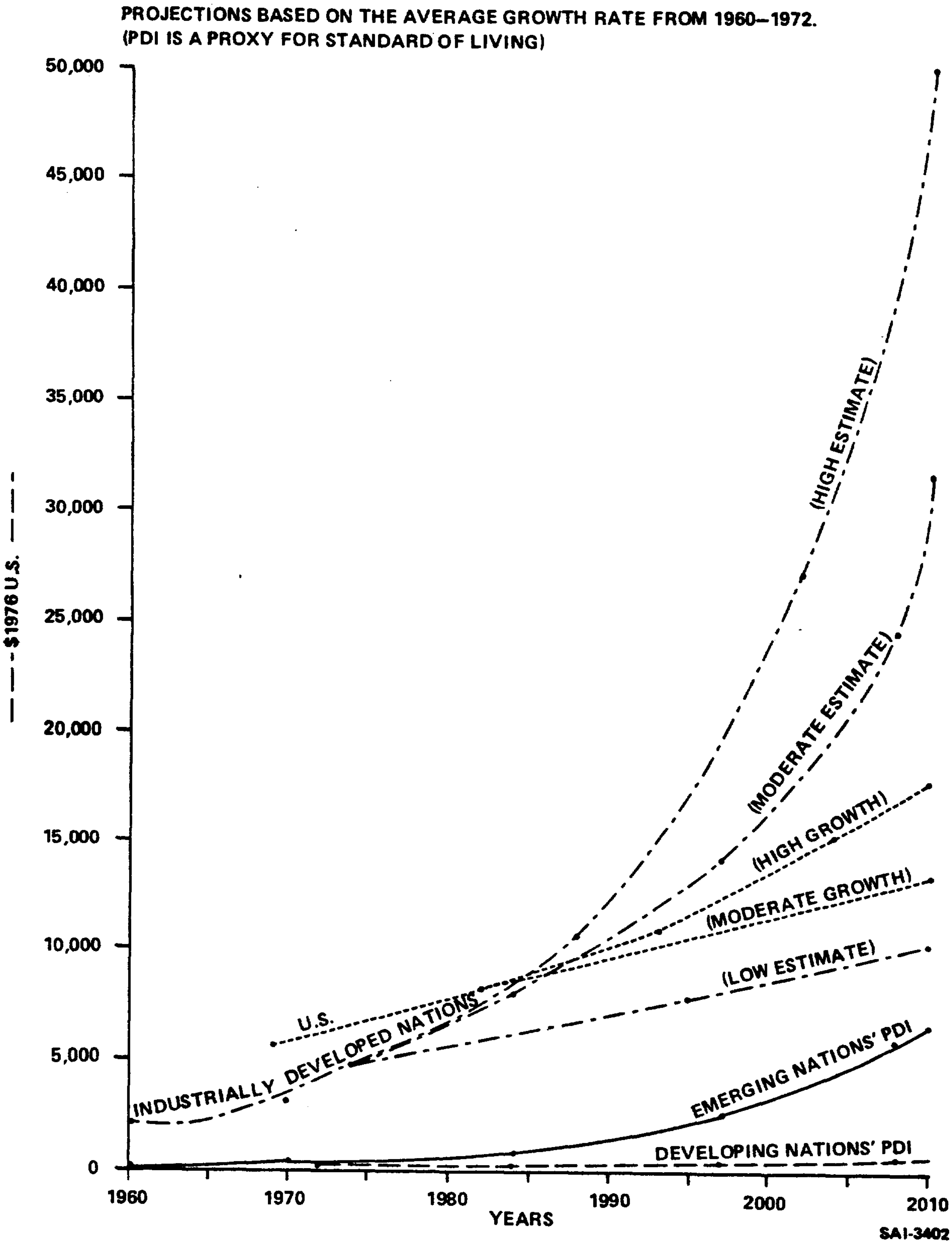


Figure 2-4. Various Nations' Average of Per Capita Disposable Income in $1976 (U.S.)

TABLE 2-1.

Gross product originating[1] in various sectors of the private economy, selected years 1955–72 and projected to 1980 and 1985

Sector	1955	1960	1968	1972	1980	1985
	Billions of 1972 dollars					
Total	555.2	620.6	904.3	1,019.7	1,500.6	1,767.6
Agriculture	29.2	30.6	32.6	34.4	35.3	37.1
Nonagriculture	526.0	590.0	871.7	985.3	1,465.3	1,730.5
Mining	13.7	14.0	17.4	18.2	20.2	20.4
Contract construction	47.1	49.3	54.0	56.0	71.5	77.9
Manufacturing	159.6	168.1	261.9	290.7	428.6	499.1
Durable	98.2	98.5	160.4	170.7	268.5	313.5
Nondurable	61.4	69.6	101.5	119.9	160.1	185.6
Transportation, communication and public utilities	46.6	53.7	84.5	102.3	164.7	202.0
Transportation	27.9	28.5	42.1	45.8	71.8	83.6
Communication	8.2	11.0	20.3	28.5	50.5	64.8
Public utilities	10.5	14.2	22.1	28.0	42.4	53.6
Trade	100.5	115.0	167.8	194.5	281.1	318.9
Wholesale	34.5	42.1	67.0	77.7	116.0	132.6
Retail	66.0	72.9	100.8	116.7	165.1	186.3
Finance, insurance, and real estate	82.1	99.9	148.4	163.8	250.5	303.5
Other services	72.0	88.0	123.8	135.9	223.6	269.9
Government enterprises	8.9	9.3	15.3	18.0	25.8	30.9
Rest of world plus statistical discrepancy	−4.5	−7.3	−1.4	6.0	−.7	7.8
	Percent distribution					
Total	100.0	100.0	100.0	100.0	100.0	100.0
Agriculture	5.3	4.9	3.6	3.4	2.4	2.1
Nonagriculture	94.7	95.1	96.4	96.6	97.6	97.9
Mining	2.5	2.3	1.9	1.8	1.3	1.2
Contract construction	8.5	7.9	6.0	5.5	4.8	4.4
Manufacturing	28.7	27.1	29.0	28.5	28.6	28.2
Durable	17.7	15.9	17.7	16.7	17.9	17.7
Nondurable	11.1	11.2	11.2	11.8	10.7	10.4
Transportation, communication, and public utilities	8.4	8.7	9.3	10.0	11.0	11.4
Transportation	5.0	4.6	4.7	4.5	4.8	4.7
Communication	1.5	1.8	2.2	2.8	3.4	3.7
Public utilities	1.9	2.3	2.4	2.7	2.8	3.0
Trade	18.1	18.5	18.6	19.1	18.7	18.0
Wholesale	6.2	6.8	7.4	7.6	7.7	7.5
Retail	11.9	11.7	11.1	11.4	11.0	10.5
Finance, insurance, and real estate	14.8	16.1	16.4	16.1	16.7	17.2
Other services	13.0	14.2	13.7	13.3	14.9	15.3
Government enterprises	1.6	1.5	1.7	1.8	1.7	1.7
Rest of world plus statistical discrepancy	−.8	−1.2	−.2	.6	.0	.4
	Average annual rate of change[2]					
	Actual		Projected			
	1955–68	1968–72	1968–85	1968–80	1972–80	1980–85
Total	3.8	3.0	4.0	4.3	4.9	3.3
Agriculture	.9	1.4	.8	.7	.3	1.0
Nonagriculture	4.0	3.1	4.1	4.4	5.1	3.4
Mining	1.9	1.1	.9	1.3	1.3	.2
Contract construction	1.1	.9	2.2	2.4	3.1	1.7
Manufacturing	3.9	2.6	3.9	4.2	5.0	3.1
Durable	3.8	1.6	4.0	4.4	5.8	3.1
Nondurable	3.9	4.3	3.6	3.9	3.7	2.9
Transportation, communication, and public utilities	4.7	4.9	5.3	5.7	6.1	4.2
Transportation	3.2	2.1	4.1	4.5	5.8	3.1
Communication	7.2	8.9	7.1	7.9	7.4	5.1
Public utilities	5.9	6.1	5.4	5.6	5.3	4.8
Trade	4.0	3.8	3.8	4.4	4.7	2.6
Wholesale	5.2	3.8	4.1	4.7	5.1	2.7
Retail	3.3	3.7	3.6	4.2	4.4	2.4
Finance, insurance, and real estate	4.7	2.5	4.3	4.5	5.5	3.9
Other services	4.3	2.4	4.7	5.1	6.4	3.8
Government enterprises	4.3	4.1	4.2	4.5	4.6	3.7

[1] The concept of gross product originating attributes to each industry only that part of income gross national product originating there.

[2] Compound interest between terminal years.

SOURCES: Historical data: U.S. Department of Commerce, Bureau of Economic Analysis; projections: Bureau of Labor Statistics.

TABLE 2-2.

Gross national product and major components by purchasers, selected years 1955–72 and projected to 1980 and 1985

[Billions of 1972 dollars]

Component	Actual				Projected	
	1955	1960	1968	1972	1980	1985
Gross national product (demand concept)	$645.9	$717.1	$1,038.6	$1,155.2	$1,657.9	$1,942.5
Personal consumption	379.9	438.2	625.1	726.5	1,032.0	1,214.2
Durable goods	48.8	50.5	91.5	117.4	165.4	192.3
Nondurable goods	178.8	202.2	266.9	299.9	408.7	469.0
Services	152.3	185.5	266.7	309.2	457.9	552.9
Gross private domestic investment	112.3	106.9	152.6	178.3	266.1	309.0
Fixed investment	103.8	102.5	144.2	172.3	250.9	294.3
Nonresidential	64.4	68.4	108.1	118.2	192.0	224.7
Structures	29.5	31.4	42.5	41.7	68.0	79.1
Producer durable equipment	34.9	37.0	65.6	76.5	123.9	145.5
Residential	39.4	34.1	36.1	54.0	58.9	69.7
Changed in business inventory	8.4	4.5	8.4	6.0	15.3	14.7
Net exports of goods and services	3.6	4.8	.3	−4.6	3.8	3.8
Exports	27.2	35.4	59.4	73.5	133.6	169.7
Imports	23.6	30.7	59.7	78.1	129.8	166.0
Government purchases of goods and services	150.2	167.2	261.2	255.0	356.1	415.5
Federal government	87.0	87.9	133.9	104.5	126.4	140.0
National defense	76.2	73.8	106.2	74.4	85.8	93.1
Other	10.8	14.1	27.7	30.1	40.7	46.9
State and local government	63.1	79.3	127.3	150.5	229.6	275.5
	Percent distribution					
Gross national product (demand concept)	100.0	100.0	100.0	100.0	100.0	100.0
Personal consumption	58.8	61.1	60.2	62.9	62.2	62.5
Durable goods	7.6	7.0	8.8	10.2	10.0	9.9
Nondurable goods	27.7	28.2	25.7	26.0	24.7	24.1
Services	23.6	25.9	25.7	26.8	27.6	28.5
Gross private domestic investment	17.4	14.9	14.7	15.4	16.1	15.9
Fixed investment	16.1	14.3	13.9	14.9	15.1	15.2
Nonresidential	10.0	9.5	10.4	10.2	11.6	11.6
Structures	4.6	4.4	4.1	3.6	4.1	4.1
Producer durable equipment	5.4	5.2	6.3	6.6	7.5	7.5
Residential	6.1	4.8	3.5	4.7	3.6	3.6
Changed in business inventory	1.3	.6	.8	.5	.9	.8
Net exports of goods and services	.6	.7	−0.0	−.4	.2	.2
Exports	4.2	4.9	5.7	6.4	8.1	8.7
Imports	3.7	4.3	5.7	6.8	7.8	8.5
Government purchases of goods and services	23.3	23.3	25.1	22.1	21.5	21.4
Federal government	13.5	12.3	12.9	9.0	7.6	7.2
National defense	11.8	10.3	10.2	6.4	5.2	4.8
Other	1.7	2.0	2.7	2.6	2.5	2.4
State and local government	9.8	11.1	12.3	13.0	13.8	14.2
	Average annual rate of change[1]					
	1955–68	1968–72	1968–80	1968–85	1972–80	1980–85
Gross national product (demand concept)	3.7	2.7	4.0	3.8	4.6	3.2
Personal consumption	3.9	3.8	4.3	4.0	4.5	3.3
Durable goods	5.0	6.4	5.1	4.5	4.4	3.1
Nondurable goods	3.1	3.0	3.6	3.4	3.9	2.8
Services	4.4	3.8	4.6	4.4	5.0	3.8
Gross private domestic investment	2.4	4.0	4.7	4.2	5.1	3.0
Fixed investment	2.6	4.6	4.7	4.3	4.8	3.3
Nonresidential	4.1	2.3	4.9	4.4	6.3	3.2
Structures	2.9	−.5	4.0	3.7	6.3	3.1
Producer durable equipment	5.0	3.9	5.5	4.8	6.2	3.3
Residential	−.7	10.6	4.2	3.9	1.1	3.4
Changed in business inventory	−0.0	−8.0	5.1	3.4	12.4	−.8
Net exports of goods and services	(2)	(2)	(2)	(2)	(2)	−.1
Exports	6.2	5.5	7.0	6.4	7.8	4.9
Imports	7.4	7.0	6.7	6.2	6.6	5.0
Government purchases of goods and services	4.4	−.6	2.6	2.8	4.3	3.1
Federal government	3.4	−6.0	−.5	.3	2.4	2.1
National defense	2.6	−8.5	−1.8	−.8	1.8	1.7
Other	7.5	2.1	3.2	3.1	3.8	2.9
State and local government	5.5	4.3	5.0	4.7	5.4	3.7

[1] Compound interest rate between terminal years.
[2] Not applicable.

SOURCE: Historical data: U.S. Department of Commerce, Bureau of Economic Analysis; projections: Bureau of Labor Statistics.

A general projection of personal consumption expenditures for the United States for the long term is presented in Figure 2-5, showing percentage distributions of disposable income. Relative costs for housing, transportation, and medical services are not projected to change substantially due to any foreseen social or economic perturbations. This is undoubtedly wrong; there simply are no dramatic changes predicted based on high probability events.

2.1.1.5 National Incomes

National Income (NY) is frequently used by economists to compare economic activity in different countries because it does not include some artificial factors included in GNP. National Income is equal to Gross National Product, less capital depreciation allowances, less indirect business taxes and liabilities, less transfer payments, less government enterprise surpluses, plus subsidies.

National Income data from the *United Nations Statistical Yearbook* were grouped together for three groups of nations:

(a) 22 developed market economies;

(b) 37 emerging nations, the more progressive of the developing nations, often called the Third World;

(c) Third World and Fourth World combined, the more passive of the less developed countries being sometimes called the Fourth World.

Since the latter two groups overlap, they show approximately the same growth rate. These data are plotted in Figure 2-6, using the 1960 to 1972 growth rates for each group. The GNP and NY for the United States (projected at an expected rate of about 4.3%) are also shown in this figure.

Not surprisingly, the growth rate for the 22 developed nations (including the United States) is greater than for the other two groups, resulting in a nearly eight-fold increase from 1972 to 2010, because of significant economic activity and markets in these 22 nations. After 1980, several of these (e.g., Sweden, Norway, Germany, Kuwait, and Japan) have greater growth rates than does the U.S. The estimated growth rate for the U.S., however, is intentionally more conservative than the 1960 to 1972 rate for the group as a whole. The developing nations appear to achieve significant increases in national income by the end of the century.

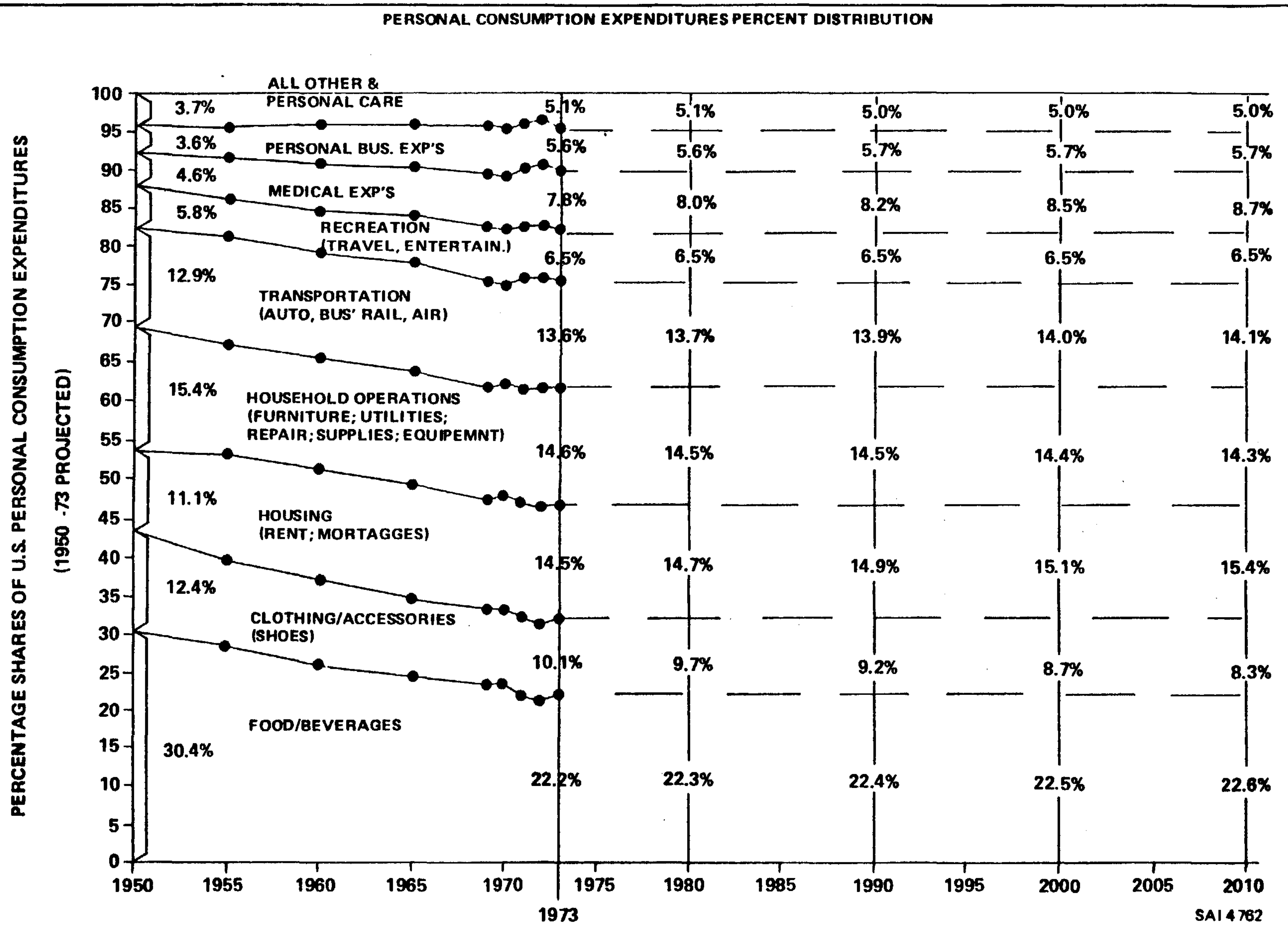

PERSONAL CONSUMPTION EXPENDITURES PERCENT DISTRIBUTION
PERCENTAGE SHARES OF U.S. PERSONAL CONSUMPTION EXPENDITURES
(1950 -73 PROJECTED)
ALL OTHER &
PERSONAL CARE
3.7%
PERSONAL BUS. EXP'S
3.6%
4.6%
MEDICAL EXP'S
5.8%
RECREATION
(TRAVEL, ENTERTAIN.)
12.9%
TRANSPORTATION
(AUTO, BUS' RAIL, AIR)
15.4%
HOUSEHOLD OPERATIONS
(FURNITURE; UTILITIES;
REPAIR; SUPPLIES; EQUIPEMNT)
11.1%
HOUSING
(RENT; MORTAGGES)
12.4%
CLOTHING/ACCESSORIES
(SHOES)
30.4%
FOOD/BEVERAGES
5.1% 5.1% 5.0% 5.0% 5.0%
5.6% 5.6% 5.7% 5.7% 5.7%
7.8% 8.0% 8.2% 8.5% 8.7%
6.5% 6.5% 6.5% 6.5% 6.5%
13.6% 13.7% 13.9% 14.0% 14.1%
14.6% 14.5% 14.5% 14.4% 14.3%
14.5% 14.7% 14.9% 15.1% 15.4%
10.1% 9.7% 9.2% 8.7% 8.3%
22.2% 22.3% 22.4% 22.5% 22.6%
100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
1973
SAI 4762
YEAR (PERCENTAGES CONTAIN ROUNDING ERRORS)

Figure 2-5.

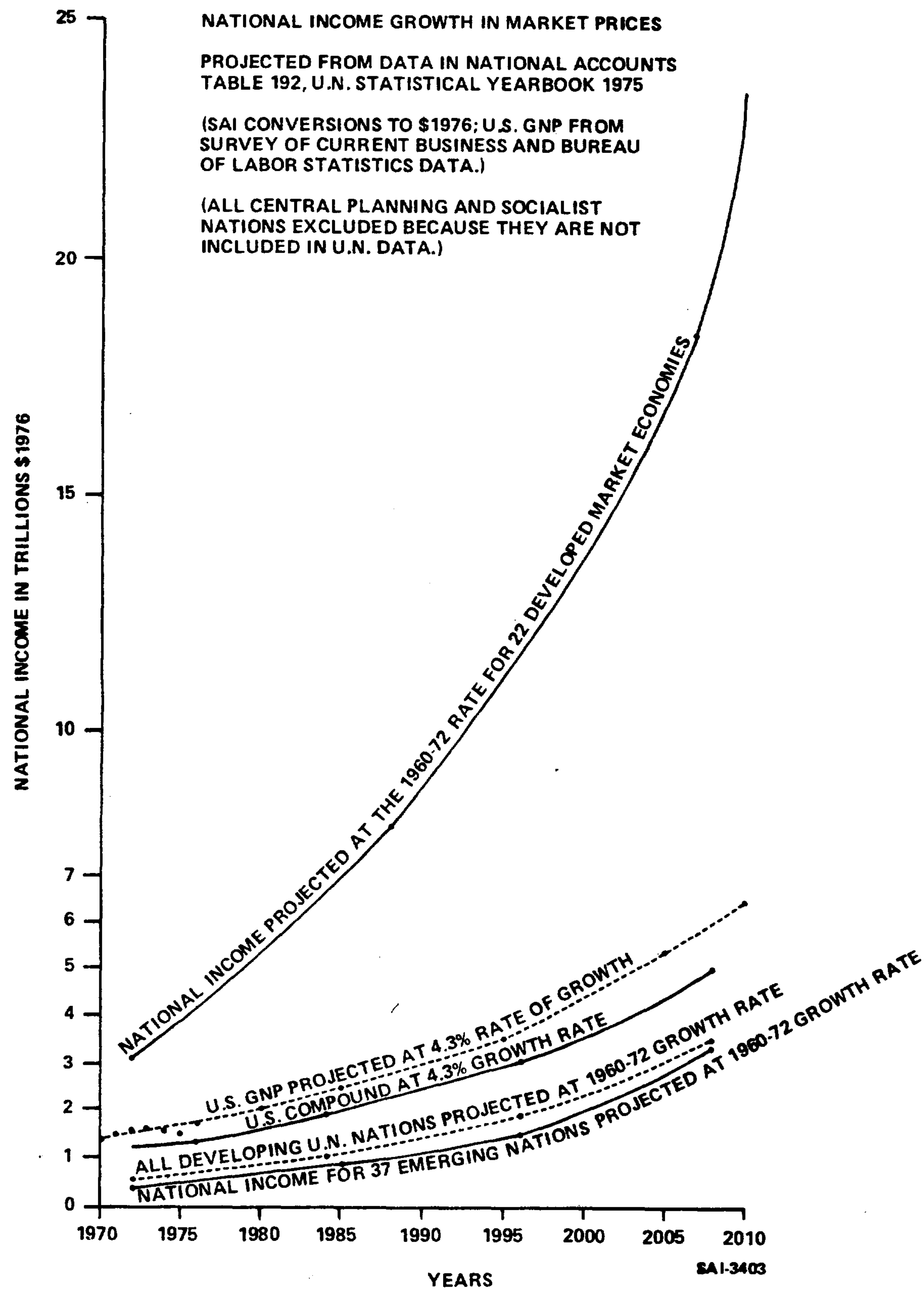

NATIONAL INCOME GROWTH IN MARKET PRICES
PROJECTED FROM DATA IN NATIONAL ACCOUNTS TABLE 192, U.N. STATISTICAL YEARBOOK 1975
(SAI CONVERSIONS TO $1976; U.S. GNP FROM SURVEY OF CURRENT BUSINESS AND BUREAU OF LABOR STATISTICS DATA.)
(ALL CENTRAL PLANNING AND SOCIALIST NATIONS EXCLUDED BECAUSE THEY ARE NOT INCLUDED IN U.N. DATA.)
NATIONAL INCOME IN TRILLIONS $1976
NATIONAL INCOME PROJECTED AT THE 1960-72 RATE FOR 22 DEVELOPED MARKET ECONOMIES
U.S. GNP PROJECTED AT 4.3% RATE OF GROWTH
U.S. COMPOUND AT 4.3% GROWTH RATE
ALL DEVELOPING U.N. NATIONS PROJECTED AT 1960-72 GROWTH RATE
NATIONAL INCOME FOR 37 EMERGING NATIONS PROJECTED AT 1960-72 GROWTH RATE
25
20
15
10
7
6
5
4
3
2
1
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
YEARS
SAI-3403

Figure 2-6.

2.1.2 Energy Supply and Demand

2.1.2.1 The United States

Figure 2-7 shows projected demand for energy in the United States based on the studies indicated. (Energy demand is cumulative in this figure.) The industrial sector demand and the derived demand by the electric utilities show sizeable increases by 2000, with more moderate growth in demand by the transportation sector. Residential, commercial, and non-energy demands remain relatively stable.

Figure 2-8 shows projected supply sources meeting the total demand shown in Figure 2-7. These projections by the Bureau of Mines are based on a number of simple assumptions, some of which no longer appear to be valid. The assumptions include:

(a) that strip mine regulations will not prevent surface mining of coal;

(b) that offshore oil leasing will be accelerated;

(c) that Western coal, oil shale, and geothermal lands will be leased for commercial development;

(d) that coal gasification will make a significant contribution by 1985;

(e) that oil prices will be decontrolled and natural gas prices will (at least) be relaxed; and

(f) that breeder reactor research will continue to be a major focus of national R&D efforts, with breeder (or fusion) reactors commercially viable between 1985 and 2000.

Under these assumptions, domestic petroleum does not decline until after the turn of the century. Natural gas remains remarkably stable because of future price increases and because of the development of the geopressurized natural gas deposits (methane dissolved in salt water trapped in porous rock formations under the Gulf Coast at greater-than-hydrostatic pressures). Coal expands its contribution until 2000, remaining relatively stable thereafter. Synthetic fuels provide little energy until 1990, but expand as a source after 2000. Because of limited resources, hydro/geothermal energy never expands very much. Most published forecasts of energy supply project

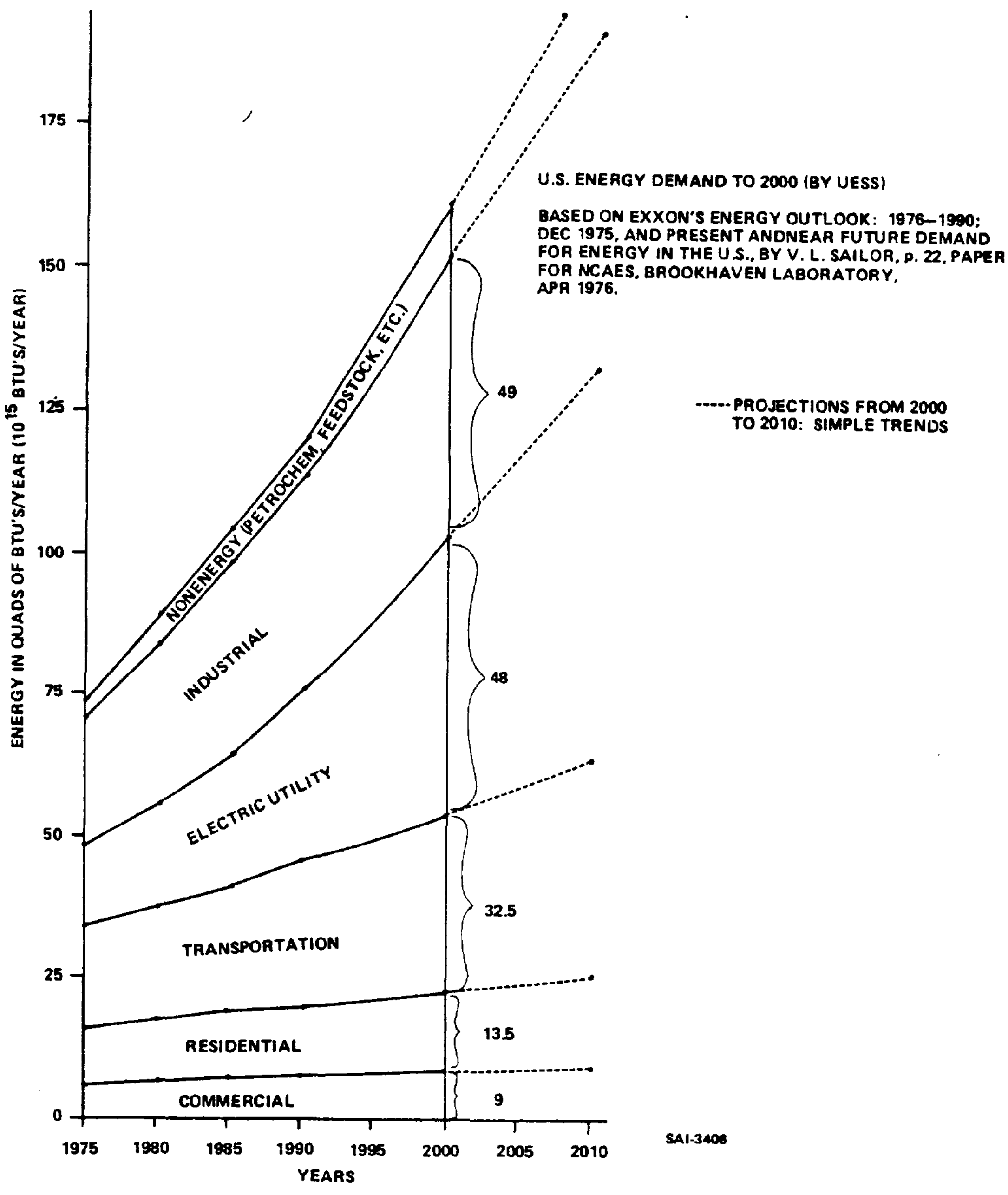
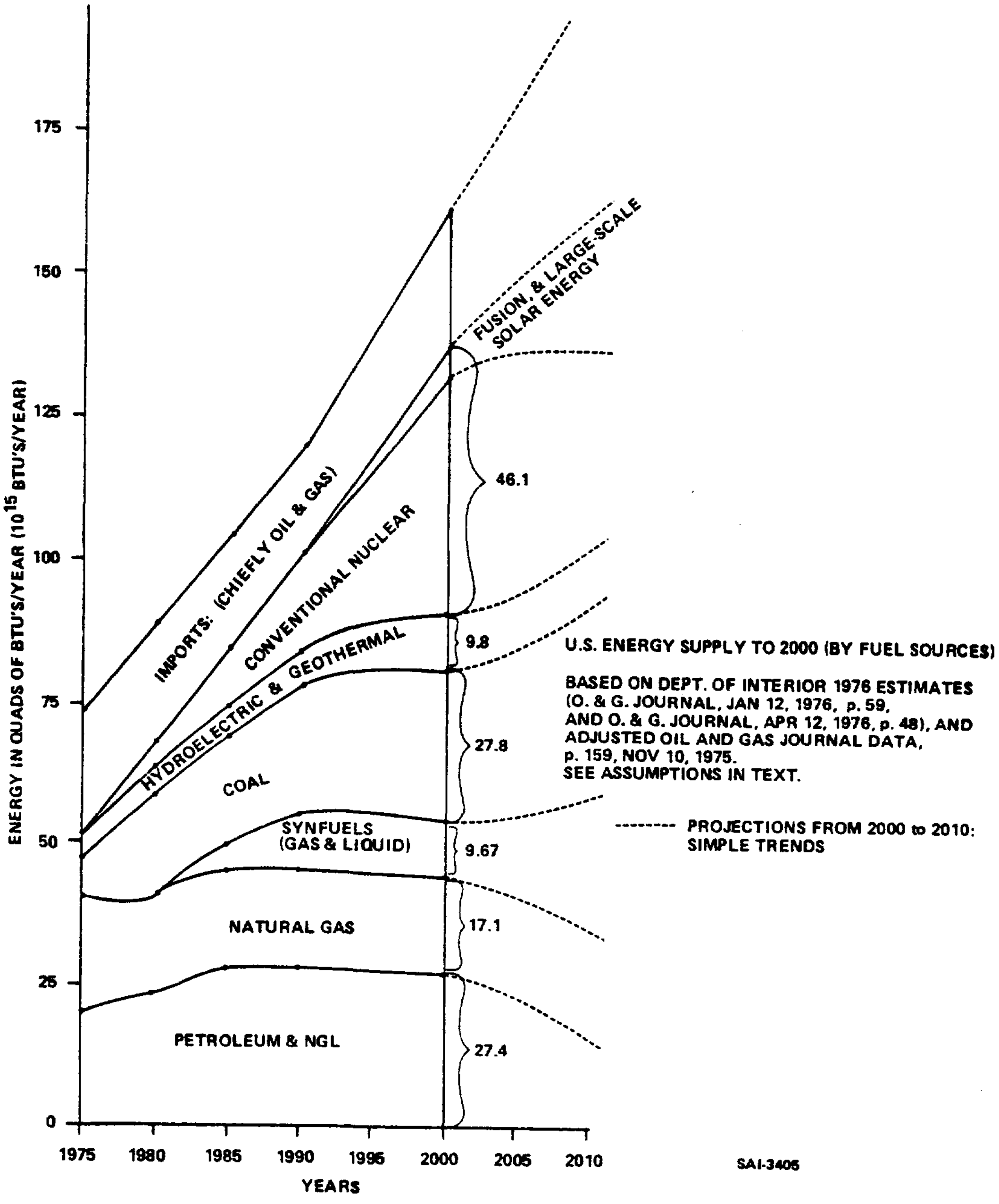

U.S. ENERGY DEMAND TO 2000 (BY UESS)
BASED ON EXXON'S ENERGY OUTLOOK: 1976–1990; DEC 1975, AND PRESENT ANDNEAR FUTURE DEMAND FOR ENERGY IN THE U.S., BY V. L. SAILOR, p. 22, PAPER FOR NCAES, BROOKHAVEN LABORATORY, APR 1976.
-----PROJECTIONS FROM 2000 TO 2010: SIMPLE TRENDS
ENERGY IN QUADS OF BTU'S/YEAR (10^{15} BTU'S/YEAR)
175
150
125
100
75
50
25
0
NONENERGY (PETROCHEM, FEEDSTOCK, ETC.)
INDUSTRIAL
ELECTRIC UTILITY
TRANSPORTATION
RESIDENTIAL
COMMERCIAL
49
48
32.5
13.5
9
1975
1980
1985
1990
1995
2000
2005
2010
YEARS
SAI-3406

Figure 2-7.



ENERGY IN QUADS OF BTU'S/YEAR (10^{15} BTU'S/YEAR)
175
150
125
100
75
50
25
0
1975
1980
1985
1990
1995
2000
2005
2010
YEARS
IMPORTS: (CHIEFLY OIL & GAS)
CONVENTIONAL NUCLEAR
HYDROELECTRIC & GEOTHERMAL
COAL
SYNFUELS (GAS & LIQUID)
NATURAL GAS
PETROLEUM & NGL
FUSION, & LARGE-SCALE SOLAR ENERGY
46.1
9.8
27.8
9.67
17.1
27.4
U.S. ENERGY SUPPLY TO 2000 (BY FUEL SOURCES)
BASED ON DEPT. OF INTERIOR 1976 ESTIMATES (O. & G. JOURNAL, JAN 12, 1976, p. 59, AND O. & G. JOURNAL, APR 12, 1976, p. 48), AND ADJUSTED OIL AND GAS JOURNAL DATA, p. 159, NOV 10, 1975.
SEE ASSUMPTIONS IN TEXT.
-------- PROJECTIONS FROM 2000 to 2010: SIMPLE TRENDS
SAI-3406

Figure 2-8.

no significant contributions to energy supply from solar energy, wind energy, or sea energy, and indicate little contribution before the end of the century from fusion or large-scale solar electric systems.

In the near term, imports are very important in supplying energy to meet projected demand. Conventional nuclear power should relieve some of the pressure to import more fuels during the mid-term, if it expands rapidly, barring accidents and prohibitive legislation, although the latter appears to be more and more likely. After the turn of the century, imports will again assume major importance, unless fusion, solar energy, and synthetic fuel can take over a growing share of the market. Syngas is assumed to be commercially viable sometime after 1980 in small volumes from petroleum, and in larger volumes from coal after 1985. Shale oil will become commercial to a limited extent after 1985, but synthetic liquids can be expected in significant amounts from coal and oil shale only toward the turn of the century.

All of these projections will depend strongly on political decisions, which can alter the mix of supply or change the growth of demand by placing strong incentives, for instance, on improvements in the efficiency of energy utilization.

2.1.2.2 World Energy Demand and Supply

Projections from the United Nations and from the Department of Interior have been extended by simple extrapolation in Figure 2-9. A more sophisticated analysis would involve regression analysis of energy use versus, perhaps, subsets of world population and average per capita income, correcting for serial correlations and multi-colinearity. However, the simplistic projection appears to represent the concensus of projected trends and will suffice for the present study purposes. U.S. total demand for the period 1975 to 2005 has also been superimposed on this graph. No distinctions have been made between fission reactors and fusion reactors, and solar power, sea power, and wind power have been ignored in the expectation that they will continue to be minor sources.

Figures 2-10, 11, 12 and 13 show SAI projections of world production of crude oil, natural gas, coal, and uranium, respectively, based on

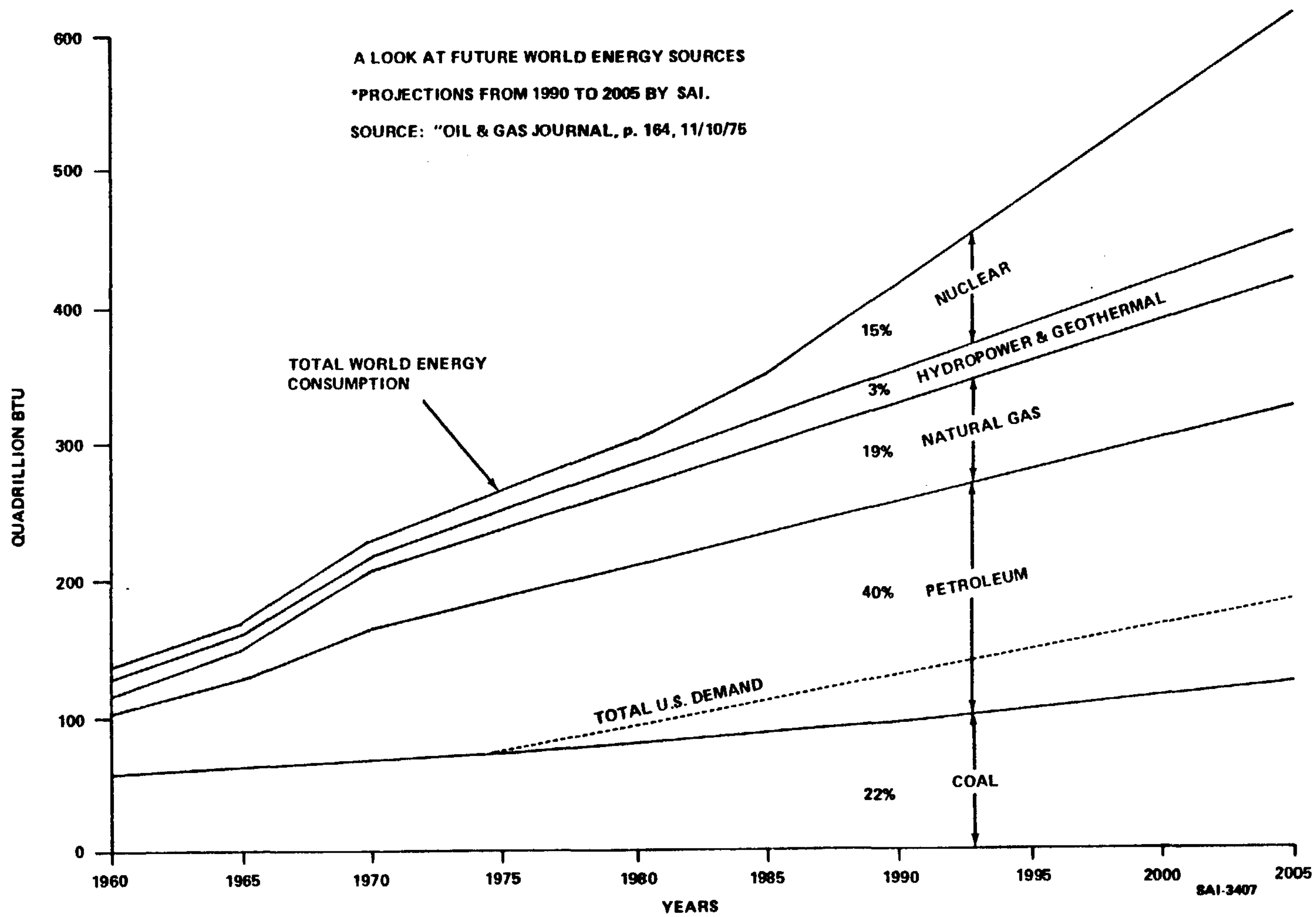

A LOOK AT FUTURE WORLD ENERGY SOURCES
*PROJECTIONS FROM 1990 TO 2005 BY SAI.
SOURCE: "OIL & GAS JOURNAL, p. 164, 11/10/75
TOTAL WORLD ENERGY CONSUMPTION
NUCLEAR
15%
HYDROPOWER & GEOTHERMAL
3%
NATURAL GAS
19%
PETROLEUM
40%
TOTAL U.S. DEMAND
COAL
22%
QUADRILLION BTU
600
500
400
300
200
100
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
YEARS
SAI-3407

Figure 2-9.

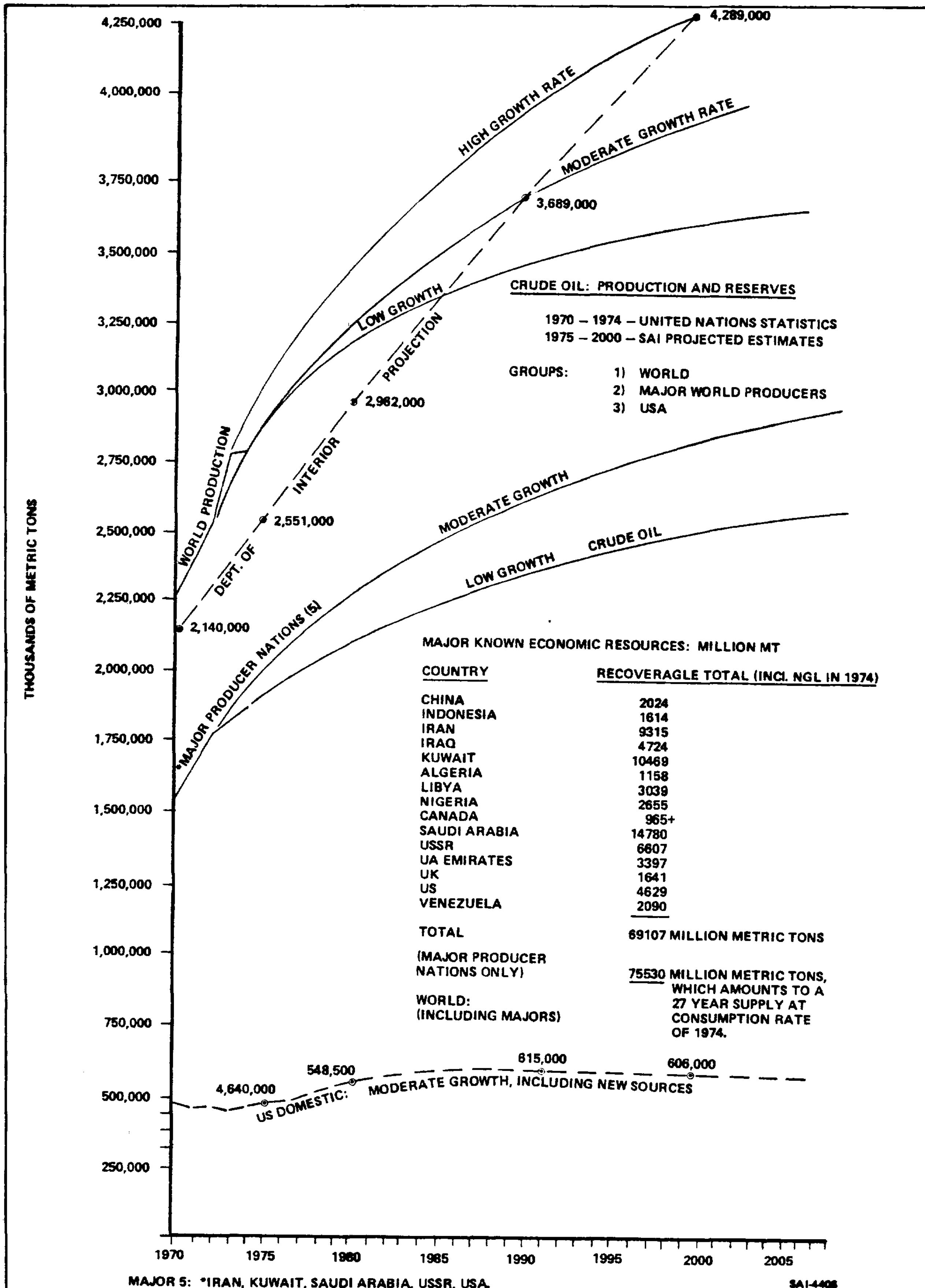
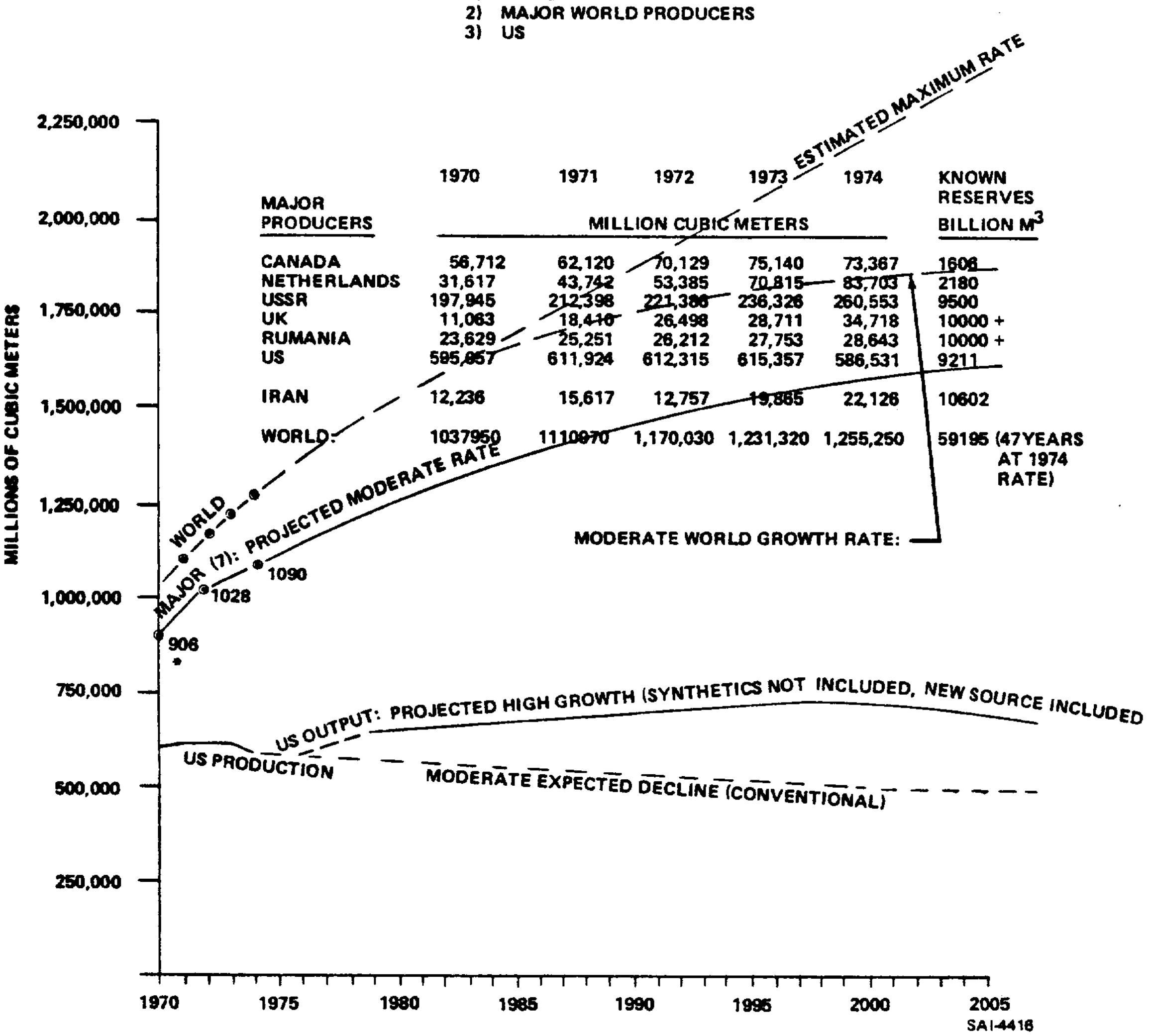


Figure 2-10. Current and Projected Crude Oil Production and Reserves

NATURAL GAS – RESERVES AND PRODUCTION

1970 to 1974: UNITED NATIONS STATISTICS
1975 to 2000: SAI ESTIMATES

3 CATEGORIES: 1) WORLD
2) MAJOR WORLD PRODUCERS
3) US



MAJOR PRODUCERS	1970	1971	1972	1973	1974	KNOWN RESERVES BILLION M^3
	MILLION CUBIC METERS					
CANADA	56,712	62,120	70,129	75,140	73,367	1606
NETHERLANDS	31,617	43,742	53,385	70,815	83,703	2180
USSR	197,945	212,398	221,386	236,326	260,553	9500
UK	11,063	18,416	26,498	28,711	34,718	10000 +
RUMANIA	23,629	25,251	26,212	27,753	28,643	10000 +
US	595,857	611,924	612,315	615,357	586,531	9211
IRAN	12,236	15,617	12,757	19,865	22,126	10602
WORLD:	1037950	1110970	1,170,030	1,231,320	1,255,250	59195 (47 YEARS AT 1974 RATE)

MAJOR 7: *U.S., CANADA, USSR, NETHERLANDS, UNITED KINGDOM, IRAN, & ROMANIA (BRAZIL, NORWAY, ALGERIA AND SAUDI ARABIA ALSO HAVE GOOD POTENTIAL.)

Figure 2-11. Current and Projected Natural Gas Production and Reserves.

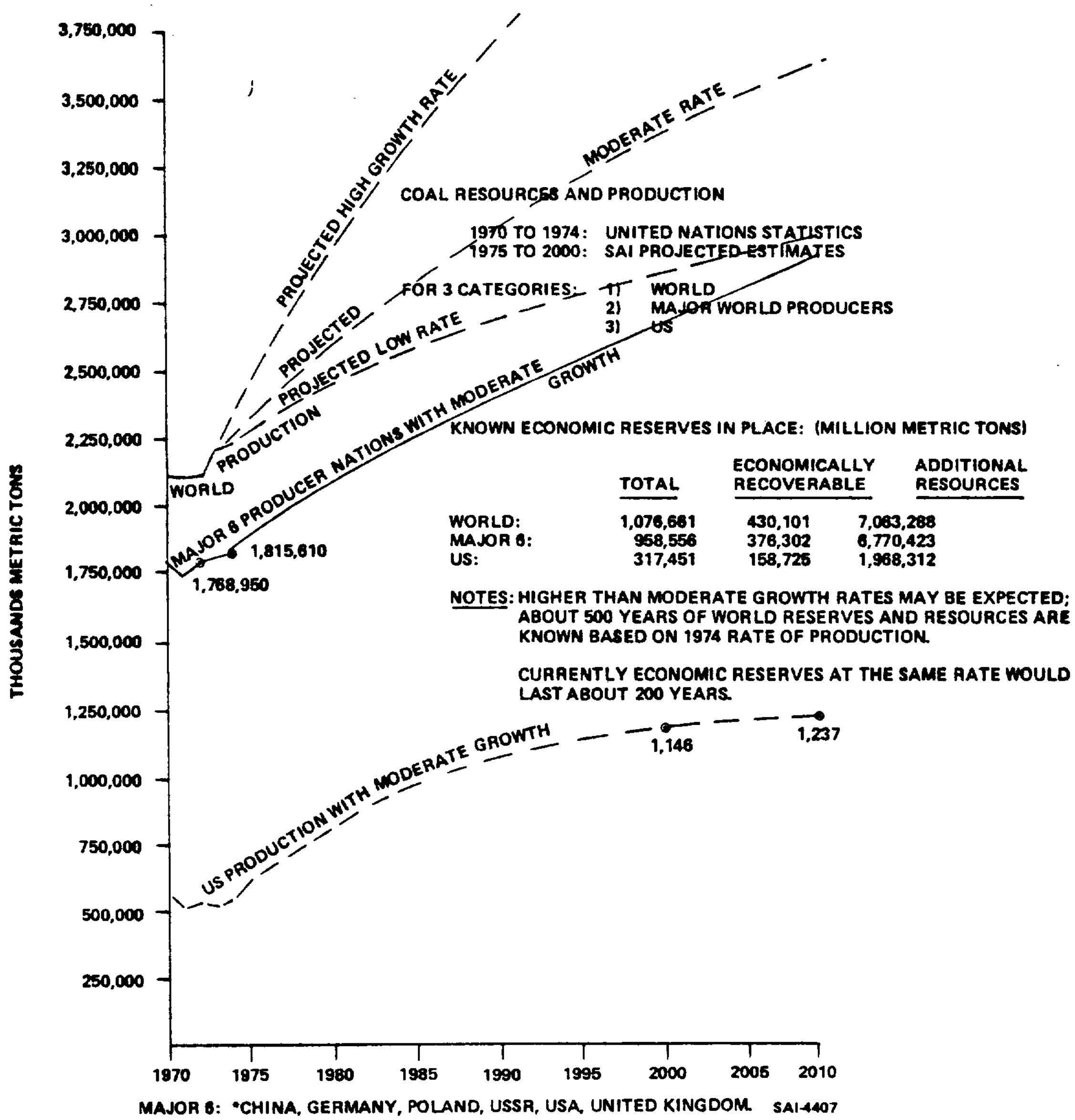


Figure 2-12. Current and Projected Coal Production and Reserves.

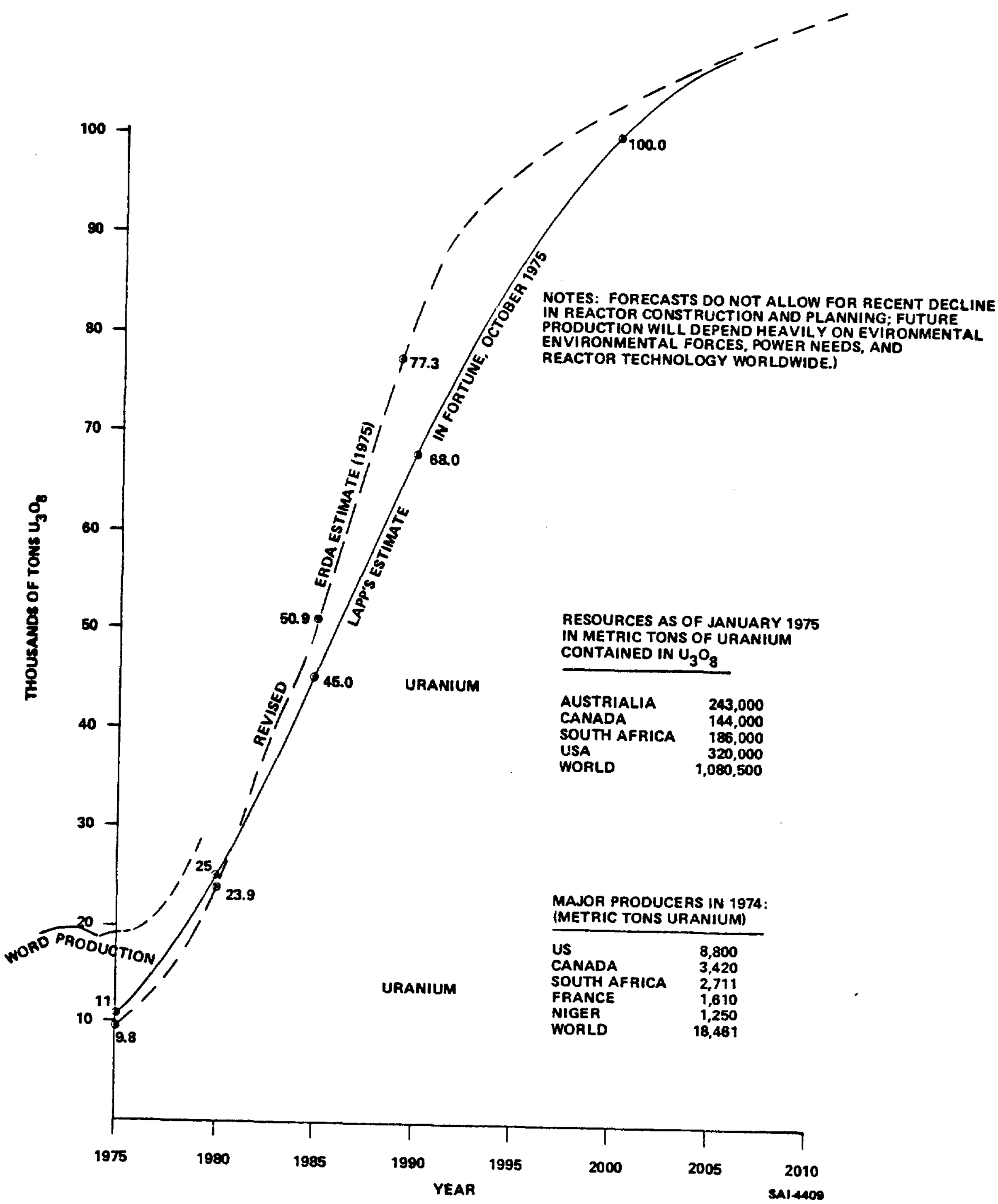


Figure 2-13. Current and Projected Uranium Demand and Production (See Note)

Department of Interior projections and United Nations data, tempered by other factors explained in the notes on these graphs. In several instances, low-, moderate-, and high-growth rate projections have been given. Recent output and known economically extractable reserves are shown for each of the major producer nations, along with global totals.

The sums of these trends provide a reasonable match to the total energy demand trend shown in Figure 2-9, provided moderate-to high-growth rates can be sustained for crude oil, natural gas, and coal. Based on currently known reserves, producer nations have approximately a 27-year supply of crude oil, a 47-year supply of natural gas, and at least enough coal for 200 years of production. These figures are expected to change with new discoveries and new technologies. Projected production for the United States show relative stability or only moderate growth with the exception of uranium; substantial imports will be required if nuclear power development is much delayed.

Most projections show a deceleration in growth or worldwide production for petroleum, natural gas, coal, and uranium by about the turn of the century, indicating a need for solar power or fusion power early in the twenty-first century.

In summary, it appears that conventional energy sources are sufficient for worldwide needs for the next few decades, although economic dislocations may result from political factors and from inequities in distribution. Unconventional energy sources (such as geopressurized natural gas deposits) may extend the use of fossil fuels significantly without major innovations in technology or large increases in real price, but the necessity of research and development on newer sources of energy in the long term is very clear.

2.1.3 Mineral Raw Materials

Before we proceed with our case-by-case examination of some important mineral raw materials, it is useful to look at the overall structure of mineral consumption in an industrialized economy. Table 2-3 presents a breakdown (by weight) of the per capita use of non-renewable resources mined in 1975 for use in the United States economy. The total

TABLE 2-3

NONRENEWABLE RESOURCES EXTRACTED IN 1975
FOR USE IN THE UNITED STATES

(Table adapted from John D. Morgan, "The World Supply/Demand Outlook for Minerals," in A.G. Chynoweth and W.M. Walsh, eds., *Materials Technology--1976*, AIP Conference Proceedings No. 32, American Institute of Physics, New York, 1976.)

Mineral	Weight per capita (lbs)		Fraction by weight of all minerals (%)	
FOSSIL FUELS	17,050		45.95	
Petroleum		7,650		20.62
Coal and lignite		5,200		14.01
Natural gas		4,200		11.32
NON-METALS	18,940		51.04	
Sand and gravel		8,000		21.56
Stone		8,000		21.56
Cement		660		1.78
Clay		450		1.21
Salt		430		1.16
Phosphate		315		0.85
Other		1,085		2.92
METALS	1,118		3.01	
Iron and steel		1,000		2.69
Aluminum		46		0.12
Copper		16		0.04
Zinc		14		0.04
Lead		11		0.03
Other		31		0.08
TOTAL MINERALS	37,108		100.00	

weight per capita of finished materials derived from virgin ores was 16,867 kg (37,108 pounds). Nearly half of this amount was fossil fuels which were discussed in the previous section on energy. Slightly more than half of the total was non-metals; all of those listed (except for phosphate rock) are very widely distributed in vast abundance, sufficient for at least several million years of consumption at present rates. Typical prices for most of these non-metals are a few cents per pound or less. For metals, on the other hand, typical prices today are an order of magnitude higher, so that their total economic value is comparable to that of all non-metals although the metals account for a much smaller fraction of the total consumption by weight. Taconite (an iron ore) and bauxite (an aluminum ore) are available in supplies sufficient for a few centuries (globally), with extreme variability in geographic distribution. Iron laterites and unexploited aluminum ores such as kaolin appear to be much more uniformly distributed in sufficient abundance to provide several million years of iron supply and several hundred million years of aluminum supply. Because of the economic importance of these two metals, however, and because of their versatility in industrial applications, short term supply and demand factors for these metals are discussed in detail below.

Most of the remaining metals, however, appear to be much more scarce on Earth, with currently known economically extractable reserves sufficient for only a few decades of use at present rates of extraction. Fourteen of these metals have been examined and are discussed below. For most of these metals, recycling can significantly extend supply, with relatively modest increases in price sufficient to create strong incentives for substitution.[(4)] These metals were selected because of their potentially critical role in industry or because of particularly significant issues in supply sources.

Two non-metals have also been examined and are discussed below. These are phosphate rock, important in agriculture as a fertilizer with relatively small supplies available globally, and fluorine, of vital importance in metallurgical extraction processes.

(4) See, for example, H. Kahn, W. Brown, and L. Martel, *The Next 200 Years: A Scenario for America and the World*, William Morrow and Company, Inc., New York, 1976, for a scenario describing the effects of a sudden rise in the price of copper.

2.1.3.1 Iron

Large capital investments are required to establish modern large capacity operations ($100 to 400 million for an operation producing 3 to 10 million tons of iron per year), so financial consortiums or partnerships are common in the industry. New projects begun in 1975 required capital costs of about $33 to $53 per ton per year of capacity, with lower costs for existing developed areas.

Labor contracts influence production costs considerably, since labor costs account for about 50% of production costs. Transportation costs are significant (20 to 50% of price) and play an important role in the relative competitive strengths of companies in the industry. Shipment by water is less expensive per unit than overland freight, but typical distances are greater. Large ships indirectly compete with unit trains and slurry pipelines.

Environmental controls amount to 5 to 10% of capital investment for taconite production which produces an increasing fraction of ore pellets from open pit mines (95% in the United States; 85% worldwide). Taxes and royalties can be a financial burden to some firms in particular areas.

Because of the complexities of competition, domestic prices of iron-in-ore had remained constant (in real terms) for more than ten years until 1975. Prices are likely to continue to rise, however, because of fuel, materials, labor and equipment costs.

The average ratio of wastes to crude ore (volumetrically) was a sizable 1-to-1 in 1974, so that large acreages are required for mines and tailings disposal areas, in addition to large acreages required for steel mills. Large volumes of water (much of it recycled) are required in the U.S. Mesabi range for washing ore concentrates. In northern areas, ore is either not mined during the winter or merely stockpiled.

Figure 2-14 shows projections of iron demand in relation to actual production in recent years. Iron ore supply should be adequate to meet foreseeable demands. Known reserves of economically extractable ores

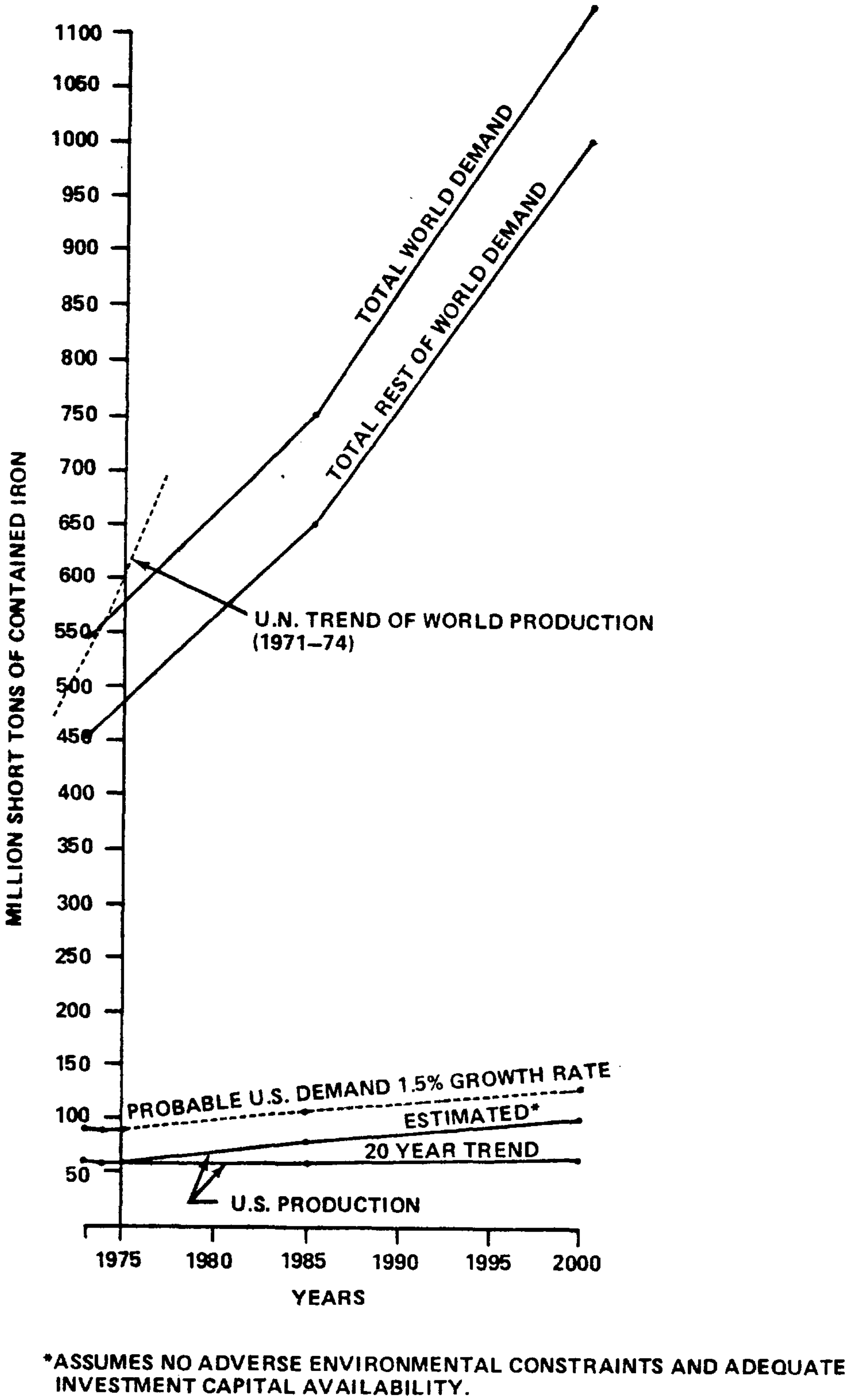


Figure 2-14. Supply and Demand of Iron Ore 1973 - 2000

(using present technologies) total about 4 billion tons in the United States and about 96 billion tons in the rest of the world, versus cumulative demands up to 2000 of about 3 billion for the United States and 19 billion for the rest of the world. If U.S. production costs do not rise faster than foreign prices, domestic supply should provide about 75% of U.S. demand, although variations in the ratio of pig iron to scrap iron could alter demand. Developing countries will likely increase iron and steel capacity in step with growth of their GNP, while growth of demand in the developed countries is more likely to match population growth.

Mining equipment is expected to continue to grow in size and capacity. Beneficiation is likely to improve the rate of iron recovery without high impurity content, while direct reduction techniques are likely to improve the iron content of ores and pellets. Concentrated iron ore will likely be piped in slurry form, while computer-controlled unit trains and larger ore ships can also be expected.

2.1.3.2 Aluminum

Figure 2-15 presents projections of aluminum demand (both primary and secondary metal) based on *Mineral Facts and Problems*, Bureau of Mines Bulletin 667, which explains the projected growth in terms of projected values for gross economic indicators. The world supply of aluminum appears to be adequate beyond 2000, given known reserves*, the high probability of additional discoveries, and possible alternative supply sources (such as aluminum-rich clays). An increasing amount of U.S. aluminum consumption will be imported from countries with low-cost electrical power. Whereas domestic production in 2000 can be expected to satisfy about 80% of demand for all other primary metals, domestically mined bauxite is likely to provide only about 9% of aluminum consumed then in the United States.

Domestic output may increase substantially, however, if a foreign cartel were to be formed in the future, if domestic clays can be economically processed, if large capital requirements for plants and mine sites can be met, if environmental degradation can be avoided or minimized, and/or if

* In the language of resource economics, "reserves" are known deposits of ore which can be extracted at economically competitive prices with *present* technologies; "resources" are those ores which are presently not competitive.

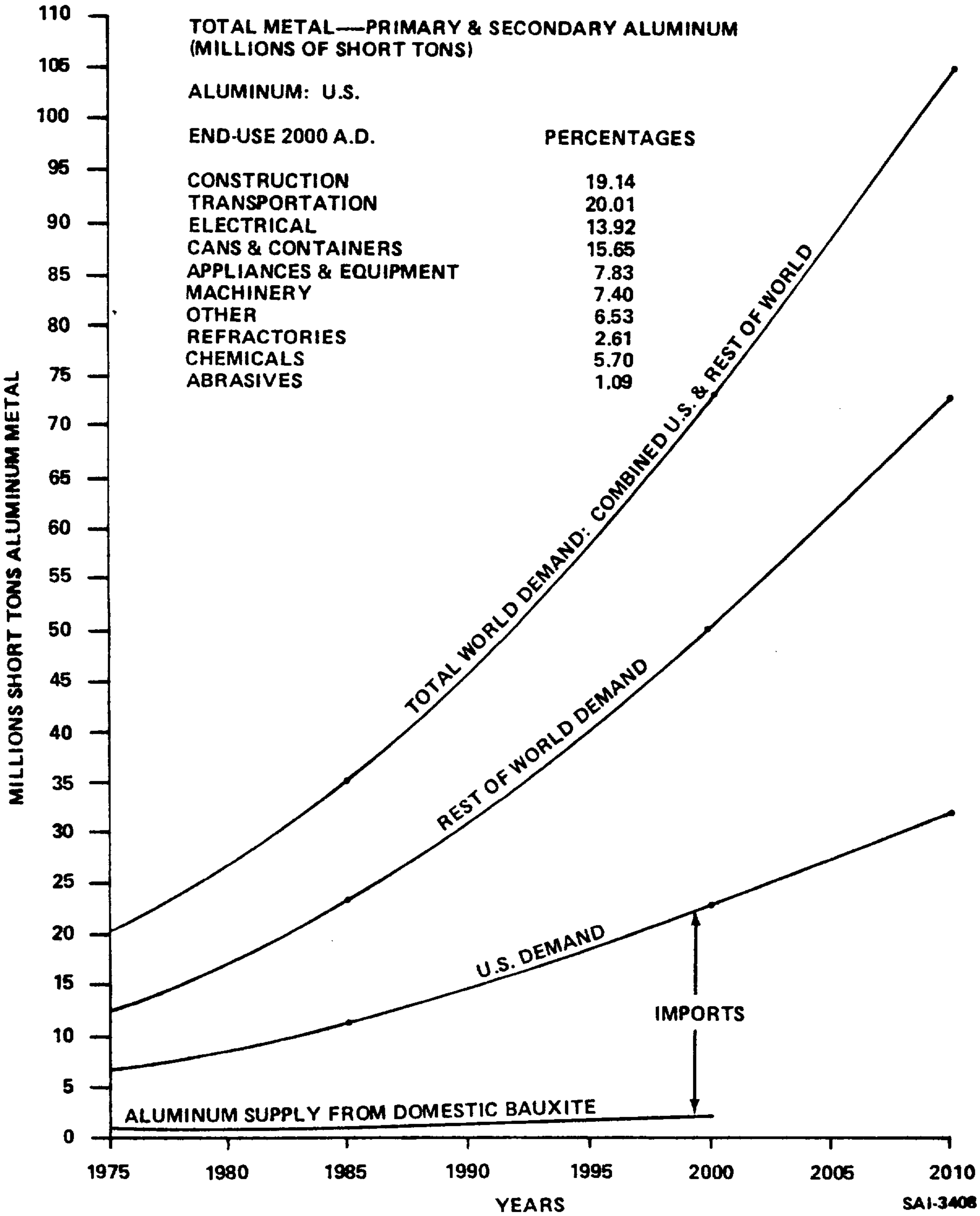


Figure 2-15. Supply and Demand of Total Metal - Primary & Secondary Aluminum (Millions of Short Tons)

U.S. government policy is amenable to domestic production development. The environmental effects of processing and the efficiency of processing should be improved by technological developments which can be expected to include a shift away from fluoride processing of alumina, the addition of lithium carbonate, and the use of new electrode materials such as titanium boride.

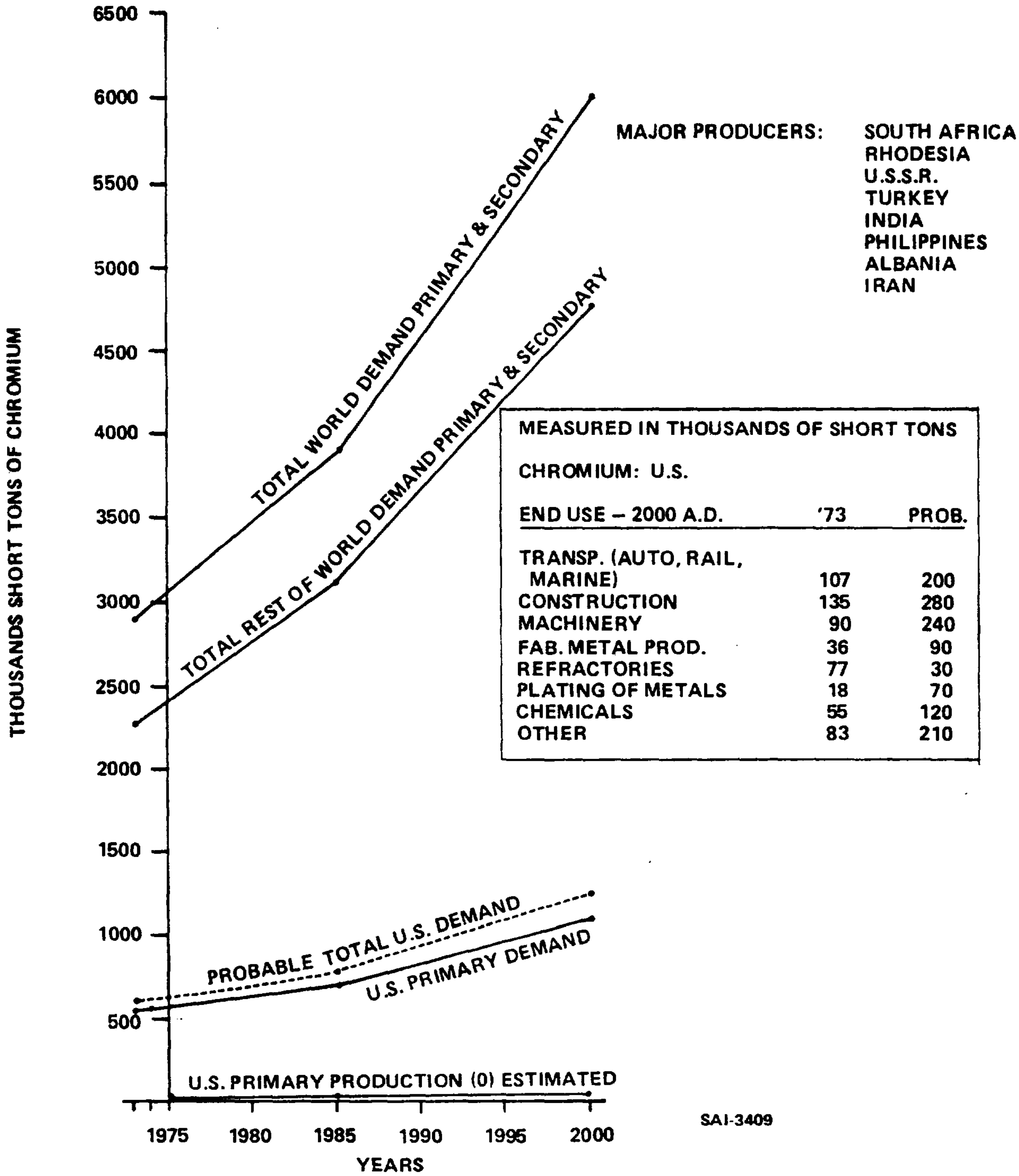
The price of aluminum has varied sharply (when measured in constant 1972 dollars) due to changing technology, market forces, and additional supply sources. Between 1956 and 1976, ignoring discounts below quoted prices, the lowest price was about 27¢ per pound in 1972, and the highest price was about 44¢ in 1976. Relative to other goods and services, the price of aluminum is not expected to rise much above 50¢ per pound (in 1977 dollars). Assuming this price, estimated U.S. demand for the year 2000 would have a value of $23 billion; and for the year 2010, about $32.5 billion. The value of finished aluminum, of course, would be higher than quoted here if costs for process energy rise faster than the general inflation rate.

2.1.3.3 Chromium

Strong demand and inflationary pressures have increased chromium prices in recent years, with intensive competition both in the domestic and foreign supplies of ferrochromium alloys. Figure 2-16 shows projected demand based on end-use consumption, adjusted by contingency analyses for technological, economic, and social factors. Primary demand abroad will grow faster than in the United States because of increasing industrialization in countries with low-cost resources and energy.

Large automated furnaces have helped to reduce production costs by increased output and by reduced labor costs. Pollution control equipment is now a necessity, requiring about 20% of new investment capital. Dust and slag disposal are still problems, but economic recycling of recovered fines and dust will increase chromium yields.

Chromium reserves in the United States are not economic except for dire emergency needs. African reserves are sufficient for at least the next 25 years, while increased use of lower grade resources (including extraction from laterites) and recovery of fines and dust will extend



MEASURED IN THOUSANDS OF SHORT TONS

CHROMIUM: U.S.

END USE – 2000 A.D.	'73	PROB.
TRANSP. (AUTO, RAIL, MARINE)	107	200
CONSTRUCTION	135	280
MACHINERY	90	240
FAB. METAL PROD.	36	90
REFRACTORIES	77	30
PLATING OF METALS	18	70
CHEMICALS	55	120
OTHER	83	210

Figure 2-16. Supply and Demand of Chromium 1973 - 2000

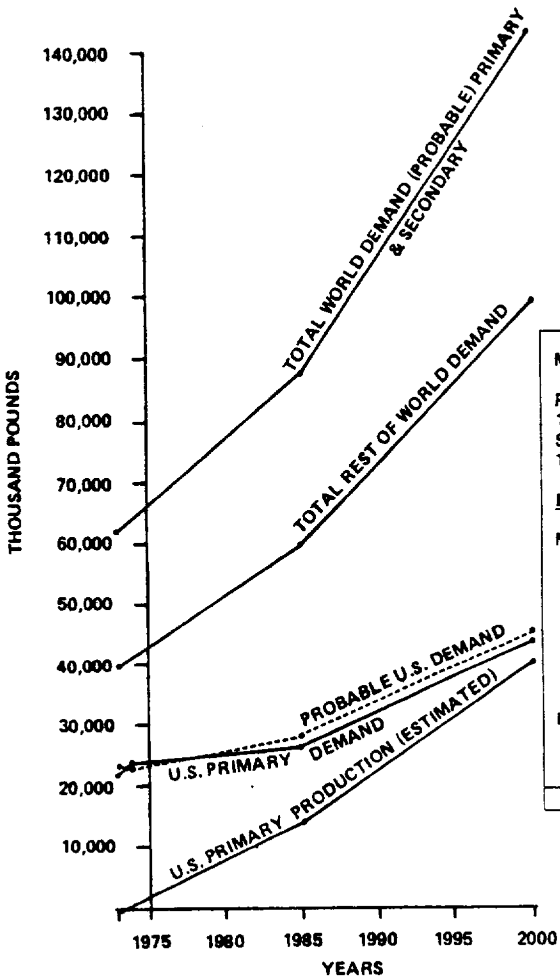
world reserves. World output in 1974 was about 3,310,000 metric tons of chromate (Cr_2O_3), with the U.S.S.R. and South Africa each producing about 825,000 metric tons; Turkey, 270,000 metric tons; Southern Rhodesia, 292,000 metric tons; Albania, 286,000 metric tons; India, 195,000 metric tons; and the Phillipines, 192,000 metric tons. A number of these countries have shown signs of political instability; occasionally, imports from some of these countries have been embargoed for political reasons. Stockpiling of chromium is used in the United States as a precaution against sudden interruptions in supply.

2.1.3.4 Cobalt

Cobalt is an essential additive in many extremely hard and tough steel alloys. Demand for these alloys and the continuing development of new alloys and new applications for such alloys will increase demand for cobalt. Rare-earth/cobalt magnets will be an important new market. Figure 2-17 projects cobalt demand and U.S. domestic primary production.

Cobalt is usually a byproduct of copper or nickel production, so that its production costs and availability are strongly linked to the primary metal. The costs of mining and refining cobalt have risen in constant dollars, pushing up prices somewhat. Short term factors such as nationalization of mines in Zaire, a nickel industry strike in Canada, and changes in export rules have also increased cobalt prices. In the long run, price rises should be controlled by new sources of production and technological advances. New capacity may be needed in the next decade, but supply is mainly a function of the output of particular sources of nickel and copper. Supply appears to be adequate beyond 2000 when new sources of cobalt are also considered. Presently, the major conventional suppliers are Zaire, Zambia, Canada, and Finland.

Nickel laterites in Australia are expected to become economical in the next decade. Currently, the processes to separate cobalt from the nickel in these laterites are too expensive, but research is expected to reduce these costs sufficiently. Recovery and production of secondary cobalt is now possible for some scrap alloys at about 10% more than the price of virgin cobalt. It is expected that U. S. domestic mining and certainly



MEASURED IN THOUSANDS POUNDS

PROJECTIONS FOR PROBABLE U.S. COBALT DEMAND: 1973 TO 2000
SOURCE: U.S. DOI, MINERAL FACTS & PROBLEMS: 1975 ED.

END USE	1973	2000
METAL		
TRANSPORTATION		
AIRCRAFT	4035	5800
ELECTRICAL	6478	14400
MACHINERY:		
MACHINE TOOLS	2459	4900
CONST. MACH.	2037	4700
OTHER:	639	1000
NON METAL		
PAINTS	2654	6200
CHEMICALS	1640	4900
CERAMICS/GLASS	2234	2800
TOTAL	22176	44700

SAI-3410

Figure 2-17. Supply and Demand for Cobalt 1973 - 2000 refining of nickel/cobalt will soon resume. Recycling of cobalt scrap from super alloys is expected to increase.

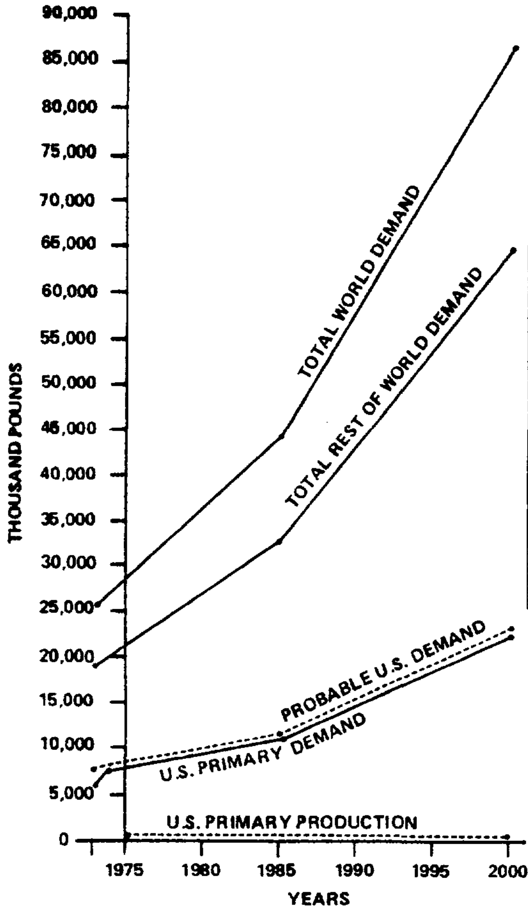
Ocean nodules are likely to become a cobalt supply source after about 1985, although formidable legal, political, and environmental problems must be worked out. Pending resolution of the outstanding issues of the Law-of-the-Sea conference, federal indemnification of U.S. companies would appear to be a prerequisite for ocean nodule mining. Important and interesting new technology is under development in the meanwhile to extract metals economically from these nodules.

2.1.3.5 Columbium (Niobium)

Columbium is an essential ingredient in steel alloys with very high strength-to-weight ratios or with high resistance to elevated temperatures and corrosion. Advances in end-use technologies will further stimulate demand for columbium. Some of these uses are likely to be in the aerospace and nuclear industries; control and containment of fusion reactions, for example, will likely require columbium superalloy conductors. Projected demand is shown in Figure 2-18. Department of Interior forecasts are based on contingency analysis of probable technological and economic influences on end uses, with consideration of Federal Reserve Board forecasts of the Index of Industrial Production.

Countries with highly developed metallurgical industries use significant amounts of columbium. Increased use of high strength-to-weight steel alloys could increase demand for columbium, but its future use in construction applications would be reduced correspondingly by the substitution of vanadium and low-carbon ferrochrome in steel alloys. In particular machinery applications, tungsten or tantalum could also be substituted.

Currently, all columbium ores are mined and milled outside the United States, chiefly as a byproduct of tin ore. Ore concentrates are processed to high-purity grades of columbium oxide in the United States. Processing the ore can create a disposal problem with low-level radioactivity in the wastes. World reserves appear to be ample to meet demand past the turn of the century. Canada and Brazil ship pyrochlore concentrates to the U.S.; Nigeria exports columbite and tin slag; South Africa, columbite/



WORLD RESERVES:
23–76 BILLION POUNDS

MEASURED IN THOUSANDS POUNDS

PROJECTIONS & FORECASTS FOR U.S. COLUMBIUM DEMAND BY END USE, 1973 – 2000

END USE	1973	2000
CONSTRUCTION	2420	8300
MACHINERY		
METAL WORKING MACH.	363	1300
SPECIAL INDUSTRY MACH.	847	3400
OIL & GAS INDUSTRIES	1089	2700
TRANSPORTATION	1210	4100
OTHER	120	2500
TOTALS	6049	22300

SAI-3411

Figure 2-18. Supply and Demand for Columbium 1973 - 2000 tantalite concentrate; Malaysia and Thailand, tin slag. Brazil is the largest columbium exporter. Improved geochemical and geophysical techniques could lead to U.S. mining and production of domestic ores.

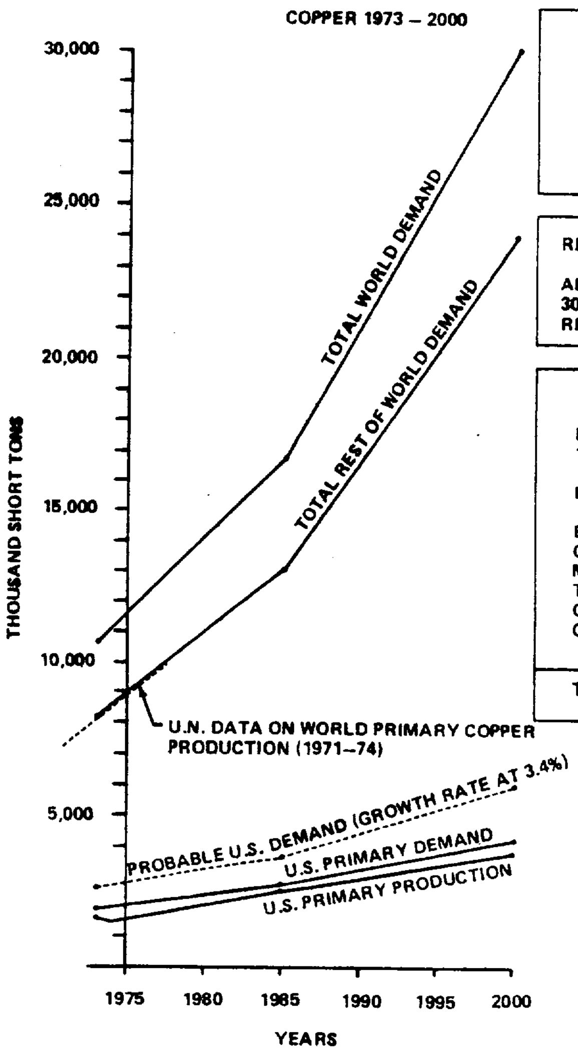
Reductions in the cost of extracting columbium can be expected which will make it more competitive with alternative materials. Possible developments include direct chlorination of high-grade concentrates with carbon and carbothermic reduction of low-grade materials to ferrocolumbium.

2.1.3.6 Copper

Nearly 60% of copper demand at present comes from electrical applications because of copper's excellent electrical conductivity and thermal conductivity. Aluminum can be substituted for many of these applications if the price of copper should rise steeply. Figure 2-19 projects total demand for copper based on estimates of demands for each category of end uses. Forecasts for each end use were based on the most appropriate economic indicator, such as GNP, electrical power consumption, new construction, output per capita, population, or productivity. Technological developments were considered among other contingencies to give a range of likely demands for each end use.

World reserves presently known appear adequate through the turn of the century. The major producers are the United States, the U.S.S.R., Chile, Canada, Zambia, and Zaire. Copper prospecting is underway in Argentina, Columbia, Iran, Indonesia, and some of the Pacific Islands. Brazil is another prime candidate for copper resources. The U. S. industry has the advantages of stable government, proximity to markets, existing mines, and large scale operations which should keep the domestic industry viable despite increased costs due to more extensive environmental safeguards and conflicting demands for use of water, land and energy.

Costs of producing and marketing copper are highly variable, depending on the type of ore and the location of the deposit. Nationalization of copper mines and a trend toward greater retention of value-added in copper exporting countries will create some technical, capital, and marketing problems; producer-consumer agreements may be required to improve supply and demand conditions.



LARGEST PRODUCER NATIONS (1974):

U.S.
U.S.S.R.
CHILE
CANADA
ZAMBIA
ZAIRE

REST OF WORLD RESERVES: 360 MILLION TONS

ADEQUATE TO MEET CUMULATIVE DEMAND OF 301 MILLION TONS, NOT INCLUDING U.S RESERVES AND DEMAND.

MEASURED IN THOUSANDS SHORT TONS

FORECASTS FOR U.S. COPPER DEMAND: 1973 to 2000

END USE	1973	2000
ELECTRICAL	1445	4300
CONSTRUCTION	355	600
MACHINERY	253	400
TRANSPORTATION	198	250
ORDNANCE	57	150
OTHER (JEWELRY, COINAGE)	120	300
TOTALS	2428	6000

SAI-3412

Figure 2-19. Supply and Demand for Copper 1973 - 2000

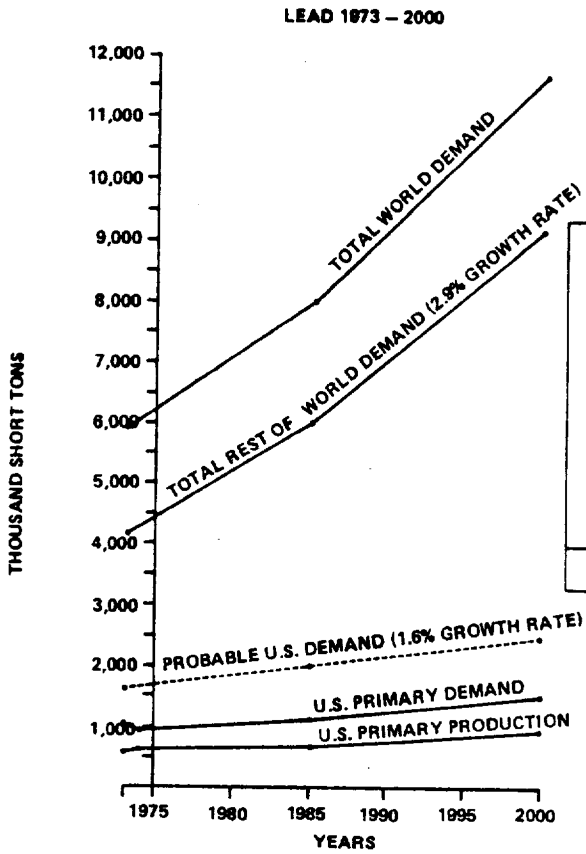
Declining ore grades continue to stimulate economizing innovations to keep costs from rising beyond reasonable levels. Productivity has increased steadily in the mining and processing of copper as a result of more extensive mechanization and automation, new technology, and economies of scale. Greater efficiency is expected through the ore-handling systems. Major improvements in electrodeposition or precipitation from leach solutions may provide a replacement for copper processing in smelters and refineries. Costs may be reduced by increasing total yields through ion exchange electrowinning the dumped leach solutions. However, energy costs are substantial and have increased. The costs of adding pollution control equipment impose a large cost burden on the domestic industry. The flotation processes require large quantities of water, with possible problems of availability in the future.

About 80% of U.S. copper is mined from open pits. Some 58% of the mined material is moved and discarded before milling, while only 2% of the milled material goes into ore concentrates, causing a large problem in disposal of tailings. Sulfur dioxide emissions are a serious problem in air pollution, while arsenic emissions inside smelters create safety problems for workers.

The growth of recycling has been considered in the projections of total demand and primary demand shown in Figure 19. Deep sea nodules and laterite deposits are important as potential future sources. Improvements in geochemistry and geophysics will aid further exploration and discovery. After the turn of the century, copper demand may outpace supply unless new processes in hydrometallurgy, increased recycling, and development of new sources such as ocean nodules and laterites fill the gap.

2.1.3.7 Lead

The largest uses of lead today are in the transportation sector (lead-acid batteries and gasoline additives). Figure 2-20 shows projected demands for lead based on technological, social and economic changes and their probable effects on lead demand. Since lead is a toxic material, problems of air pollution, waste disposal, and land use are serious issues



MEASURED IN THOUSAND SHORT TONS
FORECASTS FOR U.S. LEAD DEMAND:
1973 – 2000

END USE	1973	2000
GASOLINE ADDITIVE	274	110
TRANSPORTATION	700	1600
CONSTRUCTION	87	120
PAINTS	109	150
AMMUNITION	81	100
ELECTRICAL	135	150
OTHER (ALLOYS)	212	200
TOTALS	1598	2430

SAI-3415

Figure 2-20. Supply and Demand for Lead 1973 - 2000 confronting the industry, accounting also for the large decrease in projected demand for lead as a gasoline additive. Solutions to these issues will require substantial capital investments and imply higher operating costs. Prices have risen in response, but foreign competition and the availability of scrap lead limit the improvements possible. (Most of the lead in lead-acid batteries used in transportation is recycled.)

Smelters are generally equipped with collectors for lead dust and fumes and with dispersal units to reduce sulfur dioxide concentrations in the emissions. Care in handling, ventilation, and monitoring minimize contact between workers and lead compounds.

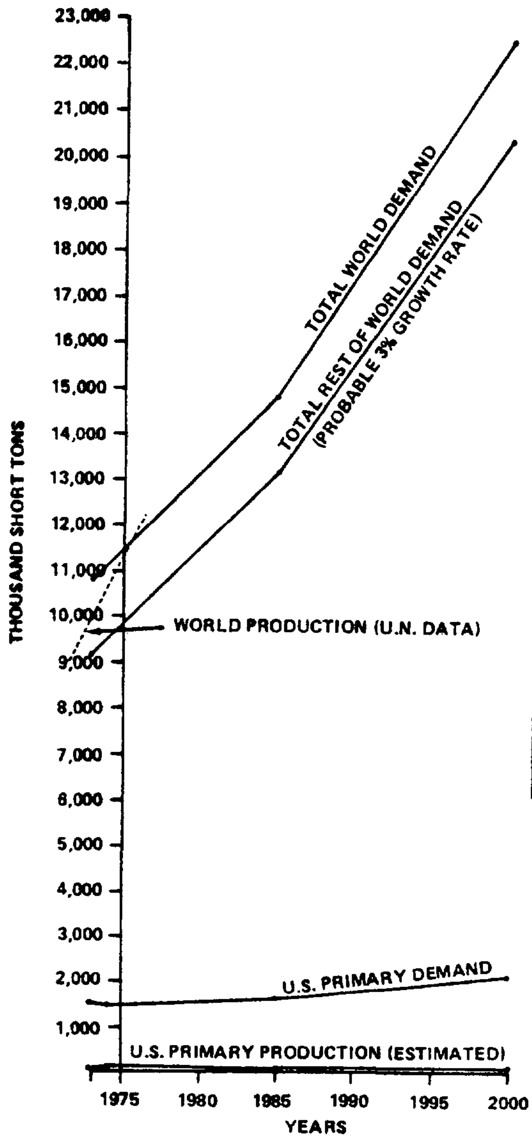
No domestic or world shortages are foreseen through the end of the century. World reserves are currently about 165 million short tons and are expanding with continued exploration in Canada, Australia, Ireland, and Yugoslavia. Mine production has doubled in ten years. For the United States, some growth in lead imports will be necessary to meet anticipated demand. Environmental requirements (both here and abroad) can affect supplies, but better techniques of waste disposal and emission controls are expected.

Electrochemical methods of refining lead, improvements in scrap processing, and the development of new processing techniques are needed and expected in the next few decades, tending to stabilize prices and to extend reserves.

2.1.3.8 Manganese

Manganese is a necessary component of steel. Figure 2-21 presents projections of demand for manganese based on forecasts of steel demand tempered by influential economic, social, and technical factors. Manganese is also used in the chemical industries as a catalyst, an oxidizer, and an intermediate.

Variability in ore quality causes variability in the costs of ore processing. Ore prices are negotiated on the basis of content, quantity, freight rates, delivery terms, insurance, duties, and availability of ore. The key to manganese supply, however, is transportation: high



MEASURED IN THOUSAND SHORT TONS

FORECASTS FOR U.S. MANGANESE DEMAND: 1973 TO 2000

END USE	1973	2000
CONSTRUCTION STEEL	325	480
TRANSPORTATION STEEL	340	470
MACHINERY STEEL	229	280
CANS & CONTAINERS STEEL	72	105
APPLIANCES & EQUIPMENT INDUSTIRES	68	90
OIL & GAS	63	65
CHEMICALS	54	165
BATTERIES	18	25
OTHER	385	450
TOTALS	1554	2130

SAI-3418

Figure 2-21. Supply and Demand for Manganese 1973 - 2000 freight rates, congested ports, and a shortage of available gondolas or ships all create problems in the supply chain.

World reserves are more than adequate to meet foreseeable demand. The estimated cumulative world supply capability is about four times greater than cumulative demand from 1975 to 2000. South Africa, the U.S.S.R., Brazil, Australia, and Gabon all have ample reserves. At higher prices (or improved, lower-cost technologies), the United States has resources that could become reserves, but metallurgical examination of manganese ores in Arizona and Arkansas are needed before the extent of these potential reserves can be assessed. Manganese ocean nodules contain high concentrations of the metal, but legal, political, and environmental problems must be resolved, as discussed earlier in the case of cobalt. In recent years, there has been an attempt to stabilize manganese prices through United Nations action.

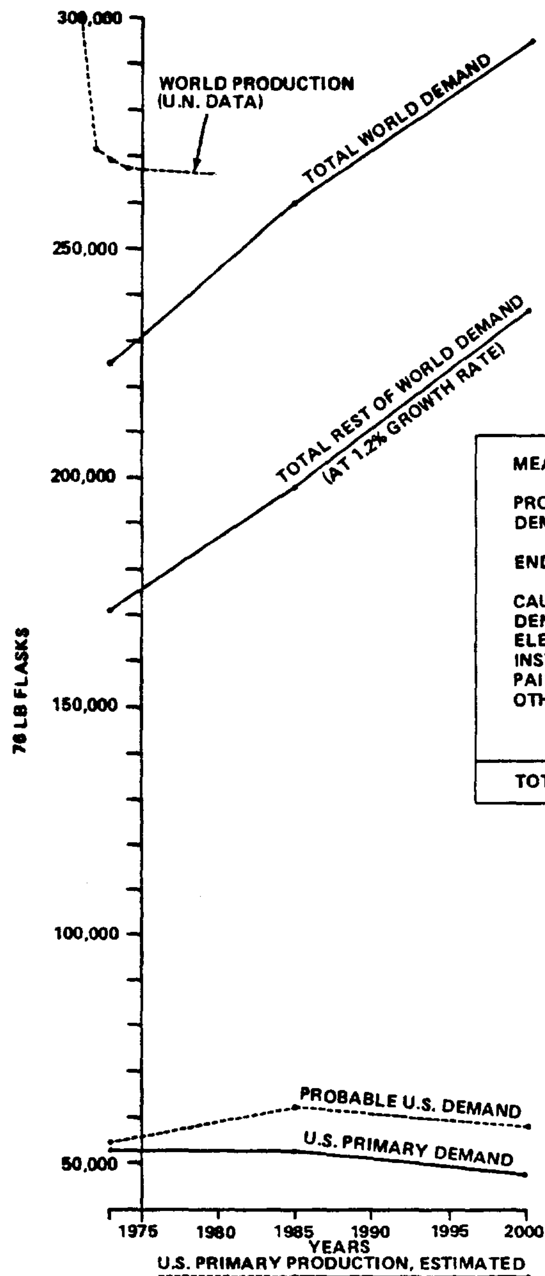
The United States imports all of its manganese requirements from Brazil, Gabon, Australia, South Africa (both ore and alloy), and France (alloy).

2.1.3.9 Mercury

Projections of mercury demand by end uses are shown in Figure 2-22. Most of these are expected to grow in step with either population or with GNP. "High" and "low" projections by the Department of Interior result from contingency analysis for shifts in social, technological, and economic factors. The rate of growth in demand is expected to be higher in the emerging countries than in either the developed countries or in the under-developed countries.

Major producing nations include Spain, the U.S.S.R., China, Italy, Mexico, Yugoslavia, Canada, Algeria, and Turkey. Erratic fluctuations in demand cause severe fluctuations in price from time to time.

Imports will provide the major portion of U.S. requirements, although domestic production is expected to increase. Domestic ores are low grade, averaging 3 pounds of mercury per ton in open pit operations and about 7 pounds per ton in underground mines. Processing is relatively simple. But mercury and its organic compounds are very toxic, posing dangers



MEASURED IN UNITS OF 76 LB FLASKS

PROJECTIONS FOR PROBABLE U.S. MERCURY DEMAND: 1973 TO 2000

END USE	1973	2000
CAUSTIC SODA & CHLORINE	13070	15000
DENTAL SUPPLIES	2679	3000
ELECTRICAL	18000	25000
INSTRUMENTS	7155	5000
PAINTS	7603	5000
OTHER	5776	5000
TOTALS	54283	58000

WORLD PRODUCTION 1974 (76 LB FLASKS)

SPAIN	60175
U.S.S.R.	53940
ITALY	25984
MEXICO	25926
CHINA	26100
CANADA	15428
ALGERIA	13485
TURKEY	8874
YUGOSLAVIA	15834
WORLD:	267960

SAI-3417

Figure 2-22. Supply and Demand for Mercury 1973 - 2000 in handling and in breathing the air in the immediate vicinity of operations. Dust collectors can prevent air pollution surrounding operations, while detectors, respirators, and careful cleaning are all necessary on site.

More serious are the problems of mercury released to the environment after use. Many end uses of mercury are dissipative (chemical catalysts, agricultural fungicides, paint, paper processing). Because of the proven toxicity of mercury compounds in the air and in the water, the Environmental Protection Agency has recently banned many of these uses, and others are likely to be added to the EPA's bans.

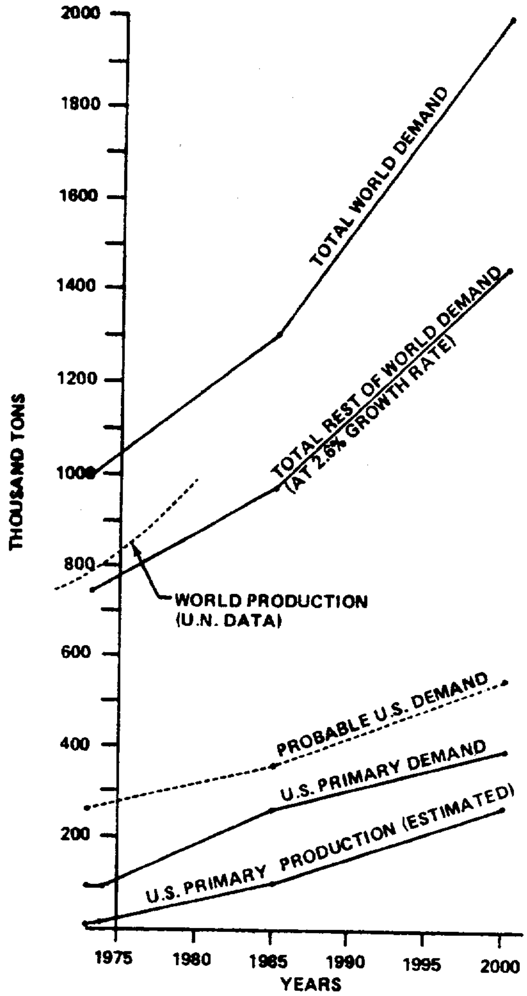
More efficient use of mercury could result from changes in the design of mercury cells, and greater efficiency in beneficiation of low grade ores is expected. Pollution control requirements promote recovery of mercury from effluents, and secondary recovery of mercury from mine tailings is expected to increase as well. Some further substitution of other materials for some present uses of mercury can also be expected. Should prices rise or newer extraction methods be developed, lower grade deposits will become economically extractable reserves to cover cumulative demand. Algeria and Turkey are likely to provide new sources of supply.

2.1.3.10 Nickel

Figure 2-23 shows projected demand for nickel based on end uses which are forecast to grow in association with population, GNP, or other industrial and economic indices. Nickel prices had been stable (in constant dollars) until the nickel industry strike of 1969, after which the price rose to $1.58 per pound in 1974. Further price increases are expected as energy costs increase due to the high consumption of electricity and fuel oil for smelting and calcining nickel ore.

Laterite open pit mines cover large acreages, posing some environmental and land use problems. Air pollution controls are necessary at smelters, and nickel workers have a higher risk of respiratory system cancers.

Canada, the U.S.S.R., and New Caledonia will continue to be the leading producers of nickel, with some contributions from Australia, Cuba, the Dominican Republic, and a few other nations. U. S. reserves in low



MEASURED IN THOUSAND TONS

PROJECTIONS FOR PROBABLE U.S. NICKEL DEMAND: 1973 TO 2000

END USE	1973	2000
CHEMICALS NI-ALLOYS	38.9	110
PETROLEUM NI-ALLOYS	23.3	70
FABRICATED METAL PRODUCTS	26.0	46
AIRCRAFT PARTS	18.1	45
MOTOR VEHICLES	28.5	33
SHIPBUILDING	7.9	14
ELECTRICAL	33.6	100
HOUSEHOLD APPLIANCES	18.1	22
MACHINERY	18.1	36
CONSTRUCTION	23.3	40
OTHER	23.2	34
TOTALS	259.0	550

WORLD PRODUCTION 1974

	TONS NI CONTENT
CANADA	299,576
U.S.S.R.	134,444
New CALEDONIA	150,781
AUSTRALIA	46,556
CUBA	35,264
DOMINICAN REP.	34,382
WORLD:	287,051

SAI-3418

Figure 2-23. Supply and Demand for Nickel 1973 - 2000 grade laterites are small. Assuming that low grade laterites and gabbro in the United States will be economic sources of nickel, world supplies should be adequate to meet total projected world demand to the turn of the century at least.

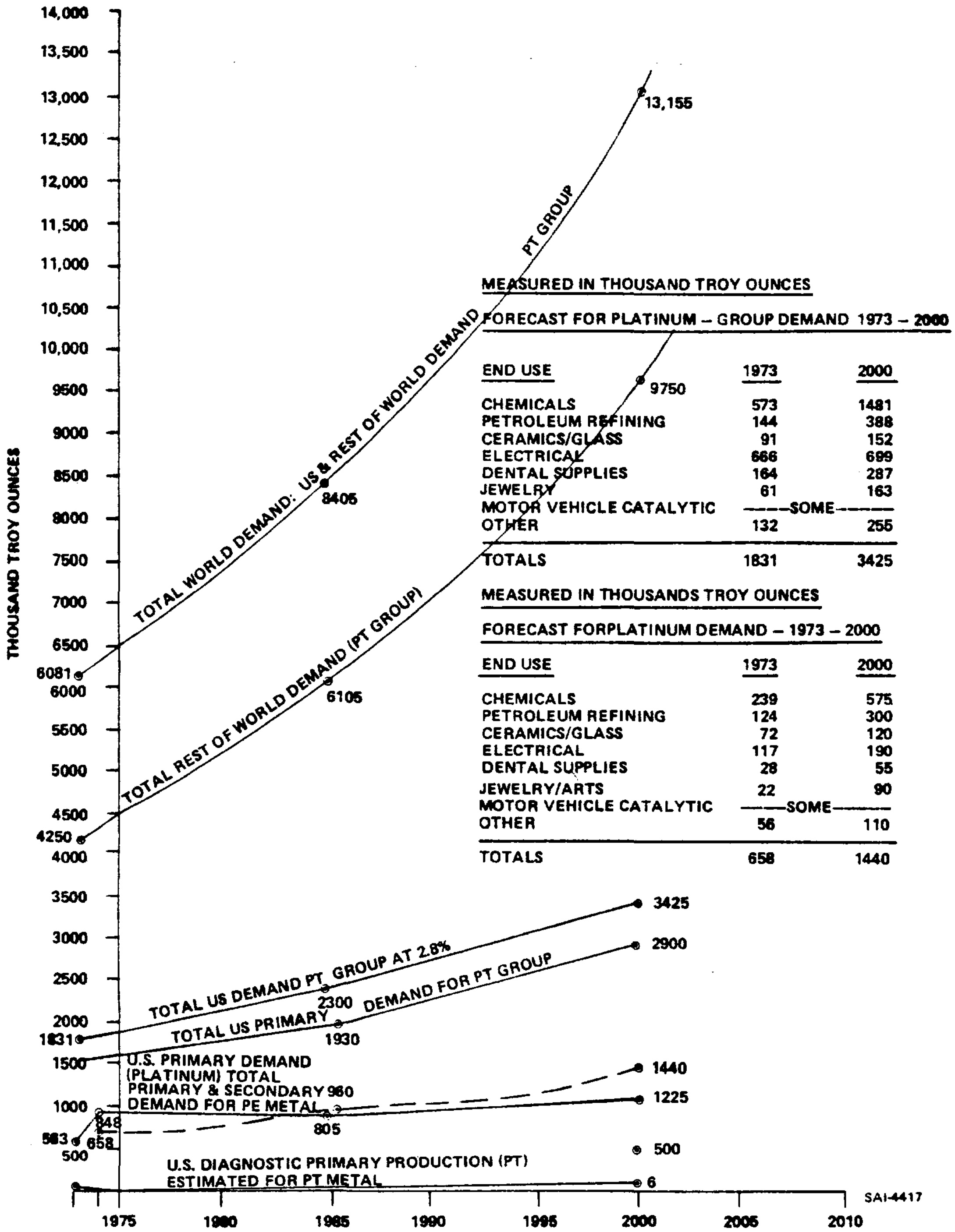
U.S. domestic supply has been projected in Figure 2-23 on the basis of the present ratio of domestic supply to total U.S. demand. Most of the future supply for the United States will, as in the past, come from imports. Although expansion of U.S. domestic supply will involve unusual economic, social and environmental costs, that is probably not the case for nickel supplies elsewhere in the world.

Availability and price stability for nickel in the future will tend to be helped by a number of new techniques and the use of larger-scale processing equipment. As lower grades of ore are mined by more automated methods, sophisticated control of ore blending can be expected. Such smelting techniques as electric furnaces presently used in the iron and steel industry are likely to be applied to nickel. New processes to recover more byproducts (such as cobalt) from laterites and to process scrap nickel alloys can be expected, including pressure leaching, hydro- and vapor- metallurgical innovations at higher temperatures and pressures. Ocean nodules will be an important new source pending resolution of major issues mentioned before. Many of these innovations will be hastened by the need to minimize air and water pollution.

2.1.3.11 Platinum Group Metals

Strictly speaking, these include only osmium, iridium, and platinum; we shall also include ruthenium, rhodium, and palladium in this discussion. Platinum and palladium are economically the most important of these metals.

Forecasts in Figure 2-24 are based on Department of Interior estimates; these are subject to major uncertainties, as consumption of these metals has correlated very poorly in the past with such economic indices as population growth, GNP, or the Federal Reserve Board Index of Industrial Production. The forecasts were thus based on past trends, with ranges based on contingencies for major end uses. The future use of platinum/



MEASURED IN THOUSAND TROY OUNCES

FORECAST FOR PLATINUM – GROUP DEMAND 1973 – 2000

END USE	1973	2000
CHEMICALS	573	1481
PETROLEUM REFINING	144	388
CERAMICS/GLASS	91	152
ELECTRICAL	666	699
DENTAL SUPPLIES	164	287
JEWELRY	61	163
MOTOR VEHICLE CATALYTIC	SOME	SOME
OTHER	132	255
TOTALS	1831	3425

MEASURED IN THOUSANDS TROY OUNCES

FORECAST FORPLATINUM DEMAND – 1973 – 2000

END USE	1973	2000
CHEMICALS	239	575
PETROLEUM REFINING	124	300
CERAMICS/GLASS	72	120
ELECTRICAL	117	190
DENTAL SUPPLIES	28	55
JEWELRY/ARTS	22	90
MOTOR VEHICLE CATALYTIC	SOME	SOME
OTHER	56	110
TOTALS	658	1440

Figure 2-24.Supply and Demand for Platinum Group Metals

palladium catalytic converters in automobiles will depend on the availability of replacement technologies and on the final shape of automobile emission standards.

South African producers control the world price of platinum while the U.S.S.R. controls the price of palladium. Prices climbed steadily until the mid-1970's when still sharper increases occurred. Iridium and osmium prices have fluctuated widely.

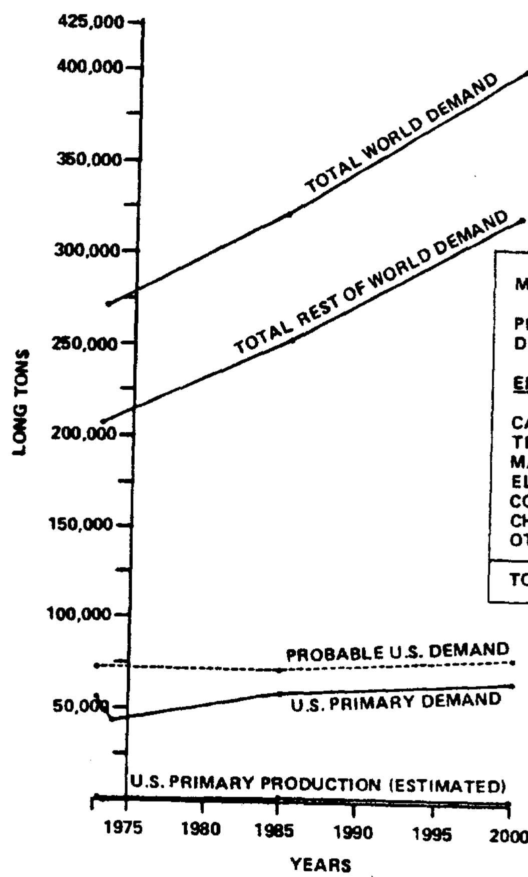
Currently known world resources are about two to three times estimated reserves, and are about seven times greater than cumulative demand expected up to 2000. U.S. domestic reserves are only about one million troy ounces, but resources total 210 million troy ounces. The Stillwater Complex in Montana may add to reserves. Most platinum used in the United States is recycled or imported, with 44% of platinum demand supplied by imports from South Africa; 51% of palladium demand is supplied by imports from the U.S.S.R. This pattern is expected to continue, although increased copper refining is likely to provide a slight increase in platinum production as a byproduct. A small amount of primary platinum is also produced in Alaska by hydrometallurgy and electrochemical methods from placers.

Advances in hydrometallurgy, electrowinning, and in situ leaching techniques could add low grade ores to U.S. reserves. If recovery from fission reactor radioactive wastes becomes legally and economically possible, fission-product nuclides may provide some palladium, rhodium, and ruthenium.

2.1.3.12 Tin

Projections of demand for tin are shown in Figure 2-25. These are based on end uses whose trends were projected on the basis of the most appropriate economic indices from the previous ten years' experience, with contingencies estimated to obtain ranges. Outside the United States, a larger fraction of tin demand is used for tinplate than is the case for the U.S.

World reserves appear to be sufficient to meet cumulative demand to 2000. Malaysia is presently the largest producer. The International Tin



MEASURED IN LONG TONS

PROJECTION FOR PROBABLE U.S. TIN DEMAND: 1973 TO 2000

END USE	1973	2000
CANS & CONTAINERS	20800	26000
TRANSPORTATION	9400	9000
MACHINERY	7500	9000
ELECTRICAL	11500	12000
CONSTRUCTION	9500	9000
CHEMICALS	4800	12000
OTHER	2400	3000
TOTALS	65900	80000

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Figure 2-25. Supply and Demand for Tin 1973 - 2000

Council sets floor and ceiling prices between producer and consumer nations, balancing long term production and consumption by buffer stocks and export controls. Prices are quoted on three markets: Penang, Malaysia; London LME; and New York. In the long run, Indonesia and Thailand could replace Malaysia as the largest tin producers.

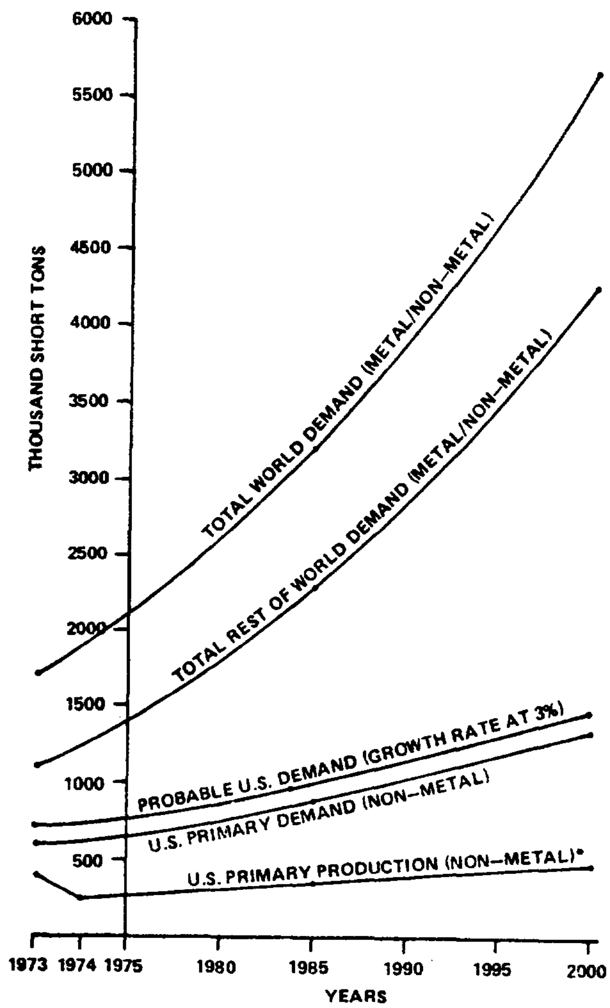
U. S. demand is 50,000 tons per year at the present time. Total domestic reserves are only 42,000 tons, with only 200 tons produced per year. Tin shipped from the Far East takes two months of travel time via three routes. U.S. Production will remain negligible. About 20% of U.S. demand is supplied by secondary sources (drosses, dust, and detinning of steel) and this ratio can be expected to remain unchanged. The remainder must be imported from traditional sources.

Improvements in mining techniques and increased recovery of tin from the slimes in beneficiation would have major impact on production and world reserves.

2.1.3.13 Titanium

While titanium metal has excellent metallurgical properties, about 95% of titanium consumed at present in the United States is for non-metal uses, nearly half going into paints as titanium oxide pigment. Demand based on anticipated end use projections is shown in Figure 2-26. As standards of living improve in the rest of the world, greater use of pigments can be expected, leading to more rapid growth of demand abroad than in the United States (except for use as a metal).

World reserves are estimated at 375 million tons of titanium, well above the anticipated cumulative demand beyond the turn of the century. Prices were relatively stable until 1973, when a jump of about 50% occurred. Economic and technological problems associated with environmental regulations are likely to make any large scale expansion of U.S. production unattractive, and the same factors apply to some other countries as well. Rutile pigment and sponge metal are freely traded, but most ilmenite sources are captive. Because of severe environmental problems in mining and because of increased costs in mining low grade ilmenites, further price rises may be expected unless major innovations in extraction are developed.



MEASURED IN THOUSAND SHORT TONS

PROJECTIONS FOR PROBABLE U.S. TITANIUM DEMAND: 1973 TO 2000

END USE	1973	2000
METAL		
TRANSPORTATION EQUIP.	26	60
FABRICATED METAL PRODUCTS	4	10
NON METAL:		
PAINTS	312	700
PAPER PRODUCTS	137	400
PLASTICS	58	140
RUBBER PRODUCTS	22	12
CERAMIC/GLASS	17	50
FLUXES	12	20
OTHER	57	58
TOTALS	645	1450

SAI-3422

*DOMESTIC PRIMARY METAL PRODUCTION ESTIMATED TO BE ZERO.

Figure 2-26. Supply and Demand for Titanium (Primary/Secondary: Metal/Non-Metal) 1973 - 2000

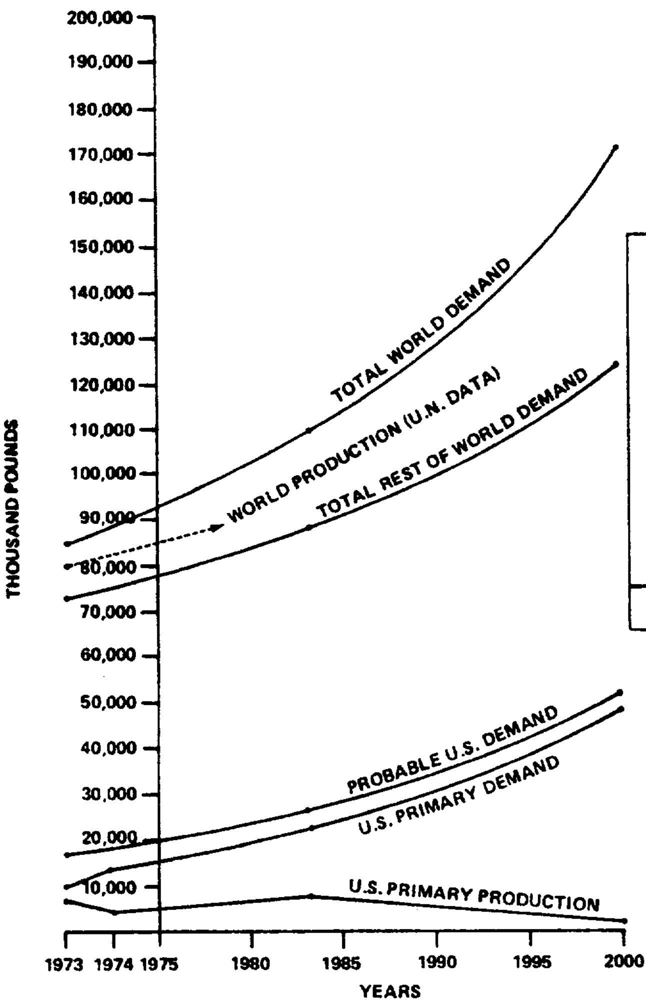
Pigment and sponge metal are presently imported from Japan, the U.S.S.R., and the United Kingdom. Imports will increase, probably from Australia, Canada, and Norway for non-metal uses. Some metal will be recovered from scrap. By the year 2000, the U.S. may supply about one-third of its own titanium requirements. Titanium oxide in 85 to 90% concentrates is presently extracted by flotation from a massive titaniferous iron deposit in the United States. Large capital investments are needed for production plants, inhibiting large scale expansion of the domestic industry.

Biocidal solutions of ferrous sulphate are generated as wastes, so that mounting waste disposal costs appear to be the rule for future U.S. production facilities. Domestic resources must become reserves beyond 2000, if the U.S. is to continue to supply a significant part of its titanium requirements. Development of a process to produce synthetic rutile directly from ilmenite by chlorination will be a necessary step.

2.1.3.14 Tungsten

Tungsten is indispensible in some alloys used in metal cutting and shaping operations where hardness and abrasion retention are very important. Figure 2-27 shows projected demand based on modified steels used for particular purposes. Some substitution by titanium, tantalum carbide, or aluminum oxide ceramics is possible at present, but is not a major factor in meeting the demands projected. Demand in developing countries is expected to grow somewhat faster than in the United States.

Major producing countries for tungsten are the U.S.S.R., China, the United States, Bolivia, North Korea, South Korea, Australia, Canada, Thailand, Peru, and Portugal. Prices are expected to increase further unless improved extraction processes can be developed to reduce costs. New electrolysis and molten processes, however, hold promise, and more efficient recovery of low grade ores is anticipated in the U.S. Improvements in high temperature alloy properties of tungsten will increase demand, while increased recovery of tungsten from scrap will reduce primary demand. In recent years, large releases of U.S. tungsten stockpiles and sales at the Canton (China) trade fair have heavily influenced tungsten prices. The world price in 1975 was about $5.24 per pound.



MEASURED IN THOUSAND POUNDS

PROJECTIONS FOR PROBABLE U.S. TUNGSTEN DEMAND: 1973 TO 2000

END USE	1973	2000
MACHINERY:		
METALWORKING MACH.	8080	31000
CONST./MINING MACH.	2840	9000
TRANSPORTATION		5000
LAMPS	1076	2100
ELECTRICAL	615	2100
CHEMICALS	460	1350
OTHER	470	1250
TOTALS	13541	51800

SAI-3423

Figure 2-27. Supply and Demand for Tungsten 1973 - 2000

U. S. domestic reserves of tungsten are about 240 million pounds, and known resources total about 960 million pounds. About 125 million pounds of the resources would become economically recoverable reserves if the price rose to about $6.50 per pound, and the remainder would become recoverable at prices above $10 per pound with present technologies.

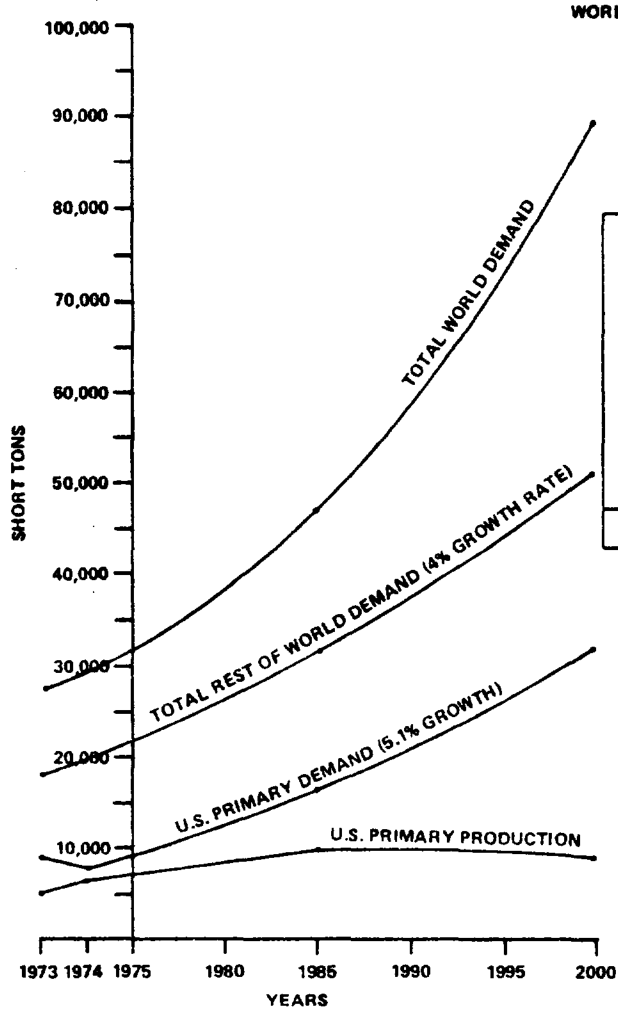
Domestic production now supplies 48% of U. S. primary demand for tungsten. Projections of tungsten supply included consideration of production capacity and reserves of the principal U. S. producers. Imports will likely increase in importance, especially when government stockpiles are either depleted or no longer released. Most of the domestic supply comes from hydrometallurgical techniques which product APT (ammonium paratungstate) from which recovery of tungsten metal averages 90%. About 10% of domestic tungsten is obtained as a coproduct of molybdenum operations. Prices and substitution are both likely to increase as demand puts pressure on tungsten reserves, especially after 1990.

New extraction technologies are needed to keep prices reasonable. Environmental degradation from tungsten mining and processing is minimal, and air pollution is easily controlled.

2.1.3.15 Vanadium

Vanadium is used in special-purpose alloys, especially in construction equipment and metal-working tools. Projected demand is shown in Figure 2-28, based on anticipated end-uses with consideration of contingency factors.

World reserves can cover projected demand beyond 2000. Major producers include South Africa, the United States, the U.S.S.R., Finland, Namibia, and Norway. Vanadium is commonly a coproduct or byproduct of uranium mining, with a variety of extraction processes including ion exchange and solvent extraction. South Africa, the U.S.S.R., and Chile export vanadium slag. In the U. S., only one open-pit operation is based solely on vanadium production from ores yielding 1% V_2O_5. In uranium-vanadium production, radiation and toxicity are major mine problems. Vanadium also occurs as a coproduct of phosphorus.



WORLD PRODUCTION (1974): METRIC TONS

U.S.A.	4418
U.S.S.R.	3900
SOUTH AFRICA	8401
FINLAND	1484
NAMIBIA	819
NORWAY	780
WORLD:	20180 = 22238.4 SHORT TONS

MEASURED IN SHORT TONS

PROJECTIONS FOR PROBABLE U.S. VANADIUM DEMAND: 1973 TO 2000

END USE	1973	2000
CONSTRUCTION	1370	6800
MACHINERY		
CONST. EQUIPMENT	1073	3500
METAL WORKING TOOLS	1211	4000
TRANSPORTATION	2208	9500
CHEMICALS	533	1100
OTHER	2154	8100
TOTALS	8549	33000

SAI-3431

Figure 2-28. Supply and Demand for Vanadium 1973 - 2000

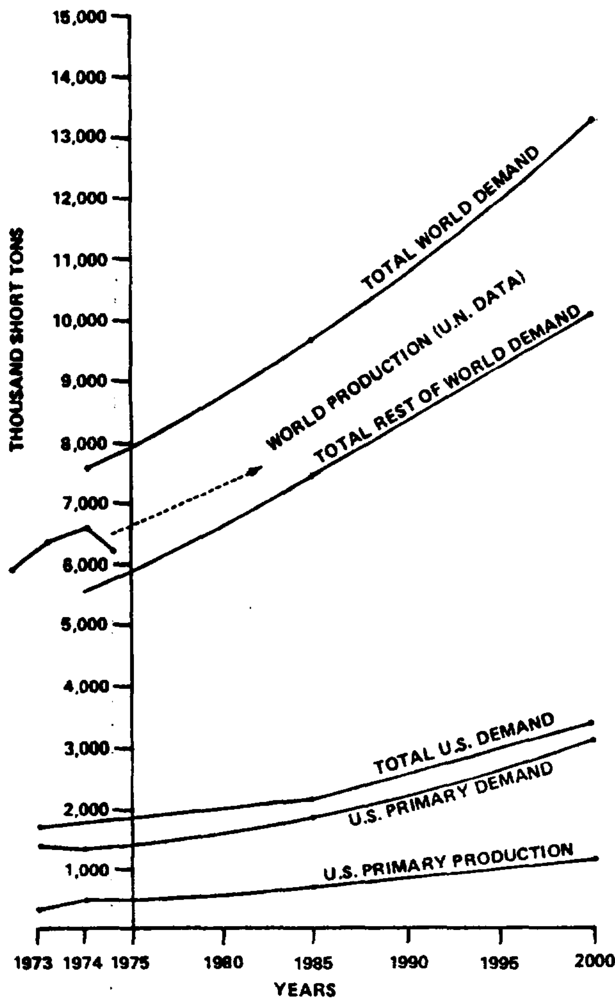
Domestic supplies presently meet about 64% of U. S. demand. Present reserves which can be mined solely for vanadium amount to 30,000 tons, while total resources are about 10 million tons. An additional 85,000 tons of reserves can be produced as a coproduct with uranium or phosphorus. Imports are expected to increase, however, since demand will increase faster than coproducts are mined, unless new technologies make processing easier and cheaper. The availability of vanadium slag from abroad discourages expansion of domestic production. South Africa and the U.S.S.R. are expected to supply the bulk of future imports either as slag or as ferroalloys. Additional vanadium imports will be supplied by Finland (as V_2O_5) and Norway (as ferrovanadium).

Increased substitution is likely in the United States. Tungsten, molybdenum, and columbium alloys are competitive, but relative costs will be decisive. Canadian sources may include tar sands and ilmenite and magnetite deposits in Quebec. Potential new sources of vanadium include high sulfur/vanadium petroleum processing, titaniferous magnetites, shales, some beach sand deposits, and oil/tar residues, all of which could significantly extend world supplies. Scrap recovery may later become significant.

2.1.3.16 Zinc

Projected demand for zinc is shown in Figure 2-29, based on industrial end-uses. Expanded use of zinc in galvanized products would result in a high forecast, while extensive substitutions (which are possible) would result in a low forecast. Demand in the rest of the world is expected to grow faster than in the United States, where demand for zinc correlates closely with economic activity including short-term fluctuations.

World reserves, currently about 149 million tons, fall short of cumulative demand expected by 2000; the same holds for U. S. reserves and U. S. cumulative demand. With technological changes and/or increased prices, other world resources would become reserves. Costs presently vary widely depending on type and grade of ore, byproducts extractable from the zinc ore, accessibility of the ore, and processing methods required. Sulfides are the most commonly produced commercial zinc minerals, ranging from 3 to 10% in zinc content. Concentrates usually contain 55 to 60% zinc, and



MEASURED IN THOUSAND SHORT TONS

PROJECTIONS FOR PROBABLE U.S. ZINC DEMAND: 1973 TO 2000

END USE	1973	2000
METAL:		
CONSTRUCTION	533	1100
TRANSPORTATION	367	500
ELECTRICAL	180	500
MACHINERY	140	300
OTHER	185	350
NON METAL:		
PAINT	37	60
CHEMICALS	60	150
RUBBER PRODUCTS	130	200
OTHER	17	40
TOTALS	1649	3200

SAI-3432

Figure 2-29. Supply and Demand for Zinc (Primary/Secondary: Non Metal) 1973 - 2000 are relatively costly to process, with significant environmental problems with effluents and processing wastes.

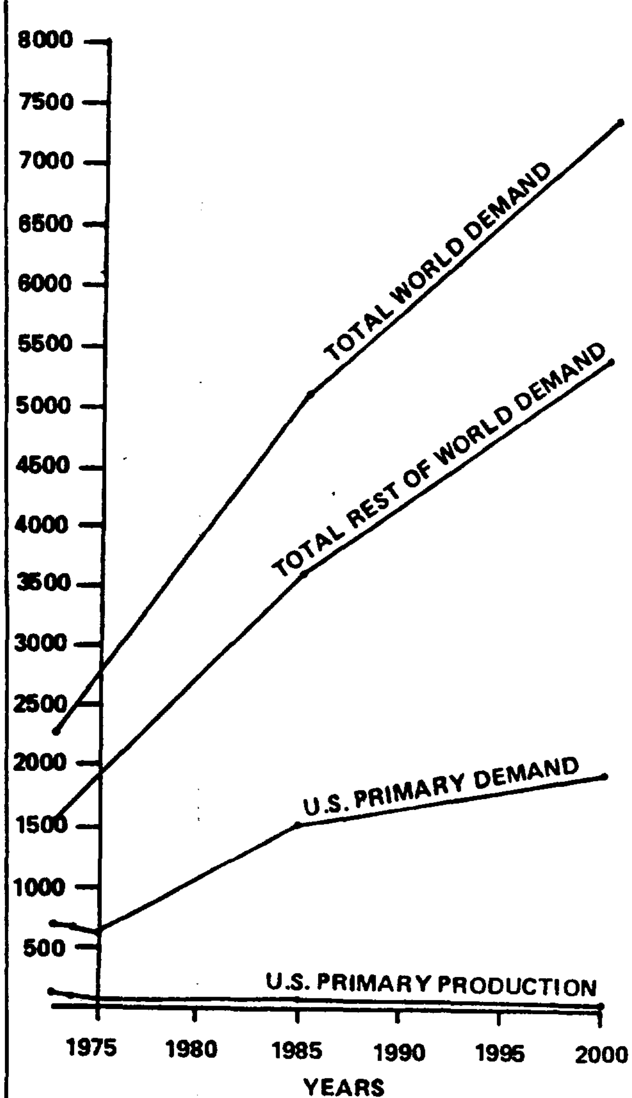
Leading zinc producers are Canada (20%), the U.S.S.R. (12%), the United States and Australia (8% each), and Peru (7%). Major producers of refined zinc metal are Japan (16%), the U.S.S.R. (13%), the U. S. (9%), Canada (8%), and Australia (5%). Smelter production has declined by half in the U. S. in the last ten years, while it has increased in all the other leading metal-producing countries. The costs of large environmentally acceptable smelters will be a key factor in expansion of U. S. capacity.

More than half of the U. S. zinc supply is imported, mainly in the form of zinc metal from Canada, Mexico, and Peru, since domestic smelter capacity is inadequate. Domestic mines produce 20 to 50% of U. S. demand. Should demand increase sufficiently and zinc prices rise, reserves in Tennessee and Missouri may be developed. Secondary recovery will also increase as more incentives are available. Zinc casting technology has improved, and newly developed alloys will require more zinc. As costs rise, increased automation can be expected, with pressure leaching, electrowinning, and co-production with sulfur likely to be emphasized.

2.1.3.17 Fluorine

Fluorine is used extensively as a flux in steelmaking, as an electrolytic flux compound in smelting alumina, and in uranium enrichment by gaseous diffusion. Fluorine is also used in a large number of industrial chemical compounds for which no substitutes presently exist. The use of fluorochlorocarbons (CFC's) as aerosol propellants is expected to decrease sharply because of suspected environmental effects (possible depletion of stratospheric ozone) leading to legislative bans. Projected demand is shown in Figure 2-30, based on contingency analysis of technological, economic, and social factors. (Chemical demand, for example, will likely grow in step with GNP.) Aggregate U. S. demand should almost triple by 2000.

The present situation globally is one of oversupply, principally in the form of producers' stockpiles. North American production capacity in 1975 totalled about 1.1 million tons of acid-spar per year; Western Europe, 900,000 tons per year; Africa, 450,000 tons per year; and other



PROJECTIONS & FORECASTS FOR U.S. FLUORINE DEMAND BY END USE 1973–2000

(THOUSANDS SHORT TONS FLUORINE CONTENT)

END USE	1973	2000
CHEMICALS	237	750
IRON & STEEL PRODUCTS (FLUX)	293	700
NONFERROUS METAL PRODUCTION	153	400
CERAMICS & GLASS	9	10
IRON & STEEL FOUNDRIES	19	40
OTHER	6	40
TOTALS	717	1940

SAI-3413

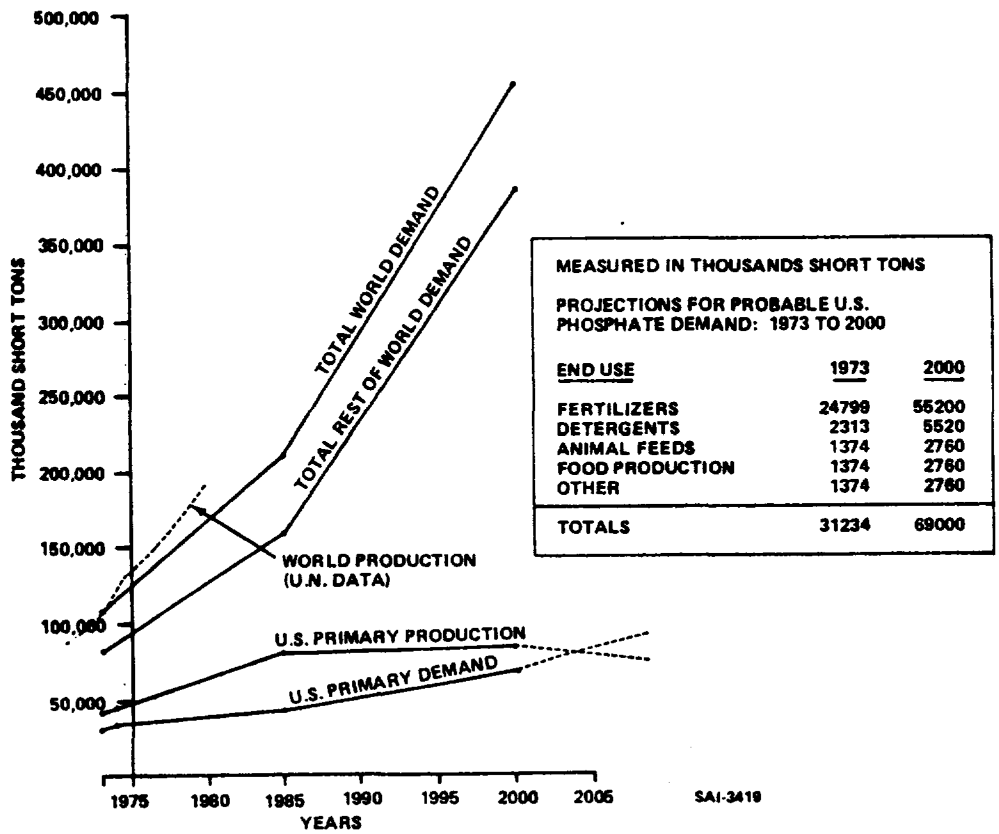
Figure 2-30. Supply and Demand for Fluorine 2973 - 2000 industrially developed nations about 150,000 tons per year. U. S. capacity is about 350,000 tons per year and could be increased by 200,000 tons per year additional if prices remained high and stable.

Argentina, Brazil, Kenya, Tunisia, Morocco, Southern Rhodesia, Thailand, Mongolia, and China export most of their output, while the United States, the U.S.S.R., Canada, and Japan depend largely on imports. About 85% of U. S. supply is imported, most of it from Mexico, with additional significant amounts from Italy and Spain. The phosphate rock industry in Florida is recovering more of the fluorosilicic acid used at wet-process phosphoric acid plants by installation of recovery circuits. Both the steel and aluminum industries are experimenting with methods of reducing the amount of fluorine used as flux. The steel industry is also experimenting with possible substitutes because of fluorine toxicity and to reduce their production costs. Recovery and recycling of fluorine in these metallurgical applications are of minor importance economically and environmentally.

2.1.3.18 Phosphate

The largest end-use for phosphate is fertilizer. Figure 2-31 shows projected demand and projected U. S. supply, based on contingency analysis applied to population projections which are the principal determinant of phosphate demand, although demand could be significantly altered by agricultural innovations and greater efficiency in the use and application of fertilizers.

World reserves of phosphate are large, but depletion of specific deposits toward the end of the century is likely to cause significant regional disruptions in supply until new areas can be opened up. Shallow open pit operations may have to be supplemented by the development of deep deposits. New beneficiation techniques are needed for lower-grade deposits and for carbonate rocks, such as occur in Florida and the Western states of the United States. Direct acidulation of concentrates or of matrix rocks by hydrochloric acid or sulfuric acid show technological promise of reduced wastes and improved yields. North Africa, the U.S.S.R., Australia, the Middle East, and Peru all have potential for development of new production. Improved recovery rates, of course, would extend the life of current operations.



MEASURED IN THOUSANDS SHORT TONS

PROJECTIONS FOR PROBABLE U.S. PHOSPHATE DEMAND: 1973 TO 2000

END USE	1973	2000
FERTILIZERS	24799	55200
DETERGENTS	2313	5520
ANIMAL FEEDS	1374	2760
FOOD PRODUCTION	1374	2760
OTHER	1374	2760
TOTALS	31234	69000

Figure 2-31. Supply and Demand for Phosphate 1973 - 2000

The U. S. phosphate industry produces enough fertilizer to allow substantial exports. About 45% of U. S. phosphate production is exported as phosphate rock, mixed fertilizer, or industrial chemicals. Principal sources are in Florida and Tennessee, but the industry is attempting to expand in Florida and North Carolina in the face of vigorous opposition by environmentalists demanding assurances of clean air, water reclamation, and sufficient water supplies to residents of nearby communities in view of past abuses in the industry. Phosphate reserves on public lands are under heavy environmental regulations, while a number of federal, state, and local agencies enforce environmental regulations fairly strictly, while air and water quality guidelines for the industry become progressively more stringent. New plants must comply with all environmental regulations, and mines and beneficiation plants cost about four times more than a decade ago. Capital has been scarce and more expensive. The domestic industry has, in addition, been plagued in recent years with power interruptions, accidents with draglines and at loading terminals, breakdowns at beneficiation plants, and a shortage of rail cars.

2.1.3.19 Summary

None of the minerals discussed above present the likelihood of critical exhaustion within the period addressed by this study. Because the newer population projections suggest slower population growth than was presented in the discussion above, on which many of these mineral demand projections were based, cumulative demand for all of these minerals is likely to be somewhat lower than suggested here. For many of the minerals discussed, prices (in constant dollars) have increased in recent years. In most cases, these price increases can be traced to increased energy costs due to political factors (the 1973 Arab-Israeli war, the Arab oil embargo of 1973-1974, and the strengthening of the OPEC cartel) more than to increased production costs associated with imminent depletion. Additional transient factors unrelated to progressive depletion of the minerals discussed included more stringent environmental regulations requiring more expensive pollution control equipment. Technological advances tending to reduce production costs could be foreseen for most of the minerals discussed. No mineral, however, appears to be so critical to the economy or so in danger of sudden depletion that we would be compelled to rapidly develop nonterrestrial sources for these minerals.

2.1.4 Agriculture

The adequacy of agricultural production in the face of population growth has been at issue since the appearance in 1798 of the first edition of Thomas Robert Malthus's essay on population growth. A simple reality generally overlooked by neo-Malthusians is that agricultural production around the world has more than kept pace with population growth since World War II, although the population has more than doubled, with little or no evidence of an increase in relative costs. Much of the period, in fact, was characterized by large surpluses of grains especially in the developed countries.

A recent study of world food problems shows that no nation today lacks sufficient resources to be completely self-sufficient in food production.(4) The key to eliminating the malnutrition and occasional famines seen in Third World countries lies in social and political reforms to provide social justice for the small farmer who is almost always more productive per acre than the large farmer who is often an absentee landlord. The necessary reforms have been implemented in South Korea, Taiwan, and China in recent decades, with dramatic results. A change in emphasis from cash crops for export to food production for domestic consumption would also have major economic benefits for most of the countries suffering from inadequate food supplies.

Improvements in food storage techniques can also extend current production significantly at very low cost. Up to 40% of India's annual grain production is lost to vermin (principally rats and mice). The nutrient values of many foods deteriorate when inappropriate storage methods are used or proper methods are applied incorrectly. The potential for improvement in these areas for many of the poorer nations of the world cannot be ignored in discussions of population and food issues. Much can be done using simple technologies and minimal investment.

In the discussion below, projections for three major grains (corn,

(4)Frances Moore Lappé and Joseph Collins, *Food First!*, Houghton-Mifflin, New York, 1977.

rice, and wheat) and for two major meat animals (cattle and pigs) will be discussed. These projections are based on relatively simple-minded trend analyses, rather than carefully correlated with population growth, national income per capita forecasts, and trends toward less clement weather conditions than were experienced in the 1930's through 1950's. All of these are based on the older figures for population growth which are now believed to be too high.

2.1.4.1 Corn

The United States produces the bulk of current world corn production. Although higher growth rates are expected among other nations than for the U. S., the U. S. will remain the largest corn-producing nation until well into the next century. Corn production is forecast in Figure 2-32. Total world production is expected to double by 2000, with 2.4 times the present output by 2005. Lower rates of population growth would result in a decline in the slopes of the growth curves shown.

Growth rates in the rest of the world are likely to exceed the growth rate for U. S. corn production. For greater accuracy, corn production should be correlated with GNP or with per capita income across intervals reflecting differences in farm technology and national progress. Table 2-4 shows corn output projected if linear trends were feasible.

TABLE 2-4. CORN OUTPUT PROJECTIONS

Group of nations	Millions of metric tons of corn			
	1974	1990	2000	2005
United States	118	205	250	272
23 developed nations (excluding U. S.)	58	132	172	200
29 emerging nations	79	117	138	145
Rest of the world (including the U.S.S.R.)	38	64	79	85
Totals	293	518	639	702

2.1.4.2 Rice

Figure 2-33 and Table 2-5 show rice production trends and projections

THOUSANDS OF METRIC TONS

	61–65 AVERAGE	1968	1971	1974
23 DEVELOPED NATIONS (INCLUDING U.S.A.)	128,520	154,106	193,101	175,950
29 EMERGINGNATIONS*	53,631	65,225	74,902	78,624
U.S.S.R.	13,122	8,828	8,597	12,104
REST OF WORLD	20,829	24,123	28,936	26,865

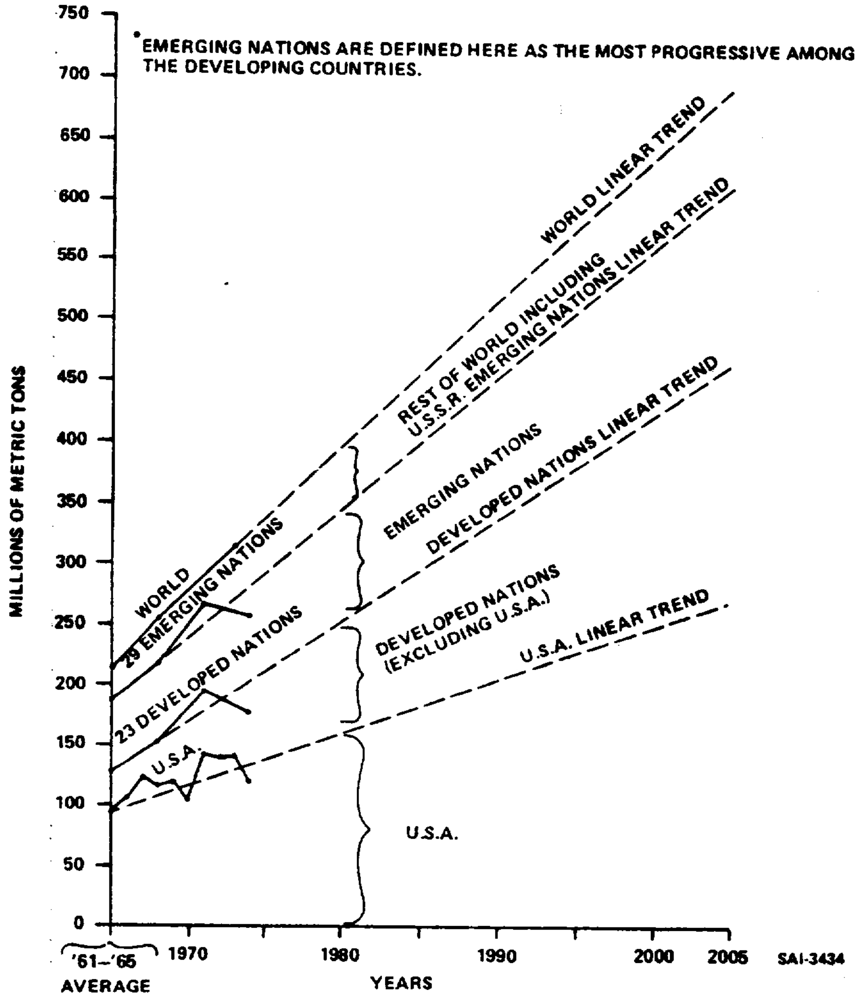


Figure 2-32. Maize (Corn) Crop Trends (Additive)

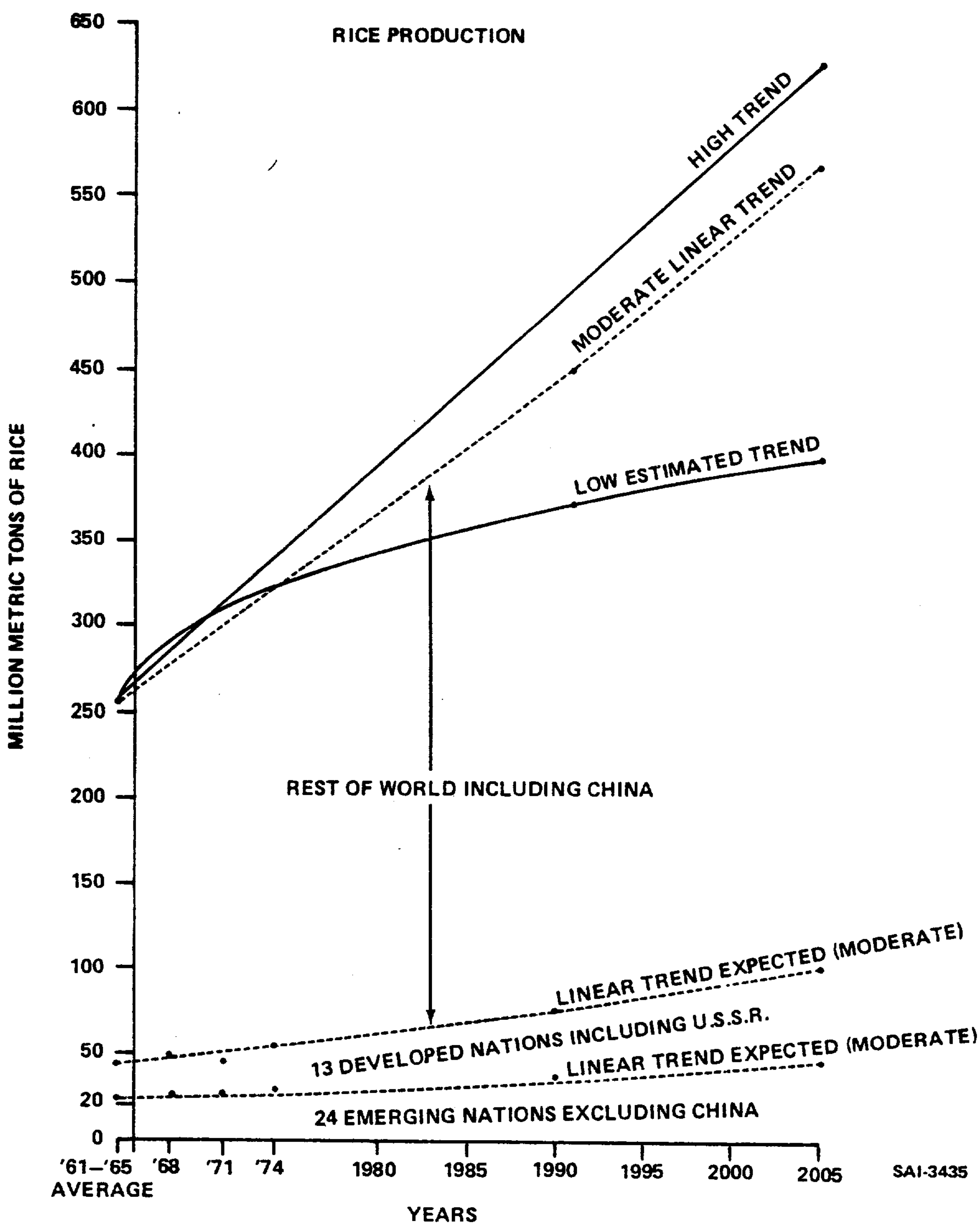


Figure 2-33. Rice Production Trends

based on simple extrapolation. The poorer nations will increase rice output at a much higher rate than either the emerging or the developed nations because of general climate conditions, their cultural tendency to use more rice per capita, and their greater needs in total. Traditional rice varieties require about 180 days in the rice paddy; newer strains developed in the "green revolution" require as little as 110 days, so that in the warmer climates three crops per year could be grown given sufficient irrigation water year-round. The more developed nations are unlikely to increase production much above 90 million metric tons by 2005, although total world output of rice should more than double.

TABLE 2-5. RICE OUTPUT PROJECTIONS

Group of nations	Millions of metric tons of rice					
	Average 1961-65	1968	1971	1974	Projected 1990	2005
24 emerging nations (excluding China)	21.8	24.0	26.7	20.5	37.5	44.0
13 developed nations (including U.S.S.R.)	21.6	26.3	21.6	25.0	34.5	47.0
Rest of the world	209.9	236.2	260.7	267.2	378.0	478.0
Totals	253.2	286.5	309.0	321.7	450.0	568.0

2.1.4.3 Wheat

Figure 2-34 shows possible trends in wheat production. Output during the 1970's increased at surprisingly low rates due to poor weather conditions. Assuming linear trends at moderate growth rates, however, output would grow as shown in Table 2-6. Although output should increase at higher rates in the emerging countries and in the rest of the world than in the developed nations, this latter group will still contribute about 60% of the total world output, compared to 69% in 1974.

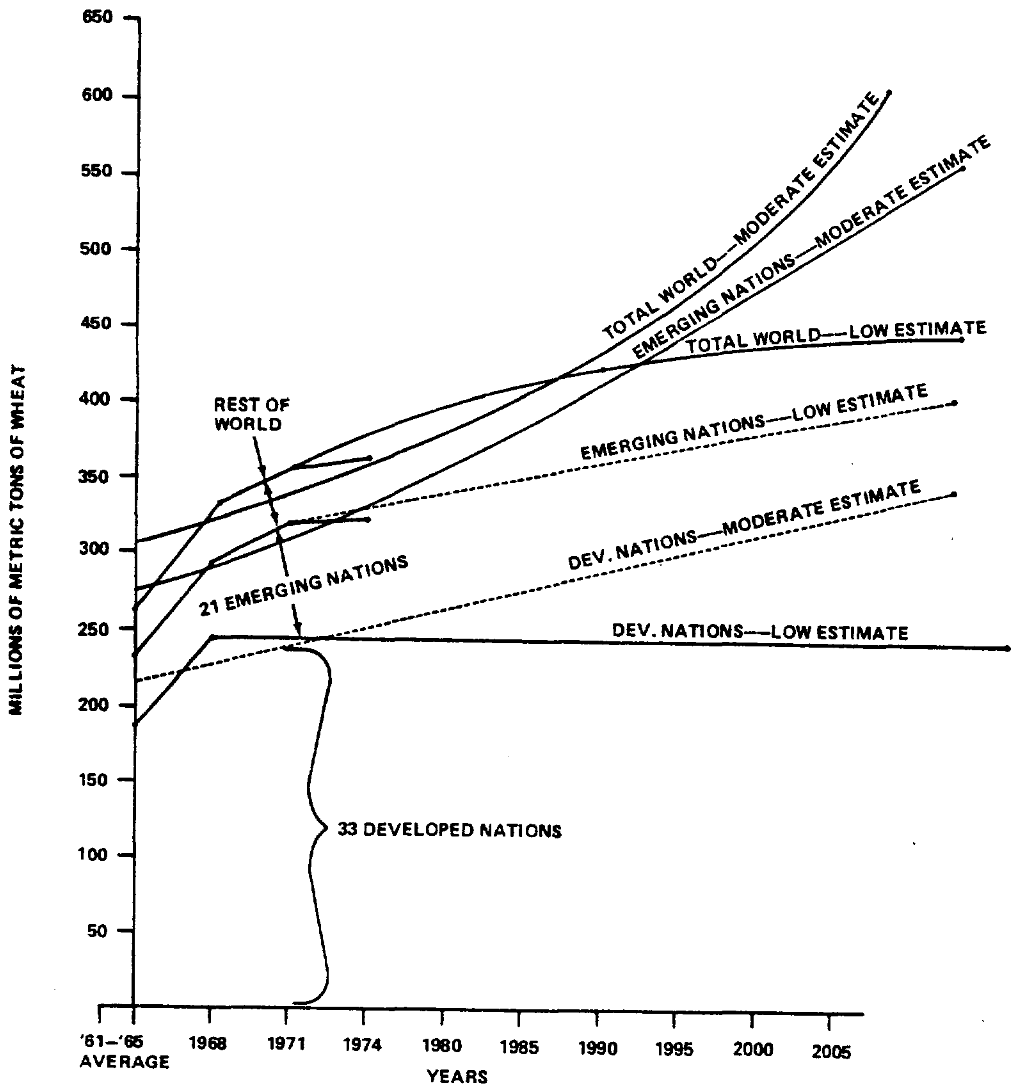


Figure 2-34. Wheat Production Trends

TABLE 2-6. WHEAT OUTPUT PROJECTIONS

Group of nations	Millions of metric tons of wheat Average 1961-65	1968	1971	1974	Projected 1990	2005
33 developed nations (including U.S.S.R. and Eastern Europe	182.6	246.6	249.6	249.9	315.0	370.0
21 emerging nations (including China)	47.3	55.4	65.3	70.9	105.0	135.0
Rest of the world	24.6	28.4	39.2	39.1	58.0	75.0
Totals	254.4	331.5	354.1	359.8	478.0	580.0

2.1.4.4 Cattle

Figure 2-35 shows cattle raising trends and projections. The developed and the emerging nations show obvious exponential growth trends which may be tempered into more nearly linear growth trends. World totals were too volatile in recent years (due to droughts and other fluctuations) to indicate any clear trend. Medium growth trends are shown in Table 2-7. The emerging nations show a slightly greater rate of growth to feed population growth at rates higher than those in the developed nations.

TABLE 2-7. CATTLE RAISING PROJECTIONS

Group of nations	Millions of cattle 1973	1900	2000	2010
25 developed nations (including U.S.; excluding U.S.S.R. for lack of data)	283	425	510	595
35 emerging nations	372	545	645	745
Rest of the world	397	---	---	---

2.1.4.5 Pigs

Figure 2-36 shows pig raising trends and projections. The developed nations have probably saturated per capita consumption of pork,

THOUSAND HEAD OF CATTLE

YEAR	1969	1970	1971	1972	1973
25 DEVELOPED NATIONS:	259,104	262,275	266,025	273,474	283,486
35 EMERGING NATIONS:	341,305	346,317	352,563	361,061	371,562
			1,111,003	633,795	1,051,865

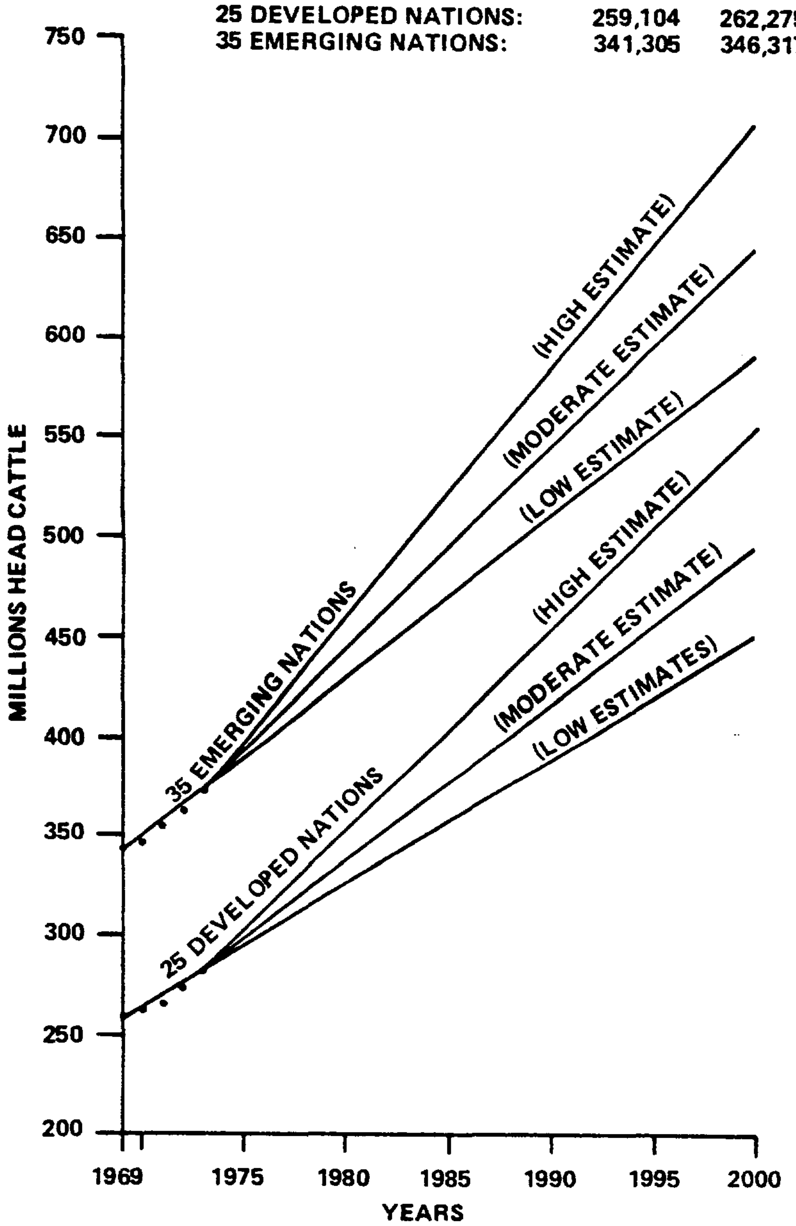


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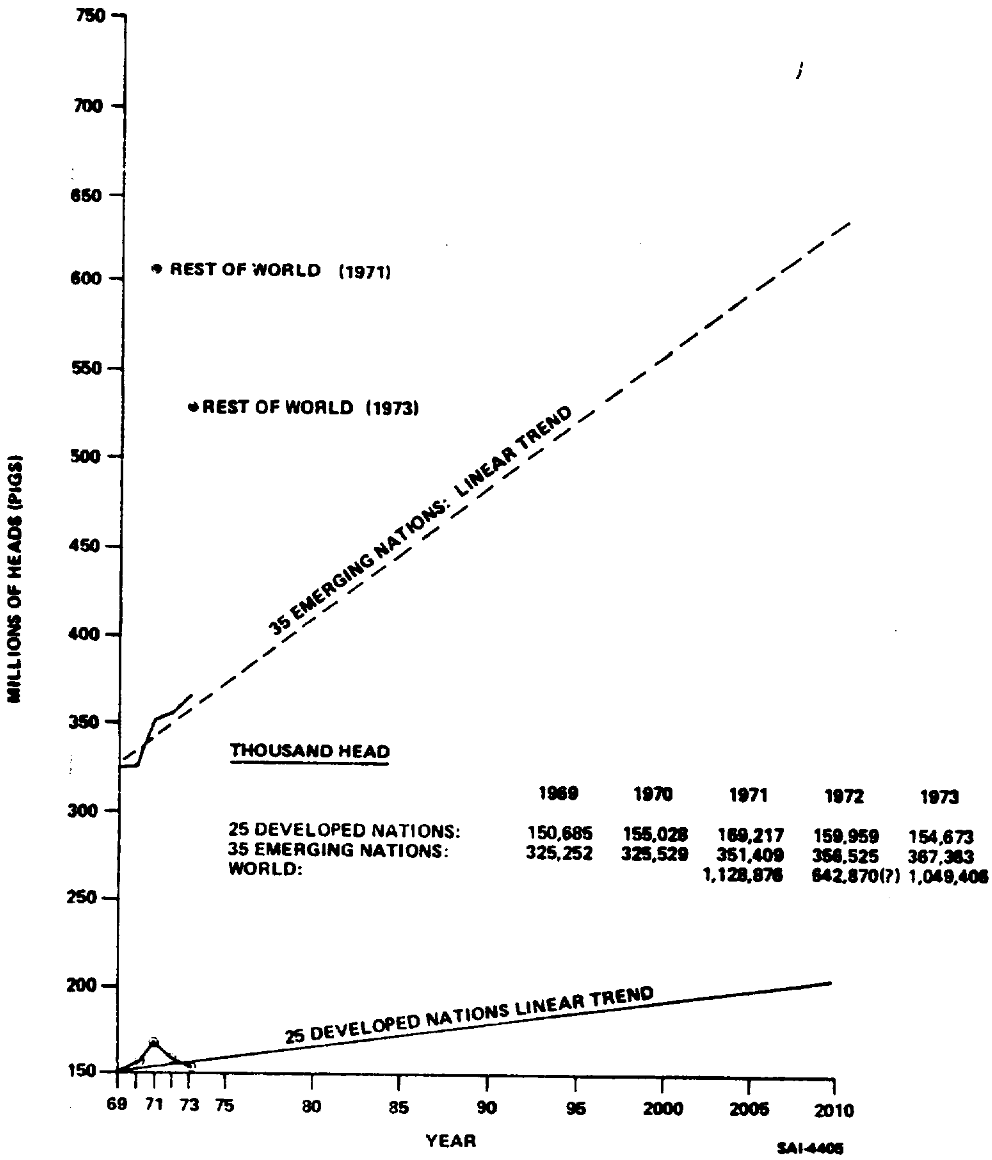
Figure 2-35. World Cattle Raising Trends



THOUSAND HEAD

	1969	1970	1971	1972	1973
25 DEVELOPED NATIONS:	150,685	155,028	169,217	159,959	154,673
35 EMERGING NATIONS:	325,252	325,529	351,409	356,525	367,383
WORLD:			1,128,876	642,870(?)	1,049,406

Figure 2-36. Current and Projected Pig Raising Trends

resulting in much lower growth rates for the developed nations than for the emerging nations. Data for the rest of the world does not show any definite trend in the short period sampled here. Longer term data should be used, with consideration of population growth rates, to formulate projections for these countries.

2.1.5 Conclusions

It does not appear, on the basis of our examination of energy, minerals, and food production issues over the period 1980 to 2010, that any of these will pose any critical threat to the survival of industrial civilization. The spectre of impending scarcities does not, therefore, provide a credible basis for the political support necessary to mount a major thrust into space at public expense on a crash program schedule. The importance of long-range solutions to the problems of energy supply, however, is clear in the discussion above. The economic value of energy and minerals imported from space may be significant and may provide sufficient motivations for Space Industrialization; these possibilities should not be dismissed lightly. But their justification, during the period of interest in this study, must be found elsewhere. "Limits to growth" cannot justify Space Industrialization during the next three or more decades.

2.2 BACKGROUND SCENARIOS FOR SPACE INDUSTRIALIZATION PROGRAMS, 1980 - 2010

2.2.1 Introduction

The evolution of the Space Industrialization system during the next few decades will be shaped in part by its own internal logic: once certain activities or systems approach maturity, additions to the system will be suggested by what already exists, so that "bootstrapping" will play an important role. Throughout these early stages of Space Industrialization, however, the rest of the human system and its terrestrial environment will continue to evolve as well, providing a continually changing context for Space Industrialization. The criteria which will define which activities are economically profitable and socially desirable (as well as technically feasible) will thus change throughout the period, and consideration must thus be given to this changing context.

An important task in this study of Space Industrialization has thus been the development of a set of background scenarios describing a range of alternative futures for the human system and its environment. We cannot *predict* the future, and none of our scenarios should be considered as attempts to predict what will happen. For the purposes of this study, we have defined a scenario as *a description of a plausible course of events in the human system and its environment beginning from the present (early 1977) state of the world,* extending out to about 2010. It would be most astonishing if the actual future closely approximated any one of our scenarios; we expect, however, that the actual course of events will include elements from most of the scenarios presented below, but the dates or locations for major events or for the emergence of new trends which we postulate in these scenarios can be little more than educated guesses.

From our examination of projected supply and demand for raw materials, for energy, and for major grains and meats, we have concluded that there will be no shortages in the next three decades or more of a kind which would *require* us to go into space just to survive. Based on these considerations and numerous historical analogies, it is most likely that the primary reasons for Space Industrialization activities during the early stages will be economic profitability in the short term, national prestige, political considerations (some resulting from pure human curiosity), and spin-offs from possible military programs. We thus view the present task as a form of contingency planning in which we have attempted to gain some insight into those conditions in the human system and its environment which would either encourage or discourage particular activities in space. This analysis allows us to identify *opportunities for the advocacy of particular space programs* within the specific contexts of a wide range of possible futures.

Possible futures have been the subject of numerous studies in recent years, and we have reviewed a number of these, including several studies made for the purpose of planning space programs. In many of these studies, if more than one scenario for the future is presented, the various alternatives are usually arranged in a linear progression from "pessimistic" to "optimistic". This approach, it seemed to us, was inadequate for our goals in this study. We have instead approached the generation of alternative scenarios by means of a morphological analysis. Our concern has been to identify those large scale aspects of the human system and its environment which have a direct connection to Space Industrialization and which would alter the mix of space development programs appropriate to each of the alternative futures. For the purposes of morphological analysis, such large scale aspects of the human system and its environment can be categorized into political, societal, economic, technological, environmental, and military factors. (The distinctions between these categories are admittedly somewhat arbitrary.)

2.2.2 Construction of Alternative Scenarios

We have selected a list of twelve events or developments which appear to have a reasonable chance of occurring in the next two or three decades and which would be likely to have major effects on the shape of the future. Arranged according to the morphological categories listed above, these "triggering" events or developments are as follows:

Political

Major advances in space by other nations
U. S. committment to space

Societal

Major breakthrough in human longevity
U. S. disenchantment with space

Economic

Entrepreneurial exploitation of space technologies
Artificial shortages of critical minerals
Economic collapse due to shortage of capital

Technological

Breakthrough in a new energy source
Breakthrough in artificial intelligence
Contact with extraterrestrial intelligence

Environmental

Human-generated ecological catastrophes
Rapid cooling of the Northern Hemisphere.

(By the ground rules ofthe study, military factors have been excluded from consideration as stimuli for Space Industrialization.) While this list is certainly not exhaustive, it appears to cover a diversity of possible futures.

Our approach to scenario generation has thus been to develop a baseline extrapolative scenario ("surprise-free") which does not include any of the above developments but accepts existing forecasts of population growth; economic indicators such as GNP, personal incomes, unemployment, and so forth; minerals supply and demand, and similar factors. Fleshing these out with social and political trends which have been evident for several years (at least), we obtained a basic scenario which contains no surprises.

For our alternative scenarios, we then assumed that the baseline scenario was modified by the addition of *one* of the above listed triggering events or developments and followed through, on the basis of our best understanding of how the human system works, the likely consequences of that trigger. Doing this in turn for each of the triggering events above would thus have produced twelve alternative scenarios in addition to the baseline scenario. Two of the developments, however, proved to be "bizarre" issues in the sense that their likely consequences will depend too strongly on unforeseeable details. These issues are a breakthrough in artificial intelligence and contact with extraterrestrial intelligence.

We thus obtained a family of eleven alternative scenarios for the future. Necessarily, the emphasis in all of these has been the United States, but we have attempted to incorporate as much understanding of other nations as we found credible among ourselves. We do not expect that macroeconomic factors which can be quantified (such as GNP, population growth, etc.) will vary enormously from one scenario to the next in most of these alternative futures. in a few cases, where major deviations might be expected, we will explicitly mention these.

The principal differences among these alternative futures with respect to Space Industrialization prospects lie in public perceptions of the most urgent policy issues at each moment and in personal lifestyle preferences, not in material needs. Since communications satellites are already commercially successful, it is not surprising that they appear to play a major role in all eleven scenarios.

The scenarios are presented in the following pages, with a brief discussion presenting some background information about the assumed triggering events or developments and, in some cases, about the results. The scenarios have been detailed in chart form, listing events and trends by morphological categories and in chronological sequence. A useful approach to reading these charts is to begin with the triggering events at the top of each chart, tracing down across morphological categories to see the effects shortly thereafter. Bear in mind that most of the events postulated in the baseline scenario also occur in most of the alternatives unless explicitly noted otherwise.

The scenarios are presented in the following order:

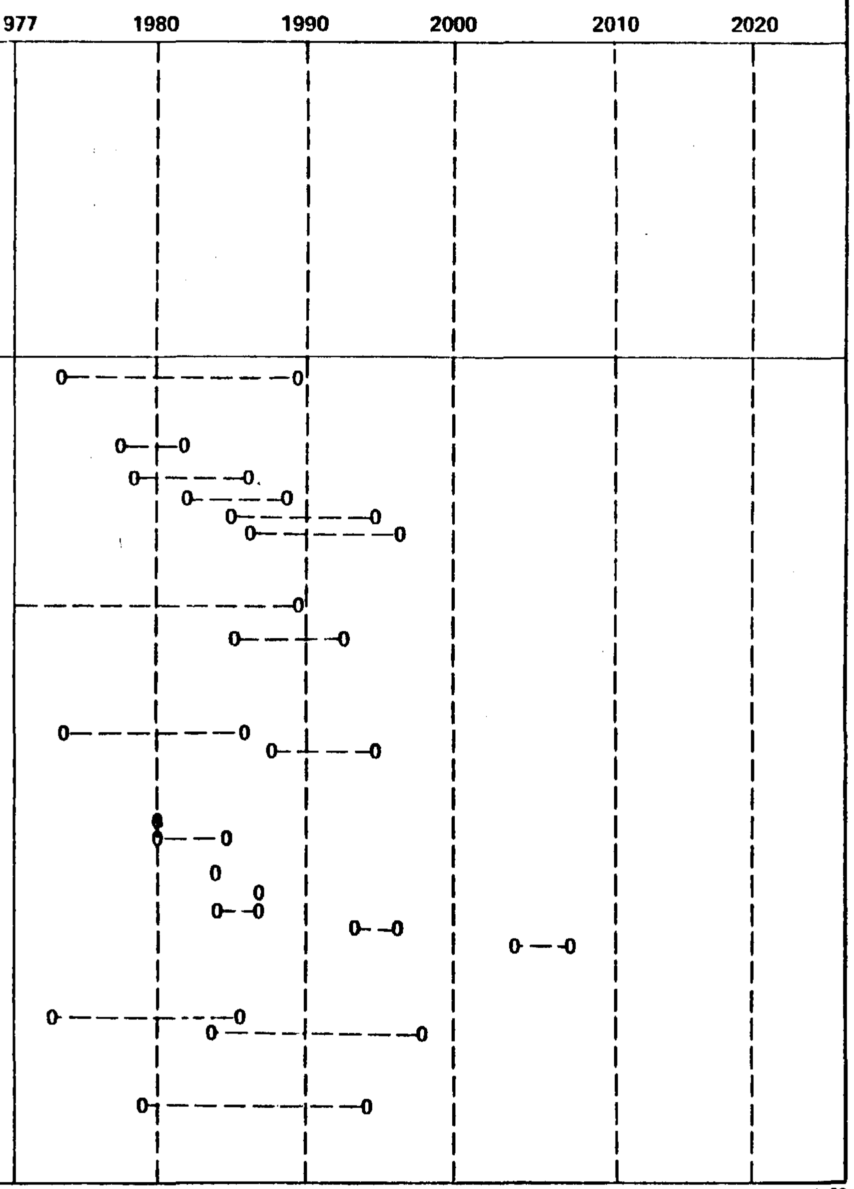
I. Baseline
II. Challenge of Foreign Space Advances
III. Committment to Space
IV. Longevity Breakthrough
V. Disenchantment with Space
VI. Space Entrepreneurs
VII. Shortages of Critical Minearls
VIII. Economic Collapse
IX. Energy Breakthrough
X. Ecological Catastrophes
XI. Cooling of the Northern Hemisphere

In each scenario, the factors which we believe will present the best opportunities for advocacy of specific space programs (or the greatest obstacles to advocates) are underlined. How these factors interact to push, pull, or resist space programs will be discussed in the next section.

2.2.2.1 Scenario I: Baseline

The basic premise of this scenario is that present trends continue essentially unchanged, and that federal and state governments continue to emphasize short-term (less than four years) programs and goals at the expense

I. BASELINE, "MUDDLE-THROUGH" SCENARIO



BASIC TRENDS THROUGHOUT PERIOD 1977 TO 2010

- Federal and state governments do little effective planning for more than four years ahead. Some moderately effective planning by business and industry up to 5 or 10 years ahead.
- Fraction of population over 65 years old increases steadily. Social Security and other welfare costs continue to climb faster than inflation.
- Demand for all forms of leisure-time activities continues to grow. Demand for more wilderness preserves and for recreational uses of public land grows rapidly. Increasing concern for clean environment, with special focus on possibly carcinogenic pollutants.
- Continued economic growth throughout the world. West Germany and Japan become economic "superpowers". World petroleum prices climb about evenly with inflation.
- Continued mixed attitudes toward technology in the industrialized countries. Steady growth of repair and maintenance services in the private sector.
- Continued US/USSR competition in all arenas. US and USSR defense budgets remain about constant in real purchasing power. Sporadic brushfire and civil wars in Third World nations. No nuclear holocaust despite the addition of one new member of the "nuclear weapons club" ever 3 – 6 years.

POLITICAL

- Increasing emphasis in Third World on agrarian and rural development; less emphasis on industries; more attention to development of mineral resources.
- National Health Care plan implemented in US, followed by regional emergency and trauma centers throughout the country.
- "Star Trek" generation become voters; growing public interest in space.
- Growing awareness of need for diversity in national energy sources.
- Increasing federal and state land use planning.
- Increasing polarization of economic/environmental/energy issues.

SOCIETAL

- Rural rennaissance ("back-to-the-land") movement grows in numbers and political importance.
- Urban core areas revitalized due to increasing energy costs; suburbs become less fashionable among middle class in US.

ECONOMIC

- Appalachian coal production stepped up until limited by scarcity of mine workers.
- Western coal strip-mining rapidly expanded.

TECHNOLOGICAL

- Space Shuttle's first orbital flight.
- Spacelab mateials processing epxeriments show a number of economically attractive possibilities.
- First VIP trip aboard Space Shuttle.
- Halley's Comet rendezvous mission stirs up public interest in space.
- USSR deploys major new space system.
- First pilot fusion powerplant.
- First commercial fusion powerplant; costs higher than for fossil fuel or fission powerplants.

ENVIRONMENTAL

- Increasing regulation of international shipping due to marine pollution incidents.
- Growing public awareness of environmental problems of coal mining and combustion.

MILITARY

- Increased R&D in strategic systems and space systems.

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of longer range planning. Thus tax laws and regulations encourage short-term views by business and industry as well. Some companies nonetheless manage to do some effective planning, up to perhaps ten years ahead.

As the elderly (over 65) population increases in numbers faster than the total population, Social Security costs, Medicare costs, and welfare costs escalate even faster than inflation. This trend is exacerbated by further liberalization of benefits and extension of benefits to more categories of people. Simultaneously, the growing numbers of the elderly, increasingly vigorous and healthy, stimulate demand for all forms of leisure time activities, including adult education, travel, and entertainment. Increasing leisure time among the younger generations further stimulates demand for more wilderness and more recreational facilities both in the cities and in the countryside. The environmentalist movement continues to gain in political strength, focussing its attention especially on biotoxic and carcinogenic pollutants.

Despite fluctuations about the upward trend, macroeconomic indicators continue to show growth. Growth of personal incomes, gross national product, and major industrial and agricultural commodities have been projected in another part of this study, both for the United States and for the world as a whole. Third World nations also share in this continuing growth, averaging somewhat higher rates of growth than the industrialized nations, especially as greater emphasis is placed on rural and agricultural development to make the largest sectors of their economies more productive. West Germany and Japan continue rapid and strong economic growth, assuming economic dominance in Europe and in the Pacific, respectively. Under international development programs, many of the Third World nations which have hitherto been considered "resource poor" devote more intensive effort to geological surveying and prospecting, resulting in the discovery of numerous unsuspected mineral resources which can be developed with foreign investment funds and loans. Strong economic ties between the OPEC countries and the industrialized nations bring the rate or increase of world petroleum prices into line with the general inflation rate.

No major shifts in international alignments occur during the entire period. U. S. foreign policy continues to be shaped largely by competition with the U.S.S.R. in every arena - political, economic, military (including guerrilla insurgency), and prestigious. Third World civil wars and local brushfire wars continue, with frequent gestures of support for the combatants from the U. S. and the U.S.S.R., but no major committments or direct involvement by either superpower. Real defense spending by the U. S. and by the U.S.S.R. remain about steady (in constant purchasing power) at present levels in a perennial standoff. Despite efforts by the more senior members of the nuclear weapons club to prevent proliferation, one more nation joins the club every three to six years, but no use of nuclear weapons ensues.

In the United States, National Health Care is implemented in the early 1980's and is rapidly extended to most of the population within a few years. As part of this plan, regional emergency and trauma treatment centers are designated throughout the nation. In rural areas, the system includes subsidized ambulance service (frequently airborne), designed to provide maximum response times of one hour. The costs of this system aggravate the escalating costs of welfare programs already mentioned above.

During the 1980's Appalachian coal mining expands significantly, but lags after the mid-1980's because of a severe limitation of workers willing to mine coal. After extensive legislative and judicial struggles, environmental restrictions on strip mining are sufficiently relaxed to allow rapid expansion of strip mining in the Western states. Subsequently, however, the environmental costs of mining and burning coal arouse greater public concern, and public recognition of the necessity of more diversification of energy sources in the national energy system grows rapidly. Numerous incidents of marine pollution result in tightened regulations on international shipping, especially on the use of flagships of convenience in U. S. ports. Other industrialized nations soon follow suit.

The "back to the land" movement continues to grow in size and importance, but is still a minority of the total population. Rising energy costs and increasing personal concern about food additives and about the possibility of total social breakdown in urban areas contribute to this movement's growth. The growing difficulties and sharply rising costs of commuting simultaneously stimulate a return by the middle class to urban living or into new cities of medium size developed around new industrial centers in the hinterlands. Suburbs become much less fashionable places to live. State and federal governments and proliferating supra-local agencies, reacting to these trends and to environmentalist pressures, undertake more and more comprehensive land use planning.

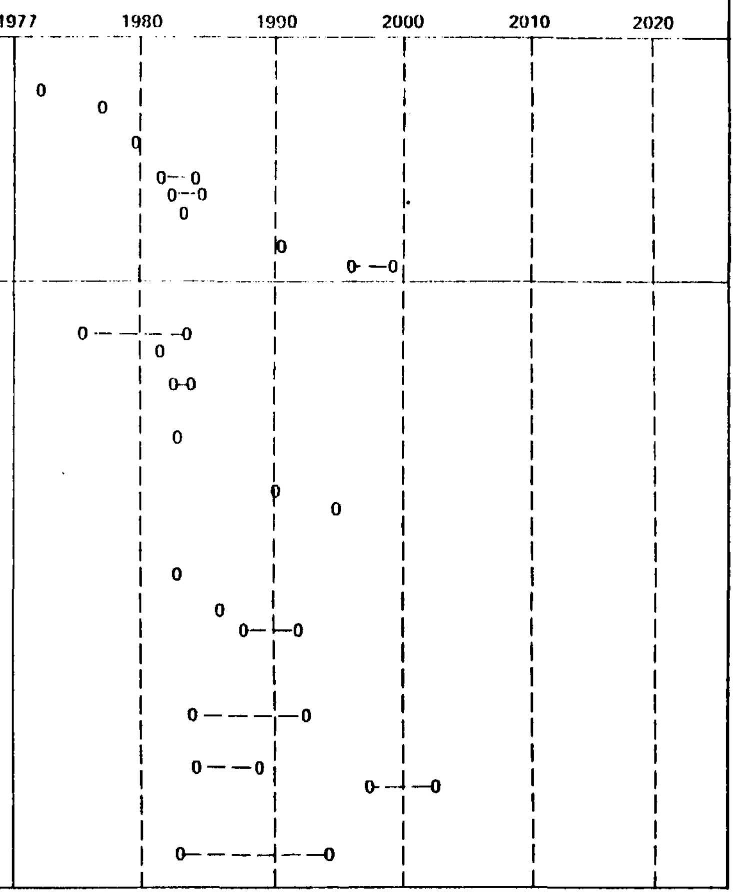
The first Space Shuttle flight in 1979 or 1980 stimulates some renewal of interest in space, especially in the wake of "Star Wars" and as the "Star Trek" generation reaches voting age. Materials processing experiments aboard Spacelab soon show a number of economically promising possibilities. A handful of high-technology companies with active, longer range planning begin to invest in Shuttle payloads during the mid-1980's for further experimentation and for small-scale pilot production runs. Public enthusiasm for space is further aroused when a popular V.I.P. takes a highly publicized ride aboard a Shuttle flight in the mid-1980's, especially since the entertainment value of the event responds so well to the ever-growing demand for leisure-time activities. Shortly thereafter, the U.S.S.R. deploys a major new space system (either a new heavy-lift vehicle or a reusable Shuttle-like vehicle). A probe launched by the U.S.S.R. in 1982 to rendezvous with Halley's Comet in 1986 is highly successful and stimulates still further interest and excitement about space activities in general.

In the military arena, increased research and development activities in strategic systems and in military space systems (reconnaissance, communications, and interception) contribute to concern about U.S.S.R. activities of a non-scientific nature in space, and some sophisticated satellite hardware results from military programs, providing some technological spinoffs for non-military space applications.

2.2.2.2 Challenge of Foreign Space Advances

While the Soviet program to develop the so-called G-vehicle has had multiple difficulties over the last ten years, it is unlikely to be abandoned. It is thus merely a matter of time before the U.S.S.R. deploys a new launch vehicle comparable in payload to the Saturn V. In addition, the U.S.S.R. is reportedly working on a reusable human-rated vehicle comparable to the Shuttle, although likely to have a smaller payload capacity. Long

II. CHALLENGE OF FOREIGN SPACE ADVANCES



TRIGGERING EVENTS AND FACTORS

- France successfully tests [illegible] launch vehicle (6000 lb. payload to LEO; 2000 lbs to GSO).
- U.S. military satellite permanently incapacitated, apparently by deliverate foreign action, but responsibility cannot be proved conclusively. U.S. issues stern warning to U.S.S.R.
- U.S.S.R. sucessfully launches LEO laboratory for 10 people with new G-class vehicle (175 ton payload).
- U.S.S.R. assembles [illegible] permanently occupied LEO station for 24 people, in orbit.
- Foreign electronics companies capture all contracts for new satellites for INTELSAT, COMSAT.
- U.S.S.R. launches Shuttle-like orbiter with 15-ton payload to LEO, vehicle executes successful rendezvous with U.S. military satellite but does not touch or tamper with it.
- First manned U.S.S.R. landing on the moon establishes lunar outpost.
- U.S.S.R. constructs [illegible], permanent lunar settlement, with 300 inhabitants.

POLITICAL

- Growing concern in U.S. about national prestige, security, and technological leadership.
- U.S. Congress authorizes expanded Earth observation, communications satellite programs for international use, especially for development programs in Third World.
- Early successes of Space Shuttle materials processing experiments win political support for expanded space capabilities; special incentives for commercial participation provided by Congress.
- U.S. accelerates program to deploy pilot Solar Power Satellite for Third World development, U.S. needs for energy, international image. Go ahead for pilot night illumination satellite follows.
- U.S. committment to space settlement by 1996.
- U.S. committment to Mars landing by 2010.

SOCIETAL

- Movies made in LEO during first VIP trip aboard the Space Shuttle stimulate global interest in U.S. space programs.
- Photos, movies of Halley's Comet from LEO further excite public interest.
- Beneficial effects of satellite communications, Earth observation satellites in Third World gain public recognition.

ECONOMIC

- Communications, Earth monitoring satellite uses accelerate Third World economic growth; stimulate extension of PSP system to global scale; create demand for night illumination for large-scale construction, mining.
- Materials processing in LEO becomes major new growth industry in U.S.
- SPS's further accelrate Third World development.

TECHNOLOGICAL

- Technologies accelerated across the board due to expanded space programs.

range Soviet goals in space are known to include large, permanently inhabited space stations. While U. S. reaction to such advances is not likely to be as strong as the 1957 reaction to *Sputnik*, it is unlikely that there would not be some increase in support for space programs.

A further factor on the international scene is the loss of economic revenues to the United States because of successful competition for vital space-related electronics hardware from other countries, as has already happened to a significant degree in the case of Japanese manufactured ground stations for communications satellites. Launch vehicle development programs in France, Japan, and several other countries may also take away launch service revenues from the U. S. during the early to mid-1980's. Concern for U. S. trade deficits could stimulate greater efforts to exploit our space technology base for economic reasons.

2.2.2.3 Committment to Space

Many large-scale shifts in the direction of motion of entire nations have resulted from decisions made for purely political reasons; many of these have been subsequently justified (in economic terms) by hindsight. Given the pre-eminence of U. S. space technology and some evidence of rising public interest in space (such as demonstrated by successes of "Star Trek" and "Star Wars") a purely political decision to focus U. S. efforts on a major thrust into practical uses of space is a distinct possibility. The present void on the national political scene of any serious supporter of space also seems to present an opportunity for political exploitation. A deliberate effort to develop an international space program could also be used as a tool to enhance U. S. image abroad and as a vehicle for international cooperation in other areas as well.

2.2.2.4 Longevity Breakthrough

Gerontology (the scientific study of the aging process) has made major advances in understanding the mechanisms by which the genetic code has programmed us to age and die. A number of possible directions for the development of therapeutic means to significantly retard (or, perhaps, even reverse) the aging process have been identified. These are all being vigorously pursued in pharmaceutical and biomedical research laboratories around

III. COMMITMENT TO SPACE

1977 | 1980 | 1990 | 2000 | 2010 | 2020

TRIGGERING EVENTS & FACTORS

- "Star Trek" fans and space-oriented citizen groups raise general public awareness of space benefits.
- First Space Shuttle flight highly successful, and well publicized.
- U.S. invites United Nations participation in Halley's Comet rendezvous probe, with hardware components contributed by each participating nation. 87 countries join as symbol of Humanity united.
- U.S. Congress and President declare 1980's a decade of space development for benefit of all humanity, with emphasis on Third World economic and environmental development. U.S.S.R., Japan, and West Germany offer cooperation and devote significant resources to Earth-oriented space programs.
- Movies made during first VIP trip aboard Space Shuttle illustrate deployment of communications and Earth resources satellites as well as pre-pilot production of biomedicals.
- Materials processing experiments aboard Shuttle/Spacelab show enormous commercial potential; experiments with large scale construction in space highly successful.

POLITICAL

- International conference expands frequency band assignments for space communications, microwave power beams.
- Congress creates special incentives for business and academic involvement in space development.
- New lunar treaty signed by U.S., U.S.S.R., and most members of INTELSAT, recognizing legality of lunar and asteroidal prospecting and mining operations, with international controls.
- U.S. accelerates program to deploy pilot Solar Power Satellite/Electric Propulsion system, both for energy needs of Earth and for alternative space propulsion systems.
- U.S. and U.S.S.R. undertake satellite nightlighting program for Third World development as joint project.

SOCIETAL

- Growing interest in futurology.
- Return of heroism in entertainment, television, books, movies.
- Renewed interest in space among students, social commentators, and intellectuals.
- Success of Halley's Comet rendezvous missions (both solar sail and electric propulsion) stimulates global enthusiasm for international cooperation in space.
- Progress with Closed Habitats supports growing belief in humanity's destiny in space.

ECONOMIC

- New commercial ventures formed to exploit new materials processes in space provide major new growth industry.
- Economic growth in Third World from use of satellite communications and Earth observations greater than expected by economic forecasters, stimulating demand for expanded communications satellites and acceleration of powersats.
- Expanded commercial use of Shuttle and uprated Shuttle give support to HLV development.
- Acceleration of global economic growth creates large expansion of long term investment capital.

TECHNOLOGICAL

- Technologies accelerated across the board due to expanded space programs.
- Interest in, and development of, Closed Habitats leads to greater understanding of interactive biological systems and to new microbiological technologies.

ENVIRONMENTAL

- Rising global concern about environmental effects of coal and of nuclear power provide additional support for Solar Power Satellites.
- Civilian program to remove accumulated nuclear waste from the Earth follows successful secret tests by U.S. military to remove some of its nuclear wastes.
- Congress mandates study of feasibility of removing all recombinant DNA experimentation to orbital laboratories.

MILITARY

- De-emphasis of military uses of space, except for surveillance and communications.
- Secret program by military to dispose of nuclear waste materials in space, avoiding Environmental Impact Statements; program highly successful.

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IV. LONGEVITY BREAKTHROUGH

1977 | 1980 | 1990 | 2000 | 2010 | 2020

TRIGGERING EVENTS AND FACTORS

- Anti-aging drugs found which reduce death rates above age 55 by 75%.
- Druges become commercially available at moderate price in several countries; in U.S., the FDA projects approval process required by law will take 7 to 10 years.
- Further advances result in major rejuvenation of elderly patients.

POLITICAL

- Insurance company actuaries detect decreased death rates among policyholders over 55; projecting decreased death benefits approaching $10 billion a year within 5 to 10 years, the insurance industry lobbies in Congress for early federal approval of anti-aging drugs.
- Growing fiscal pressures on Social Security system forces Congress to overhaul retirement laws, social security tax laws, and to adopt generalizations of Employee Stock Ownership Plans (ESOP), with new tax preferences for dividend income.
- Government agencies around the world undertake serious long-range planning studies, stressing greater global cooperation.
- U.S.S.R. undertakes major economic development and settlement program in Siberia with U.S. economic cooperation.

SOCIETAL

- Black market for anti-aging drugs springs up overnight in U.S. and other countries where drug approval process is slow; surge in tourism to countries with rapid approval.
- Market penetration in U.S. to one third of adults over 55;
  to 60% of adults over 50;
  to virtually 100% of adult population.
- Declining need for medical and custodial care facilities for the aged.
- Growing flood of civil lawsuits against "rest homes" by rejuvenated former inmates.
- Rapid expansion of interest in futurology and space as well as in historical and nostalgic entertainment and study.
- Accelerated turnover of careers among middle-aged; demand for adult education explodes.
- Expansion of parttime work and of limited tenure rules; growth in all leisure activities.
- Growing belief in humanity's destiny in space.

ECONOMIC

- With legalization of anti-aging drugs, insurance companies underwrite drug costs for larger policyholders.
- Decreased payments of death benefits by insurance companies provide growing source of long-term investment capital; economic growthspeeds up.
- Economic overhaul to replace Social Security by ESOP's provides further expansion of investment capital and acceleration of economic growth; greater automation and more interdisciplinary managerial personnel also help.

TECHNOLOGICAL

- Increased demand for personal computation, communications, recreation.
- Acceleration of sophisticated automation and robotics in industry especially for routine, tedious jobs.
- Growing demand for reliability, durability in consumer goods.

ENVIRONMENTAL

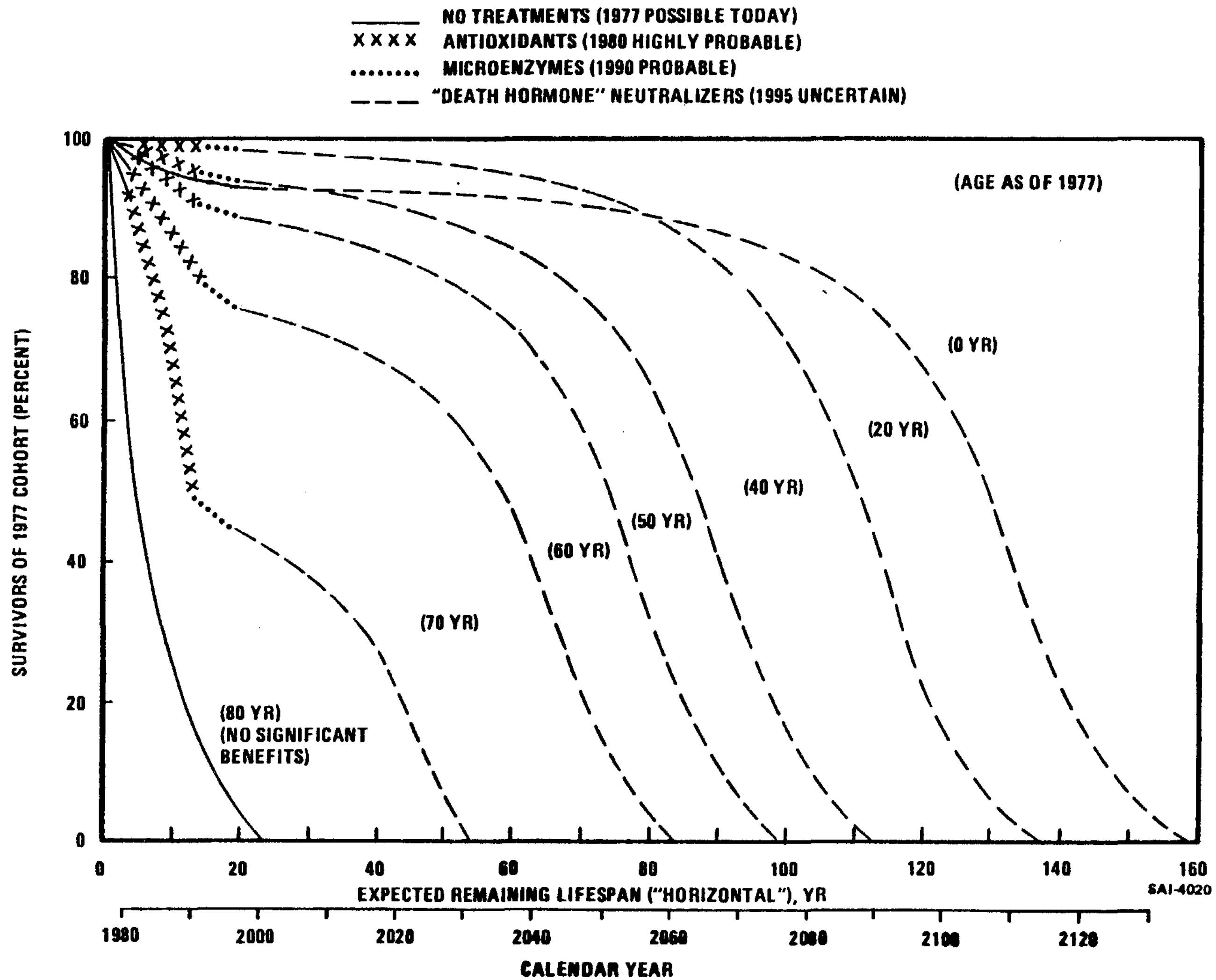
- Expanded personal time horizons leads to greater concern about cleaning terrestrial environment.

the world, and knowledgeable researchers in the field have guessed anywhere from ten to fifty years of further research before a major breakthrough, that is, before the discovery of therapeutic means to at least *double* normal human lifespans. In the U.S.S.R. and in Rumania, recent five-year plans have given high priority to life-extension research.

If we postulate that such a breakthrough occurs in 1985, the demographic impact on the United States would be as shown in the table on the following page under the assumptions given in the scenario chart. The effect on total population would be fairly slow; but the effects on the age *structure* of the population would be dramatic. Because of these structural changes, major economic reforms would be required. We envisage rapid implementation of the economic ideas of Louis Kelso as the national response to this economic crisis.

But a more profound change would also have come about by a sudden and dramatic change in our lifespan. Individuals would become much more prone to change careers several times in their lives, rather than spending forty to fifty years in a single lifetime career. Moreover, with greatly extended personal time horizons, greater interest in futurology and in space would be very likely. The expression "I won't live to see that in my lifetime," frequently used today to justify short-term planning to the exclusion of long-term planning and research, would lose much of its political clout. This effect is shown in the accompanying graph, which illustrates horizons resulting from possible progress in longevity research. The assumptions of this figure are somewhat different from those of the Longevity Breakthrough Scenario, but the effects on time-horizons for the individual are comparable. The discontinuities in slopes indicate the possible changes in death rates for each of the specific therapeutic techniques expected during the next 18 years. If you are 40 years old, for example, you would have about a 50% chance of living another 86 years, surviving to age 126 in 2063. People under 30 years old would have at least a 50% chance to living to celebrate the U. S. Tricentennial. If such breakthrough materialize, the expression "That will never happen in my lifetime" will lost its force as a political factor in discussion of long-term programs and policies.

EXTENDED HORIZONS
RESULTING FROM POSSIBLE PROGRESS IN LONGEVITY RESEARCH



(The status of gerontological research as of 1976 is reviewed in "Prolongevity", by Albert Rosenfeld. The economic ideas of Louis Kelso are described in his books "How to Turn 80 Million Workers into Capitalists on Borrowed Money" and "The Capitalist Manifesto". These ideas have already been implemented in part by the 1976 legislation creating Employee Stock Ownership Plans - ESOP.)

U. S. DEMOGRAPHIC SHIFTS FOR LONGEVITY BREAKTHROUGH SCENARIO

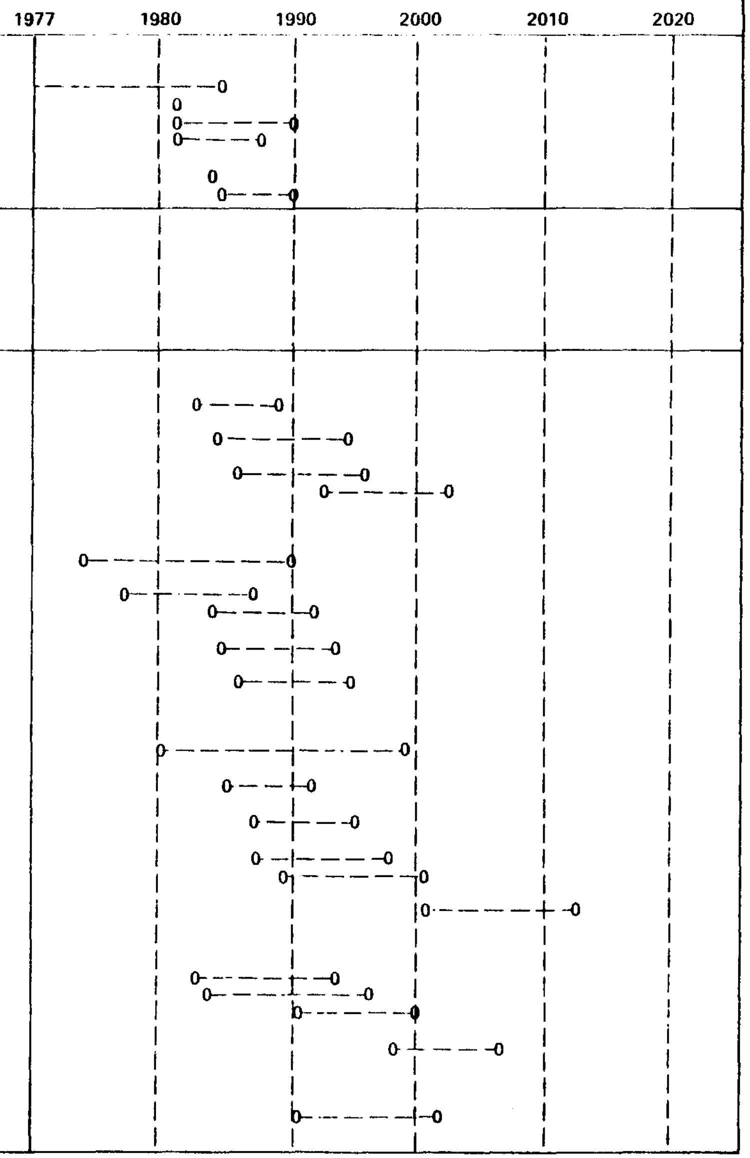
Year	Population above age 65 (millions)		Fraction of total population based on Census Bureau projections -		Total population (millions) based on Census Bureau projections -	
	Without Breakthrough	With Breakthrough	Ser. II	Ser. III	Ser. II	Ser. III
1980	24.5		11.0%	11.1%	222.8	220.4
1990	28.9		11.8%	12.3%	245.1	235.6
		31.0	12.5%	13.0%	247.5	238.0
2000	30.6		11.7%	12.5%	262.5	245.1
		43.6	15.8%	16.8%	277.2	259.8
2010	33.5		12.0%	13.4%	279.0	250.0
		59.2	18.6%	21.3%	317.4	278.4

The Census Bureau's Series II and Series III projections are based on different assumptions about mean completed fertility trends; Series II assumes fertility will rise from present 1.8 children per woman to 2.1 (the replacement rate), while Series III assumes fertility will continue to decrease down to about 1.7 children per woman. Net migration into the U. S. is assumed to be the same in all cases.

2.2.2.5 Disenchantment with Space

Several factors visible in social, economic, and political trends in the United States today could lead to further reductions in national interest in space. These include the vacuum at the national level of strong political committment to space; growing costs of social welfare programs; and generally short-term planning with little consideration for projects with longer times before payoff. Continuation or exaggeration of these trends could result in a slowdown of the Space Shuttle/Spacelab programs to such a degree that few if any opportunities for economic returns using

V. DISENCHANTMENT WITH SPACE



TRIGGERING EVENTS AND EVENTS

- Continued inflation, unemployment, rising urban crime rates.
- "Quality of life" proclaimed by President and Congress as the theme of the 1980's.
- National Health Care program expands to cover half of population.
- Space Shuttle program funding reduced; materials processing experiments slowed down; few profitable processes found.
- Guaranteed minimum income plan implemented.
- Acceleration of rural renaissance movement.

CONCOMMITANT DIFFERENCES FROM BASELINE SCENARIO

Reduced economic growth rates in U.S. after mid 1980's. Decreased U.S./U.S.S.R. competition due to U.S. isolationism. Decreased energy consumption with far less use of coal. Waning interest in all forms of high technology, including space. Significantly less land use planning at federal level, due to disaffection and distrust toward centralism. No major new space systems deployed by U.S.S.R. during 1980's.

POLITICAL

- Rapidly growing tax burdens accelerate disenchantment with centralized government; increasing populism among candidates for elective office at all levels.
- U.S. foreign policy grows more isolationist, especially as petroleum imports decline in importance; U.S.S.R., Japan, and W. Germany dominate international affairs.
- Increasingly heavy taxation on large centralized businesses.
- Search begins for new diversities.

SOCIETAL

- Human relationships emphasized; small village groupings and communes become more popular; explosion in "pop psychology" and meditation techniques.
- Growing interest in ecologically benign, small scale technologies and production methods.
- Consumption-oriented marketing of goods de-emphasized in favor of advertising for "human services".
- Industrial growth still further hampered by reluctance of working force to accept industrial and assembly line jobs.
- Growing demand for "escapist" entertainments.

ECONOMIC

- Budgetary constraints severely limit total spending for space programs; make new starts very difficult.
- De-emphasis of high technologies and heavy industry results in lessened industrial output and revenue; accelerated migration out of larger cities.
- Decreased exports of high technology products replaced in foreign trade mix by agricultural products and by surplus uranium.
- Rapidly rising taxation discourages new capital investment.
- Rural groups shift toward exchanges of goods and services to escape taxation of monetary transactions.
- Expanded export market for new automation machinery and know-how.

TECHNOLOGICAL

- Increased emphasis on durability of materials and manufactured goods.
- Growing need for communications services for widely dispersed population and settlements.
- Shortage of industrial workers spurs development of new automation technologies, bringing "economies of scale" down to smaller scales.
- Space programs reconsidered in view of new automated technologies.

ENVIRONMENTAL

- Moderation of energy/environment issues.

these systems would be found simply for lack of trying.

Even in such a pessimistic scenario, some opportunities remain open for space advocates to successfully push through some Space Industrialization projects, principally in the area of communications and Earth resources satellites.

2.2.2.6 Space Entrepreneurs

Assuming only that bureaucratic and legal obstacles to commercial ventures in space can be minimized or otherwise circumvented. commercial exploitation of opportunities in space could become significant factors in the evolution of space programs and activities. Communications, of course, is already a viable industry in space; further exploitation of communications satellites can be expected to be a significant feature of the 1980's. Japanese electronics companies have already captured much of the global market for the ground stations for communications satellites. Private ventures in other countries have already invested in R&D programs for low-cost launch vehicles (most notably, OTRAG in West Germany, which has also leased a private launch site on the equator in Zaire, conducting its first apparently successful sub-orbital test flight in the spring of 1977).

With reasonable success of the Shuttle/Spacelab program during the 1980's, materials processing applications could become attractive investments for high-technology companies. With sufficient numbers of such flights by a number of different commercial ventures, it would also become feasible for such companies to pool resources to develop and operate support facilities in space (such as a power module for the Shuttle, and, eventually, living quarters for workers).

Success by a few companies early in the Shuttle era would stimulate innovation and competition, not only by U. S. companies, but by foreign and multinational companies. The economic advantages of equatorial launch may provide sufficient motivation to permit case-by-case solutions to the obstacles presented by existing international space law, providing space users with several alternatives for launch services, all of them stressing minimization of red tape.

VI. SPACE ENTREPRENEURS

	1977 — 1980 — 1990 — 2000 — 2010 — 2020
TRIGGERING EVENTS AND FACTORS	
• Continued rapid growth of electronic communications needs worldwide.	– – – – – – – – – – – – – – – – 0
• Experiments aboard Space Shuttle, Spacelab, and EDEF identify numerous zero-G materials processing applications with commercial promise.	0– – – – – 0
• Methods for assembly in orbit of large structures developed and tested successfully.	0– – 0
• First privately-owned and operated equatorial launch site opened, with minimal red tape.	0
POLITICAL	
• Business and labor become strongly pro-space.	0– – – 0
• Three additional equatorial countries begin construction of spaceports with special economic incentives for commercial users; U.S. and other space-going nations sign economic cooperation treaties with these countries.	0– – 0
SOCIETAL	
• Tv programs, movies, space-built products stimulate public interest in space.	0– – – – 0
• Expanding interest among students in careers in space.	0– – – – – – 0
• Growing public exposure to orbital travel, living and working in space, and to First Space Olympiad produce widespread belief in destiny of humanity in space.	0– – – 0
ECONOMIC	
• New companies formed to exploit space opportunities, including several multinational consortia.	0– – – – – 0
• Datalink services via satellite become widely available for business and government; larger multinationals use these for internal corporate communications.	0– – 0
• First VIP trip aboard Space Shuttle used as basis for commercial TV program produced in orbit.	0
• New space companies and INTELSAT undertake joint venture to develop and deploy global PSP system.	0
• Payload reservations for commercial processing equipment saturate Space Shuttle capacity; space companies agree to participate in development of second-generation shuttle.	0– 0
• Space ventures stocks become glamor issues, stimulating stock market boom.	0– – – 0
• Consortium of space manufacturers formulates plans for an "industrial park" in orbit.	0
• First PSP and pilot Night Illumination Satellite used several times in disaster relief operations, with major savings in insurance benefits paid out; insurance industry agrees to participate in NIS deployment program.	0– – 0
• Reduced launch costs and rising capital costs for powerplants push utility companies into participating in pilot Solar Power Satellite program.	0– – 0
• Space workers develop new low-gravity sports, apply to International Olympic Committee for recognition; IOC approves Space Olympics events for year 2000.	0– – – 0
TECHNOLOGICAL	
• McDonnell-Douglas SSUS tested successfully.	0
• New products, materials, techniques developed in space processing stimulate acceleration of technological innovation throughout.	0– – – – – – 0
• Experiments aboard orbital Semi-Permanent Quarters for closed ecological systems.	0– – – – 0

2.2.2.7 Shortages of Critical Minerals

While the hypothesis of *The Limits to Growth* is that intrinsic global shortages of industrial raw materials pose a serious threat to technological and industrial civilization in the next few decades has been largely laid to rest, there are a number of minerals having significant economic leverage which are in relatively short supply and which are very unequally distributed on the Earth. Disruptions of international trade in some of these commodities could cause temporary but economically important dislocations in trade, production, and prices of finished products.

Natural gas is one such commodity. Present planning assumes significant increases in U. S. imports in the next decade, much of it in LNG transported by special tanker ships. Adverse public reaction to the explosion of such a tanker in a major harbor could delay LNG imports for years.

Some scarce metals such as chromium, manganese, vanadium, and colombium (niobium) are vital ingredients in stainless and special high-strength steel alloys. Most of the annual consumption of these metals in the United States is supplied by imports from South Africa, Southern Rhodesia, Brazil, and the U.S.S.R. Half of our annual platinum consumption comes from South Africa. For each of these metals, domestic stockpiles (both in industry and in the government) are sufficient fro two or three years, perhaps sufficient to carry us through a transition to other suppliers or to develop substitutes for essential uses. (Titanium, for example, could be substituted for many applications of stainless steel or for some uses of high-strength steels.) During the transition, however, sharp dislocations would be felt in some parts of the domestic economy. Any of these imported metals (and a number of others as well) could be interrupted by political factors, some domestic, others foreign. Guerrilla wars, political revolutions, and trade embargos are a few of the mechanisms by which such supplies could be disrupted for more than a few days or weeks.

2.2.2.8 Economic Collapse

As has been pointed out by a number of critics of U. S. energy planning, the capital demands for the energy industry in the next few decades appear to be staggeringly large. The "traditional" share of net private

VII. SHORTAGES OF CRITICAL MINERALS

Event	1977 – 1980 – 1990 – 2000 – 2010 – 2020
TRIGGERING EVENTS AND FACTORS	
• Continued OPEC price rises and shortages of natural gas lead to increased LNG (liquefied natural gas) imports and authorization for several new LNG ports along U.S. coasts.	– – – – – –+0
• Major LNG tanker explosion in a U.S. port, with large death toll.	0
• Leftist coups in several Third World mineral exporting countries, followed by isolationist policies or steep increases in mineral prices for Cr, Mn, Pt, V, Cb, and Ti.	0 – –0
POLITICAL	
• Public outrage and fear after LNG disaster results in prohibition of onshore unloading of LNG.	0
• U.S. negotiates long-term trade agreement with U.S.S.R. for Cr, V, Ti in exchange for wheat and other agricultural commodities.	0-0
• Japan negotiates long term trade agreement with U.S.S.R. for Cr, V, Ti in exchange for electronics equipment (including computers and industrial controls), scientific instrumentation, plastics, and semiconductors.	0-0
• Increased agricultural exports to U.S.S.R. reduce food exports to Third World nations.	0– – –0
ECONOMIC	
• Fertilizer, food, and plastics prices up due to scarcity of natural gas.	0— — —0
• Imports of critical metals to U.S. and Europe down sharply; stockpiles hold down prices for a few months, until speculation breaks through; stainless and high strength steel prices skyrocket.	0— —0
• Rapid expansion of Ti mining in U.S.	0– –0
• First floating platform/pipehead for offshore unloading of LNG opened; LNG prices (in $/BTU) slightly higher than for petroleum.	0
• Accelerated expansion of Western states coal strip mining; coal gasification and liquefication.	0— — —+—0
• Expanded production of Ti and Al to replace special steels places large demands on electrical generating capacity.	0— —0
• Substitutions for special steels reduce demand; steel prices relax back to pre-crises levels.	0— —0
SOCIETAL	
• Environmental versus economic issues polarize U.S. society and aggravate isolationist tendencies; increase public recognition of need for diversity in energy sources.	0— —0
• Increased raw materials prices stimulate repair and recycling industries; encourage home entertainment and hobbies.	0— — –+– –0
TECHNOLOGICAL	
• Accelerated research in extraction technologies and prospecting methods; in materials science for steel substitutes and lighter weight materials for automobiles.	0— — —+— –0
• Acceleration of U.S.S.R. technologies across the board due to availability of large Japanese computers.	0— — +—0
• Lightweight, high strength materials become available for use in space vehicles and structures.	0— —+— — — —0
ENVIRONMENTAL	
• Increasingly severe environmental problems from expanded reliance on coal.	0— — — —+— 0
• Severe local pollution problems due to Ti mining.	0— — —+—0
• Catalytic converters removed from new car production; Pt reserved for essential industrial and military uses.	0
• Military hardware costs climb sharply.	0– –0
MILITARY	
• Moderate decreases in U.S. and U.S.S.R. military procurements following increasing trade	0– – –+—0

VIII. ECONOMIC COLLAPSE

1977 | 1980 | 1990 | 2000 | 2010 | 2020

TRIGGERING EVENTS AND FACTORS

- Energy industry focuses on highly capital intensive expansion programs; energy industry's share of net private capital investment (NPCI) rises from 25% to 55% forcing long term interest rates upward.
- Energy poor Third World countries continue to borrow more heavily from U.S. banks, with rising interest burdens, to pay for petroleum imports.
- OPEC nations shift investments away from U.S. into industrialized nations with shorter term investment returns as well as new factories in Third World countries.

CONCOMMITANT DIFFERENCES FROM BASELINE SCENARIO

- Significantly reduced economic growth; emphasis on social and economic issues; stronger federal government.
- Greater attention to efficiency of capital investments and to importance of innovation in economic growth.

ECONOMIC

- Continuing severe unemployment, accelerating double-digit inflation and government deficits; growth of GNP in real terms slows to near halt, reducing NPCI availability still further.
- Several medium-sized banks with large overseas loans are bailed out by Congress as a few Third World governments default.
- Construction industry in U.S. crippled by double-digit mortgage interest rates, aggravating unemployment.
- Capital crisis in short-term money market; several banks and medium-sized corporations, overextended in short-term debt, collapse during Congressional recess, exhausting FDIC reserves overnight. Bank panic and stock market crash follow. One month bank holiday declared. Most merchants refuse checks or credit cards. Numerous incidents of violence in cities.
- Full scale depression in U.S. and other free market economies. Soviet bloc economies also stagnate. OPEC reduces petroleum prices 45%, but response is too late. Third World economies accelerate due to reduced petroleum prices.
- Gradual economic recovery as new less capital-intensive equipment and technologies come into use.

POLITICAL

- Rapid growth of social welfare programs with increasing governmental centrism.
- Congress guarantees all personal losses in bank failures, but public confidence remains very low, with little personal savings kept in banks or other financial institutions.
- U.S. agricultural production and exports drop sharply, Third World countries focus greater efforts on agriculture.
- Concerted effort to stimulate development of less capital-intensive technologies, especially through new Science & Technology Institutes in universities based on Land Grant Colleges model, with long-term federal funding.
- New emphasis on space to stimulate economic recovery.

SOCIETAL

- Reduced travel, with more bicycling, hiking, etc.; more cheap entertainment (especially escapist), more communications.
- Swing toward greater governmental centrism partly balanced by growth of community self-help projects, work exchanges, adult education, etc.

TECHNOLOGICAL

- Economic stimulus programs include expanded support for research on cheaper non-depletable energy sources and on role of technological innovations in economic growth.

ENVIRONMENTAL

- Energy consumption decreases significantly; older, dirtier powerplants shut down and dismantled.
- Environmental aspects of new powerplants to be built during economic recovery emphasized.

capital investment has been 25 to 30%; extensive deployment of nuclear power plants, coal gasification projects, and shale extraction facilities could push that share up toward 65% by the mid- to late-1980's.

Since the OPEC price rises of 1973-1974, Third World countries which have no domestic energy production comparable to their energy consumption have been forced to borrow extensively to pay for current oil imports. Much of this borrowing has been long-term, low-interest loans from U. S. banks.

Both of these demands for U. S. capital funds have been rising upward, with little evidence of compensating increases in capital supply. Carrying these trends forward has resulted in a scenario for economic collapse.

2.2.2.9 Energy Breakthrough

Petroleum, natural gas, and electricity prices show no sign of decline for some time to come. Both nuclear power and coal mining and burning have encountered significant environmentalist opposition which can be expected to continue. Coal gasification and liquefication appear to have very high capital costs as well as serious environmental and technological difficulties. Fusion power appears to be several decades away from commercialization as yet, and seems likely to have very high capital costs. Solar energy schemes (except for water heating and for space heating and cooling) have generally been stymied by the necessity for very expensive storage systems.

In this climate, the opportunity remains for the development of new energy technologies or sources by private industry, even if federal energy policy fails to develop a clear direction with viable goals. One such possibility is geopressurized natural gas deposits beneath the western Gulf of Mexico and adjacent onshore areas, where large quantities of methane appear to be dissolved in high temperature, pressurized brine in proous aquifers. (See Fortune Magazine, October, 1976.) Preliminary estimates suggest that natural gas could be produced from these deposits at prices of about $2.50 to $3.00 per thousand cubic feet. If natural gas prices were deregulated, development of this resource would permit the electrical

IX. ENERGY BREAKTHROUGH

1977 | 1980 | 1990 | 2000 | 2010 | 2020

TRIGGERING EVENTS AND FACTORS

- Federal and state governments provide major new tax incentives for energy efficient equipment in homes, business, and industry.
- BReakthrough in stable catalytic materials needed for photoelectrolysis (P/E) process.
- Pilot P/E plant built and tested, demonstrating 25% efficiency in converting solar energy into chemical energy in hydrogen gas.
- Demonstration P/E plant (1 hectare) built and tested; shows costs for full scale H_2 production and pipeline delivery would be about $3.00 to $3.50 per MBTU.

ECONOMIC

- Rate of growth of total energy demand declines with improvements in energy efficiency.
- Capital demands of energy industry stabilize.
- Utility companies make major committments to build P/E plants in Sunshine Belt of U.S.
- Samll scale P/E units commercially available for commercial and rural applications; propane distributors in some areas become dealers for P/E manufacturers.
- Accelerated economic growth due to expanded supply of capital; energy efficient devices and P/E units provide new growth industries.
- First commercial P/E farm online; H_2 used to supplement natural gas in pipelines.
- Rapid expansion of P/E for utilities, farms, large apartments, and industries worldwide.
- OPEC reduces petroleum prices to $4 per MBTU.
- Third World economic development accelerated.

POLITICAL

- Decreased rate of growth of energy demand and prospects for clean energy from P/E reduce polarization over energy/environment/economy issues.
- Mediterranean nations sign various trade agreements with northern European nations for H_2 from P/E farms.
- International development agencies provide large loans for P/E farms in Third World nations.

SOCIETAL

- Decreased anti-technological attitudes result from abatement of energy issues and success of new technologies.

TECHNOLOGICAL

- New incentives for improved efficiency devices and breakthrough in P/E stimulate renewed efforts in all areas of materials sciences.
- Increased R&D on materials processing methods using H_2; availability of cheap H_2 stimulates search for liquid-hydrogen-temperature superconductors.
- GSA encourages auto industry to study design feasibility of air/hydrogen fuel cells for cars with metal hydride fuel storage.

ENVIRONMENTAL

- Demonstration P/E plant delivers by-product oxygen to sewer treatment plant for higher-level water purification.
- Industrial users of hydrogen near P/E plants use oxygen instead of air, reducing NO_x and SO_x emissions substantially.
- One-third of sewage from largest 50 U.S. cities treated with oxygen.

utilities to convert most power plants to natural gas, reducing the capital requirements for new power plant construction by nearly one-half.

For this scenario, however, we have postulated a breakthrough in the photoelectrolysis process which uses solar energy to split water into hydrogen and oxygen which are evolved at physically separate plates. The energy required to split water is about 2 eV per molecule. Only a small fraction of the solar flux consists of photons with 2 eV or more. But the photoelectrolysis reaction is mediated by two photons whose energies together total 2 eV or more, so that much more of the solar spectrum can be used. The theoretical efficiencies for photoelectrolysis can be as high as 40 to 45% in conversion of sunlight into hydrogen fuel, and this process circumvents the need for cumbersome and expensive thermal stroage systems.

At the present time, the principal difficulties involve materials problems at the cathode and the anode, especially the latter, where nascent atomic oxygen creates a corrosive environment. Such a situation is subject to an unexpected breakthrough at any time in finding suitable materials. (Consider Edison's search for a material for a light bulb filament.) Costs for hydrogen produced by photoelectrolysis could be competitive with deregulated natural gas of equivalent energy content. (See A. J. Nozik, "P-N Photoelectrilysis Cells", Applied Physics Letters 29, 150 (1976), and references given there.)

2.2.2.10 Ecological Catastrophes

Ecological concerns have become a major public policy issue in the last two decades. Despite a great deal of attention to air pollution and spoiling of the landscape by mining, industrial, and municipal wastes, no sources of air or land pollution appear to be capable of producing a global or nationwide impact of major epidemiological or economic significance, with the possible exception of a major nuclear reactor accident or of the accidental dispersal of nuclear reactor wastes including plutonium over a large area. The same case seems to hold for the open seas as well: no long-term ecological damage seems to have resulted from any of the few dozen oil tanker disasters of the last decade or two.

X. ECOLOGICAL CATASTROPHIES

1977 | 1980 | 1990 | 2000 | 2010 | 2020

TRIGGERING EVENTS OR FACTORS

- Yugoslav freighter *Cavtat* sinks near mouth of Adriatic Sea
- Drums of Pb compounds from *Cavtat* corrode through
- *Argo Merchant* breaks up off Cape Cod; releases 7.6 million gals crude oil
- Freighter carrying indus. chem's. + supertanker (110 million gals. crude) collide, break up outside Marseilles
- Freighter breaks up off coast of northern Chile, spilling 35 tons indus. chem's.: currents carry northward through anchovy spawning areas off Peru + Ecuador as well
- Disabled freighter in North Sea driven by heavy seas in winter storm against 3 drilling platforms breaking off well pipes deep below surface; wells gush crude oil for months before sealed off in calm weather late in the spring, but not before 200 million gals. have escaped.
- Alaskan North Slope wellhead accident produces major oilwell fire; lasts 4 weeks before controlled.

ENVIRONMENTAL IMPLICATIONS

- *Cavtat* cargo poisons fish, animals, people all around lower half of Adriatic
- Oil slick from supertanker covers entire western half of Mediterranean; most marine life (except near shore) suffocates: indus. chem's. also poison fish, people in Sardinia, Corsica
- Anchovies decimated along N. Chile, Peru, Ecuador; make slow recovery; tuna also decline, with comeback even slower, lasting until 96
- Oil from North sea accident carried in globs under Arctic ice pack; combined with warm spring in 91, and with extensive soot deposits from Alaskan accident, entire rim of Arctic ice pack melts in 91, fails to refreeze in winter 91 -- 92, after which ice pack shrinks more and more each year.
- N. Hemisphere climate altered; rain belts shifted southward 200 miles; severe drought in Calif., Alberta, Northern plains; Soviet grain areas

EFFECTS ON TECHNOLOGY

- ICMO seeks better ocean navigation/geolocation technologies; traffic control communications
- ICMO sponsors research into toxic effects on marine life; ocean current modeling
- ICMO, UNESCO, FAO become vitally concerned with climatic modeling and modification

SOCIAL IMPLICATIONS

- Growing pressure on industry for closed-cycle manufacturing to minimize chem. shipment for resupply
- Increasing number of community gardens for local food production; after 95, acceleration of controlled environment gardening and truck farming

ECONOMIC CONSEQUENCES

- Adriatic tourism crippled; recovery slow to 86; fishing indus. in Adriatic destroyed
- W. Mediterranean seaside tourism all but eliminated; fishing indus. killed
- Fishing indus. in Peru, Ecuador sharply curtailed; worldwide food + fertilizer prices sharply up; petroleum prices also escalate as demand for fertilizer shoots up; US switches more cattle from corn-feed to range, with overgrazing problems in many Western states
- Grain prices worldwide again soar

POLITICAL CONSEQUENCES

- Mediterranean nations create Int'l. Civil Maritime Organ (ICMO) patterned after ICAeronautics); require all commercial shipping in Mediterr. to be under positive traffic control; extensive list of proscribed mat'ls may not be shipped on Mediterr.
- Int'l law-of-the-sea conf. convened; stringent safety requirements for large shipments by sea of long list of mat'ls.
- ICMO traffic control avail. worldwide on voluntary basis; mandatory in Red Sea, Black Sea, Persian Gulf, Baltic Sea
- Soviet Union/Warsaw Pact sign 20-year treaty with W. Germany to use port of Hamburg.

MILITARY IMPLICATIONS

- ICMO treaty exempts military vessels from positive traffic control, but may obtain info on all known shipping in real time; failure to do so imposes severe liability on flag nation
- Reduction of East/West tensions in Europe; significant reduction in NATO and Warsaw Pact troops in Europe follows in 94 95
- Soviet + US subs + aircraft carriers begin patrolling Arctic Sea

But marine pollution could have major impacts if the incidents involved one of a few identifiable "leverage points", including closed waters, the Arctic ice cap, and certain fisheries of critical significance in the global economic system. These possibilities were the basis for this scenario.

Dissipative mechanisms for large oil spills at sea initially depend on wave action to break up the slick into small patches which are then dispersed by strong currents and by the wind. Should a large slick occur in the Western Mediterranean during a period of calm weather, a large slick could prevent the build-up of waves by wind action. Since the Western Mediterranean (which loses more water by evaporation than it collects from rivers flowing directly into it), currents are generally weak. The breakup of a very large supertanker could produce a slick large enough to cover the entire Western Mediterranean.

The Arctic ice floes melt at the top, accumulating new ice at the bottom. If large quantities of oil spilled near the edge of the Arctic Ocean were transported under the ice and frozen into the ice, after a period of a few years the oil would significantly increase the absorption of solar heat by the ice during the summer, accelerating polar melting without any increases in the rate of freezing during the winter. With extensive dam construction on northward flowing rivers in the U.S.S.R., the salinity of Arctic waters in the eastern hemisphere has been increasing, making it more difficult to refreeze the Arctic icecap should melting advance too far. (See Mesarovich and Pestel, "Manking at the Turning Point: The Second Report to the Club of Rome", E. P. Dutton & Co. and Reader's Digest Press, New York, 1974, pp. 149-150.)

Approximately one-third of the annual marine catch of fish is used for agricultural fertilizers and for livestock feed supplements. A major component of this fishing activity is the anchovetta fisheries off the coast of South America. The global importance of these fisheries was demonstrated when meat and soybean prices in the United States and Japan skyrocketed as a result of a sharp drop in the anchovetta catch in 1973 which further aggravated the effects of the OPEC oil boycott and price increases.

2.2.2.11 Cooling of the Northern Hemisphere

Since World War II, the average growing season (i.e., the interval between the last frost of spring and the first frost of autumn) has decreased by about ten days in Great Britain and Ireland. In that same period, glaciers on Mount Rainier (near Seattle, Washington) have advanced about one-third of the distance they had retreated between 1900 and 1950. Numerous other scattered bits of data strongly suggest that the mean temperature of the Northern Hemisphere has been declining for the last two or three decades from a period of exceptionally favorable weather during the first part of this century. Since the United States, Canada, and the Soviet Union grow a major and decisively important share of the world's total grain production, an adverse change in the climate of the Northern Hemisphere could have grave consequences in the face of rising global population.

Although technological means of increasing agricultural productivity have played an important role since World War II, it has also become increasingly apparent that land reform offers major opportunities for rapid increases in productivity without major expenditures of capital or energy. This approach has had remarkable success in Taiwan, China, and South Korea. Moreover, technological means (such as the introduction of "green revolution" seeds) have been most successful where land ownership patterns provide equity for the small farmer, as was the case in India's Punjab State. (The same situation also applied in the United States in the 1930's when new hybrid varieties of corn were introduced.) A severe, global crisis in food production might bring about such measures in Third World countries which could not afford to compete with industrialized nations for the purchase of imported grain.

2.2.3 General Observations

The scenarios described here span a wide range of possible futures. While opportunities for the advocacy of a variety of specific Space Industrialization activities appear in every scenario, many of these opportunities are apt to fall in the private sector rather than in NASA or other governmental agencies. Because of the strong possibities of synergisms between various space activities, however, NASA can no more ignore private

XI: COOLING OF NORTHERN HEMISPHERE

	1977	1980	1990	2000	2010	2020
TRIGGERING EVENTS OR FACTORS						
• Average growing seasons in U.S., Canada, Europe, U.S.S.R. decrease 10 – 15 days	0 – – –	– – – –	– –0			
• Length of growing season stable			0 – – –	– –0		
• Further 5 – 8 day decrease in growing seasons				0 – – –	– –0	
ENVIRONMENTAL						
• Increasingly intense cultivation of marginal lands in areas with better climates		0– – – –	– – –0			
• Rapid development of strip-mining for coal increases land and water pollution; air pollution standards relaxed to permit use of high-sulfur fuels.		0– – – –	0			
TECHNOLOGICAL						
• Climate modeling, forecasting, and modification research given top national priority; joing NASA/NOAA climatology program funded at $1 billion/year		0				
• U.S.D.A., state Agricultural Extension Services begin to push controlled-environment-agriculture, mariculture; U.S.D.A. and NASA begin major new program in crop inventory and forecasting by satellite		0				
• Prototype regional climate modification experiments				0		
• First global scale experiments					0	
SOCIAL						
• Gasoline rationing in U.S. due to fertilizer/fuel oil needs		0– – –0				
• Some southward relocation/migration in North America, Europe, U.S.S.R		0– –	0			
• Increased demand for electronic communications and for home entertainment to reduce fuel consumption		0– – –	0			
ECONOMIC						
• Petroleum demand increases faster than expected; prices climb at 12% per year; fertilizer and food prices up 15% per year; U.S. balance of trade deteriorates		0– – –0				
• U.S. food exports dwindle to insignificance		0– –0				
POLITICAL						
• OPEC governments denounced around the world; OPEC and U.S. embassies targets of riots and protests		0– –0				
• Multiple political revolutions in S. America, Africa, Asia as lack of U.S. and Canadian food exports hit.		0– –0				
• India, Bagladesh, S. America, Africa have first significant steps toward land reform to improve productivity		0– – –0				
• NASA given go-ahead to construct several powersats and solettas for possible use in climatic modification experiments			0			
MILITARY						
• Increasing tensions along U.S.S.R./P. R. China borders		0– –0				

SAI-3524

sector activities and developments than the private sector can ignore NASA plans for development of new launch vehicles. If NASA's efforts are to have the greatest benefit, those efforts must be based on up-to- date understanding of the opportunities for advocacy presented to the private sector and to the public sector by developments in the human system as a whole. This requires *continuous* examination by NASA of the changing opportunities and of the changing fabric of the human system. Planning Space Industrialization cannot be done effectively if it is done only in fits and starts; the volatility of the human system requires reassessment of alternative futures on a continuous basis to identify, at each moment, what space systems and space technologies are most likely to be used by a wide variety of Space Industrialization opportunities. *Just as short-range planning is done on a continuing, day-to-day basis, mid- and long-range planning must be done continuously to prepare for contingencies.*

3. INDUSTRIAL OPPORTUNITIES IN SPACE

3.1 INTRODUCTION

The establishment of future markets and a Space Industrialization program for each future scenario required a compilation of potential opportunities. These were established to a level of detail and breadth of application sufficient to allow gross market survey and preliminary program formulation.

The purpose of this compilation was not to create an exhaustive shopping list of opportunities but rather to key in certain indicative possibilities within each industrial activity identified (Information Services, Energy, Products, People). The goal was of sufficient breadth to insure representative program formulation and appropriate market survey. The result of this is a compilation of over 250 potential applications for space related goods and services.

3.2 METHODOLOGY FOR OPPORTUNITY IDENTIFICATION

An in-depth literature survey of over 100 documents was conducted by SAI and Southern Research Institute (SoRI) and opportunities for space industry noted and compiled. Additional ideas were obtained by review with consultants and conceptualization of applications based on the accumulated data. The elements of the overall compilation procedure were accomplished within each industry activity (Information Services, Energy, Products, People) and the results combined into one document. Although all team members participated in the four activity areas, specific responsibility for accumulation of opportunities under Information and People rested with SAI while SoRI investigated Energy and Products. Overall responsibility for assembly, dissemination and reporting was assigned to SoRI.

An extensive survey of existing literature including NASA funded studies, results of experimental programs, reports on operational experience, projections by futurists and privately funded study publications was conducted. Several recent publications were particularly useful and are listed below by their popular name.

Outlook For Space
Aerospace "New Initiatives" Study
G E BUS Study
NASA SPS Studies
Enricke Papers on "Extraterrestrial Imperative"

As previously noted, all study team members (including consultants) made inputs. Specific interested parties who supported this compilation included Ivan Bekey of the Aerospace Corporation, Don Waltz of TRW, Hans Wuenscher (retired for MSFC, now consulting) and a number of engineers and scientists at MSFC and NASA Headquarters.

The "brainstorming" portion of the approach encompassed both individual and group activities with no constraint other than technical feasibility applied. This resulted in identification of a broad range of specific applications.

The output of the literature search, individual review and brainstorming were consolidated into a single document. This document became the basic input to the market survey, program formulation and system characterization subtasks. The scope of the applications and opportunities identified ranged from descriptors of a few words to extended discussions of technical and operational detail gleaned from previous studies.

3.3 OPPORTUNITIES AND USES IDENTIFIED

As previously noted, the opportunities and their identified representative usage were compiled under four industry activity categories: Information Services, Energy, Products and People (in space). Each of these categories was further subdivided into subcategories as follows.

Information Services	Energy
Communications	Solar Power Satellite
Observations	Redirected Insolation
Navigation	Nuclear Waste Disposal
Location	Nuclear Power/Breeder Satellite
Sensor Polling	Power Relay

Products	People
Biologicals	Tourism
Electronics	Medical
Electrical	Entertainment/Art
Structural	Recreation
Process	Education
Opticals	Support

Within each of these subcategories a number of aggregations were defined in order to facilitate market survey and system characterization. A tally of various characteristic uses identified for each aggregated product area was then made and summed by subcategory. The listing of product aggregations and results of the tally are presented in Tables 3-1 through 3-4. In a few instances a specific use shows up under more than one aggregated product since more than one way to accomplish an end objective exists. The numbers are for reference only, however, and no influence on markets, programs or systems results from multiple appearance of a "use".

The extended compilation of opportunities is contained in the Appendices (Volume 4).

TABLE 3-1. OPPORTUNITIES IDENTIFIED

INFORMATION SERVICES	AGGREGATED PRODUCTS	SPECIFIC USES IDENTIFIED	
Communications	Individual 2-Way	1	25
	Group 2-Way	9	
	Down/Up Link Only	9	
	Remote Control	6	
Observations	Environmental Monitoring	10	19
	Resources Monitoring	7	
	Surveillance	2	
Navigation	Aerial	2	3
	Nautical	1	
Location	Individual	4	9
	Packages/Vehicles	5	
Sensor Polling	Individual	3	11
	Groups	4	
	Automated Polling	4	
		67	

TABLE 3-2. OPPORTUNITIES IDENTIFIED

ENERGY	AGGREGATED PRODUCTS	SPECIFIC USES IDENTIFIED	
Solar Power Satellite	Electric Power Heat	2	2
Redirected Isolation	High Intensity Low Intensity	5	5
Nuclear Waste Disposal	Long Term Safety	1	1
Nuclear Power/ Breeder Satellite	Electric Power	1	2
	Nuclear Fuel	1	
Power Relay	Power Distribution	2	3
	Aircraft Power	1	
		13	

TABLE 3-3. OPPORTUNITIES IDENTIFIED

PRODUCTS	AGGREGATED PRODUCTS	SPECIFIC USES IDENTIFIED	
Biologicals	Separation/Purification Culturing	8	8
Electronics	Semiconductors	7	
	Rectifiers	1	11
	Devices (Microcircuits, etc.)	3	
Electrical	Magnets	8	
	Wiring	5	19
	Devices (Switching, etc.)	6	
Structural	Casting	2	
	Immiscible Alloys	28	
	Float Zone Refining	8	62
	Directional Solidification	6	
	Composites	14	
	Joining	4	
Process	Catalysts	1	
	Membranes	4	
	Powders	5	23
	Purification	11	
	Devices (Thermostat, etc.)	2	
Opticals	Fibers	7	
	Lenses	8	24
	Filters	2	
	Special (Electronically conductive glass, etc.)	7	
Exterrestrial	Consider all of above where raw materials compatible	-	
		147	

TABLE 3-4. OPPORTUNITIES IDENTIFIED

PEOPLE	AGGREGATED PRODUCTS	SPCIFIC USES IDENTIFIED	
Tourism	Short Term (Days)	2	5
	Long Term (Weeks)	1	
	Transport	1	
Medical	Isolation	2	5
	Treatment	2	
	Augmentation	1	
Entertainment/Art	Objects (From Space)	3	6
	Activities (In Space)	3	
Recreation	Amusement Park	1	3
	Lodging	2	
Education	Classes From Space	1	3
	In-Space Classroom	2	
Support	Social Isolation	3	6
	Ecological Isolation	3	
		28	

4. THE TERRESTRIAL ALTERNATIVES

4.1 METHODOLOGY

Thirty-two candidates for space utilization were compared to potential Earth based alternatives. Comparisons were based on examining the initial cost of installation on a first order basis and a cursory review of qualitative factors such as ease of use, reliability, technology requirements, etc. If costs and capability obtained appeared comparable between the alternatives, they were retained for further study. In certain instances the identified space uses exhibited much lower cost for similar capability. These were identified as clearly viable candidates. Where cost and/or capability were clearly superior for the Earth alternative, the candidate was dropped from further consideration.

Because of the substantial list of space preferred or preference undetermined candidates (19) in the areas other than products, a grouping approach was taken in further alternative comparisons. A representative space candidate was drawn from the information and energy areas to serve as a "strawman" against which to consider terrestrial options. While clearly not the equivalent of an item by item analysis, it was felt that this technique would, nevertheless, reveal implications of a generic nature. The materials candidates were dropped from further consideration owing to two factors: 1) unique characteristics which did not support easy grouping and, 2) most identified products could have terrestrial alternatives in terms of alternate means of manufacture, substitute materials or replacement of need.

Once these groupings were in place, they and previously established alternative data were input to efforts to conceptualize specific alternative configurations for consideration. Not only were existing ground systems considered, but also systems based on existing or logically extended technology.

Comparisons were then made between space and ground concepts concerning equivalency and viability. The results and implications of these comparisons are discussed in Section 4.4. Figure 4-1 displays the methodology discussed above.

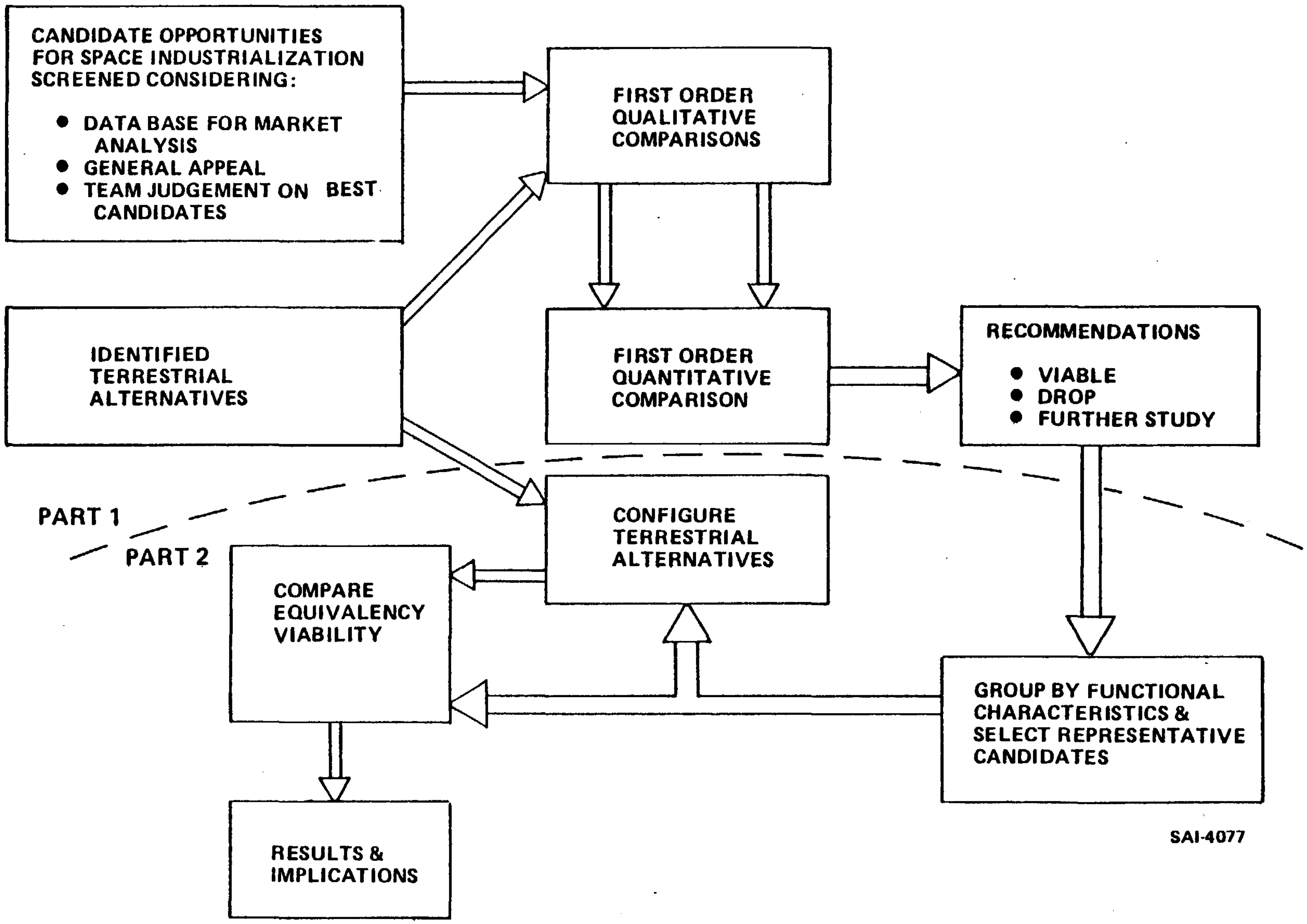


Figure 4-1. Methodology for Terrestrial Alternative Assessment

4.2 RESULTS AND GENERIC GROUPINGS

Comparative arguments for terrestrial alternatives are presented below. The comparisons are drawn from Part 1 study of specific candidates, but organized by the Part 2 groupings. Table 4-1 presents the results for specific candidate opportunities.

4.2.1 Energy

Nuclear Fission - Although light water fission reactors utilize demonstrated technology and have a known cost (37 MILS/KWH, $1000-1700/KW), environmental controversy rages over the expanded use of this technology. Well publicized incidents at Browns Ferry, AL. and the Russian satellite reentry have increased public awareness. Waste disposal and security present problems for future large scale reliance on nuclear fission. Supply of uranium is an issue as well. The National Uranium Resource Evaluation (NURE) begun in 1973 is scheduled for completion in early 1980. Pending that report DOE estimates indicate uranium shortfalls by the end of the century. Other estimates (Lieberman, Science, April 1976) predict supply difficulties by the late 1980s. The potential of this power source for long term use is thus intimately tied to breeder reactor progress.

Breeder Reactor - This newer nuclear technology is now entering a phase of development that will demonstrate its commercial potential. Waste, security, and environmental concerns identifical to those of light water reactors are amplified by characteristically higher plutonium levels in breeder reactor fuels. Even though breeder efficiency is potentially high, the economics are still under question. Additionally, recent administrative decisions, fears of proliferation, and delight over fusion progress have begun dialogues entertaining concepts of "skipping" the breeder.

Nuclear Fusion - Fusion research has received increased attention in recent years, with several techniques at the forefront of current research. While convergence on the Lawson Criteria (a measurement of nearness to possible energy production) is displayed; the progress is a result, not of a single maturing technique, but rather several jumps to new concepts. Laser fusion particularly, and other inertial confinement

TABLE 4-1.

PART 1 COMPARISON RESULTS

Information	Preference ?-No clear preference S-Space E-Earth
Mobile Communications	
Portable Telephone	?
Police Wrist Radio	E
Disaster Communications	S
Global Search and Rescue	S
Nuclear Fuel Locators	S
Transportation Services (Equipment Sales)	*
Coastal Anti-Collision System (Equipment Sales)	E
Rail Anti-collision System	*
Personnel Navigation Sets (Equipment Sales)	S
Vehicle/Package Locator	S
Voting/Polling Wrist Set	?
Fixed Point Communications	
3-D Holographic Teleconferencing	?
National Information Services	?
Electronic Mail	?
Advanced TV Broadcast	?
Vehicle Inspection	*
Observations	
Earth Resources	S
Energy Monitor	E
Energy	
Solar Power Satellite (Operation 1996)	
49@ 5GW ea - 27 MILS/KWH	?
60@ 10GW ea - 11.5 to 7.1 MILS/KWH	S
60@ 10GW ea - 27 MILS/KWH	?
Night Illumination	
Urban lighting	?
Disaster lighting	S
Nuclear Waste Disposal	*

* Data not readily available on alternatives

TABLE 4-1 (Continued)

PART 1 COMPARISON RESULTS

Materials	Preference ?-No Clear Preference S-Space E-Earth
Drugs and Pharmaceuticals	?
Electronics	
Semiconductors	?
Electrical	
Magnets	?
Superconductor (Generating Only)	?
Electron Tubes	E
Optical	
Fiber Optics	?
Special Metals	
Perishable Cutting Tools	?
Bearings and Bushings	?
Jewelry	S
Wire (High Strength; Low Resistance; etc.)	E

methods are producing much optimism, with overall energy break-even predicted by the late 1980's (Farley, Research/Development, Jan 1978). On the down side it should be also pointed out that:

a) Initial fuel cycles will be "dirty fusion" using deuterium and radioactive tritium.

b) Tritium is produced from lithium, the abundancy of which is comparable to that of ^{238}U.

c) Regardless of the fuel cycle, a waste problem will exist in that the neutron flux will make the structure containing the reaction extremely radioactive and short lived. Some estimates place wall life at less than 10 years and waste volumes at 250 tons per reactor per year.

Sea Thermal - This option apparently features a true long term opportunity. Estimates place total possible production at 200 times world demand by the year 2000. Environmental concerns include: 1) long term temperature modification of the ocean and 2) effects caused by a working fluid spill. Produced from such a plant could be several items:

a) Ammonia
b) Methanol
c) Fresh water
d) Oxygen
e) Nitrogen
f) Carbon dioxide
g) Hydrogen

The latter product could enhance interface with incremental power production schemes (geothermal, ground solar, wind) in a so called hydrogen economy. Power transmission by conventional means would be complicated by the location of ocean thermal plants.

Magnetohydrodynamics - Under development, MHD power generation would afford a relatively clean (1/9 and 1/6 EPA emission and particulate standards) and efficient (40 - 60%) technology to utilize U.S. coal supplies. Unanswered are concerns about carbon dioxide pollution and the impact of strip mining operations from the large scale use of coal. Recent reporting on coal conversion efforts (J.P. Smith, Washington Post, Jan 1978) underscores the fact that coal will be in demand for markets other than power generation (such as gasoline). Supply is also in question, GAO studies halving previous estimates of recoverable coal (H.J. ERB, AP, Jan 1978).

4.2.2 Mobile Communications

Truly mobile communications based on RF techniques have been commercially available for a number of years. Creation of the CB frequency allocations has dramatically illustrated the demand for this type of service. Mobile telephone operations provide a direct link to the basic telephone system. These and other RF systems however suffer common problems in terms of range, frequency crowding, and regulatory constraints. Many similar functions are served over wide frequency ranges. Substantial restructuring of the existing services on a nationwide basis could give genesis to more universal systems, but would involve complex issues concerning vested user, manufacture, and communications interests.

4.2.3 Fixed Point Communications

Current point to point communications are well established but rising in cost. The potential for increased demand in terms of data transmissions, TV conferences, and interactive cable TV is substantial. Increased use of microwave transmissions could provide the needed capacities but at a high cost. There are environmental questions surrounding this option also. Fiber optics and RF wave guides are receiving much attention and offer significant advantages.

High density data transmission is also possible using holographic disks, but requires special equipment and cannot support real time or interactive transactions.

4.2.4 Observations

Fundamental alternatives for terrestrial earth resources capabilities lie primarily with aircraft. Despite the maturity of space technology, specialized aerial applications persist. Improved electronic equipment has permitted smaller and cheaper aircraft. Adjunct advances in computer technology have lessened the burden of data reduction from distributed sources and sensors.

4.2.5 Representative Candidates

The representative candidate opportunities selected from the generic groups of Part 1 are the following:

Representative Candidate	Generic Group
Space born reflectors providing urban or disaster lighting	Energy
Portable Telephone	Mobile Communications
Wide Band Point to Point	Fixed Point Communications
High Resolution Earth Resources	Observations

4.3 TERRESTRIAL ALTERNATIVE CONCEPTS

4.3.1 Night Illumination

Terrestrial alternatives to the Lunetta are considered in two functional areas, urban illumination and disaster lighting.

The following characteristics were considered essential to a disaster system:

a) Extreme mobility or low cost multiple systems for rapid deployment.

b) Terrain independent application.

c) Deployment and operation not affected by the disaster.

Limited resupply is clearly a desirable feature to avoid adding to supply burdens and manpower requirements. The operation of such a disaster system should either be easy for the untrained, or have alternate "nominal" uses so that trained crew are available. Low storage cost is also an enhancing feature. There are a wide range of potential disasters against which to size such systems (Table 4-2). The systems considered were the following:

AIR	GROUND	HYBRID
Fixed and Rotary Wing Aircraft	Free Standing Light Generator	Tethered Balloons/ Generators
Blimps	Large Tower/Generators	Stand-off Laser with Aerial Reflectors

TABLE 4-2. DISASTER TYPES

DISASTER	COMMENTS
Hurricane	Wide spread destruction possible envolving many people. Operations during and after are difficult. Logistics is a central problem.
Earthquake	Ground mobility easily disrupted. Limited warning at present often results in an immediate need to aid large numbers of people.
Flood	Operations in area are difficult.
Tornado	Multiple simultaneous occurances possible. Short warning time.
Snow	Can cover extremely wide areas.
Volcano	Evacuation often required.
Nuclear or Chemical	Could involve evacuation, with possible panic and a variety of population densities.
Blackout	Urban environment; disorder possible.
Aircraft	Search and Rescue requires large area and time; collision, rapid response.

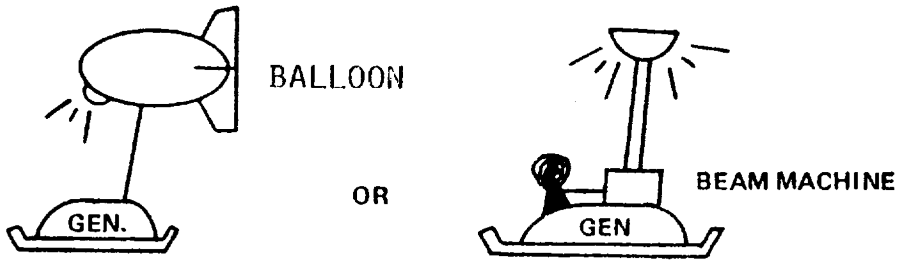
AIR	GROUND	HYBRID
Nuclear Dirigible	Starlight Glasses	Flares and Parachutes

The nuclear dirigible could have alternate uses that would make adoption for disaster lighting relatively low cost. Conventional air-carft, generators, poles and balloons represent established technologies. Devices to aid individuals with poor night vision are in production, giving rise to a concept of mass produced "starlight" glasses. Consideration of requirements and disaster characteristics led to rejection of many of the concepts.

REJECTED SYSTEMS	REASON
Fixed and rotary wing aircraft	• Loiter time • May be critical resource for other operations
Blimps	• Small payload • Slow response • Alternate use questionable
Nuclear dirigible	• Slow response • Major technology issue
Free standing light poles	• Set up time/manpower
Starlight glasses	• Technology/cost • Adds to distribution problems
Flares and parachutes	• Resupply • Fire hazard • Moving multiple shadows

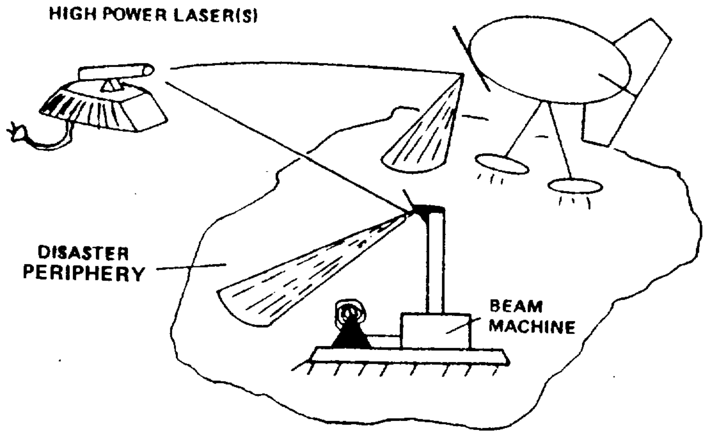
Two remaining concepts for disaster lighting are shown in Figure 4-2. Both systems are air dropped and resupplied.

Air Dropped Aerial Light



- Low Technology
- Distributed Capacity
- Transported Rapidly

Stand-Off High Power Laser and Reflectors



- Operation/Supply Removed from Disaster Theater
- Central Power Source

Figure 4-2. Disaster Lighting Concepts

The space option for disaster lighting remains unique in terms of providing an extreme wide area lighting. It clearly would not require short term resupply. No terrestrial system for wide use has been implemented to provide a similar scope of lighting.

Urban illumination alternatives invariably tie to centralized sources because of the total power requirement. The cost and utility of such lighting is clearly dependent on future ground cost per KWH_e and the conversion efficiency of lighting devices. It should be noted that during periods of energy limitations this form of lighting has proved "discretionary." During future periods of resource scarcity (dollars or KWH) perceived value added could legislate reduced demand for such services.

The Lunetta costs as developed by Ehricke (Space and Energy Sources May 1977) provide the following estimate.

- Assumptions
  - a. Lighting efficiency 50 lumens/watt
  - b. Terrestrial cost (energy and maintenance) 70 $MILS/KWH_e$
- Equivalent Lunetta cost (best sky - worst overcast)
  - a. 1 city serviced 32-61 $MILS/KWH_e$
  - b. 2 cities serviced 16-30 $MILS/KWH_e$

Basing these estimates on sodium vapor lighting (100 lumen/watt) alters the equivalent Lunetta costs.

a. 1 city serviced 60-117 $MILS/KWH_e$
b. 2 cities serviced 30-58 /$MILS/KWH_e$

For a clear space based winner, multiple cities (probably greater than two) must be served by reflector sets and/or terrestrial power price increases be sufficiently provocative.

Possible social-economic issues may also be part of Lunetta cost. Consider, as an admittedly simple example, the impact of all night light on drive-in theaters.

a. Assume $1 penalty to use a sit down theater
b. Assume per capita attendance of .2/yr, all diverted to sit down theaters.
c. If per capita use of outdoor lighting is 10 w-yr with terrestrial lighting at 70 $MILS/KWH_e$, then the impact of undesired lighting would be 4% of the best Lunetta savings.

Other more complex mechanisms may exist, suggesting the cost significance of these issues. Additionally, traditional systems can be conventionally defended.

4.3.2 Mobile Communications

As mentioned, various systems are currently used for mobile applications. Several of these systems and their limiting features are shown in Figure 4-3.

LIMITING FACTORS FOR UNIVERSAL APPLICATION

EXISTING SYSTEM TYPES	RANGE LIMITED	ONE WAY	POWER FOR USER SET HIGH	OPEN CHANNELS	MANUAL SWITCHING	FREQUENCY ALLOCATION IN MASS MARKET
PAGING SYSTEMS	✓	✓			✓	
SWISS CAR CALL		✓			✓	
MOBILE WITH REPEATERS	✓		✓	✓		✓ LICENSE REQ'D
CITIZENS BAND	✓		✓	✓		✓ CURRENT
RADIO TELEPHONE	✓		✓		✓ AUTO. SOON	✓

SAI-3722

Figure 4-3. Existing Mobile Communications

The Swiss Car Call system is a vehicular paging system implemented throughout the Swiss highway system. It uses a single frequency and a coded command to page drivers.

Radio telephone systems in the U.S. are currently being converted to computer switching. In reality all manual systems could easily be so operated. Except for remote "backwoods" operation, the typical user environment is often in sight of the existing phone system, ties to which are used in radio telephone systems. A concept for an advanced radio telephone is displayed in Figure 4-4.

- MINATURIZED
- AUTOMATED ACCESS/SWITCHING TO FIXED NETWORK
- DISTRIBUTED
  1) INCREASED COVERAGE
  2) REDUCED BANDWITH FOR RF LINK
  3) LOWER POWER USER SETS

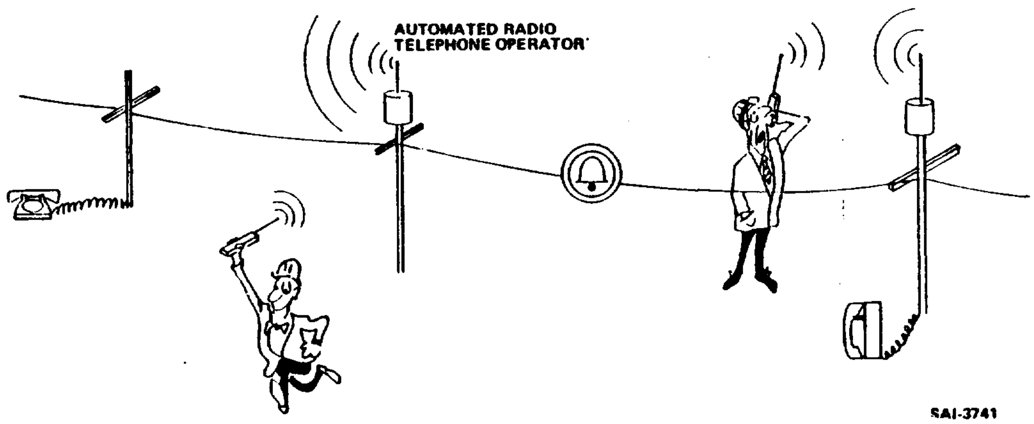


Figure 4-4. Advanced Radio Telephone

Several other concepts such as Spread Spectrum Communications and Packet Switching offer near term functional equivalence, but employ high power central antennas.

What can be described as first generation implementations of the distributed system of Figure 4-4 are already underway in the Washington-Baltimore and Chicago (2100 sq. miles) areas. The centralization that results from these concepts encourages monopolization of the communications market. Radio Common Carriers that operate existing radio telephone service are ill-equipped to fund computerized switching and transmitter networks and are attempting to block development of advanced systems (J. Mason, Popular Science, Jan. 1978).

4.3.3 Fixed Point Communications

Optical Fiber techniques are receiving much attention as possible wide-band, low-cost transmission methods. They offer many advantages, such as:

a. Significantly increased information transmission rates (half billion bits per second - laser FED)

b. Immune to EMI/no cross talk

c. Low power requirements

d. Light cable weight (1% wt of copper, ½" fiber cable = 4" copper)

e. Quantity use could drop current price by 90%

Other concepts such as millimeter wave guides are also under development. Should cost reductions prove out, replacement of current microwave links could occur. This would ease both environmental and security concerns incurred in using RF transmissions.

Use of fiber optics is foreseen in three stages. First, inter-component computer communications, then cable TV, and finally, general telephone use. However, success with advanced radio telephone service and current experiments in interactive TV could easily bring about earlier opportunities.

4.3.4 Observations

Aircraft continue to be useful for certain types of resource data collection. Even at a limited 800 miles a day, current operation of low level aircraft for pinpoint location of mineral deposits is expanding (B. Kocivar, Popular Science, Jan 1978). For a perspective on aircraft use, consider that whole earth coverage in 20 mile bands (60^o field of view from 92,000 ft) can be achieved with 9.852 million air miles. This represents .4% of the U.S. commercial air traffic for 1976 and perhaps an upper cost bound of $67.1 million. A mixed fleet of sub/supersonic aircraft (V_{AV} = 1200 MPH) hypothetically provide this coverage every 30 days (utilization = 14.1 hr/day, 20 aircraft).

A mix of advanced electronics and RPV technology could conceivably provide automated high altitude platforms for remote sensing. Consider the Boeing Compass Cope System:

a. 24 hr duration with 1200 lb payload

b. 60,000 FT altitude

c. Radar capable of detection/tracking of tanks at 100 n. miles

Operating cost of an auto-RPV system would be well below airline costs. Such RPV platforms would allow schedule, payload, and mission flexibility. On the downside, upper atmosphere pollution might require advanced fuels and overflight of some countries is clearly doubtful.

4.5 RESULTS AND IMPLICATIONS

The comparison of terrestrial alternatives and generic candidates suggest the following rankings/rationales for Space Industrialization.

1) High Resolution Earth Resources.

   Satellite technologies have a firm base for remote sensing work. Upset of space access/economics could provide sufficient encouragement to terrestrial systems such as an advanced auto-RPV. Indeed, military efforts on-going in command, control, and communications may do this regardless. However, without major perturbations, sensor development for satellite use represents less risk than developing a complete new system for terrestrial use.

2) Point-to-Point Communications

   Fiber optic techniques have become a strong near term candidate. Several demonstration projects are currently operational. Space options, however, would support more rapid deployment of wide band point-to-point communications should the necessary space systems become available.

3) Disaster Lighting

   The overall utility of any disaster related system may hinge on rapid deployment. Few disasters give long lead time warnings. Flexibility and rapid response would be a prime requirement of a space system as well as ground systems, probably best met as a divertable resource of another system. Undertaken as a national project, ROI would not be an inhibiting issue. An experiment in space reflectors might attractively be configured as part of a large structures program, with disaster use as a "spin-off" proposition.

4) Urban Lighting

Without resolution of complex social and energy issues urban lighting is a doubtful candidate. The relative cost of other energy needs overshadows potential space light savings, at least for the near term. Should decentralized concepts for energy production achieve prominence, space lighting could become more attractive.

5) Mobile Communications

Because of the potential of this market, commercial terrestrial capabilities are being developed currently. Advanced electronics and computer technology can likely meet demand in the near term, and support growth. Although developing ground systems will not soon provide the universal geographic coverage required for systems such as a search and rescue system (a viable space option), they will provide coverage to a large majority of potential users. Space applications, by the time they might be ready, may be placed in the position of having to cost justify only increments of then existing performance.

The generic lessons culminate with the conclusion that alternatives do exist, or can be visualized for most space initiatives. "Uniqueness" of the space candidates detailed was not deemed strong enough to warrant special consideration in a competitive environment. Significant technological "lead" for space options was found only in the area of Earth resources. And, in the case of communications, implementation may be tipped already toward terrestrial options. In concert with these arguments it is concluded that market softness, in terms of systems requirements, remove the constraint that terrestrial alternative systems must duplicate exactly space products and services.

The relative viability between specific space and terrestrial competitors is often influenced by more complex factors than cost performance. The predominate of these factors being: 1) Uncertainty in space and other technologies, 2) environmental concerns, 3) vested interests, and 4) regulator/international constraints. The impact of the above exemplified by questions such as: 1) Will international policies limit the availability of geosynchronous positions before demand?

2) What are the long term subphotoperiodic effects on plants and animals of wide area (Lunetta) lighting?

3) Would an orbiting space light be perceived as a military resource?

4) How would new large volume communications be interfaced with existing regulations and facilities?

5) What are the privacy/security problems associated with wide ground access to communications beams?

The implications of the above statements gives rise to the following observations on the viability of terrestrial alternatives.

1) Complexity from detailed assessment of non-cost issues substantially reduces the opportunity to develop a "winning" mix of space efforts based on generalized benefits.

2) In lieu of a mandate, space viability must be aggressively advocated/ studied against competitors in the mid 1980's.

3) The current involvement of an existing industry will typically indicate which alternative would be favored by it unless forced by competition to change directions. New entries in an industry will select a path based on investment and risk considerations. Most space initiatives considered in this study will appear highly favorable over terrestrial alternatives only after steps toward risk reduction are implemented.

5. POTENTIAL MARKETS AND REVENUES

5.1 APPROACH

After compilation of the list of Industrial Opportunities was complete, a review process was undertaken to select initiatives for preliminary market analysis. The primary criteria applied in the screening process were availability of data and probable advantage over terrestrial competitors. Assumptions were made based on the data available after the analysis was underway.

Different specific methodologies were applied according to which industry was being examined. For example, market analyses for Products were much more speculative than those for Information Services since much less is known about the specific use and probable cost of a prospective product. A common set of general methodology guidelines were used wherever appropriate and provide the foundation for understanding the philosophy and assumptions which guided these market surveys.

5.2 METHODOLOGY FOR DETERMINING THE MARKET POTENTIAL FOR GOODS AND SERVICES FROM SPACE

1. Identify product and anticipated year of technological availability. Define advantages of product or service over competition.

2. Assess any entry delay barriers. . .Low (0 delay); Medium (5 year delay); High (10 year delay). Barriers can be legal, political, financial, or economic.

3. Determine/assess approximate end user cost of product and/or service - at entry and at saturation. Graph as a learning curve on log paper to determine price at a given year.

4. Identify societal characteristics (advanced, developing, subsisting).

5. Define attributes of product (satisfies fundamental need, more sophisticated need,. . . .). Match product attributes with societal needs.

6. Define the universe of buyers (e.g., everyone; businesses; steel companies;. . .).

7. Assess the level of saturation within the universe of buyers... Low (25%); Medium (50%); High (75%). This saturation level can be assessed by prior determination of level of completition, whether the product is incremental or innovative, and by the fit of the product/service with society's needs.

8. Define the percent value of the space input to the end product or use. In all cases, assume the cost to produce a product is 50% of the price to the end user (rule of thumb).

9. Assess any resistance to change factors after entry. . . Low (0 stretchout); Medium (5 year stretchout); High(10 year stretchout). This will affect the time until the product sales elbow up into the growth phase. Resistance to change can be assessed from such factors as - How much better is this product than competition it's replacing; and How much change is required of the end user?

10. Assess a period of ideal saturation. . . at which time the product/service will have achieved 99.9% of ultimate saturation level. Slow (30 years); Moderate (20 years); Fast (10 years). Use present day analogies.

11. Assume the first 10% of saturation level will occur within (30% + resistance to change factor) of period of ideal saturation. Assume the last 10% of saturation level will be penetrated within 30% of period of ideal saturation.

12. For period of anticipated sales, define a band of anticipated population levels within the universe of buyers.

13. Assess a replacement level. . .Low (5%); High (10%). Replacement sales will come from lifetime of product factors and from expected product improvements.

14. Over the anticipated years of sales, multiply population and ultimate saturation level by level of saturation in given year (as defined by product life cycle S-curve assessed earlier), to determine unit sales.

15. In year of elbow up into growth phase, begin to enter replacement volume into total volume. This will come from replacement level multiplied by cumulative number of units in the market.

16. Over anticipated years of sales, define cost by year from learning curve chart assessed earlier. Multiply units sold by cost/unit to get sales volume.

17. Once dollar volumes are calculated, test numbers for reasonableness against common sense and present day analogies.

18. Band the total basic projection by a low end/worst case curve (least optimistic scenario, risks, disadvantages, barriers, etc.); and a high end/best case curve (most optimistic scenario, benefits, advantages, impellers, etc.).

19. If some numbers are highly uncertain, perform a sensitivity analysis on the relevent parameters to show effect on ultimate volume.

20. Graph or chart anticipated market volumes (low, probable, high) by society type, over anticipated years of market penetration.

5.3 RESULTS OF MARKET/REVENUE ANALYSES IN INFORMATION SERVICES FOR UNITED STATES ONLY

5.3.1 Portable Telephone

This communication device would allow citizens to communicate through exchanges by voice, from anywhere. Through a multichannel switching satellite and transmitter-receivers, people could be connected directly or by telephone networks. The exceptional mobility of the unit makes it ideal not only for business and recreational use, but also for use in emergencies (rescue missions, etc.).

Portable telephone could satisfy needs ranging from fundamental to peripheral. The need for on-the-spot communications in business and professional activities is evidenced by the rapid growth in use of pocket pagers. Satisfaction of more peripheral needs is evidenced by the rapid growth of CB radios (and a concomitant increase in allocated channels) in the U.S. This implies a wide spread of potential users of portable telephones, with a wide spread of needs being met by the radio.

To determine how many of these potential users would be actual users, what revenues they would generate through unit sales and call tolls, and the time phasing of the revenues, several assumptions have been made. It is assumed that the primary market is the United States - employing U.S. population projections to the year 2025. Combined with these population figures are assumptions concerning the user universe (calculators as an example) and market saturation (telephones as an example).

The universe of users/buyers would likely be limited to professionals and businesses at the high price levels. This is precisely what happened with calculators and pagers: for two to five years, the marketing approach was toward the professional and businessman. As costs declined and these markets became saturated, the overall market was expanded to the entire population - resulting in the present situation of sophisticated electronic devices being purchased by school children. Thus the potential universe of buyers will be assumed to include the entire population age 16 and over, over the course of the product's life.

The incidence of telephone use provides a sound basis for assumptions about portable telephone saturation. In 1973, there were 121 million phones in the U.S., serving a population of roughly 210 million. This implies, in a rough way, that a 50% saturation of market of communications instruments can be attained. Further, during a peak period of sales (1970-1973), six million new phones were added each year. From this we get a reasonable estimate of the upper limit on annual sales volume for portable telephones. However, since there are many competing forms of fine communications techniques in place (phones - stationary and mobile; CB radios; television; etc.) since other forms of communication will be needed to carry transmissions other than voice; and since improved techniques such as optical fibers may vastly improve reception quality of in-place units (which themselves may be made mobile once broad-band transmission is available) - then the ultimate saturation of protable telephones may ultimately and ideally reach 25% (best case) or 10% (worst case) of the potential universe of buyers in the anticipated period.

The product appears to be analogous to calculators, digital watches and color television in favorable reception by the end user. While the number of people ultimately desiring the product may be high, the complexity of producing such a large volume and then making such a complex system operational may imply a Moderate track (20 years) to ultimate saturation. This is in line with the saturation rate of color televisions. With ideal saturation coming in 20 years, and a Medium stretchout from resistance to change factors, 10% of the saturation level will come in 11 years after entry (30%(20 years) + 5 years). The final 10% will take six years. The calculations to this point are given in Table 5-1. Table 5-2 indicates the rates due to replacement. The product appears to have high potential for incremental marketing improvements (as with calculators and CB radios), implying a high replacement level. Replacement level during rapid saturation is 10% of cumulative volume (best case) and 5% of cumulative volume (worst case).

Pricing assumptions were derived from data on related products. Analogous products would be hand calculators, digital watches (battery operated) and CB radios. Calculators, when first introduced, were priced in the neighborhood of $350 (to the end user). Similar calculators can now be purchased for $10 to $30 - although addition of features has kept the price spread between $10 and $300. Average low selling price may be assumed to be around $50. Digital watches originally sold for $100 to $300, but are now selling in the neighborhood of $50 to $100, with higher watches remaining in the higher price brackets. CB radios are following a similar pricing trend. We may therefore assume an average price spread of $300 down to $30, from first sale to the average price near market saturation. These assumptions and related figures are given in Table 5-3. Further projections can be found in Table 5-4.

There will most likely be delays in the implementation of the portable telephone. Political and legal entanglements may result in a delay of 5 to 8 years. As a precedent, the FCC delayed the launch of America's first domestic communications satellite for 8 years (1965-1973). As there was controversy then, so there will be considerable controversy with a portable telephone system - a system which would threaten to radically change the existing structure of communications. AT&T would have a prime interest (even if it were one of the major proponents of portable telephones)

TABLE 5-1.

14.	Population	Level/Ultimate Saturation	UNIT SALES/CUMULATIVE SALES	
1995	195M	(0.91%)(25%) = 0.2%	.44M	.44M
1996	196M	(1.80%)(25%) = 0.4%	.44M	.88M
1997	197M	(2.70%)(25%) = 0.7%	.45M	1.33M
1998	198M	(3.60%)(25%) = 0.9%	.45M	1.78M
1999	199M	(4.50%)(25%) = 1.1%	.46M	2.24M
2000	200M	(5.50%)(25%) = 1.4%	.51M	2.75M
2001	201M	(6.40%)(25%) = 1.6%	.47M	3.22M
2002	202M	(7.30%)(25%) = 1.8%	.47M	3.69M
2003	203M	(8.20%)(25%) = 2.0%	.47M	4.16M
2004	204M	(9.10%)(25%) = 2.3%	.48M	4.64M
2005	205M	(10.0%)(25%) = 2.5%	.48M	5.12M
2006	205M	(20.0%)(25%) = 5.0%	5.1M	10.2M
2007	206M	(30.0%)(25%) = 7.5%	5.2M	15.4M
2008	207M	(40.0%)(25%) = 10.0%	5.3M	20.7M
2009	208M	(50.0%)(25%) = 12.5%	5.3M	26.0M
2010	209M	(60.0%)(25%) = 15.0%	5.3M	31.3M
2011	210M	(70.0%)(25%) = 17.5%	5.4M	36.7M
2012	210M	(80.0%)(25%) = 20.0%	5.3M	42.0M
2013	211M	(90.0%)(25%) = 22.5%	5.5M	47.5M
2014	212M	(91.7%)(25%) = 22.9%	1.1M	48.6M

TABLE 5-2.

15.	New Purchases	Replacement Purchases	Total Sales
1995	.44M	---	.44M
1996	.44M	---	.44M
1997	.45M	---	.45M
1998	.45M	---	.45M
1999	.46M	---	.46M
2000	.51M	---	.51M
2001	.47M	---	.47M
2002	.47M	---	.47M
2003	.48M	---	.48M
2004	.48M	---	.48M
2005	.48M	---	.48M
2006	5.1M	1.0M	6.1M
2007	5.2M	1.5M	6.7M
2008	5.3M	2.1M	7.4M
2009	5.3M	2.6M	7.9M
2010	5.3M	3.1M	8.4M
2011	5.4M	3.7M	9.1M
2012	5.3M	4.2M	9.5M
2013	5.5M	4.7M	10.2M
2014	1.1M	4.9M	6.0M

TABLE 5-3.

16.	Unit Sales	Cost/Unit	$ Sales	Calls/Year	Cost/Call	Call Sale
1995	.44M	$300	$132M	40.15M	$3.00	$120.4M
1996	.44M	$220	$97M	128.5M	$2.20	$282.7M
1997	.45M	$180	$81M	242.7M	$1.80	$436.9M
1998	.45M	$160	$72M	389.8M	$1.60	$623.7M
1999	.46M	$143	$66M	572.3M	$1.43	$818.4M
2000	.51M	$131	$67M	803.0M	$1.31	$$1052M
2001	.47M	$122	$57M	1058M	$1.22	$1290M
2002	.47M	$116	$54M	1481M	$1.16	$1718M
2003	.48M	$109	$52M	1826M	$1.09	$1991M
2004	.48M	$103	$49M	2206M	$1.03	$2272M
2005	.48M	$ 98	$47M	2621M	$ .98	$2569M
2006	6.1M	$ 70	$427M	6148M	$ .70	$4304M
2007	6.7M	$ 56	$375M	10471M	$ .56	$5235M
2008	7.4M	$ 48	$355M	15717M	$ .48	$7544M
2009	7.9M	$ 43	$340M	21832M	$ .43	$9388M
2010	8.4M	$ 39	$328M	28870M	$ .39	$11259M
2011	9.1M	$ 35	$318M	38884M	$ .35	$13609M
2012	9.5M	$ 33	$313M	48365M	$ .33	$15960M
2013	10.2M	$ 31	$316M	59126M	$ .31	$18329M
2014	6.0M	$ 30	$180M	69742M	$ .30	$20923M

TABLE 5-4.

	Calls/Person/Day	Average Monthly Bill
1995	.25	$22.50
1996	.40	$26.40
1997	.5	$27.00
1998	.6	$28.80
1999	.7	$30.03
2000	.8	$31.44
2001	.9	$32.94
2002	1.1	$38.28
2003	1.2	$39.24
2004	1.3	$40.17
2005	1.4	$41.16
2006	1.5	$31.50
2007	1.6	$26.88
2008	1.7	$24.48
2009	1.8	$23.22
2010	1.9	$22.23
2011	2.1	$22.05
2012	2.2	$21.78
2013	2.3	$21.39
2014	2.5	$22.50

of seeing a long transition time from standard phone service to portable telephone. Further, many new frequency bands would have to be allocated. This would require either extensive restructuring of the existing frequency allocation system, or the opening of new frequencies with their attendant uncertainties. Finally, a project of major import such as this would likely necessitate financing on the order of $1 billion. This in itself would generate a delay in startup of at least 1 to 3 years. Therefore, assume a high (10 year) delay barrier to entry.

Even after political and legal barriers are surmounted, market conditions and consumer conservatism will have an impact on the product's sales. Resistance to change by competing products implies some stretchout. It should be noted that the portable telephone will likely be a supplemental device, rather than a replacement device. Assume a Medium stretchout (5 years) before growth phase.

Finally, it should be noted that we have assumed that portable telephones cannot come to be without the benefit of space communications satellites (i.e., the value of space to the end product is 100%). The technology for this portable telephone project is available in 1985.

For summary, the portable telephone allows direct person-to-person communication without intervening stations, and the user can call and be called from any location. The product has a comparable to lower price than existing person-to-person communications methods, is much more flexible in use, and requires little change of method of the end user. Summary revenue plots (best and worst case) of both unit sales and call sales are given in Figure 5-1 and Figure 5-2.

5.3.2 3-D Holographic Teleconferencing

Travel for the purpose of business conferences is costly, time consuming and inefficient. 3-D Holographic Teleconferencing greatly reduces the need to travel for most government or private industry business conferences without a significant loss in the ability to transact business. The concept can be described as follows: Identical conference rooms are fitted with a TV camera, TV projector, laser illuminator and stereo sound system.

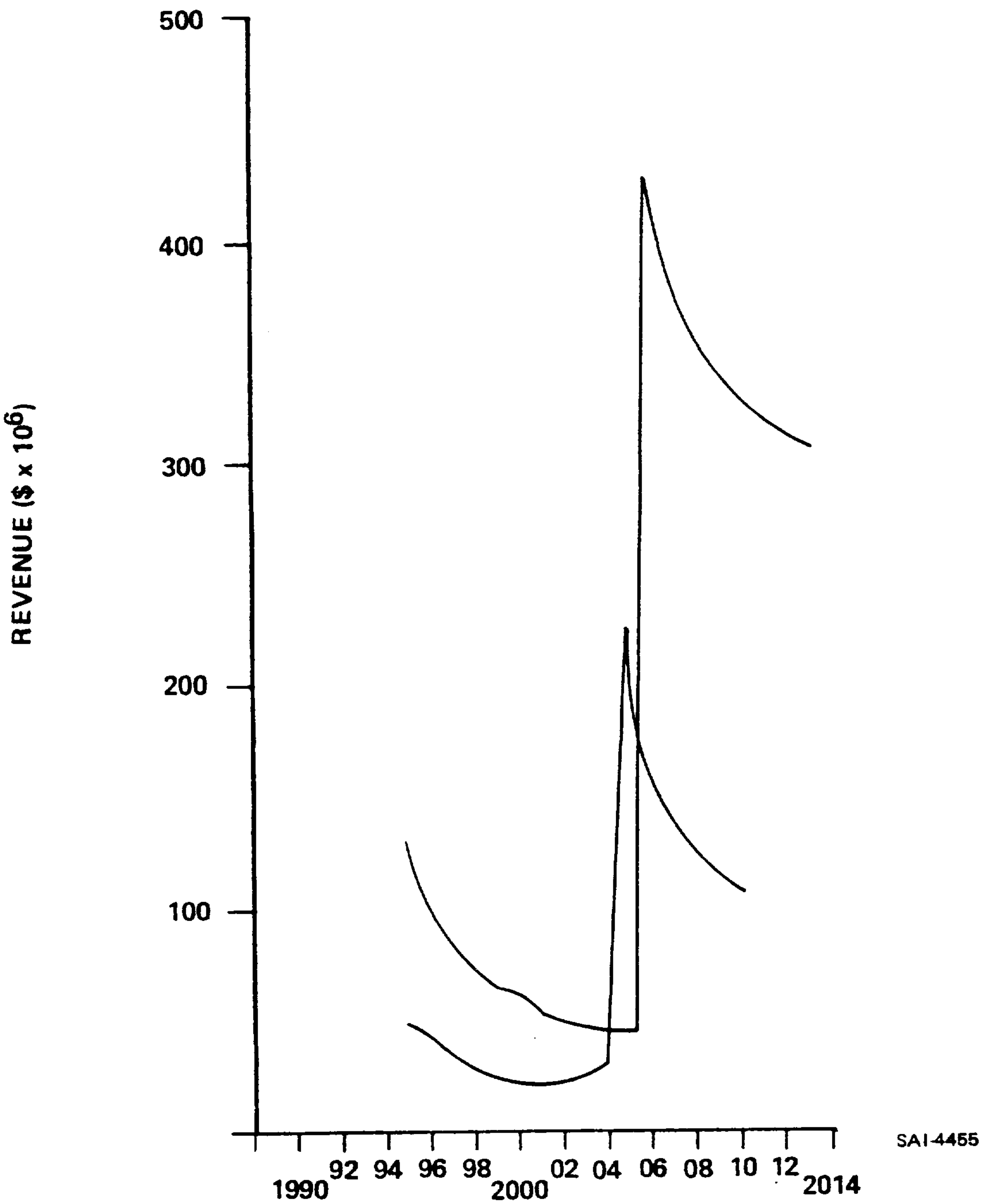


Figure 5-1. Revenues From Portable Telephones (Portable Telephone Sales)

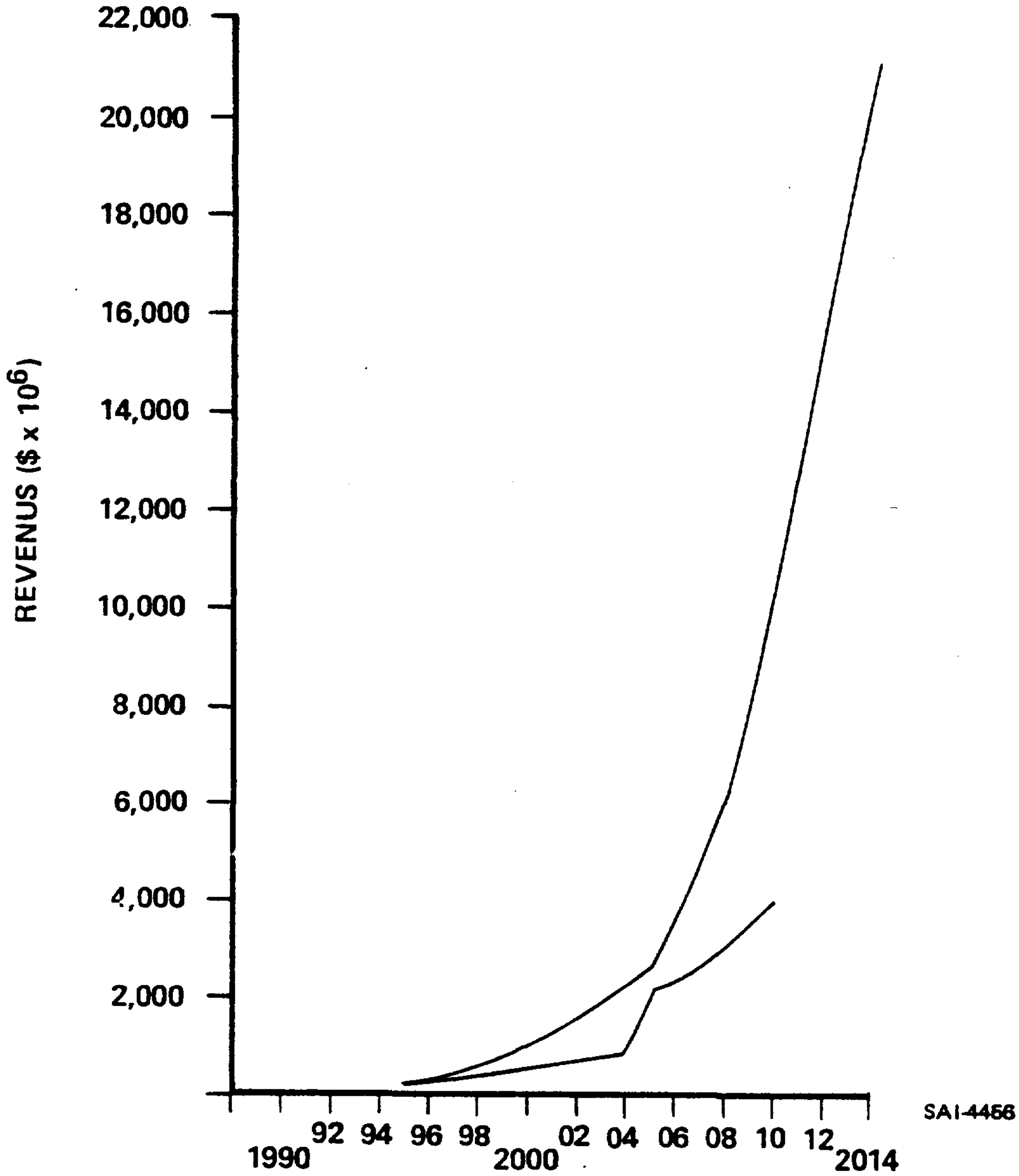


Figure 5-2. Revenue From Portable Telephone (Call Sales)

Resulting holograms produce three-dimensional images that can walk, talk and present data.

Every trip saved by a teleconferencing net means not only saved plane fare, but also gives the high paid manager more time at his home office. The number of executives and managers traveling from a company would likely be a function of the size of the company. That is, we could assume both an increasing number of divisions, and an increasing number of inter-managerial contacts needed as the size of a company increases.

As an arbitrary method of determining number of divisions (outlying plants, etc.), which thereby determine number of teleconferencing rooms needed, assume the following breakdown by assets. Included is a likely frequency of use per teleconferencing room.

Assets	Divisions	Frequency of Use
$1-10M	2	1 per 5 days
$10-25M	4	1 per 4 days
$25-50M	6	1 per 3 days
$50-100M	8	1 per 2 days
$100+M	10	1 per 1 day

Price per use is based on the assumed costs of the average air fare for two users, or $500 per use. Historical analogies such as the telephone, in-house computers and air transportation were employed in generating penetration assumptions. Ultimate penetration is 10% (worst case) to 50% (best case). Finally, the saturation time is based on projected resistance to change - 20 years.

Growth in the system apart from specific penetration and saturation trends is derived from linear projections of the population distribution of corporations (by assets).

	1970	1973	per 5 years
$1-10M	87K	108K	20K
$10-25M	10K	12K	2K
$25-50M	4K	5K	1K
$50-100M	2K	3K	1K
$100+M	3K	4K	1K

Extrapolations of average use per company according to assets category are combined with the above table to give total use tables, Tables 5-5 and 5-6. All calculations and assumptions are combined to give total revenue in best and worst case, Table 5-7. These are plotted in corresponding Figure 5-3.

It should be noted that results of the analysis for 3-D Holographic Teleconferencing do not reflect any costs for equipment costs not yet estimated.

5.3.3 National Information Services

Libraries are the current source of information for most people. Typically, a library has a reference desk which can answer inquiries either in person or by phone. The larger the library, the more likely it can handle most inquiries. Smaller libraries are beginning to use computer terminals to connect into central libraries which have greater access to information. This may be the process with a National Information Service: the first step may be that libraries will tie in and be the local information source for queries. However, as the systems become more sophisticated, and as costs go down, individual users may well begin to enter the market - perhaps starting with businesses and going on subsequently to households.

A national information satellite service would use large multi-beam antenna satellites to link facsimile, voice, data, and teletype terminals using only low power and small antennas. The satellites would be multi-channel processing repeaters. In performance, 400,000 channels of 1Mbit/sec or 1MHz capability would be serviced in 4000 areas worldwide, with 0.05 W transmitters and 3 foot antennas at the user terminals.

Because libraries are a natural source for information, and because a tie-in network has already begun to be established, assume the first decade of use sees the service being used by existing libraries. A survey of several libraries showed that there were 0.1 to 0.5 calls for reference per person per year in a given district. Thus in a larger city of 1 million people, there could be up to 500,000 reference queries per year. Small libraries would have proportionately few calls. Thus we can assume yearly user fees of $10K for the larger central libraries, and $1K for

TABLE 5-5.

($1-10M)	#	Avg use/company	Total
1990	167K	50/yr	8350K
1991	171K		8550K
1992	175K		8750K
1993	179K		8950K
1994	183K		9150K
1995	187K		9350K
1996	191K		9550K
1997	196K		9750K
1998	199K		9950K
1999	203K		10150K
2000	207K		10350K
2005	227K		11350K
2010	247K		12350K
($10-25M)			
1990	18K	125/yr	2250K
1991	18.4K		2300K
1992	18.8K		2350K
1993	19.2K		2400K
1994	19.6K		2450K
1995	20.0K		2500K
1996	20.4K		2550K
1997	20.8K		2600K
1998	21.2K		2650K
1999	21.6K		2700K
2000	22.0K		2750K
2005	24.0K		3000K
2010	26.0K		3250K
($50 - 100M)			
1990	6K	500/yr	3000K
1991	6.2K		3100K
1992	6.4K		3200K
1993	6.6K		3300K
1994	6.8K		3400K
1995	7.0K		3500K
1996	7.2K		3600K
1997	7.4K		3700K
1998	7.6K		3800K
1999	7.8K		3900K
2000	8.0K		4000K
2005	9.0K		4500K
2010	10.0K		5000K

TABLE 5-6.

($25-50M)

	#	Avg use/company	Total
1990	8K	250/yr	2000K
1991	8.2K		2050K
1992	8.4K		2100K
1993	8.6K		2150K
1994	8.8K		2200K
1995	9.0K		2250K
1996	9.2K		2300K
1997	9.4K		2350K
1998	9.6K		2400K
1999	9.8K		2450K
2000	10.0K		2500K
2005	11.0K		2750K
2010	12.0K		3000K

($100+M)

1990	7K	1250/yr	8750K
1991	7.2K		9000K
1992	7.4K		9250K
1993	7.6K		9500K
1994	7.8K		9750K
1995	8.0K		10000K
1996	8.2K		10250K
1997.	8.4K		10500K
1998	8.6K		10750K
1999	8.8K		11000K
2000	9.0K		11250K
2005	10.0K		12250K
2010	11.0K		13250K

TABLE 5-7.

REVENUE FROM 3-D HOLOGRAPHIC TELECONFERENCING

	Population	Saturation	User group	Fee	Least Case Revenue	Best Case Revenue
1990	24350K	1.5%(10%)	36K	$500	$18.3M	$91.5M
1991	25000K	3.0%	75K		37.5M	187.5M
1992	25650K	4.5%	115K		57.7M	288.5M
1993	26300K	6.0%	158K		78.9M	394.5M
1994	26950K	7.5%	202K		101.1M	505.5M
1995	27600K	9.0%	248K		124.2M	621.0M
1996	28250K	10%	282K		141.2M	706.0M
1997	28900K	20%	578K		289.0M	1445.0M
1998	29550K	30%	886K		443.2M	2216.0M
1999	30200K	40%	1208K		604.0M	3020.0M
2000	30850K	50%	1542K		771.2M	3855.0M
2005	33850K	91.5%	3097K		1548.5M	7748.0M
2010	36850K	100%	3685K		1842.5M	9212.5M

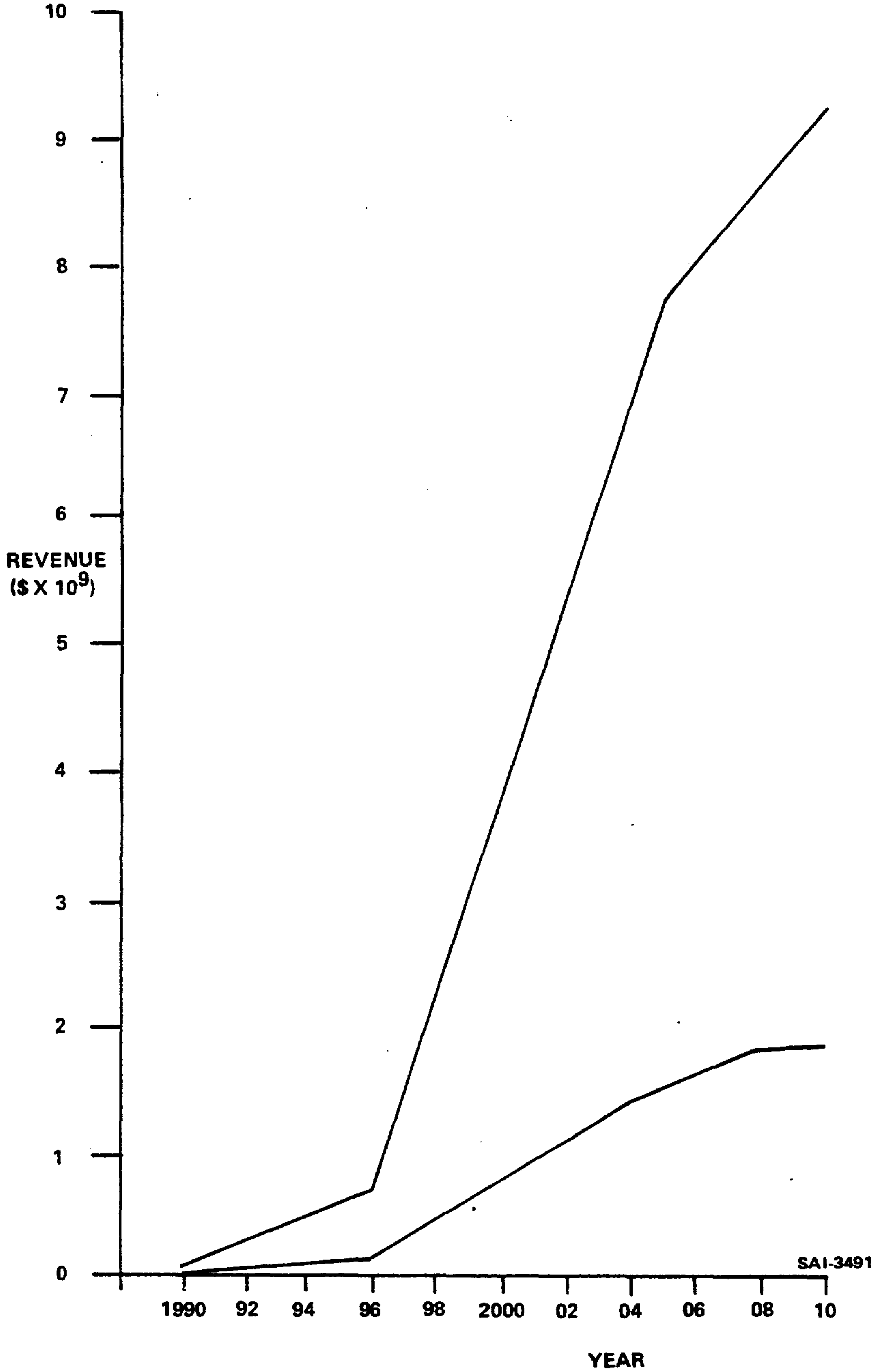


Figure 5-3. Revenue From 3-D Holographic Teleconferencing (User Fees Only)

all other libraries. (Number of each type of library is derived from the 1976 Statistical Abstract of the US.) Penetration would possibly be 75% to 100% for the larger libraries because of their prime role as information centers; and a lesser 50% to 90% for the smaller libraries (they need the service more because of limited resources, but may be less able or willing to pay the user fee.) Market saturation would be completed in 10 years.

Around the year 2000, assume businesses enter the market for information via satellite. (Land line information systems such as Dow Jones are already in use, and are growing in popularity). As a rough estimator, assume the satellite service is more desirable because of lower cost and greater capacity. Let businesses with assets greater than $1 million (as derived from the 1976 Statistical Abstracts of the US) be charged yearly user fees of $10K, and all other businesses yearly fees of $1K (this is comparable to what one person spends in fees now using the Dow Jones service). Penetration of the larger businesses would be 50% to 100%; penetration of the smaller businesses - due to less sophisticated planning needs - 10% to 25%. Assume saturation in 10 years. (This cost does not take into account the cost of user terminals or transceiving equipment.)

In 1974 there were 26,000 libraries in the US. This number was remaining fairly stable. Of this, 7600 could be considered major central libraries. By the year 1990 to 2010, we could see a growth of each to about 30,000 and 8000 respectively in the given time period.

In 1973 there were about 2.0 million corporations in the US. Of this, 131,000 had assets greater than $1 million. Businesses as a whole were increasing at the approximate rate of 100,000 per year. Major corporations were increasing at the approximate rate of 8000 per year.

Market revenue projections can be found in Tables 5-8 and 5-9 for libraries and businesses, with a total given in Table 5-10. A summary plot is shown in Figure 5-4.

5.3.4 Advanced T.V. Broadcast

Mountainous, rural and remote areas currently have poor or no T.V. service due to line-of-sight transmissions. Reception is possible

TABLE 5-8.

REVENUE FROM NATIONAL INFORMATION SERVICE

(Libraries)

Central

	Population	Saturation	User group	Fee	Least Case Revenue	Best Case Revenue
1990	8000	3.3%(75%)	198	$10K	$2.0M	$2.6M
1991		6.7%	402		4.0M	5.4M
1992		10%	600		6.0M	8.0M
1993		30%	1800		18.0M	24.0M
1994		50%	3000		30.0M	40.0M
1995		70%	4200		42.0M	56.0M
1996		90%	5400		54.0M	72.0M
1997		93.3%	5598		56.0M	74.6M
1998		96.7%	5802		58.0M	77.4M
1999		100%	6000		60.0M	80.0M
2000			6000		60.0M	80.0M
2005			6000		60.0M	80.0M
2010			6000		60.0M	80.0M

Other

	Population	Saturation	User group	Fee	Least Case Revenue	Best Case Revenue
1990	22000	3.3%(50%)	363	$1K	$.4M	$.6M
1991		6.7%	737		.7M	1.3M
1992		10%	1100		1.1M	2.0M
1993		30%	3300		3.3M	5.9M
1994		50%	5500		5.5M	9.9M
1995		70%	7700		7.7M	13.9M
1996		90%	9900		9.9M	17.8M
1997		93.3%	10263		10.3M	18.5M
1998		96.7%	10637		10.6M	19.1M
1999		100%	11000		11.0M	19.8M
2000			11000		11.0M	19.8M
2005			11000		11.0M	19.8M
2010			11000		11.0M	19.8M

TABLE 5-9.

(Businesses)
Assets greater than $1 million

	Population	Saturation	User group	Fee	Least Case Revenue	Best Case Revenue
2000	347K	3.3%(50%)	5.7K	$10K	$57M	$114M
2001	355K	6.7%	11.9K		119M	238M
2002	363K	10%	18.1K		181M	362M
2003	371K	30%	55.6K		556M	1012M
2004	379K	50%	94.7K		947M	1894M
2005	387K	70%	135.4K		1354M	2708M
2006	395K	90%	177.7K		1777M	3554M
2007	403K	93.3%	188.0K		1880M	3760M
2008	41[illegible]K	96.7%	198.7K		1987M	3974M
2009	419K	100%	209.5K		2095M	4190M
2010	427K		213.5K		2135M	4270M

Other

	Population	Saturation	User group	Fee	Least Case Revenue	Best Case Revenue
2000	4.4M	3.3%(10%)	14.5K	$1K	$14.5M	$36.2M
2001	4.5M	6.7%	30.1K		30.1M	75.2M
2002	4.6M	10%	46.0K		46.0M	115.0M
2003	4.7M	30%	141.0K		141.0M	352.5M
2004	4.8M	50%	240.0K		240.0M	600.0M
2005	4.9M	70%	343.0K		343.0M	857.5M
2006	5.0M	90%	450.0K		450.0M	1125.0M
2007	5.1M	93.3%	475.8K		475.8M	1189.5M
2008	5.2M	96.7%	502.8K		502.8M	1257.0M
2009	5.3M	100%	530.0K		530.0M	1325.0M
2010	5.4M		540.0K		540.0M	1350.0M

	Least Case Total	Best Case Total
1990	$2.4M	$3.2M
1991	4.7M	6.7M
1992	7.1M	10.0M
1993	21.3M	29.9M
1994	35.5M	49.9M
1995	49.7M	69.9M
1996	63.9M	89.8M
1997	66.3M	93.1M
1998	68.6M	96.5M
1999	71.0M	99.8M
2000	142.5M	250.0M
2001	220.1M	413.0M
2002	298.0M	576.8M

TABLE 5-10

	Least Case Total	Best Case Total
2003	$768.0M	$1464.3M
2004	1258.0M	2593.8M
2005	1768.0M	3665.3M
2006	2298.0M	4778.8M
2007	2426.8M	5049.3M
2008	2560.8M	5330.8M
2009	2696.0M	5614.8M
2010	2746.0M	5719.8M

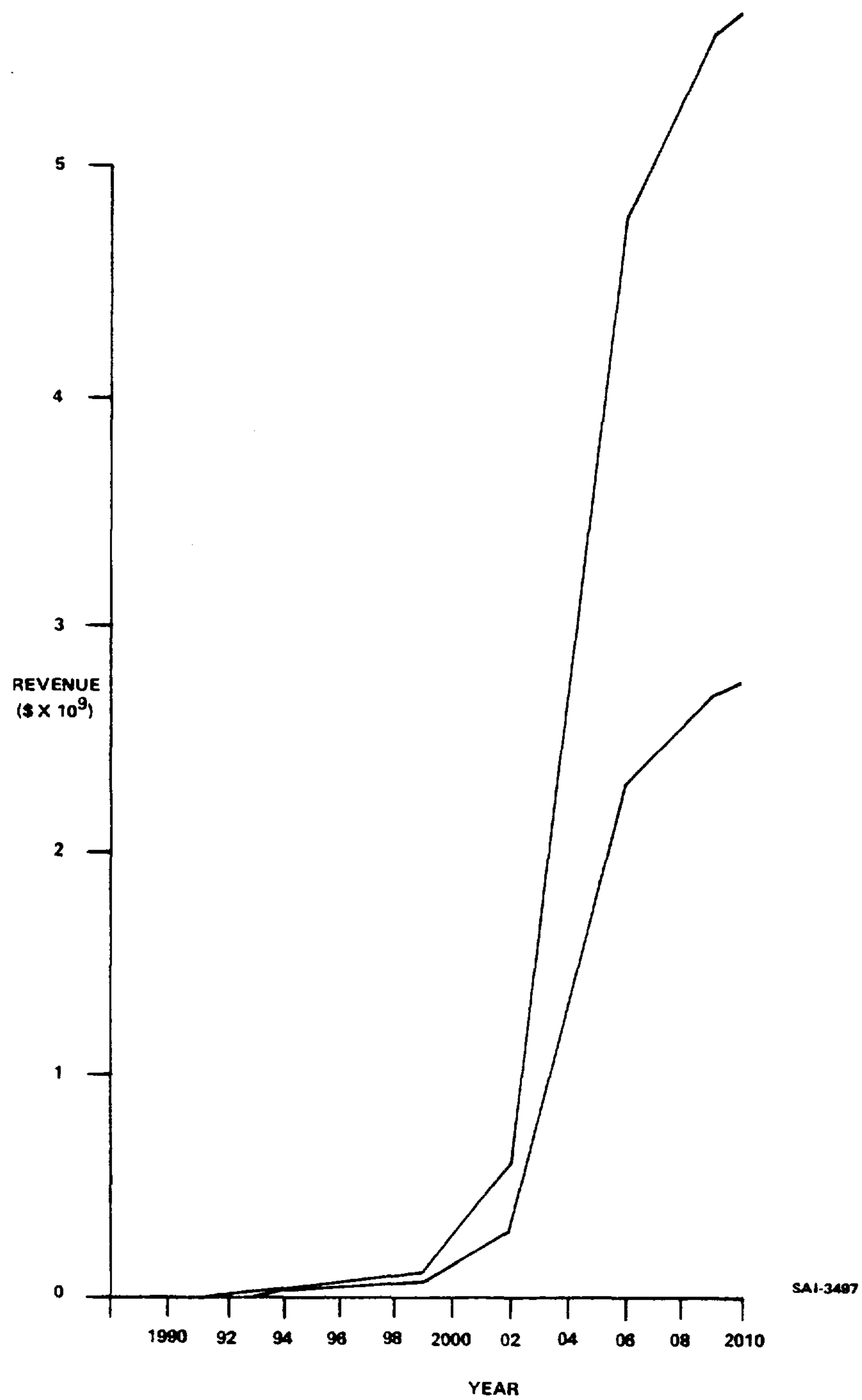


Figure 5-4. Revenue From National Information Services

in all US areas, though, with very small antennas, through a powerful satellite located in geostationary orbit. Through this system, the purely regional nature of local station programming could be alleviated. Also 512 different color T.V. channels would be possible. They would be covered in 150 beams, each with a 90-mi footprint.

Any direct-to-home T.V. broadcast system would face extensive delays at the FCC level. This means earliest implementation would occur roughly in year 2000. A significant problem would come with expansion of the number of channels from the present UHF and VHF (about 85) to the 512 indicated. However, this would likely be necessary if a national T.V. system were to take effect, since it would be difficult if not impossible to find many clear channels in the US - even in the UHF spectrum.

Assuming, however, that a new set of channels opens up, and that national clearance is given, market saturation (to 100%) would likely take about 30 years. This is approximately the saturation time for color T.V. sets. (This also assumes a sufficient supply of programming.)

In 1974 there were 71 million B&W T.V. sets. This number approximates the number of homes with T.V. sets, since it represents a 99.9% saturation of the market. It is growing at an approximate rate of 2M per year. If we approximate future growth from annual housing starts at 1M per year, then we have an anticipated number of users of the service.

User fees would be comparable to existing cable user fees ($10 to $20 per month), averaging around $100 per year. This could be assessed directly or derived from advertising revenues. Penetration of the market could range from 10% (replacing cable T.V. service) to 100%. At a 10% penetration, saturation could come in a shorter time period, 20 years.

Finally, it is thought that ground equipment would not be much more complex than existing equipment, and that acquisition and operating costs would be comparable. A table reflecting this and above assumptions and projections is Table 5-11. Figure 5-5 plots the revenue projections in best and worst case.

TABLE 5-11. REVENUE FROM ADVANCED TV BROADCAST

(Best Case)

	Population	Saturation	User group	Fee	Revenue
2000	97M	1%	.97M	$100	$97M
2001	98M	2%	1.96M		196M
2002	99M	3%	2.97M		297M
2003	100M	4%	4.00M		400M
2004	101M	5%	5.05M		505M
2005	102M	6%	6.12M		612M
2006	103M	7%	7.21M		721M
2007	104M	8%	8.32M		832M
2008	105M	9%	9.45M		945M
2009	106M	10%	10.6M		1060M
2010	107M	18%	19.3M		1930M

(Least Case)

	Population	Saturation	User group	Fee	Revenue
2000	97M	1.5%(10%)	.14M	$100	$14.5M
2001	98M	3.0%	.29M		29.4M
2002	99M	4.5%	.44M		44.5M
2003	100M	6.0%	.60M		60.0M
2004	101M	7.5%	.76M		75.7M
2005	102M	9.0%	.92M		91.8M
2006	103M	10%	1.0M		103.0M
2007	104M	20%	2.1M		208.0M
2008	105M	30%	3.1M		315.0M
2009	106M	40%	4.2M		424.0M
2010	107M	50%	5.3M		535.0M

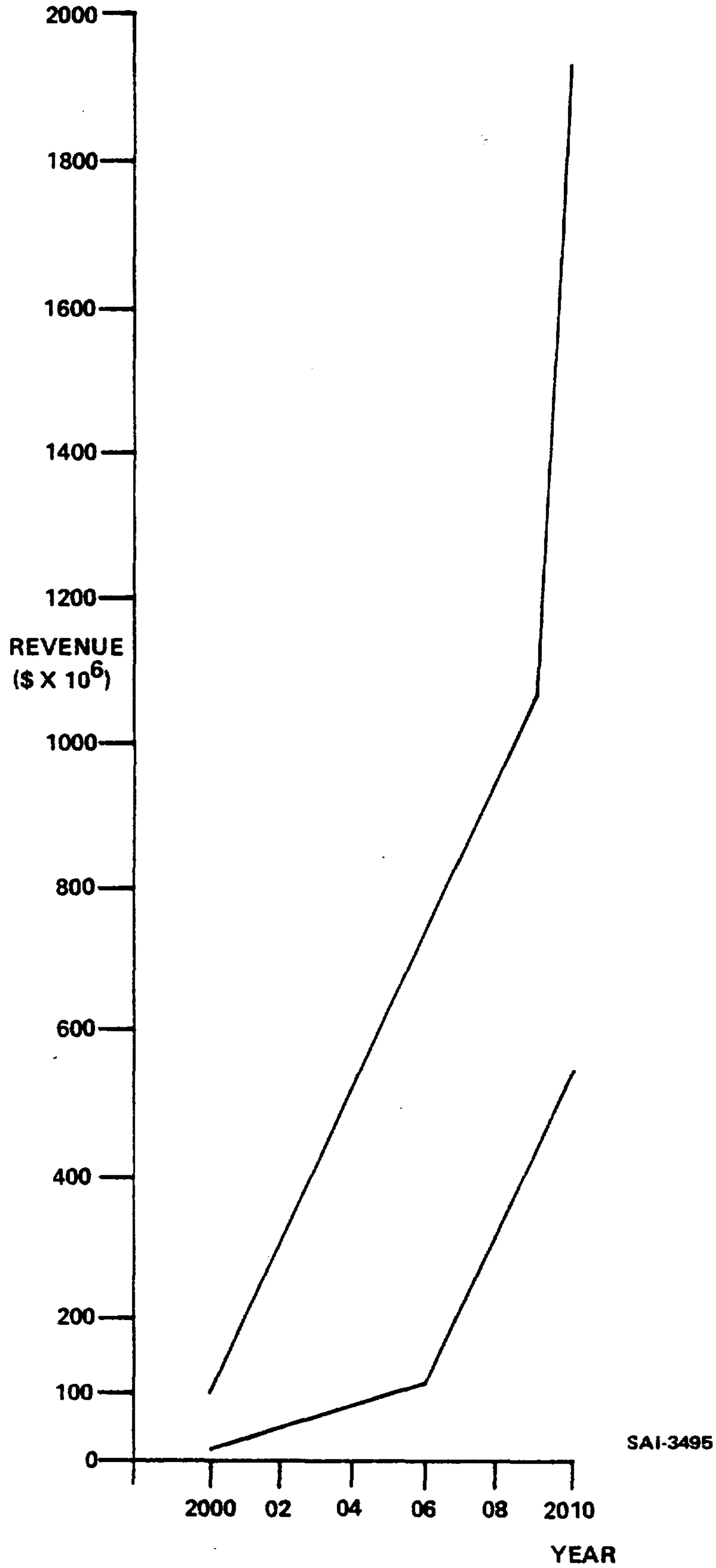


Figure 5-5. Revenue From Advanced TV Satellite (User Fees)

5.3.5 Electronic Mail Transmission

Speedy delivery and lower cost mailing are the goals of this transmission system - a system which delivers a locally reproduced facsimile rather than the physical letter. Page readers and facsimile printers at each post office read, transmit and reproduce mail. A satellite acts as a multichannel repeater.

In the United States today there are roughly 30,000 post offices. In 1970, they handled 85 billion pieces of mail, 50 billion of which were first class. In 1974, they had increased to 90 billion pieces of mail, 53 billion of which were first class. Fifty percent of the mail volume was handled by approximately 100 post offices.

Assumptions were organized so as to have three separate cases for analysis:

<u>Case 1</u>.

100 major post offices equipped for transceiving 50% of all first class mail.

Transmission charge per sheet: 10¢.

Average 2 sheets per letter.

10% of potential users use service.

Saturation in 10 years.

<u>Case 2</u>.

100 major post offices equipped for transceiving priority first class mail only.

Transmission charge per sheet: $1.00.

Average 2 sheets per letter.

1% of first class mail goes priority.

Saturation in 10 years.

<u>Case 3</u>.

30,000 post offices equipped for transceiving all first class mail.

Transmission charge per sheet: 10¢.

Average 2 sheets per letter.

Saturation in 20 years.

50% of all potential users use service.

The results of the analysis for each of the three cases are in Table 5-12. Graphical illustration of possible revenues for electronic mail transmission can be found in Figure 5-6.

5.3.6 Disaster Communications

During disasters, there is a need to provide communications, command, and control to disaster area emergency personnel, since lack of communications hampers quick and effective handling of emergencies. A single satellite in geo-synchronous orbit could provide the necessary service by connecting 2-way transceivers to each other and to control centers. Such a satellite could service 10 disaster areas and 250 urban centers with 10 channels of voice communications each. The communications would be secure and jam-proof.

In determining the size of market, one should realize that there aren't that many disasters in the US which require significant emergency coverage out of the ordinary. Those that are, are generally handled by city police or firemen. Private security guards aren't generally called on to assist in disasters. Some situations require military assistance (i.e., National Guard), but they could be expected to go through military communications channels. Also, service agencies such as the Red Cross are present at disasters, but generally have little need for rapid on-the-spot communications in the way police or firemen would. Thus, the market for a Disaster Communications Set could be expected to be somewhat smaller than that for an Urban Police Wrist Radio - which handles day-to-day communications.

In 1960 there were 364,000 fire and policemen; in 1970, 541,000. This means a population increase of roughly 175K per decade.

As with Urban Police Radio, competing systems in use place the user group in a range from 1% to 25% of the relevant population. Assume a user subscription fee equivalent to $100 per year per man, and a moderate saturation time for 10 years. While the service would be desirable to some organizations, it would take some time to change over procedures from those existing. With no entry delay, the system would be technologically feasible - hence on line - in 1990.

TABLE 5-12.
REVENUE

Case 1.

	Sheet volume (1st class)	User %	User mail	Cost	Revenue
1990	70B	3.3%(10%)	.23B	10¢	$23M
1991	71B	6.7%	.47B		47M
1992	72B	10%	.72B		72M
1993	73B	30%	2.19B		219M
1994	74B	50%	3.70B		370M
1995	75B	70%	5.25B		525M
1996	76B	90%	6.84B		684M
1997	77B	93.3%	7.18B		718M
1998	78B	96.7%	7.54B		754M
1999	79B	100%	7.90B		790M
2000	80B		8.00B		800M
2005	85B		8.50B		850M
2010	90B		9.00B		900M

Case 2.

(Same resultant revenue as Case 1.)

Case 3.

	Sheet volume (1st class)	User %	User mail	Cost	Revenue
1990	140B	1.5%(50%)	1.0B	10¢	$0.1B
1991	142B	3.0%	2.1B		0.2B
1992	144B	4.5%	3.2B		0.3B
1993	146B	6.0%	4.4B		0.4B
1994	148B	7.5%	5.6B		0.6B
1995	150B	9.0%	6.7B		0.7B
1996	152B	10%	7.6B		0.8B
1997	154B	20%	15.4B		1.5B
1998	156B	30%	23.4B		2.3B
1999	158B	40%	31.6B		3.2B
2000	160B	50%	40.0B		4.0B
2001	162B	60%	48.6B		4.9B
2002	164B	70%	57.4B		5.7B
2003	166B	80%	66.4B		6.6B
2004	168B	90%	75.6B		7.6B
2005	170B	91.5%	77.7B		7.8B
2006	172B	93.0%	80.0B		8.0B
2007	174B	94.5%	82.2B		8.2B
2008	176B	96.0%	84.5B		8.4B
2009	178B	97.5%	86.7B		8.7B
2010	180B	99.0%	89.1B		8.9B

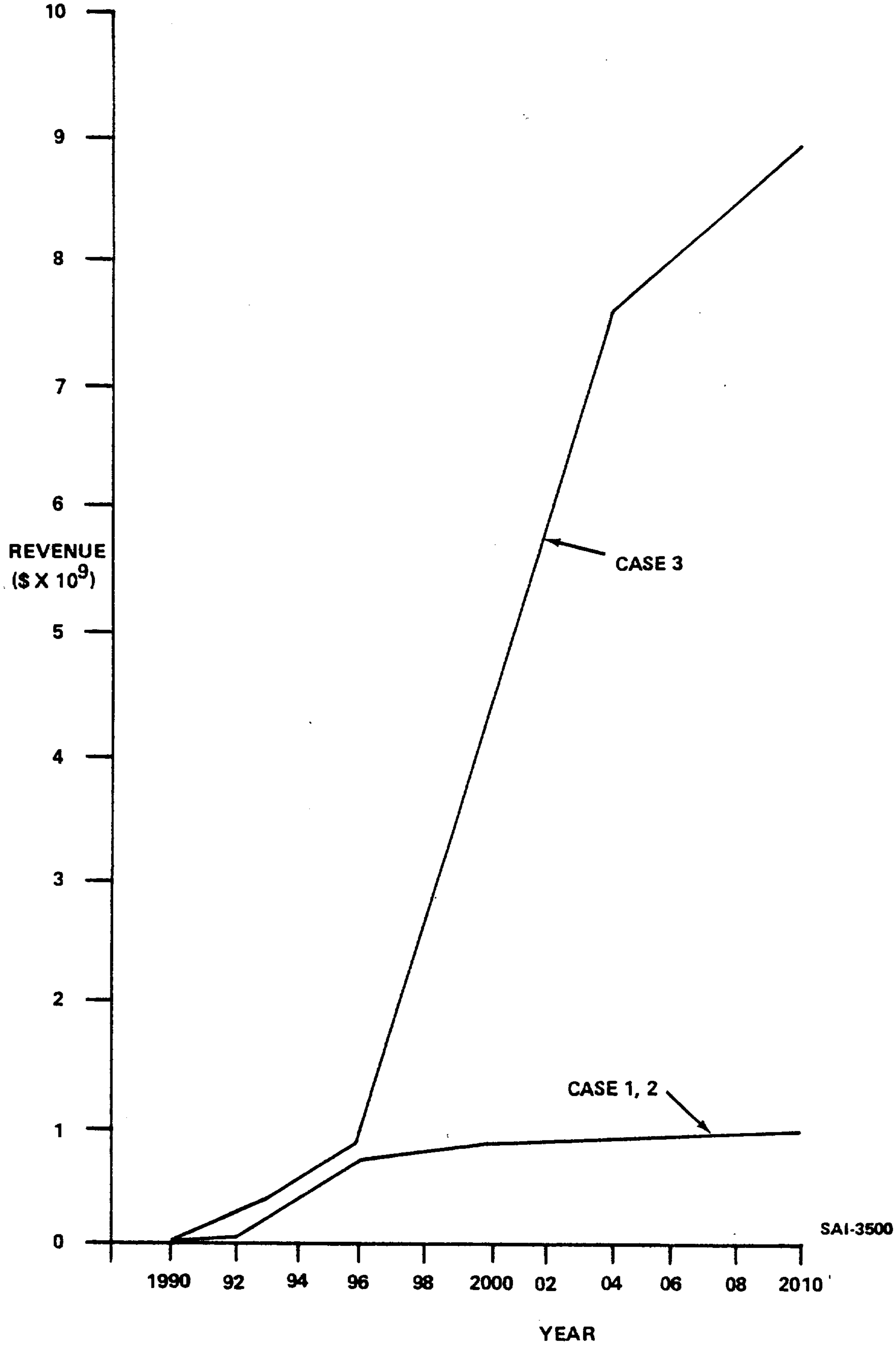


Figure 5-6. Revenue From Electronic Mail Transaction

Market revenue projections are given in Table 5-13, and a summary plot is shown in Figure 5-7.

5.3.7 Vehicle Inspection/Communications

With this system, a microprocessor located in each automobile manufactured would sample the condition of key safety items on or in the vehicle. Such items include tires, steering joints, lights, brakes, glass, etc. A small broadcast system would allow periodic sampling by satellite and identification of unsafe vehicles nationwide.

Monitoring vehicle safety at a central location becomes more and more practical as auto standards and anti-pollution laws become more stringent. However, due to the fact that most auto standards are set and enforced by the various states, it would be difficult, if not impossible, to come to terms with a national motor vehicle inspection system. Consequently, the central point of monitoring would likely be in the states which mandate this particular technique. This inspection technique would not be viable without appropriate legislative backing.

One state particularly aggressive in monitoring pollution standards is California. California is known for setting its own standards, ones which are significantly more stringent than other states, hence "California cars". It may be the case that California would be the only state benefiting from such a service - though it would also be a most likely state. With California having roughly 10% of the nation's population, we can also assume it has roughly 10% of the automobiles, and that 10% of new car sales are made in California.

For the best case, assume that the more populous states join the program because of urban air pollution, but that less populated states either cannot afford the sophisticated equipment or see no need to change existing inspection techniques. This would mean approximately 50% of cars would fall under the program.

In bringing the system into operation, typically we would see all new cars being mandated with the equipment, with older cars to be equipped by a certain deadline. For the purposes of this analysis, assume an average

TABLE 5-13. REVENUE FROM DISASTER COMMUNICATIONS SET

	Population	Saturation	User group	Fee	Least Case Revenue	Best Case Revenue
1990	891K	3.3%(1%)	294	$100	$29K	$725K
1991	908K	6.7%	608		61K	1525K
1992	926K	10%	926		93K	2325K
1993	943K	30%	2829		283K	7075K
1994	961K	50%	4805		480K	12000K
1995	978K	70%	6846		685K	17125K
1996	996K	90%	8964		896K	22400K
1997	1013K	93.3%	9451		945K	23625K
1998	1031K	96.7%	9970		997K	24925K
1999	1048K	100%	10480		1048K	26200K
2000	1066K		10660		1066K	26650K
2005	1153K		11530		1153K	28825K
2010	1241K		12410		1241K	31025K

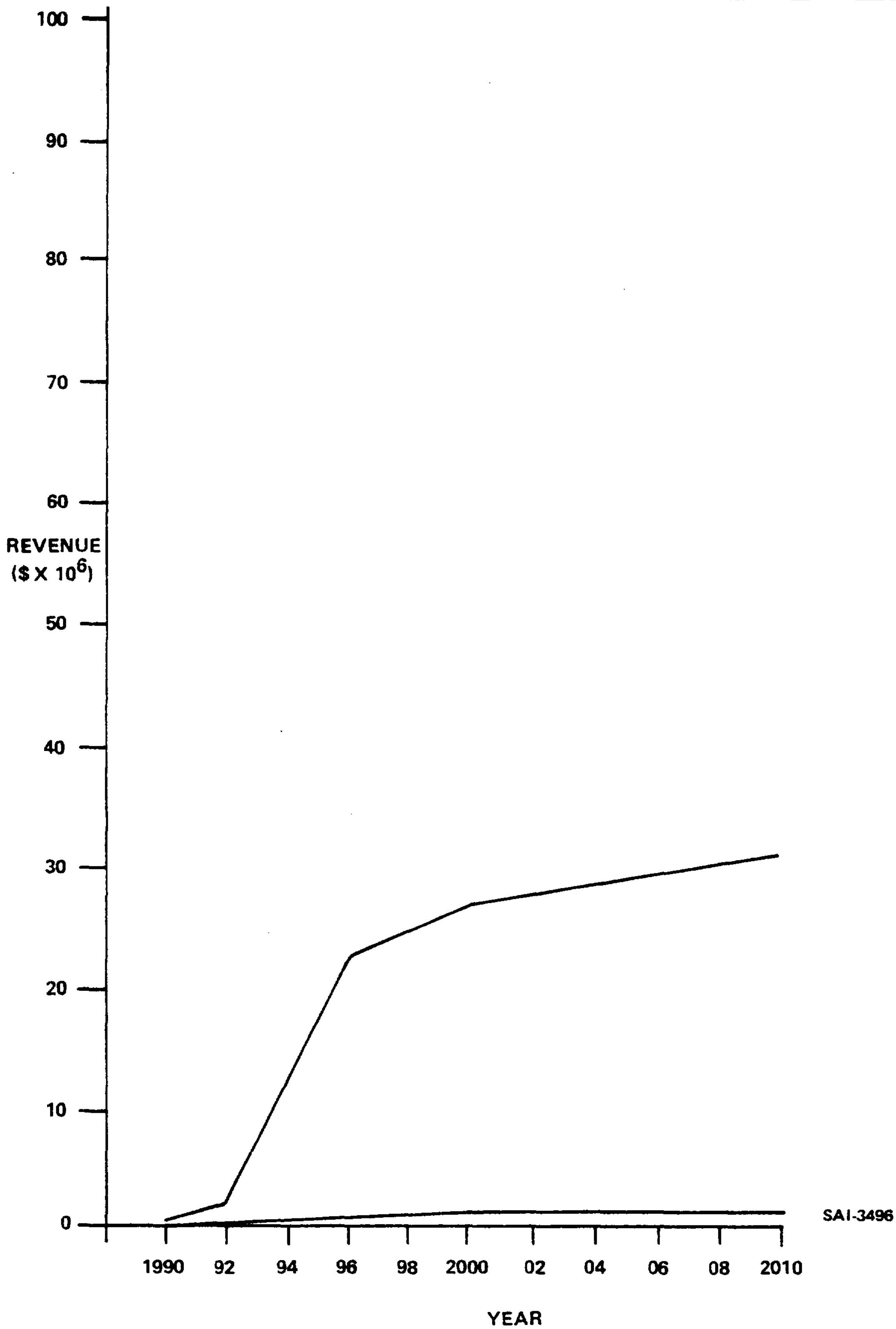


Figure 5-7. Revenue From Disaster Communications Set (User Fee Only)

yearly new car sales figure of 10 million (US); a yearly increase of cars in the US by 4 million; and a saturation time of the system in 5 years (at which time all cars must be appropriately equipped.) As part of the system, assume a $10 cost for the microprocessor - whether it is placed in a new or old car (labor extra).

Since a sophisticated diagnostic test center charges $15 - $25, a straightforward simple test such as in this inspection system should cost considerably less - say $1 per use per car. Assume each car is polled twice a year.

Best and worst case statistics for both the user fee and the microprocessor are given in Table 5-14. Summary revenue plots can be found in Figure 5-8.

5.3.8 Global Search and Rescue Locator

The efficiency of search and rescue operations could be increased with the introduction of a small coded transmitter placed in an emergency package to be carried by boats and aircraft. Signals thus generated would be received and transponded by satellites, and the location of the transmitting object computed by TDOA techniques. Placement of these transmitters worldwide is the implementation goal for this concept.

Although a global search and rescue locator would find some use in ocean-going pleasure boats and merchant vessels, the major market would likely be found in aviation. We are assuming that its use in aircraft would be mandated by law due to historical precedents in the aviation field and the excellent coverage provided by this system. There is little authority, legal or otherwise, for mandating equipment on ocean vessels. Overseas a similar device could be recommended for commercial aviation, but mandatory powers are fairly restricted, especially with regard to general aviation.

In 1974, there were roughly 160,000 general aviation aircraft in the US. This number was growing at roughly 15K per year. Commercial aircraft (US) numbered roughly 2500, with little or no anticipated change. Outside the US, general aircraft was perhaps 75% the US figure, and commercial

TABLE 5-14. REVENUE FROM VEHICLE INSPECTION/COMMUNICATIONS

(User Fee)

	Population	Saturation	User Group	Fee	Least Case Revenue	Best Case Revenue
1990	188M	20%(10%)	3.8M	$1x2	$7.6M	$38.0M
1991	192M	40%	7.7M		15.4M	77.0M
1992	196M	60%	11.8M		23.6M	118.0M
1993	200M	80%	16.0M		32.0M	160.0M
1994	204M	100%	20.4M		40.8M	204.0M
1995	208M		20.8M		41.6M	208.0M
1996	212M		21.2M		42.4M	212.0M
1997	216M		21.6M		43.2M	216.0M
1998	220M		22.0M		44.0M	220.0M
1999	224M		22.4M		44.8M	224.0M
2000	228M		22.8M		45.6M	228.0M
2005	248M		24.8M		49.6M	248.0M
2010	268M		26.8M		53.6M	268.0M

(Microprocessor)

	New systems	Cost	Least Case Revenue	Best Case Revenue
1990	3.8M	$10	$38M	$190M
1991	3.9M		39M	195M
1992	4.1M		41M	205M
1993	4.2M		42M	210M
1994	4.4M		44M	220M
1995	1.0M		10M	50M
2000	1.0M		10M	50M
2005	1.0M		10M	50M
2010	1.0M		10M	50M

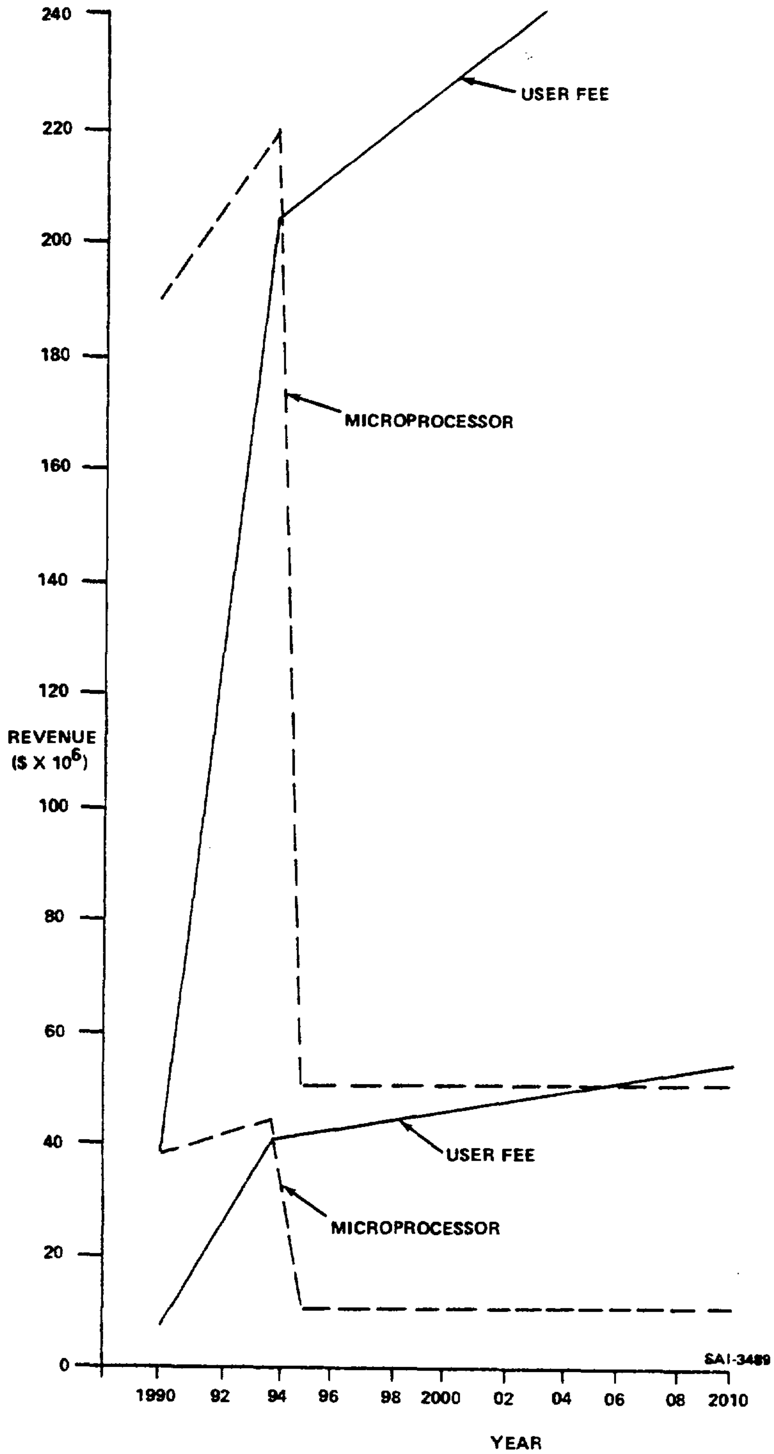


Figure 5-8. Revenue From Vehicle Inspection/Communications

aircraft twice the US figure (say 5000). Assuming a US-mandated product entry date of 1990 (five year delay from technological availability), saturation could be reached within 5 years (comparable to the experience of 1 - 3 years saturation with prior search and rescue systems). Average price can be assumed at $200 - about that of existing systems. It would be difficult, however, to assess a user fee, since this service is used only once per craft, for a very short period. There would be a negligible replacement rate.

Overseas, we can expect perhaps 10% to 50% of general and commercial aviation to use the system, saturating in a 10 year period.

While US aviation penetration would likely reach 100%, ocean vessel penetration would be significantly lower. We can ssume anywhere from 10% to 50% of merchant vessels worldwide, and 1% to 10% of ocean-going vessels (US). Assume a 10 year saturation time for boats.

Market projections of air, sea and total revenue (best and worst case) are in Tables 5-15, 5-16 and 5-17. A summary plot is given in Figure 5-9.

5.3.9 Nuclear Fuel Locator

Nuclear fuel can be stolen by terrorists to create unauthorized weapons - hence must be kept under very stringent security. While fuel reprocessing and fabrication plants are reasonably secure, the security of the system breaks down in the transporting. Transportation is the most vulnerable part of the fuel cycle.

The key, then, is real-time monitoring of the location of nuclear material to prevent proliferation of weapons and nuclear blackmail. To accomplish this, each assembly or container is tagged with a microwave generator in a tamper-indicating case. Uniquely coded signals are transponded by four satellites in 24-hour elliptical inclined orbits; the postion of each container is then computed by time-difference-of-arrival on the ground. Each fuel assembly is continuously identified and located to ± 500 feet, whether in a reactor building, in transit, or in storage.

TABLE 5-15.

AIR

(US)

	Population	Saturation	User group	New users	Cost	Revenue
1990	415K	20%	83K	83K	$200	$16600K
1991	430K	40%	172K	89K		17800K
1992	445K	60%	267K	95K		19000K
1993	460K	80%	368K	101K		20200K
1994	475K	100%	475K	107K		21400K
1995	490K		490K	15K		3000K
1996	505K		505K	15K		3000K
1997	520K		520K	15K		3000K
1998	535K		535K	15K		3000K
1999	550K		550K	15K		3000K
2000	565K		565K	15K		3000K
2005	640K		640K	15K		3000K
2010	715K		715K	15K		3000K

(World)

	Population	Saturation	User group	New users	Cost	Least case Revenue
1990	311K	3.3%(10%)	1K	1K	$200	$200K
1991	322K	6.7%	2K	1K		200K
1992	334K	10%	3K	1K		200K
1993	345K	30%	10K	7K		1400K
1994	356K	50%	18K	8K		1600K
1995	367K	70%	26K	8K		1600K
1996	379K	90%	34K	8K		1600K
1997	390K	93.3%	36K	2K		400K
1998	401K	96.7%	39K	3K		600K
1999	412K	100%	41K	2K		400K
2000	423K		42K	1K		200K
2005	479K		47K	1K		200K
2010	535K		53K	1K		200K

TABLE 5-16.

AIR

	Best Case Revenue
1990	1000K
1991	1000K
1992	1000K
1993	7000K
1994	8000K
1995	8000K
1996	8000K
1997	2000K
1998	3000K
1999	2000K
2000	1000K
2005	1000K
2010	1000K

SEA

	Population	Saturation	User group	New users	Cost	Least Case Revenue
1990	2.2M	3.3%(1%)	.7K	.7K	$200	$1400K
1991	2.3M	6.7%	1.5K	.8K		1600K
1992	2.3M	10%	2K	.5K		1000K
1993	2.3M	30%	7K	5K		10000K
1994	2.3M	50%	11K	4K		8000K
1995	2.4M	70%	17K	6K		12000K
1996	2.4M	90%	22K	5K		10000K
1997	2.4M	93.3%	22K	--		--
1998	2.4M	96.7%	23K	1K		2000K
1999	2.5M	100%	25K	2K		4000K
2000	2.5M		25K	--		--
2005	2.6M		26K	.5K		1000K
2010	2.7M		27K	.5K		1000K

	Best Case Revenue
1990	1400K
1991	1600K
1992	1000K
1993	10000K
1994	8000K
1995	12000K
1996	10000K
1997	---
1998	2000K
1999	4000K
2000	---
2005	1000K
2010	1000K

TABLE 5-17.

SEA

(World)

	Population	Saturation	User group	New users	Cost	Least Case Revenue
1990	630K	3.3%(10%)	2K	2K	$200	$400K
1991	632K	6.7%	4K	2K		400K
1992	634K	10%	6K	2K		400K
1993	636K	30%	19K	13K		2600K
1994	638K	50%	32K	13K		2600K
1995	640K	70%	45K	13K		2600K
1996	642K	90%	58K	13K		2600K
1997	644K	93.3%	60K	2K		400K
1998	646K	96.7%	62K	2K		400K
1999	648K	100%	64K	2K		400K
2000	650K		65K	1K		200K
2005	660K		66K	.5K		100K
2010	670K		67K	.5K		100K

	Best Case Revenue
1990	2000K
1991	2000K
1992	2000K
1993	13000K
1994	13000K
1995	13000K
1996	13000K
1997	2000K
1998	2000K
1999	2000K
2000	1000K
2005	500K
2010	500K

	Least Case total	Best Case total
1990	17340K	21000K
1991	18560K	22400K
1992	19700K	23000K
1993	25200K	50200K
1994	26400K	50400K
1995	8400K	36000K
1996	8200K	34000K
1997	3800K	7000K
1998	4200K	10000K
1999	4200K	11000K
2000	3400K	5000K
2005	[illegible]	[illegible]

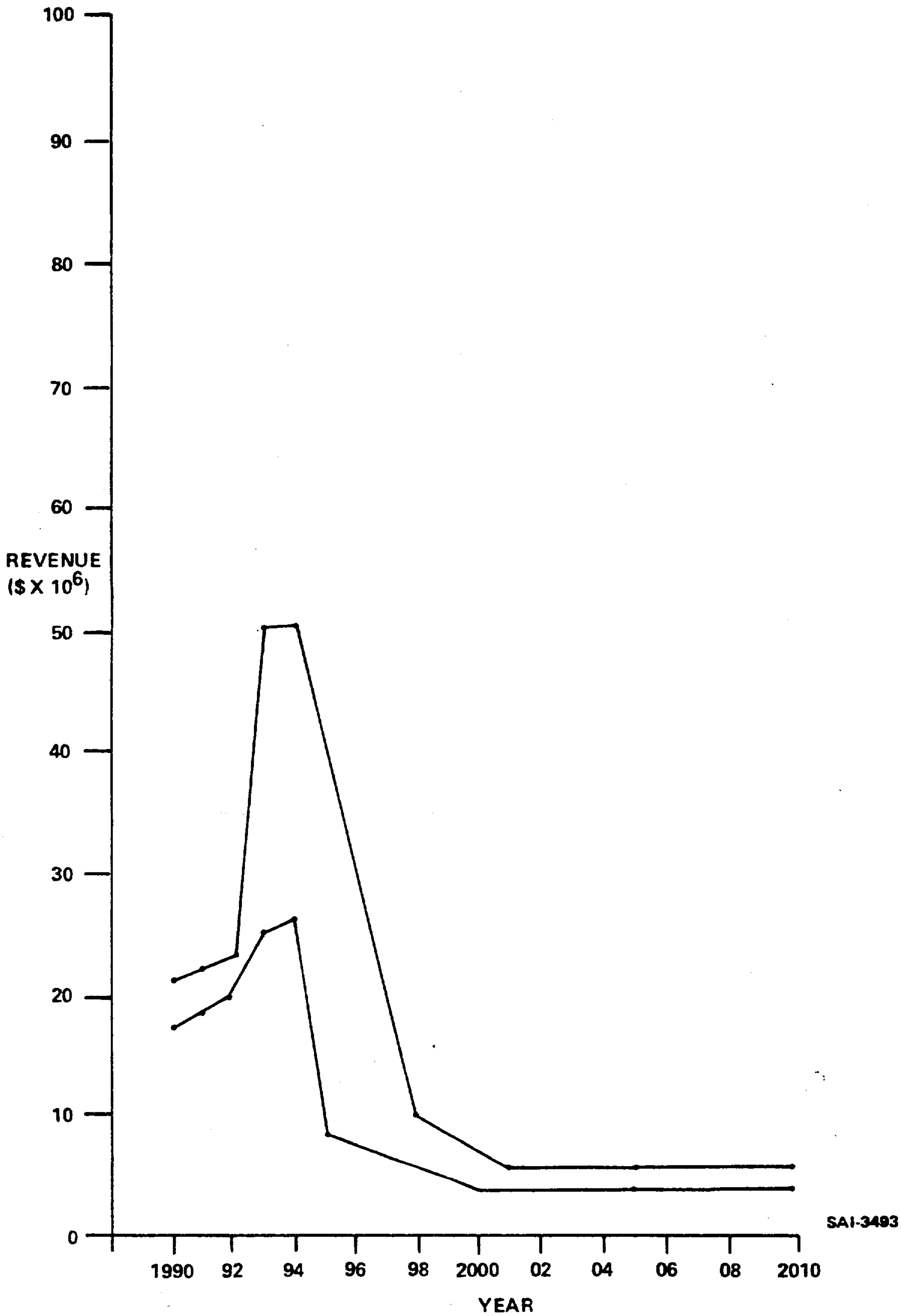


Figure 5-9. Revenue From Global Search & Rescue Locator

There are three types of nuclear fuels of concern: plutonium (Pu); high-enriched uranium (HeU); and uranium 233 (U233). The proportions of use of each of these will depend on development scenarios of Light Water Reactors (LWR) and High Temperature Gas Reactors (HTGR). (The assumption in this analysis is that - by policy dictate, Liquid Metal Fast Breeder Reactors will not come to be.)

There are two stages in the transporting process:

1. Fuel reprocessing plants or storage facilities to fuel fabrication plants;
2. Fabrication plants to power plants.

The greatest concern is in the first stage, since the fuel in this stage can be readily transformed into weaponry. After fabrication, the fuel is not of weapons grade quality. This analysis will consider locators in both stages, and in each stage alone.

Depending on whether HTGR gains favor (I) or LWR retains favor and solves its problems (II), the following figures are applicable for production of the three fuels.

(Production)

	I			II		
	Pu	HeU	U233	Pu	HeU	U233
1980	27	1.6	.05	27	1.6	.05
1985	63	30	3	69	8.4	1.8
1990	92	113	22	140	7.7	3.9
1995	103	219	76	245	7.9	4.1
2000	109	316	159	385	7.9	4.1

(metric tons produced)

In shipping, weight limits and safety factors generally imply the following load limits per shipments:

Pu	175 kg
HeU	2000 kg
U233	700 kg

This then gives a number of truckloads, from which we can derive stage I locator requirements.

(Truckloads)

	I			II		
	Pu	HeU	U233	Pu	HeU	U233
1980	154	1	1	154	1	1
1985	360	15	4	394	5	3
1990	526	56	31	800	4	6
1995	588	109	108	1400	4	6
2000	623	158	227	2200	4	6

Each truckload will have a certain number of containers, and each container will have a coding transmitter. As an average approximation, assume 25 containers (transmitters) per truckload. Then

(Transmitters)

	I	II
1980	3900	3900
1985	9475	10050
1990	15325	20250
1995	20125	35250
2000	25200	55250

Stage 2 shipments will be somewhat more extensive, but will be independent of scenario.

	Truckloads	Transmitters
1980	500	12500
1985	1000	25000
1990	2000	50000
1995	3500	87500
2000	5000	125000

It should be noted that if breeder reactors are given a policy mandate for development, then the number of stage 1 shipments (of plutonium) will drastically increase. Also, if reprocessing plants remain out of favor by policy, then the only relevant shipments are the less dangerous stage 2 type.

In determining market revenue, assume a user fee of $10 per transmitter use (dictated by economics); immediate 100% saturation in 1985; and use by all shipments. Market revenue projections are given in Table 5-18, and a summary plot is shown in Figure 5-10.

TABLE 5-18. REVENUE FROM NUCLEAR FUEL LOCATORS

	Stage 1 (I) only	Stage 2 only	Stage 1 (I) + 2	Stage 1 (II) + 2
1985	$95K	$250K	$345K	$350K
1990	153K	500K	653K	702K
1995	201K	875K	1076K	1227K
2000	252K	1250K	1502K	1802K

5.3.10 Transportation Services

There are similar and overlapping requirements by many agencies for precision air traffic navigation. A satellite system in polar orbit could simultaneously satisfy traffic control, air surveillance, navigation, position fixing, and command/control requirements for a multiplicity of users. Such a system would be composed of a number of satellites in 8000 nmi polar orbit. Comsat transponders would be used, with four in view of the user at any time at different angles and ranges, to provide TDOA position fixing and 2-way communications. Users could be positioned to 30 feet, with surveillance of beacon to 100 feet, and digital communications of 100 kb/second.

The primary market for a transportation services satellite system would seem to be commercial aviation. This market would come about only at the mandating of the FAA - since many existing systems would have to be modified or scrapped. For such a mandate to come about would mean extensive delay. Assume therefore that while it may be technologically feasible in 1985, such a system begins to come on line in 1995. Although available to general aviation, first users would likely be commercial aviation.

In 1974 there were 2700 commercial jets in operation in the US. This number could expect to remain fairly stable over the time period, with a small replacement number per year. The user market would saturate quickly (5 years), because of the mandate, to 100%. By the year 2000 we might begin to see some use by general aviation - particularly with instrument

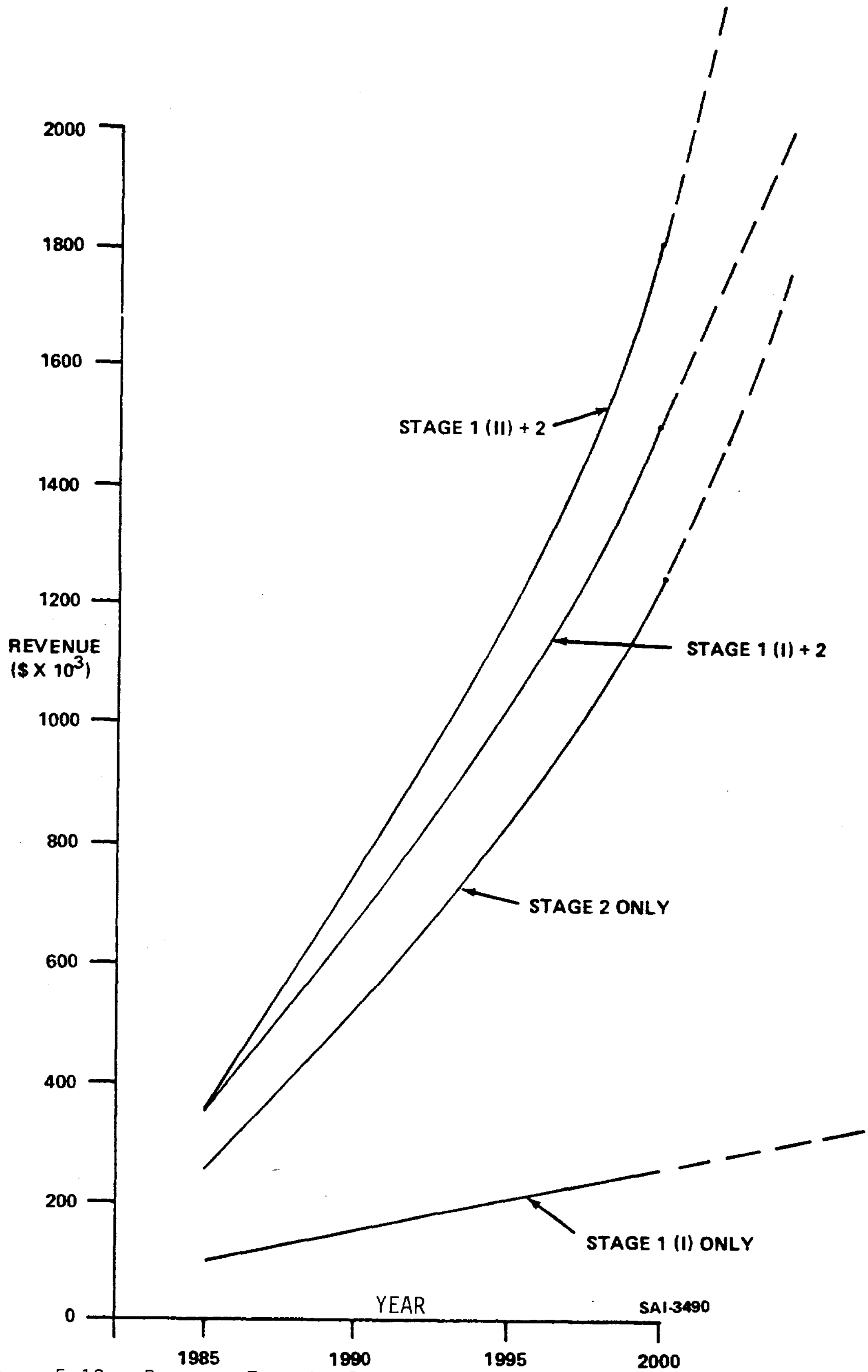


Figure 5-10. Revenue From Nuclear Fuel Locators (User Fee Only)

flights. In 1974 there were approximately 160,000 general aviation aircraft in the US. This number was growing at roughly 15,000 per year. The percentage of general aviation users could range from 10% to 100%, depending on whether or not all general aircraft were required to. Again, saturation would be quick if mandated (5 years), but slow if not (10 years).

User fees would be hidden in taxes. Definable revenue would come from sale of equipment. Assume commercial equipment would run $10,000 per plane, and general aviation equipment would average $500 per plane.

Market revenue projections for commercial and general (mandated, optional) markets are given in Table 5-19 with total revenues given in Table 5-20. A summary plot is shown in Figure 5-11.

5.3.11 Rail Anti-Collision System

Presently, losses of life, property, and productivity due to rail collisions are quite large. However, a satellite system in equatorial orbit could reduce or completely eliminate rail collisions. Such a system would be composed of three satellites, each with 116 beams of 180 nautical mile diameter on the ground. Every train participating in the service would carry a small beacon and command receiver. Location of each train would be continuously computed on the ground. Within 0.5 seconds of detection of a collision course, an alerting buzzer in the relevant trains would sound, or the trains would be stopped.

From 1970 to 1974, there were approximately 30,000 locomotives in the US. This does not necessarily represent the number of trains in operation, however, since many trains use two or more locomotives, and some locomotives are used only in the switch yard. Therefore assume the service would be available for use by up to 1/3 of the number of locomotives, as representing user trains in operation (10,000), and that the number of trains in operation remains constant in the given period.

But since some lines are short haul with little equipment, and since some major lines have sophisticated computer equipment in place, assume a band of users of 25% to 75% of the theoretical user number. Further, assume a yearly user fee of $5000 in determining revenue. (This

TABLE 5-19.

REVENUE FROM TRANSPORTATION SERVICES SATELLITE

(Commercial)

	Population	Saturation	User group	New users	Cost	Revenue
1995	2700	20%	540	540	$10K	$5.4M
1996		40%	1080	540		5.4M
1997		60%	1620	540		5.4M
1998		80%	2160	540		5.4M
1999		100%	2700	540		5.4M
2000				50*		0.5M
2005				50		0.5M
2010				50		0.5M

* new planes in replacement

(General: Mandated)

	Population	Saturation	User group	New users	Cost	Revenue
2000	565K	20%	113K	113K	$500	$56.5M
2001	580K	40%	232K	119K		59.5M
2002	595K	60%	357K	125K		62.5M
2003	610K	80%	488K	131K		65.5M
2004	625K	100%	625K	137K		68.5M
2005	640K		640K	15K		7.5M
2010	715K		715K	15K		7.5M

(General: Optional)

	Population	Saturation	User group	New users	Cost	Revenue
2000	565K	3.3%(10%)	1865	1865	$500	$0.9M
2001	580K	6.7%	3886	2021		1.0M
2002	595K	10%	5950	2064		1.0M
2003	610K	30%	18300	12350		6.2M
2004	625K	50%	31250	12950		6.5M
2005	640K	70%	44800	13550		6.8M
2006	655K	90%	58950	14150		7.1M
2007	670K	93.3%	62511	3561		1.8M
2008	685K	96.7%	66239	3728		1.9M
2009	700K	100%	70000	3761		1.9M
2010	715K		71500	1500		0.7M

TABLE 5-20.

	Least Case Revenue	Best Case Revenue
1995	$5.4M	$5.4M
1996	5.4M	5.4M
1997	5.4M	5.4M
1998	5.4M	5.4M
1999	5.4M	5.4M
2000	1.4M	57.0M
2001	1.5M	60.0M
2002	1.5M	63.0M
2003	6.7M	66.0M
2004	7.0M	69.0M
2005	7.3M	8.0M
2006	7.6M	8.0M
2007	2.3M	8.0M
2008	2.4M	8.0M
2009	2.4M	8.0M
2010	1.2M	8.0M

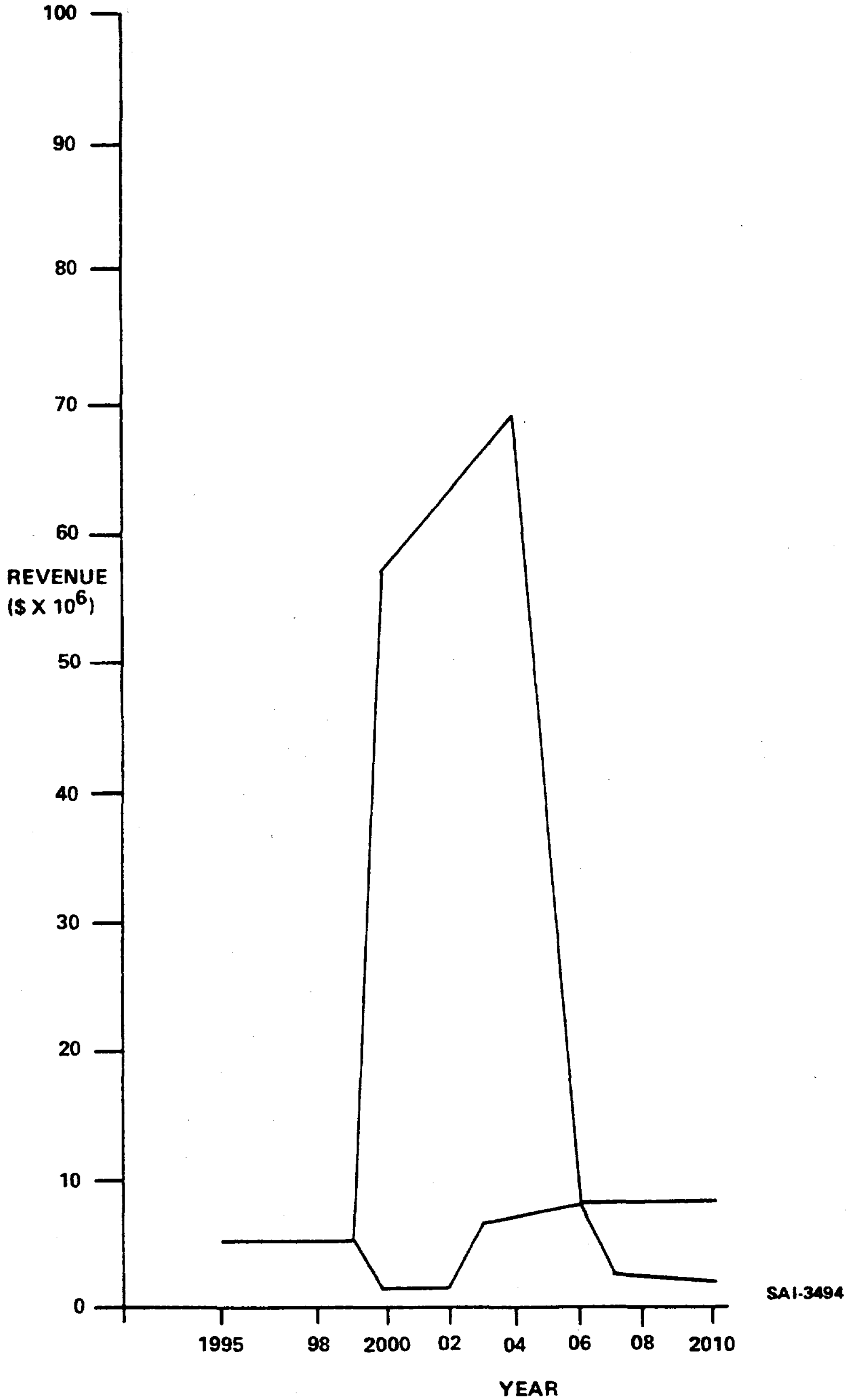


Figure 5-11. Revenue From Transportation Services (Equipment Only)

does not take into account cost of ground computing equipment, which could be substantial.) Assume time to saturation of 20 years - a medium time period because this is a safety service which, while possibly funded from insurance premium savings, does not contribute to cash flow which railroads so badly need.

Market revenue best and worst case projections are given in Table 5-21. A summary plot is shown in Figure 5-12.

5.3.12 Personal Navigation Sets

For some people, there is a need for accurate relative position determination with very inexpensive user equipment. This can be accomplished with a single large phased array in geo-synchronous orbit, which sweeps narrow beams over the country. Simple receivers then measure time elapsed between pulses received, and display distance (N-S,E-W) to a fixed point less than 100 nmi away. Position should be able to be determined to within 300 feet every 10 seconds. Such a system could be technologically feasible in 1990, with no foreseeable delays.

If we assume concurrent development of an inexpensive portable telephone system, then the upper limit of assumed purchases of a navigation set would likely be the number of purchasers of a portable communication set. That is, it's not conceivable that more people would need navigation sets than would need inexpensive communications devices. The lower limit would see particular user groups finding value in personal navigation sets. These groups would tend to be people found off the beaten track - in unmapped areas - and could include hunters and hikers (numbers taken from 1976 Statistical Abstract of the US). A moderate demand from these groups could mean a 25% penetration. Ultimate saturation level would likely take a long period, due to widespread distribution of alternative methods such as compasses, and resistance to change factors.

For pricing purposes, assume a track of declining prices similar to telephones, but with prices starting at $100 and declining to $10 (as indicated in Advanced Space Systems Concepts). For hypothetical market assumptions, assume the same growth curve as the portable telephone, starting in 1990. It should be noted that revenues from this service would come from sale of sets, not from user fees. Thus there would be a

TABLE 5-21.

REVENUE FROM RAIL ANTI-COLLISION USER FEES

(Best Case) and (Least Case)

	Population	Saturation	User group	Fee	Best case Revenue	Least case Revenue
1985	10000	1.5%(75%)	112	$5000	$0.6M	$0.2M
1986		3.0%	225		1.1M	0.4M
1987		4.5%	337		1.7M	0.6M
1988		6.0%	450		2.2M	0.7M
1989		7.5%	562		2.8M	0.9M
1990		9.0%	675		3.4M	1.1M
1991		10%	750		3.7M	1.2M
1992		20%	1500		7.5M	2.5M
1993		30%	2250		11.2M	3.7M
1994		40%	3000		15.0M	5.0M
1995		50%	3750		18.7M	6.2M
1996		60%	4500		22.5M	7.5M
1997		70%	5250		26.2M	8.7M
1998		80%	6000		30.0M	10.0M
1999		90%	6750		33.7M	11.2M
2000		91.5%	6862		34.3M	11.4M
2001		93.0%	6975		34.9M	11.6M
2002		94.5%	7087		35.4M	11.8M
2003		96.0%	7200		36.0M	12.0M
2004		97.5%	7312		36.6M	12.2M
2005		99.0%	7425		37.1M	12.4M
2010		100%	7500		37.5M	12.5M

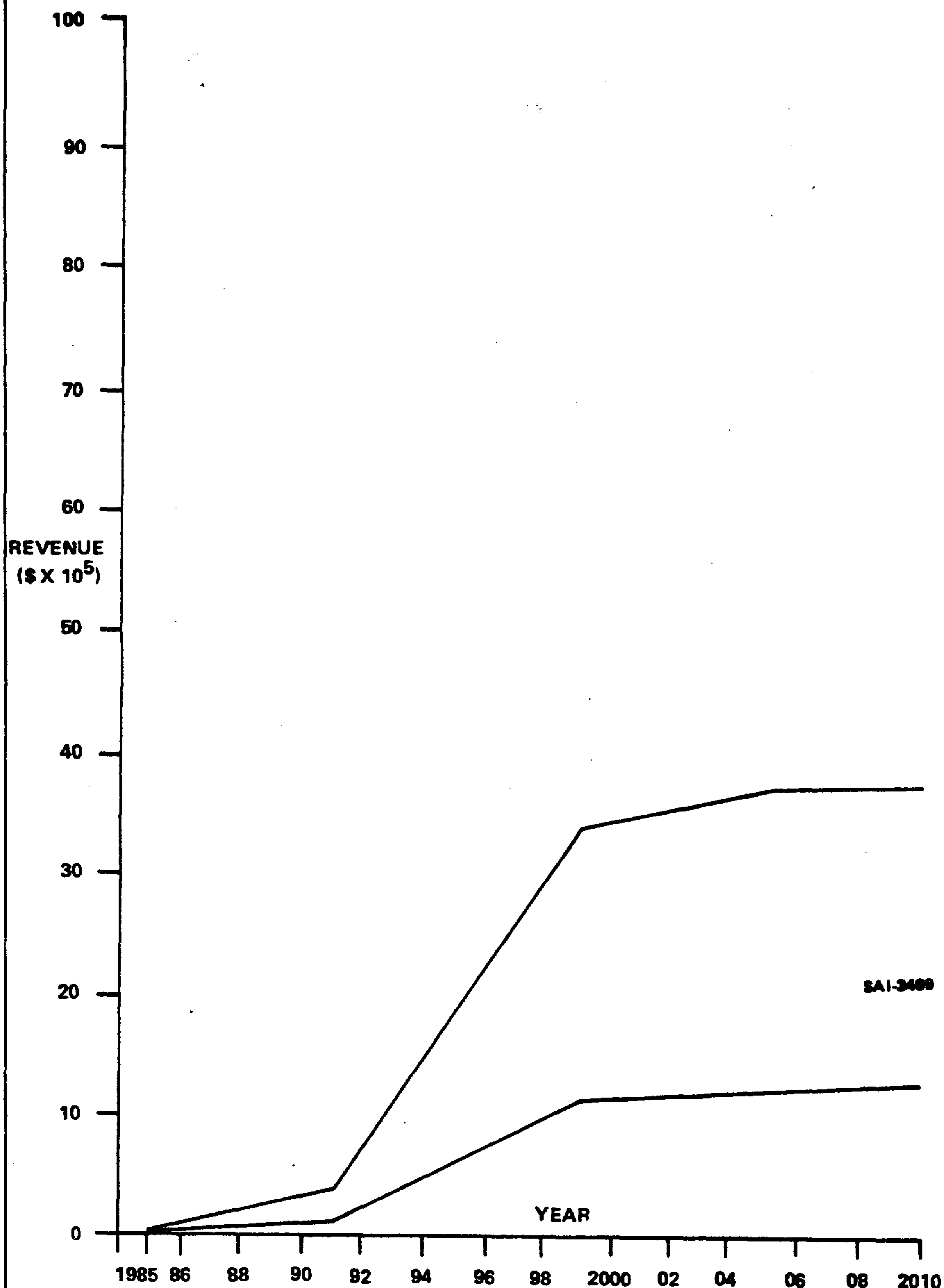


Figure 5-12. Revenue for Rail Anti-Collision System (User Fees)

limiting point, beyond which the market would be saturated, and revenues would sharply decline.

Best case and worst case market revenue projections are given in Table 5-22, with a summary plot in Figure 5-13.

5.3.13 Vehicle/Package Locator

According to recent industry reports, cargo theft is at a $1.5 billion rate, and is increasing at $250 million annually. Most of this theft (60%) is from trucks. Truck companies have found that increasing security surveillance both cuts down on losses and reduces insurance premiums.

To forestall increased theft, a satellite system may be used. In conjunction with this system, a small transceiver is attached to (or enclosed in) each unit to be tracked. The unit determines its location using a crossed antenna navigation satellite, and relays the data to a control center via a special communications satellite when queried. The transceiver could cost less than $10, weighing but 3 ounces. Up to one billion vehicles or containers could be located ± 300 feet anywhere in the country.

Revenue from this service would be a function of loading and mileage (and perhaps independent of tonnage, since there are many high value per weight items now being shipped). One close approximation would come from a revenue mile figure. A security system cost might be acceptable at an equivalent charge of 1¢ per revenue-mile. This means a truck driving 50000 miles/year would pay $500 for the service. The following figures are applicable.

	1960	1965	1970
Vehicle revenue miles x 10^6	7203	9154	11498

For projection purposes, assume an increase of 4×10^9 revenue miles per decade. Also assume a 25% to 75% penetration (theft and hijacking is an industry-wide problem) and a quick saturation (10 years) induced by reduced insurance premiums.

A second potential user is the automobile owner, in protection against theft. With both the number of cars in use and number of cars

TABLE 5-22. REVENUE FROM NAVIGATION SETS

Best Case

	Sales	Cost/Unit	Revenue
1990	0.4M	$100	$40M
1995	0.5M	$44	$22M
2001	6M	$23	$138M
2005	8.4M	$13	$109M
2009	10.2M	$10	$102M

Least Case

	Hunters/Hikers	Saturation level	Unit sales	Replacement sales
1990	39M	.2%	88K	---
1995	40M	1.4%	102K	---
2001	41M	5.0%	1025K	200K
2005	42M	15.0%	1060K	620K
2009	42M	22.5%	1100K	940K

	Total sales	Cost/Unit	Revenue
1990	88K	$100	$8.8M
1995	102K	$44	4.5M
2001	1225K	$23	28.2M
2005	1680K	$13	21.8M
2009	2040K	$10	20.4M

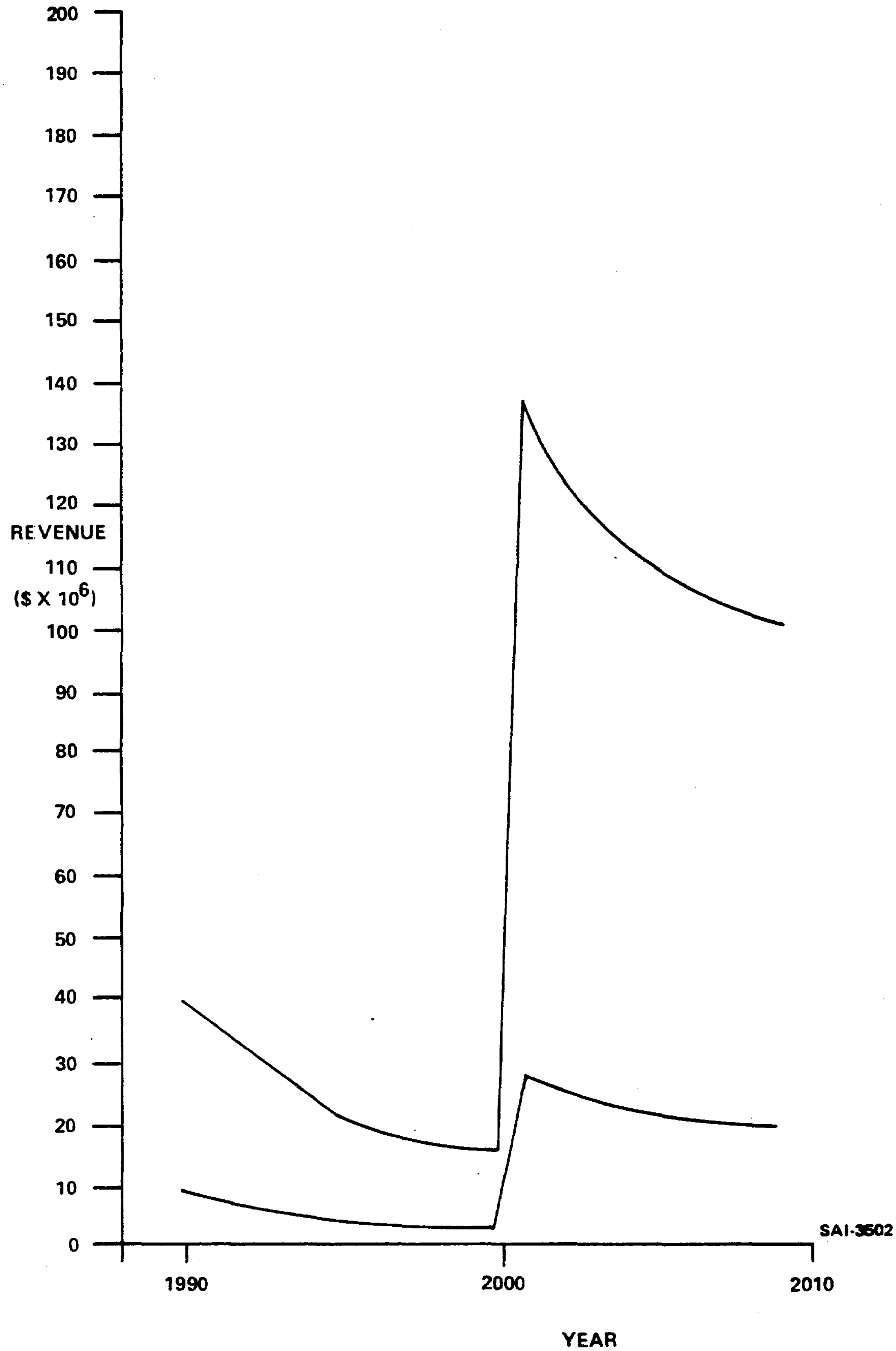


Figure 5-13. Revenue From Personal Navigation Sets

stolen rising (as well as insurance premiums), it might pay for owners in high density urban areas to invest $10 per year for a locator service in the event of theft. The market would likely be about the same as car alarm systems. Assume therefore a penetration of 1% to 5% of all cars in use, and a saturation in 10 years. In 1970 there were 108M cars registered in the US; in 1974, 132M. Assume as a conservative projection, a long-term increase of 4 million per year.

Revenue from package locators and auto locators is given in Table 5-23. Total best and worst case revenue is given in Table 5-24. A summary plot is shown in Figure 5-14.

5.3.14 Voting/Polling Set

Market and opinion surveys generally take a very limited sampling of opinion to determine likes and dislikes about various matters. In some instances, a sample as small as 2000 can be made to represent statistically the 200,000,000 people of the entire country.

Polling techniques vary with the customer and survey organization. Samples can be obtained from phone calls, from house or plant visits, from mailers, or from studio sessions. Surveys can run as short as several minutes and as long as hours, again depending on the nature and complexity of the survey.

One technique could use a multi-channel satellite which queries portable telephones, and relays responses to the originating source from the individual voter. This system would use a single satellite in geo-synchronous orbit, capable of polling 100M people in one hour. It would relay any 10-bit message automatically upon query.

The voting/polling wrist set seems to be less suited to strict statistical market samplings than to straw polls - mainly because of the element of control in sampling. Generally, straw polls are of a political or quasi-political nature. The intent is not to be precise in measuring an on-going trend, but to get a rough feel about how voters stand now on a particular issue. The service might find use therefore in setting national policy, as in a gigantic town meeting, or in breaking a politcal logjam, but would likely find little use in commercial or industrial survey situations.

TABLE 5-23. REVENUE FROM VEHICLE/PACKAGE LOCATOR

(Trucks)

	Mileage	Saturation	User mileage	Fee	Least Case Revenue	Best Case Revenue
1990	19500M	3.3%(25%)	161M	1¢	$2M	$5M
1991	19900M	6.7%	333M		3M	10M
1992	20300M	10%	507M		5M	15M
1993	20700M	30%	1552M		15M	46M
1994	21100M	50%	2637M		26M	79M
1995	21500M	70%	3762M		38M	113M
1996	21900M	90%	4927M		49M	148M
1997	22300M	93.3%	5201M		52M	156M
1998	22700M	96.7%	5488M		55M	165M
1999	23100M	100%	5775M		58M	173M
2000	23500M		5875M		59M	176M
2005	25500M		6375M		64M	191M
2010	27500M		6875M		69M	206M

(Cars)

	Population	Saturation	User group	Fee	Least Case Revenue	Best Case Revenue
1990	188M	3.3%(1%)	62K	$10	$0.6M	$3.0M
1991	192M	6.7%	129K		1.3M	6.4M
1992	196M	10%	196K		2.0M	9.8M
1993	200M	30%	600K		6.0M	30.0M
1994	204M	50%	1020K		10.2M	51.0M
1995	208M	70%	1456K		14.6M	72.8M
1996	212M	90%	1908K		19.1M	95.4M
1997	216M	93.3%	2015K		20.1M	100.8M
1998	220M	96.7%	2127K		21.3M	106.4M
1999	224M	100%	2240K		22.4M	112.0M
2000	228M		2280K		22.8M	114.0M
2005	248M		2480K		24.8M	124.0M
2010	268M		2680K		26.8M	134.0M

TABLE 5-24.

(Total)

	Least Case Revenue	Best Case Revenue
1990	$2.6M	$8.0M
1991	4.3M	16.4M
1992	7.0M	24.8M
1993	21.0M	76.0M
1994	36.2M	130.0M
1995	52.6M	185.8M
1996	68.1M	243.4M
1997	72.1M	256.8M
1998	76.3M	271.4M
1999	80.4M	285.0M
2000	81.8M	290.0M
2005	88.8M	315.0M
2010	95.8M	340.0M

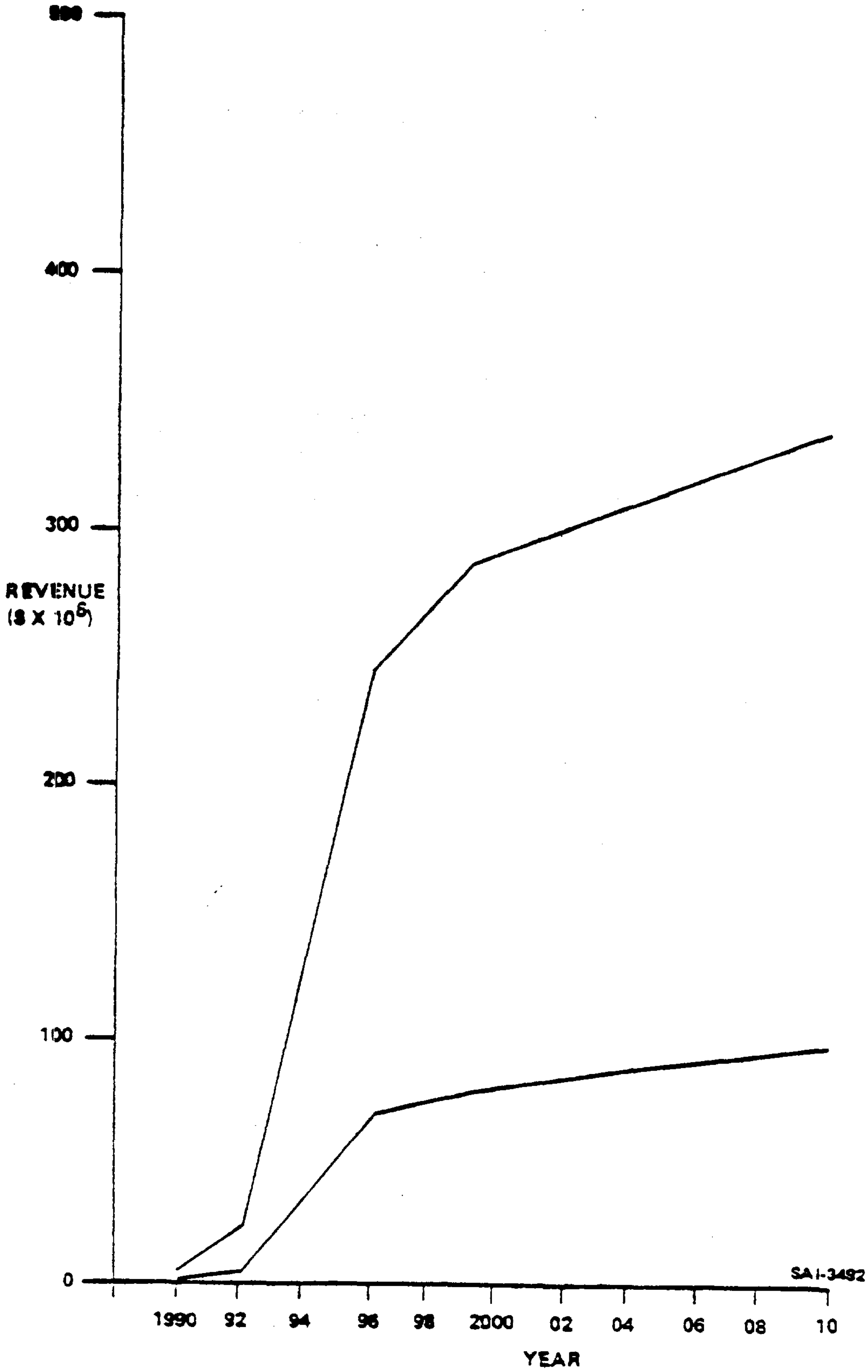


Figure 5-14. Revenue From Vehicle/Package Locator (User Fees Only)

The value of a satellite system would be its speed of response (though there must be some means of presenting the questions and issues to the voters); and presumably its low-cost on a large-scale basis. Competitive techniques would be telephone surveys, which have a rapid response time (but high cost: $1 - $10 per call); or low cost as in a mail survey (but slow response: up to 4 weeks delay).

Assuming therefore a means of presenting the issues - as with a TV tie-in on a regular basis, or other media technique - then at 10¢ per use per person polled, an instant response might be worthwhile. (This is cost of satellite use only, and does not include ground computer or data interpretation time).

As a rough estimate, take the number of portable telephones as presented in the Best Case analysis. Then assume a 10% to 50% participation banding to determine ultimate revenue. Since the telephone doesn't come into service until 1995; and since a reasonably large number of users must be on line for the poll to be effective; then assume the service starts in the year 2000. (A lesser case would imply pushing the start of the polling service out into the future.) Finally, assume a poll is taken bi-weekly, or roughly 25 times a year. This would take into account some of the larger states which might want to occasionally use the service.

Market revenue projections are given in Table 5-25, with a summary plot shown in Figure 5-15.

5.3.15 Education

Technologically available in 1980, an educational service by satellite would allow direct-to-home or to central facility education TV programs. Such a service would be particularly useful in mountainous regions where sparse population limits funding for facilities, and where mountains block reception of good quality ground-based television programming. Satellite hardware will be related to present-day large communications satellites in geo-synchronous orbit. The satellite will transmit video and audio every hour of the day, six or seven days per week. Each program will

TABLE 5-25.

REVENUE FROM VOTING/POLLING WRIST SET

	Population		User group		Annual uses	Fee	Least Case Revenue	Best Case Revenue
2000	2.7M	(10%)	.27M	(x25)	6.75M	10¢	$.67M	$3.3M
2001	3.2M		.32M		8.00M		.80M	4.0M
2002	3.7M		.37M		9.25M		.92M	4.6M
2003	4.2M		.42M		10.5M		1.0M	5.0M
2004	4.6M		.46M		11.5M		1.1M	5.5M
2005	5.1M		.51M		12.5M		1.2M	6.0M
2006	10.2M		1.0M		25.0M		2.5M	12.5M
2007	15.4M		1.5M		37.5M		3.7M	18.5M
2008	20.7M		2.1M		52.5M		5.2M	26.0M
2009	26.0M		2.6M		65.0M		6.5M	32.5M
2010	31.3M		3.1M		77.5M		7.7M	38.5M

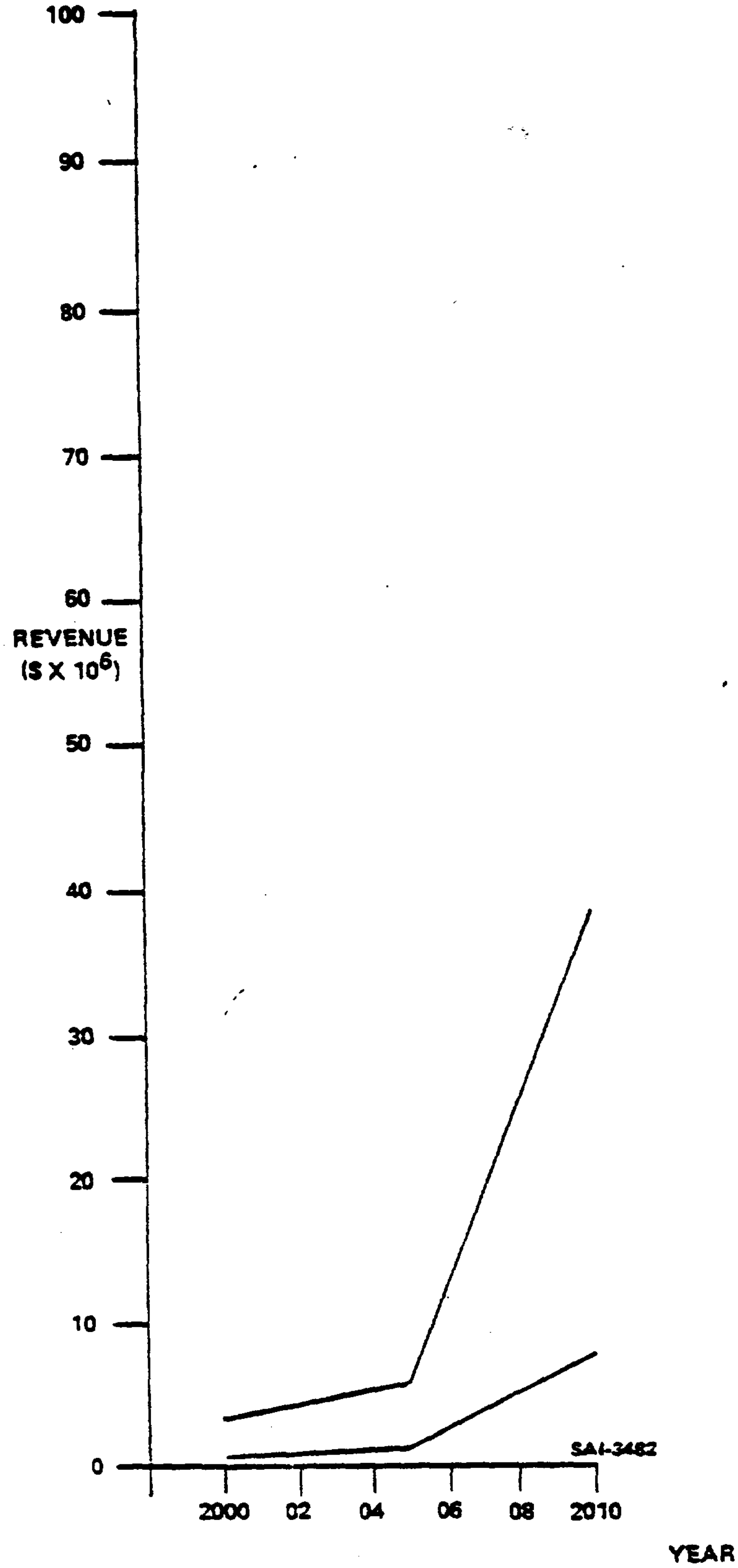


Figure 5-15. Revenue From Voting/Polling Wrist Set

be transmitted at least four times per day. There will therefore be six courses per day, with varying semester lengths. There will likely be 1 to 3 satellites to cover the entire domestic US market. The antenna/transmitter will be sufficiently powerful to require no special equipment for earth users.

Receive hardware will be no more complex than the current television and antenna setup found in most homes. High resolution requirements can be met with mass-produced, low-cost 3 meter dish antennas.

Continuing education can satisfy needs ranging from fundamental (elementary,vocational and educational skills) to advanced and peripheral (foreign languages, yoga, etc.). Education by television can satisfy many - though not all - of the educational needs. There are some situations which require either the close personal supervision of the instructor, hands-on equipment, or immediate and direct feedback by the instructor. This implies a potential television user group which is smaller in number than the total actual number of adults now in continuing education.

Initially, the universe of users would likely be limited to those mountainous regions virtually inaccessible by present means of telecommunications, and generally unable to support extensive amounts of continuing education because of low population densities. As the service becomes more widely used, the market might expand to include adults preferring to take the relevant courses in their own homes, rather than at nearby schools or universities; and facilities giving centralized course situations. Thus while the initial market might represent an addition in numbers to those adults already taking courses, this addition would seem to be a minor one, considering the low population densities in the areas served. The general market would seem to be congruent with those adults already in the market for education. The potential universe of buyers/users will therefore be assumed to be the same general population as would otherwise be taking continuing education courses.

In 1972 there were 15,734,000 adults taking some kind of continuing education. Some of these were taking courses at work, or some form of vocational training, or courses at local public schools which would probably not be readily televised on a national basis. The remainder - some 6,000,000- were taken at 2 and 4 year colleges. Many of the courses at this level would likely be amenable to televised presentation. The market would then hinge on a percentage of these course-takers which would prefer to take the course at home . . . or which of the colleges would elect to use the televised courses, to supplement or augment the existing curriculum. For a probable band of users, consider 10% to 25% of this number as ultimately being amenable to televised courses. It is likely that pressure from existing faculty members would prevent any wholesale displacement of the faculty by the television series, thus precluding a larger percentage of use. Assume also that each user would take an average of two courses per year.

The total universe of users will be assumed as a percentage of the general population of the US, age 21 and over. In this case, 6,000,000 was roughly 5% of 128,000,000 (general population age 21 and over in 1972). The projected figures will use US projected population to the year 2015 (Series II and II-X).

Analogous services would include existing adult continuing education courses, some of which are already given by T.V.; and educational television programs now received at home. While the adult education courses on public television are generally without fee (payment is by voluntary subscription), continuing education courses generally charge $20 to $50 per course at the more popular universities. Assume an average televised course charge therefore of $20, with the average course lasting three months.

There could be a significant delay in setting up the service due to the need to allocate clear channels over much of the US. This would mean the FCC might have to reallocate some existing channels, meaning some controversy at the local level. Assume therefore a moderate (5 year) delay barrier to entry.

Since the primary receiver - television - is in place in most homes and facilities already, and since the facilities for production are in place, then once the service were given a go-ahead, there should be little need for stretchout before the growth phase. Success and growth of the service will depend quite a bit on promotion of the available programs, and courses offered.

Education should not be considered a fast growth industry. Its methods are fairly well entrenched, and there are ingrained ways of doing things in this field. However, the benefits of having accredited courses in the home may outweigh any resistance to change after a reasonable time. Competition will include cable television, already in place in many areas, so we should expect a slow track (30 years) to ultimate saturation.

With ideal saturation coming in 30 years, and zero stretchout from resistance to change factors, 10% of the saturation level will come in 9 years after entry (30%(30 years)). Similarly, the final 10% will take 9 years.

The following tables are applicable to this analysis:

Table 5-26 shows the cumulative number of users (worst case) by year.

Table 5-27 shows worst case resultant revenue by year.

Table 5-28 shows the cumulative number of users (best case) by year.

Table 5-29 shows the best case resultant revenue by year.

Figure 5-16 shows a summary plot of anticipated revenues.

5.3.16 Urban/Police Wrist Radio

The wrist 2-way transceiver and channelized Comsat give instant 2-way communications to patrolmen. A high degree of mobility and safety is achieved through the radio's anti-jar, secure, and high coverage/wide area features. Users of the Urban/Police Wrist Radio system could include firemen and security guards as well as policemen.

TABLE 5-26. CUMULATIVE USERS BY YEAR (LEAST CASE)

14.	Population		User Group	Percentages		Cumulative Users
1985	158M	5%	7.9M	1.1%(10%)=	0.11%	8.69K
1986	160M		8.0M	2.2%	0.22%	17.6K
1987	161M		8.0M	3.3%	0.33%	26.4K
1988	163M		8.1M	4.4%	0.44%	35.6K
1989	164M		8.2M	5.5%	0.55%	45.1K
1990	166M		8.3M	6.7%	0.67%	55.6K
1991	167M		8.3M	7.8%	0.78%	64.7K
1992	169M		8.4M	8.9%	0.89%	74.8K
1993	170M		8.5M	10.0%	1.00%	85.0K
1994	171M		8.5M	16.7%	1.67%	141.9K
1995	173M		8.6M	23.4%	2.34%	201.2K
1996	174M		8.7M	30.1%	3.01%	261.9K
1997	176M		8.8M	36.8%	3.68%	323.8K
1998	177M		8.8M	43.5%	4.35%	382.8K
1999	178M		8.9M	50.2%	5.02%	446.8K
2000	179M		8.9M	56.9%	5.69%	506.4K
2001	181M		9.0M	63.6%	6.36%	572.4K
2002	183M		9.1M	70.3%	7.03%	639.7K
2003	184M		9.2M	77.0%	7.70%	708.4K
2004	186M		9.3M	83.7%	8.37%	778.4K
2005	187M		9.3M	90.4%	9.04%	840.7K
2006	189M		9.4M	91.5%	9.15%	860.1K
2007	190M		9.5M	92.6%	9.26%	879.7K
2008	192M		9.6M	93.7%	9.37%	899.5K
2009	193M		9.6M	94.8%	9.48%	910.1K
2010	195M		9.7M	95.9%	9.59%	930.2K
2011	196M		9.8M	97.0%	9.70%	950.6K
2012	198M		9.9M	98.1%	9.81%	971.2K
2013	199M		9.9M	99.2%	9.92%	982.1K
2014	201M		10.0M	100.0%	10.0%	1000.0K

TABLE 5-27. RESULTANT REVENUE BY YEAR (LEAST CASE)

16.	Cumulative Users		Courses	Avg Charge	Revenue
1985	8.69K	(x2)	17.38K	$20	$347K
1986	17.6K		35.20K		704K
1987	26.4K		52.8K		1056K
1988	35.6K		71.2K		1426K
1989	45.1K		90.2K		1804K
1990	55.6K		111.2K		2224K
1991	64.7K		129.5K		2589K
1992	74.8K		149.5K		2990K
1993	85.0K		170.0K		3400K
1994	141.9K		283.9K		5678K
1995	201.2K		402.4K		8050K
1996	261.9K		523.8K		10475K
1997	323.8K		647.6K		12954K
1998	382.8K		765.6K		15312K
1999	446.8K		893.6K		17871K
2000	506.4K		1012.8K		20256K
2001	572.4K		1144.8K		22896K
2002	639.7K		1279.5K		25589K
2003	708.4K		1416.8K		28336K
2004	778.4K		1556.8K		31136K
2005	840.7K		1681.4K		33628K
2006	860.1K		1720.2K		34404K
2007	879.7K		1759.4K		35188K
2008	899.5K		1799.0K		35980K
2009	910.1K		1820.2K		36403K
2010	930.2K		1860.4K		37209K
2011	950.6K		1901.2K		38024K
2012	971.2K		1942.4K		38848K
2013	982.1K		1964.2K		39283K
2014	1000K		2000.0K		40000K

TABLE 5-28. CUMULATIVE USERS BY YEAR (BEST CASE)

14.	Population	User Group	Percentages		Cumulative Users
1985	See	See	1.1%(25%)=	0.27%	21.7K
1986	Least	Least	2.2%	0.55%	44.0K
1987	Case	Case	3.3%	0.82%	66.0K
1988			4.4%	1.10%	89.1K
1989			5.5%	1.37%	112.7K
1990			6.7%	1.67%	139.0K
1991			7.8%	1.95%	161.8K
1992			8.9%	2.22%	186.9K
1993			10.0%	2.50%	212.5K
1994			16.7%	4.17%	354.9K
1995			23.4%	5.85%	503.1K
1996			30.1%	7.52%	654.7K
1997			36.8%	9.20%	809.6K
1998			43.5%	10.9%	957.0K
1999			50.2%	12.5%	1116.9K
2000			56.9%	14.2%	1266.0K
2001			63.6%	15.9%	1431.0K
2002			70.3%	17.6%	1599.3K
2003			77.0%	19.2%	1771.0K
2004			83.7%	20.9%	1946.0K
2005			90.4%	22.6%	2101.8K
2006			91.5%	22.9%	2150.2K
2007			92.6%	23.1%	2199.2K
2008			93.7%	23.4%	2248.8K
2009			94.8%	23.7%	2275.2K
2010			95.9%	24.0%	2325.6K
2011			97.0%	24.2%	2376.5K
2012			98.1%	24.5%	2403.4K
2013			99.2%	24.8%	2455.2K
2014			100.0%	25.0%	2500.0K

TABLE 5-29. RESULTANT REVENUE BY YEAR (BEST CASE)

16.	Cumulative Users		Courses	Avg Charge	Revenue
1985	21.7K	(x2)	43.4K	$20	$868K
1986	44.0K		88.0K		1760K
1987	66.0K		132.0K		2640K
1988	89.1K		178.2K		3564K
1989	112.7K		225.4K		4508K
1990	139.0K		278.0K		5560K
1991	161.8K		323.6K		6472K
1992	186.9K		373.8K		7476K
1993	212.5K		425.0K		8500K
1994	354.9K		709.8K		14196K
1995	503.1K		1006.2K		20124K
1996	654.7K		1309.4K		26188K
1997	809.6K		1619.2K		32384K
1998	957.0K		1914.0K		38280K
1999	1116.9K		2233.8K		44676K
2000	1266.0K		2532.0K		50640K
2001	1431.0K		2862.0K		57240K
2002	1599.3K		3198.6K		63972K
2003	1771.0K		3542.0K		70840K
2004	1940.0K		3892.0K		77840K
2005	2101.8K		4203.6K		84072K
2006	2150.2K		4300.4K		86008K
2007	2199.2K		4398.4K		87968K
2008	2248.8K		4497.6K		89952K
2009	2275.2K		4550.4K		91008K
2010	2325.6K		4651.2K		93024K
2011	2376.5K		4753.0K		95060K
2012	2403.4K		4806.8K		96136K
2013	2455.2K		4910.4K		98208K
2014	2500.0K		5000.0K		100000K

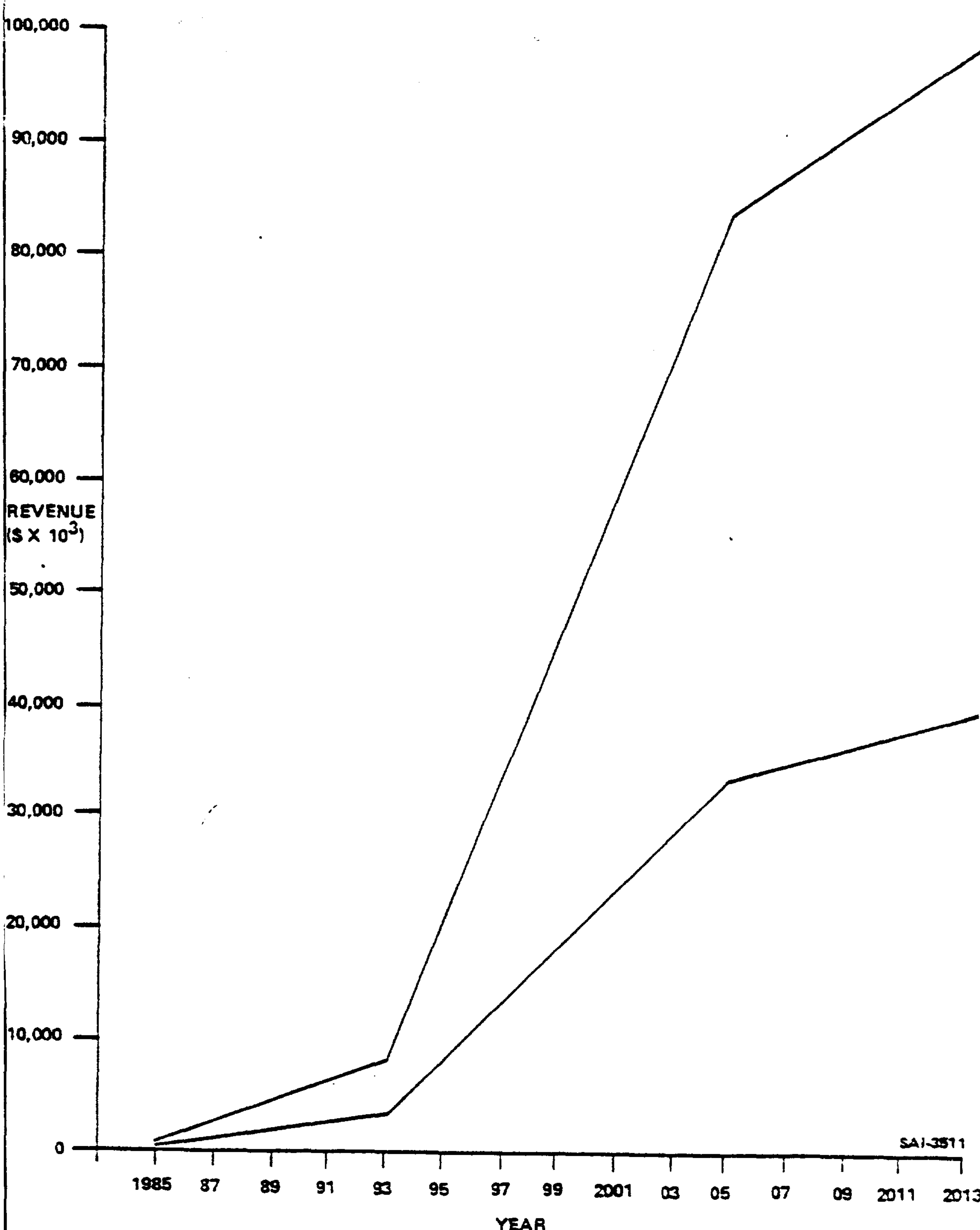


Figure 5-16. Education by Satellite

In 1960, there were 693,000 people in these categories. Ten years later this figure had grown to 908,000. From this, we assume growth in the relevant population of roughly 200,000 per decade. Not all of these people, however, will use the Urban/Police Wrist Radio system due to competing communication systems. Also, some organizations will be too small to need such sophisticated services. Consequently, we assume that the user group could range from a low 1% to a high of 25% of the relevant population.

The cost to the user will be $250 for the unit and a user subscription fee equivalent to $100 per year per user. With a market saturation period of 10 years and a replacement level (after start-up) of 10%, we can derive best and worst case revenues for both unit sales and subscription fees. The details of these revenues are given in Table 5-30 and 5-31. Summary plots can be found in Figures 5-17 and 5-18.

5.3.17 Coastal Anti-Collision Passive Radar

There is a need for an inexpensive and lightweight radar system for all coastal surface vessels, for the purpose of navigation and collision avoidance. Typically, conventional radar is too expensive, and is also interference prone, which precludes its use by many vehicles. In particular, pleasure craft are usually denied the benefits of radar.

A satellite system, composed of two large satellites 90 degrees apart in synchronous equatorial orbit, would illuminate seacoasts with scanning microwave beams. Scanning receiving antennas (3 ft X 0.5 ft) on boats would then obtain range and angle data on potential hazards. There could be an unlimited number of users, and each boat would be able to determine the relative location of all objects larger than 100 m^2 within a 12 nmi range.

(Best Case) TABLE 5-30. URBAN/POLICE WRIST RADIO

USER FEE

	Population	Saturation	User Group	Fee	Revenue
1990	1300K	3.3% (25%)	11K	$100	$1.1M
1991	1320K	6.7%	22K		2.2M
1992	1340K	10%	33K		3.3M
1993	1360K	30%	102K		10.2M
1994	1380K	50%	172K		17.2M
1995	1400K	70%	245K		24.5M
1996	1420K	90%	319K		31.9M
1997	1440K	93.3%	336K		33.6M
1998	1460K	96.7%	353K		35.3M
1999	1480K	100%	370K		37.0M
2000	1500K		375K		37.5M
2005	1600K		400K		40.0M
2010	1700K		425K		42.5M

WRIST RADIO

	New Users	Replacement	Total Units Sold	Cost	Revenue
1990	11K	---	11K	$250	$2.7M
1991	11K	---	11K		2.7M
1992	11K	---	11K		2.7M
1993	69K	10K	79K		19.7M
1994	70K	17K	87K		21.7M
1995	73K	24K	97K		24.2M
1996	76K	32K	108K		27.0M
1997	17K	34K	51K		12.7M
1998	17K	35K	52K		13.0M
1999	17K	37K	54K		13.5M
2000	5K	37K	42K		10.5M
2005	5K	40K	45K		11.2M
2010	5K	42K	47K		11.7M

(Least Case) TABLE 5-31. URBAN/POLICE WRIST RADIO

	Merchant vessels (25%)	Pleasure boats (0.2%)	Merchant + Pleasure
1995	20K	19K	39K
1996	20K	19K	39K
1997	21K	19K	40K
1998	21K	20K	41K
1999	21K	20K	41K
2000	21K	20K	41K
2001	22K	20K	42K
2002	22K	20K	42K
2003	22K	21K	43K
2004	22K	21K	43K
2005	23K	21K	44K
2010	24K	22K	46K

	Saturation level	User group	New users	Cost	Revenue
1995	3.3%	1K	1K	$500	$0.5M
1996	6.7%	3K	2K		1.0M
1997	10%	4K	1K		0.5M
1998	30%	12K	8K		4.0M
1999	50%	20K	8K		4.0M
2000	70%	29K	9K		4.5M
2001	90%	38K	9K		4.5M
2002	93.3%	39K	1K		0.5M
2003	96.7%	41K	2K		1.0M
2004	100%	43K	2K		1.0M
2005		44K	1K		0.5M
2010		46K	2K		1.0M

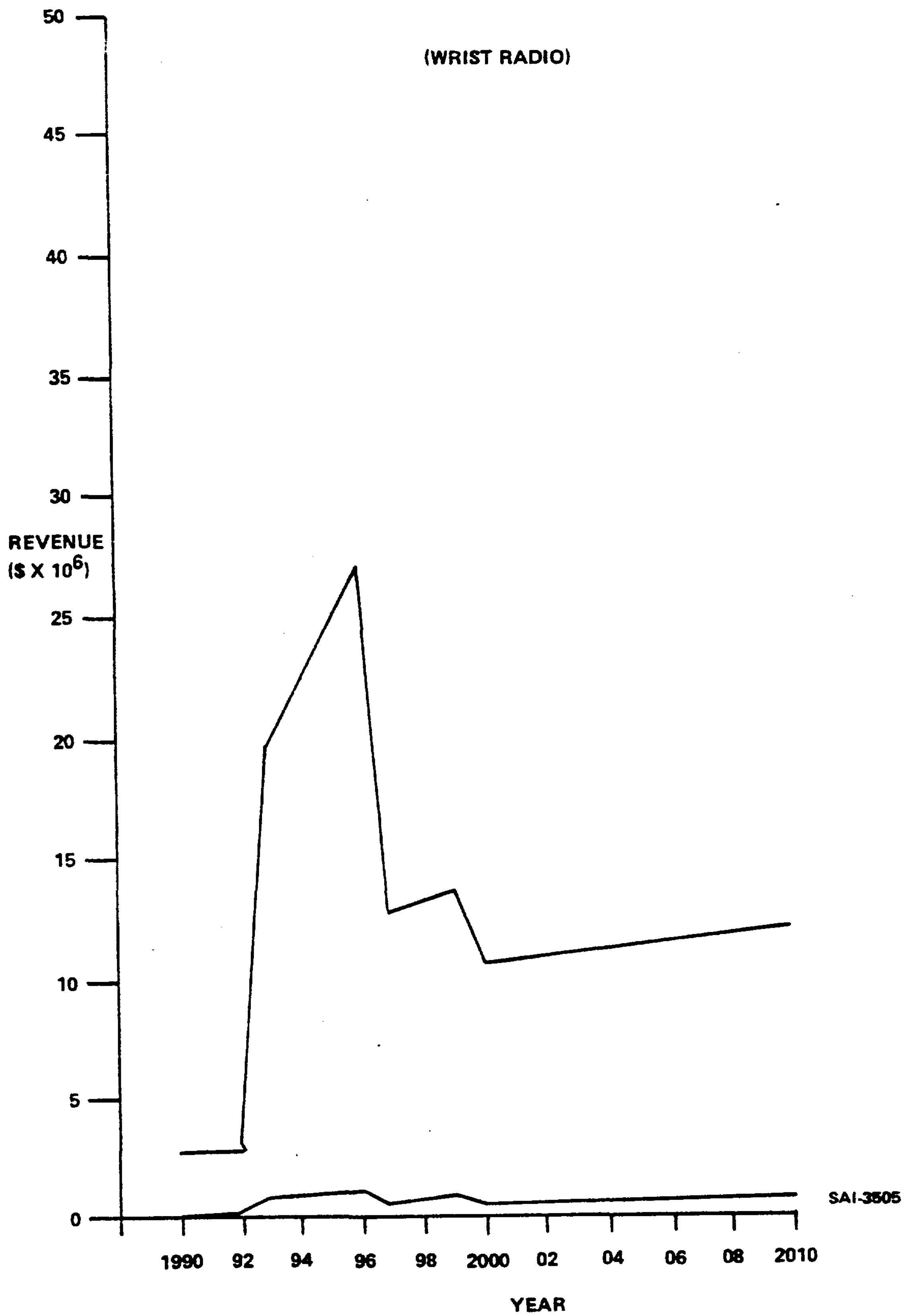


Figure 5-17. Revenue From Urban/Police Wrist Radio

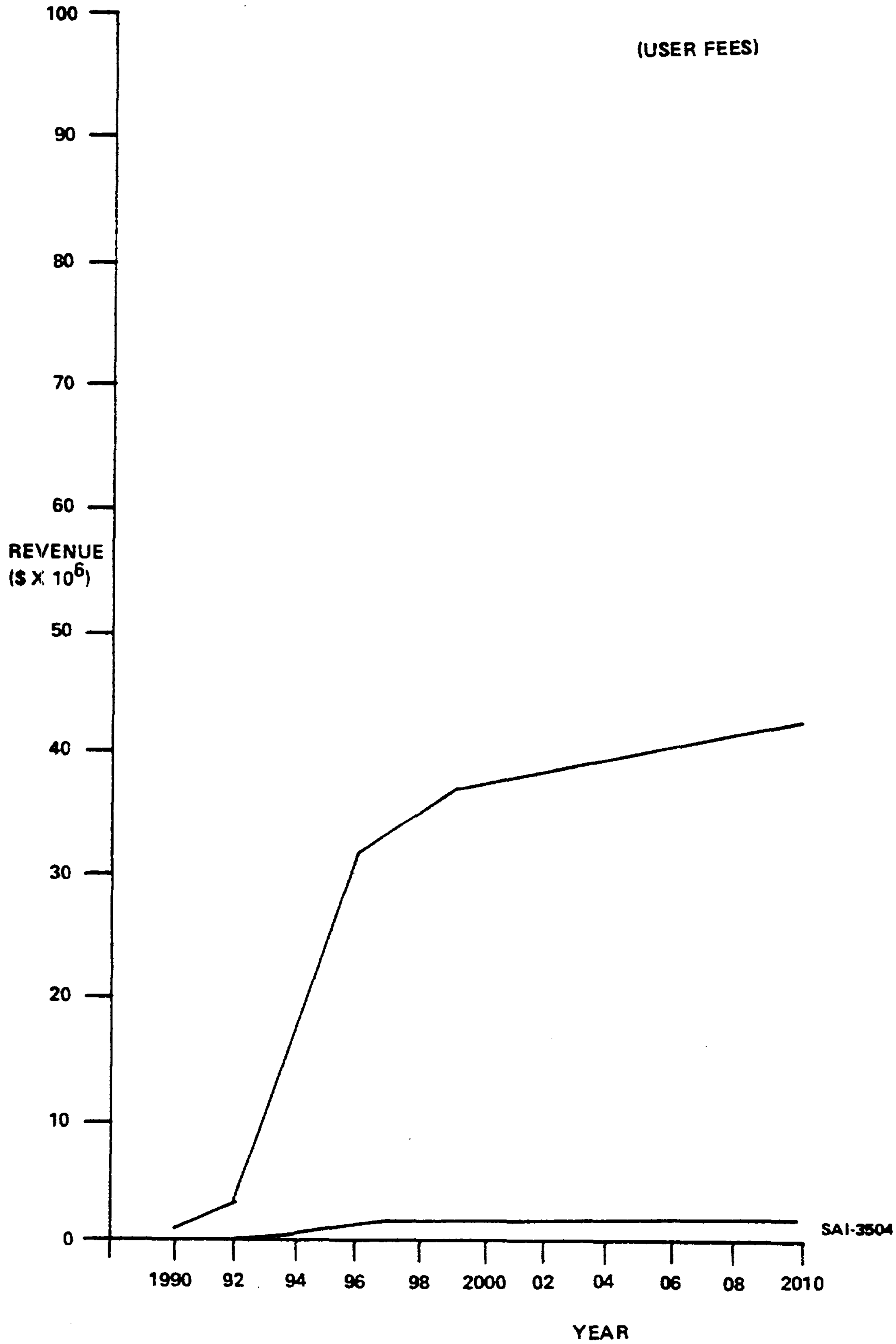


Figure 5-18. Revenue From Urban/Police Wrist Radio

According to the 1976 Statistical Abstract of the US, in 1974 there were 58,000 US merchant vessels of 5+ tons. Of these, 3600 were greater than 100 tons. There were also 7.6 million pleasure boats in the US. Assuming the need for this service is in from 25% to virtually all (100%) merchant vessels - but that most of those over 100 tons already have a radar system; and a need in 1% to 25% of all ocean-going motorized vessels including pleasure craft; then the best case and worst case market revenue projections in Table 5-32 and 5-33 could apply. (For this purpose, assume 25% of all pleasure boats are ocean-going, and 80% of these are motorized.)

There can be no user's fee for the service since this is a passive receive system. However, there will be some associated revenue from sale of radar receive sets . . . at an assumed price of $500 to correlate with analogous T.V. and oscilloscope products which use tube scans. Finally, the timing of market saturation is somewhat uncertain, but is assumed here to come in 10 years - in part because of the relative price of the receive set. The system is technologically feasible by 1995.

A summary plot is shown in Figure 5-19.

5.3.18 Land and Water Resources

Earth Satellite Corporation has performed a study relating to the potential benefits resulting from a satellite imagining system (Landsat). The time period of these benefits was chosen to be 1977 - 1986. The benefits were annualized to give a steady stream. In this case, we will assume that revenue would equal the level of benefits (low range to high), and that there are commercial users interested in each service. Each forecast assumes a two-satellite system.

Benefits in Agricultural Production related to the following applications:

TABLE 5-32.

(Best Case)

	Merchant vessels	Pleasure boats	5%	Merchant + pleasure
1995	80K	9.5M	470K	550K
1996	81K	9.6M	480K	561K
1997	82K	9.7M	480K	562K
1998	83K	9.8M	490K	573K
1999	84K	9.9M	490K	574K
2000	85K	10.0M	500K	585K
2001	86K	10.1M	500K	586K
2002	87K	10.2M	510K	597K
2003	88K	10.3M	510K	598K
2004	89K	10.4M	520K	609K
2005	90K	10.5M	520K	610K
2010	95K	11.0M	550K	645K

	Saturation level	User group	New Users	Cost	Revenue
1995	3.3%	18K	18K	$500	$9M
1996	6.7%	37K	19K		9M
1997	10%	56K	19K		9M
1998	30%	172K	116K		58M
1999	50%	287K	115K		58M
2000	70%	409K	122K		61M
2001	90%	527K	118K		59M
2002	93.3%	557K	30K		15M
2003	96.7%	578K	21K		11M
2004	100%	609K	31K		15M
2005		610K	1K		1M
2010		645K	35K		17M

TABLE 5-33

(Least Case)

	Merchant vessels (25%)	Pleasure boats (0.2%)	Merchant + Pleasure
1995	20K	19K	39K
1996	20K	19K	39K
1997	21K	19K	40K
1998	21K	20K	41K
1999	21K	20K	41K
2000	21K	20K	41K
2001	22K	20K	42K
2002	22K	20K	42K
2003	22K	21K	43K
2004	22K	21K	43K
2005	23K	21K	44K
2010	24K	22K	46K

	Saturation level	User group	New users	Cost	Revenue
1995	3.3%	1K	1K	$500	$0.5M
1996	6.7%	3K	2K		1.0M
1997	10%	4K	1K		0.5M
1998	30%	12K	8K		4.0M
1999	50%	20K	8K		4.0M
2000	70%	29K	9K		4.5M
2001	90%	38K	9K		4.5M
2002	93.3%	39K	1K		0.5M
2003	96.7%	41K	2K		1.0M
2004	100%	43K	2K		1.0M
2005		44K	1K		0.5M
2010		46K	2K		1.0M

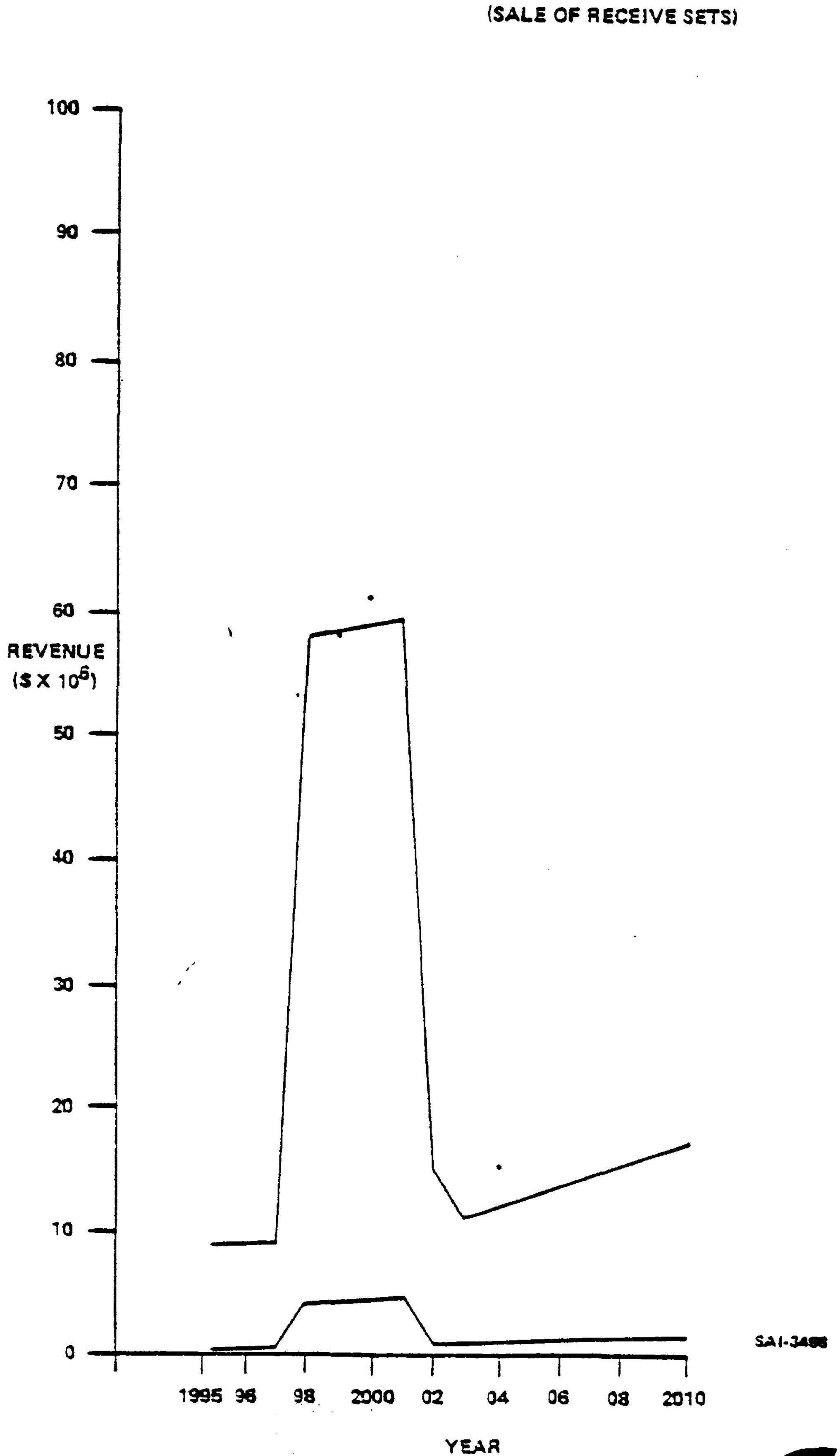


Figure 5-19. Revenue From Coastal Passive Radar

- Crop acreage forecasting
- Crop yield forecasting
- Agricultural land stratification
- Design and operation of irrigation projects
- Pest susceptibility mapping
- Flood damage assessment in agriculture

Agriculture benefits (revenue) range from 1.7M to 3.9M annually.

Benefits in Water Resources Management related to the following applications:

- Snow mapping runoff forecasting
- Surface water extent
- Location and extent of groundwater
- Hydrologic response of watershed
- Flood area assessment

Water Resources Management benefits range from 3.9M to 12.2M annually, with most coming from snow mapping and runoff forecasting.

Benefits in Rangeland Management related to the following applications:

- Range monitoring
- Range inventory
- Range feed condition
- Other

Rangeland Management benefits range from 5.2M to 22.8M annually, with most coming from range monitoring.

Benefits in Forest Management related to the following applications:

- Forest inventory
- Forest vegetation mapping
- Forest fire management
- Timber management
- Forest pest detection and control

Forestry benefits range from 0.8M to 2.9M annually.

Benefits in Land Use Planning & Management related to the following applications:

- State land use planning
- Site and route selection
- Federal land planning
- Cartographic mapping

Land use benefits range from 9.7M to 17.2M annually, with most coming from state land use planning.

Benefits in Geological Exploration and Mineral Resources Management related to:

- Petroleum exploration
- Mineral exploration

Geological and mineral resources benefits range from 0.1M to 0.6M annually.

Benefits in Marine Resources Management related to:

- Living marine resources
- Waterborne transportation
- Ocean and coastal engineering

Marine resources benefits range from 0.5M to 1.1M annually.

In summation, probable annual benefits (1977-1986) from a two satellite resource imagining system range are as follows:

Agriculture Production	$1.7M - 3.9M
Water Resources Management	3.9M - 12.2M
Rangeland Management	5.2M - 22.8M
Forestry	0.8M - 2.9M
Land Use Planning and Management	9.7M - 17.2M
Geological and Mineral Resource Mgt.	0.1M - 0.6M
Marine Resources and Ocean Survey	0.5M - 1.1M
Total	$21.9M - 60.7M

In addition, ECON, Inc. has performed a study (The Economic Value of Remote Sensing of Earth Resources from Space . . .) which provides for significantly greater benefits than the Earth Satellite study.

In particular, a typical year (1985) gives the following range of benefits:

Agriculture	$252.5 - 554.5M
Forestry, Wildlife, Range	62.2
Inland water resources	57.2
Land use	53.5
Minerals, fossil fuels	1.6 - 3.9
Atmosphere	1.5 - 10.5
Oceans	1.75 - 4.25
	$430 - 746 Million

For a broad sampling of years (1980 - 1992), the following benefits were assumed:

1980	$65M
1981	105
1982	145
1983	215
1984	310
1985	375
1986	420
1987	460
1988	495
1989	525
1990	560
1991	590
1992	600

These may be considered an upper band of potential benefits relative to the Earthsat study.

It should be noted, in using the potential benefits figures, that these benefits are not necessarily related to potential market revenues. The benefits relate to such intangibles as savings in time and energy and lower cost of end-derived product to the user. Market revenue, on the other hand, would relate to cost of the images returned to Earth and possible fees for analysing the information. Revenues, therefore, would be significantly lower than benefits.

5.3.19 Ocean Resources

Fish protein resource yield needs to be maximized due to a world protein shortage. One way of efficiently mapping this resource is to use a satellite to measure temperature and emissivity differences in surface water, caused by schools of fish, currents, and plankton concentrations.

These would be detected by the differences in self-emission in the long wave infra-red. 100 foot resolution could be attained over all ocean surfaces every 12 hours. Sensitivity of up to 0.002 degrees could be achieved.

Market for such a service would be the country's various fishing vessels in the United States, according to the 1976 Statistical Abstract of the US. This number had remained stable for several years prior, and would not be expected to change drastically over a subsequent period of years.

In a survey taken by Oregon State University, the value of electronic equipment in fishing vessels generally was shown to range from a low of 0 - $500, to a high exceeding $5000. This would seem to imply a direct correlation with willingness to subscribe to a satellite fish forecasting system.

Assuming little change in the number of craft, and taking the statistical input from the Oregon State survey, then up to 25% of the vessels might be expected to participate if there were $100 annual subscription fees for the service. With a subscription fee of $10 per year, up to 75% of the vessels might participate. These fees would not include cost of equipment needed to receive the data - and the data may well be able to be received on existing equipment.

Because of the high fee and resistance to change factors, assume 10 years to market saturation from initial service in 1985 for the best case; assume 5 years for the worst case, because of the low fee.

Market revenue projections are given in Table 5-34 with a summary plot shown in Figure 5-20.

5.4 RESULTS OF MARKET/REVENUE ANALYSES IN ENERGY FOR UNITED STATES ONLY

5.4.1 Solar Power

Two significantly different approaches have been taken to determine resultant benefits from solar power satellites. One, followed by Peter Glaser of Arthur D. Little, has assumed Solar Power Satellites placed in

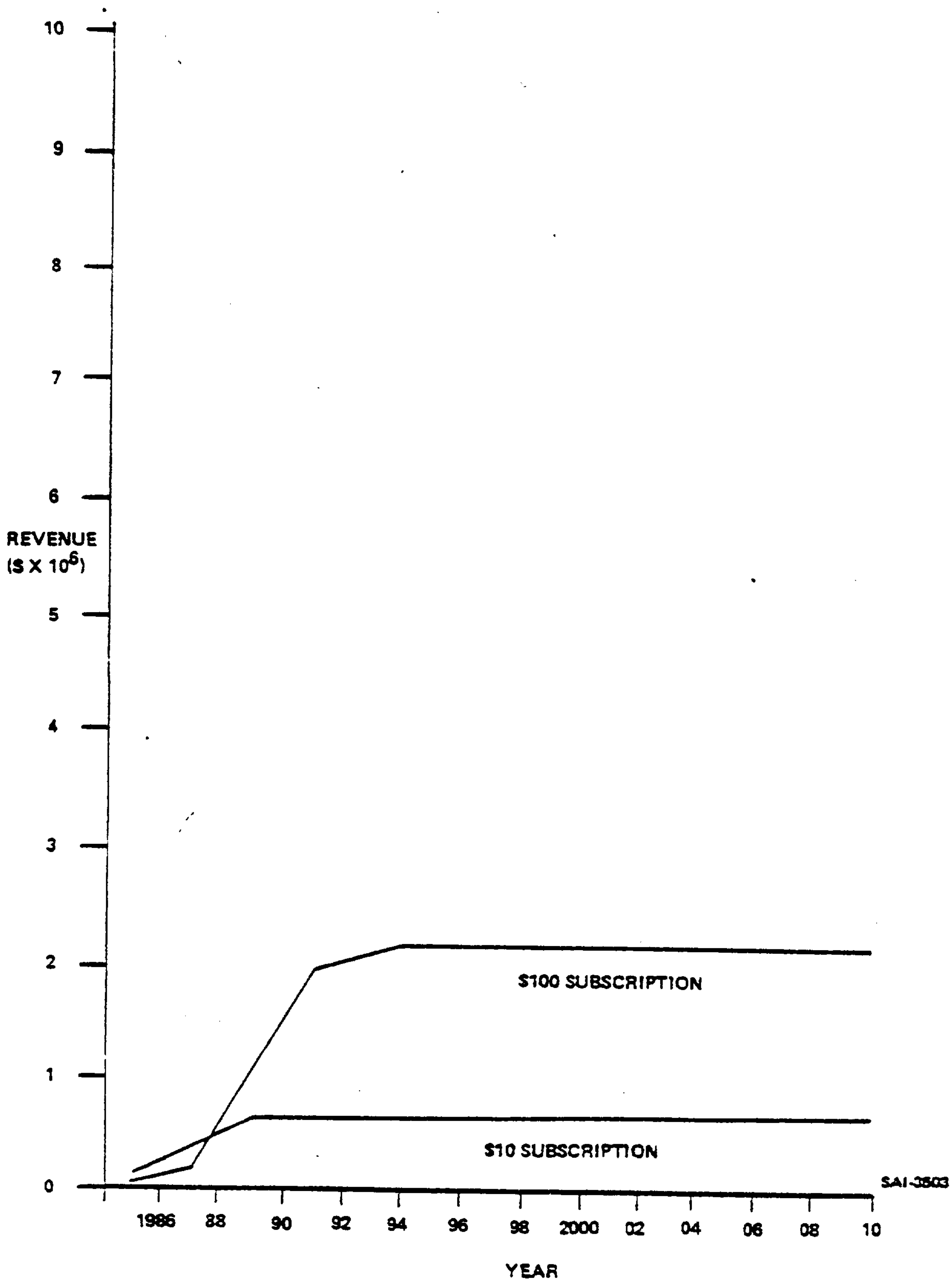


Figure 5-20. Revenue From Ocean Resources

TABLE 5-34.

REVENUE

(Best Case)

	Population	Saturation	User Group	Fee	Revenue
1985	85000	3.3% (25%)	701	$100	$70K
1986		6.7%	1423		140K
1987		10%	2125		210K
1988		30%	6375		640K
1989		50%	10625		1060K
1990		70%	14875		1490K
1991		90%	19125		1910K
1992		93.3%	19826		1980K
1993		96.7%	20549		2050K
1994		100%	21250		2125K
1995					2125K
2000					2125K
2010					2125K

(Least Case)

	Population	Saturation	User Group	Fee	Revenue
1985	85000	20% (75%)	12750	$10	$127K
1986		40%	25500		255K
1987		60%	38250		382K
1988		80%	51000		510K
1989		100%	63750		637K
1990					637K
2000					637K
2010					637K

geosynchronous orbit from earth-launched transportation methods. The other, followed by Gerard O'Neill of Princeton, has assumed solar power satellites placed in geosynchronous orbit from manufacturing plants in space. Once in geosynchronous orbit, each system functions essentially the same: each collects solar energy, converts it, and subsequently beams energy by microwave to ground stations on earth, after which the electricity is delivered via normal earth-bound transmission processes.

Both start from the premises that by the end of this century, there will be a great need for power in the United States, and that with given resources there will not be enough power generating capacity to meet the demand. However, by using the resources of solar radiation in space, enough power can be generated to meet this need.

This analysis takes the assumptions made by each (Glaser: 5 GW; O'Neill: 10 GW) and shows the resultant revenues from each system. The important difference in each calculation is that Glaser's system assumes a constant 27 mills/kwH, while O'Neills system starts at 11.5 mills/kwH and declines steadily after the first year. Because of different techniques, there are also different numbers of solar power satellites in use at any given time. Results reflect an assumed 85% conversion factor at the ground-based rectenna.

Market revenue projections for the Glaser system are shown in Table 5-35. Revenue projections for the O'Neill system are shown in Table 5-36. A summary plot is given in Figure 5-21.

5.4.2 Night Illuminator

Large area reflectors in space can reflect the image of the sun onto the earth. Such a night light - 10 to 100 times the brightness of the full moon on a clear night - can be used for many purposes. In agriculture it can provide the necessary brightness for sowing and harvesting at night, when for example it's necessary to make up for days lost by inclement weather. In construction, it can provide light in Arctic regions during the dark winter months, or can assist night-time construction of large, complex projects. And a space-based night light can be used to illuminate densely populated urban areas, in lieu of street lighting.

TABLE 5-35. REVENUE FROM SOLAR POWER

(GLASER)

	SSPS in use	Cost of power/kw-hr	Revenue
1996	1 (5 GW)	27 mills)	$1005M
1997	3	27	3016M
1998	5	27	5026M
1999	7	27	7036M
2000	9	27	9047M
2001	13	27	13068M
2002	17	27	17088M
2003	21	27	21109M
2004	25	27	25130M
2005	29	27	29151M
2006	33	27	33171M
2007	37	27	37192M
2008	41	27	41213M
2009	45	27	45234M
2010	49	27	49255M

TABLE 5-36. REVENUE FROM SOLAR POWER

(O'NEILL)

	SSPS in use	Cost of power/kw-hr	Revenue
1996	1 (10 GW)	11.5 mills	$856M
1997	2	11.0	1638M
1998	3	10.7	2390M
1999	4	10.5	3127M
2000	5	10.3	3835M
2001	7	9.8	5108M
2002	9	9.5	6366M
2003	12	9.1	8131M
2004	15	8.9	9940M
2005	19	8.6	12167M
2006	26	8.1	15681M
2007	34	7.8	19747M
2008	42	7.5	23455M
2009	51	7.3	27721M
2010	60	7.1	31720M

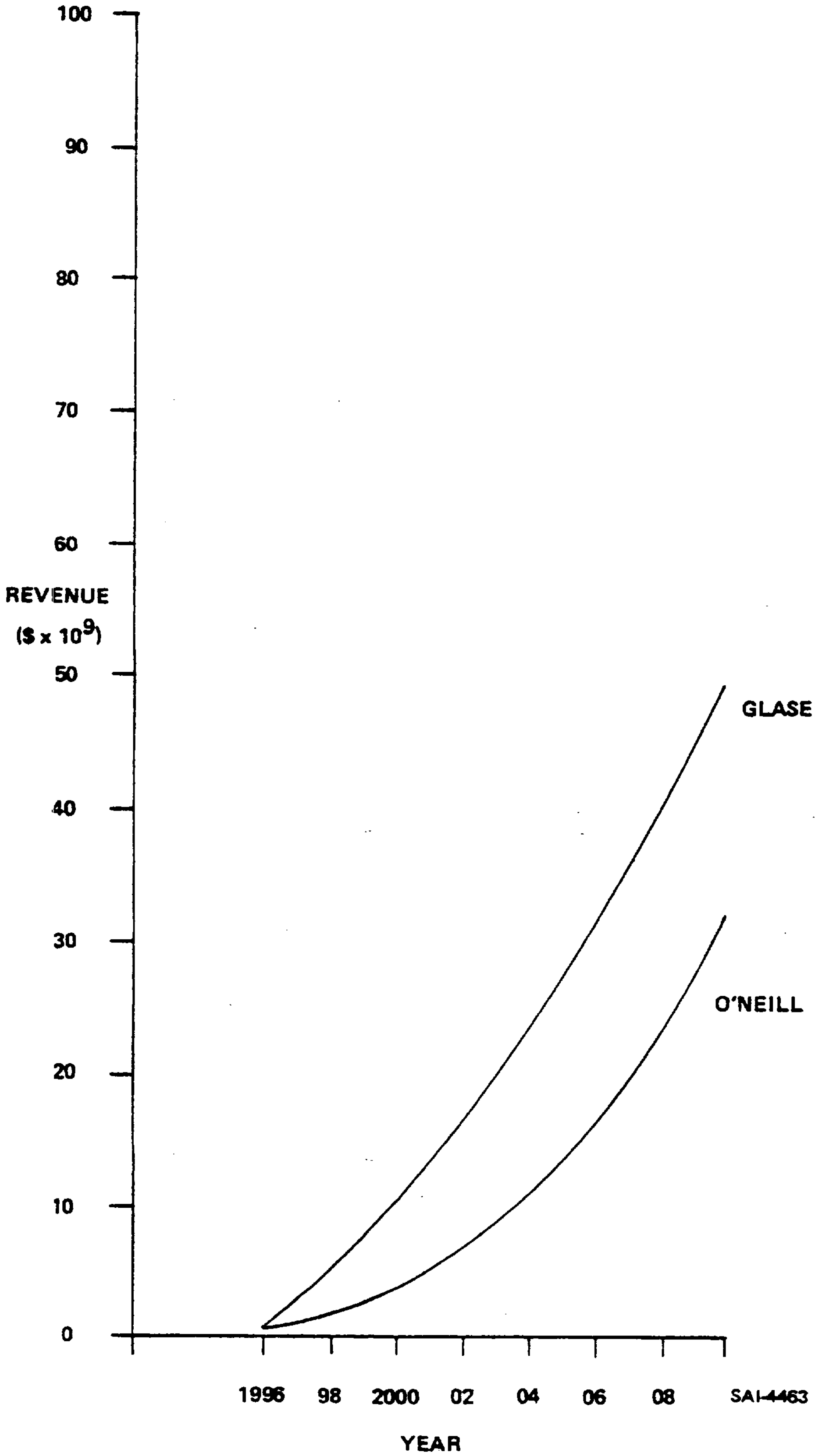


Figure 5-21. Revenue From Solar Power

One of the first commercial uses would likely be the illumination of densely populated urban areas, since street lighting uses quite a bit of energy, and since the increased cost of energy places an increased tax burden on the city dwellers who benefit from the lighting. Further, densely populated cities can provide a good economic return from the lighting of a relatively small area.

One important factor about the Night Illuminator is that it not only lights the strips of highways now illuminated by street lights, but also everything in between. There is very little focusing capability in a Night Illuminator: it covers a broad area, much as a near-Earth Moon might be seen by and illuminate a very broad area.

This means that major urban areas of the country could be illuminated with up to 100 times as much light as conventional electrical means can provide, with a cost comparable to the cost of the conventional means in densely populated areas. A major advantage in an energy-tight environment is that - once in place - it requires little energy to operate. On the other hand, since its light covers such a broad area, it might be necessary to continue using conventional street lighting systems during part of the night - say from midnight to the morning hours. There is therefore some questions as to the actual savings such a system could produce, since 60% of a city's street lighting bill is for such maintenance items as poles, fixtures, bulbs, and general repairs. Retaining the conventional system would mean savings primarily in unused energy.

At geosynchronous altitude, a reflector could illuminate an elliptical area roughly 200 miles x 300 miles. In practice this would mean simultaneous illumination of several smaller states on the East coast, or partial illumination of a larger Western state. But since it would have a direct effect on budgets and activities of people in the states, very likely the matter would have to be voted approval before operation. Gaining approval of the various states could take a number of years - particularly since (visual) environmental considerations are at stake as well as economic considerations. However, if we consider that at 25 mills per kw-hr, the average cost per capita of outdoor street lighting runs to approximately $1.64 for energy alone; and that this cost is roughly 40% of the total street lighting bill (for urban areas); and as energy costs rise in the mid-future to perhaps 40 mills then the total unaffected cost will run somewhere between $4 and $6.50 annually per capita (urban areas). In less populated areas, this figure could run considerably higher on a per capita basis.

But to win voter approval, a system such as this cannot promise improved lighting at similar cost; it must demonstrate that overall cost to the voter will be reduced - even when such a small amount is at stake. If the night illuminator displaces only one-half the street lighting per night (dusk to midnight), then the average annual energy savings runs $.82 to $1.31 (25 mills to 40 mills), with little savings on maintenance or capital expenditures: new fixtures and poles will be needed in any case and the public works department must still keep the maintenance men in force - although the bulbs will have a longer life before replacement.

An additional benefactor might be industry, which spends a considerable amount on security lighting systems. One estimate gives industry's lighting bill (for outdoor security) at 50% of the municipal bill. This would mean an additional energy savings of $.41 to $.65, or a total of $1.23 to $1.96.

Thus we have two extreme situations. To save the most money, the system must replace all street lighting (including maintenance and capital expenditures) 100% of the time. Yet it would seem difficult if not impossible to ever win voter approval for this.

On the other hand, continuing some sort of night cycle eliminates most of the potential savings since street lighting is needed anyway. A compromise might be effected whereby the night illuminator could be cut back to the intensity of a full moon or so after midnight, thus precluding the need for street lighting in smaller communities for the full night cycle, and cutting back on the need for some urban lighting.

For fee assessment purposes, assume $1.50 per capita per year in the affected regions. Also assume that the first night light comes into existence in 1995 (delays due to voter approval requirements); that first targets are the major urban corridors by population; that a new urban target is added each five years; and that 100% of the people in the area are assessed for the service. The following population figures are relevant with the figures in parenthesis indicating an approximate per capita area of the state assessed.

Population and revenue figures are given in Table 5-37. A summary plot is shown in Figure 5-22.

5.4.3 Energy Monitor

An energy monitor satellite system would measure energy flow at a very large number of points along the distribution network. This would allow improved power programming and fine tuning through increased knowledge of the energy status on the network. The technique would be to have small L-Band transmitters send instantaneous current, voltage, or power readings at each given point on the net, when queried sequentially by a multi-channel/processing communications repeater in geo-stationary orbit.

But according to spokesmen at the Electric Power Research Institute, the need for an energy monitor by satellite appears now to be quite limited. Energy transmission is presently monitored constantly at the terminal, and it is from the terminal that the power is supplied and tuned.

However, as with other techniques, the method of monitoring energy flow might well change, given the advent of satellite technologies. In this case, as the national energy grid becomes more and more complex in interconnection, and as peak demand situations leave little excess capacity in the system, it becomes necessary to quickly react to rapidly changing supply or demand situations. For instance, as with the New York blackout several years ago, unexpected dropping of a generator from the net might have adverse implications for a wide area affecting millions of people.

So consider a monitor either at crucial junctions or at regularly placed intervals along the net. For calculation purposes, assume a measuring coil at the equivalent of every 10 miles on overhead transmission lines. A discrete monitoring system (such as once per hour) would probably be of little use in sudden change situations, so assume the system can be interrogated virtually continually. The information transmitted is relatively

TABLE 5-37.

		1990	2000	2010
Boswash I	Virginia (30%)	5.8M	6.4M	7.0M
	Washington DC (100%)	.7M	.7M	.7M
	Maryland (90%)	5.6M	6.4M	7.2M
	Delaware (100%)	.7M	.8M	.9M
	Pennsylvania (60%)	12.5M	12.8M	13.1M
	New Jersey (100%)	9.5M	10.7M	11.9M
	New York (70%)	21.5M	23.2M	24.9M
Chicago	Illinois (75%)	13.5M	14.8M	16.1M
	Wisconsin (30%)	5.5M	6.1M	6.7M
	Michigan (10%)	11.2M	12.4M	13.6M
	Indiana (50%)	6.4M	7.0M	7.6M
Los Angeles	California (50%)	28.5M	32.8M	37.1M
Boswash II	Massachusetts (90%)	6.9M	7.5M	8.1M
	Connecticut (100%)	4.1M	4.7M	5.3M
	Rhode Island (100%)	1.1M	1.2M	1.3M
	New York (10%)	21.5M	23.2M	24.9M

REVENUE FROM NIGHT ILLUMINATOR

	Area served	Population	Total populations	Fee	Revenue
1995	Boswash I	41.9M	41.9M	$1.50	$62.8M
2000	Chicago	17.6M	61.4M		92.1M
2005	Los Angeles	17.4M	81.2M		121.8M
2010	Boswash II	16.4M	101.6M		152.4M

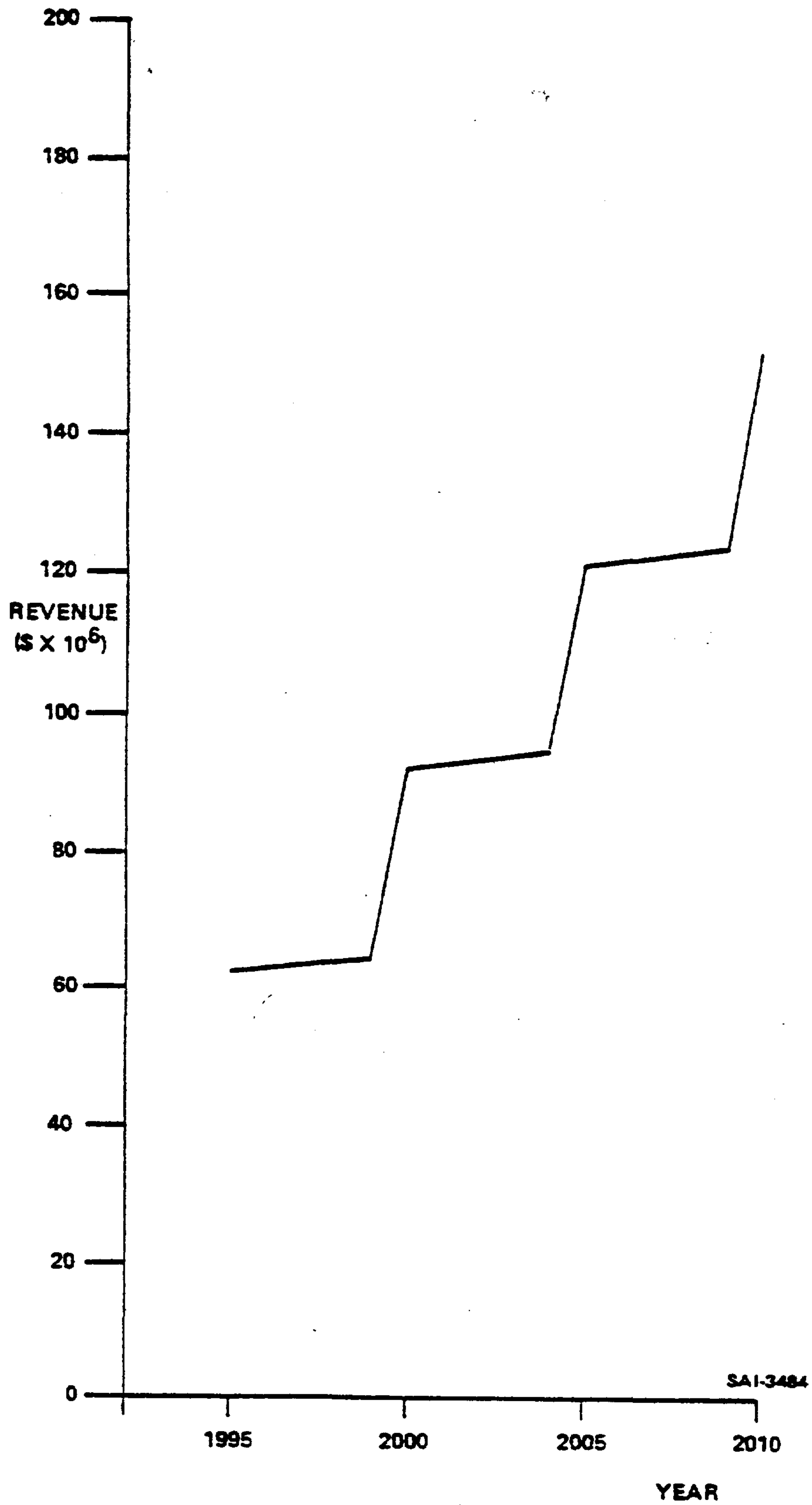


Figure 5-22. Revenue From Night Illuminator

simple, so it could use a very narrow band, implying low cost: say $1 per coil per day fee. Now the system might be needed for large metropolitan regions only, or it might be useless unless it were integrated into the entire US net. This implies a use by roughly 50% to 100 % of the transmission net, with a total in-service operational time requirement of perhaps 5 years. Finally, assuming linear continuation of past trends, 10,000 circuit miles will be added each year. This is indicated in the Fifth Biennial Survey of Power Equipment Requirements. The service is technologically available in 1990.

Market revenue projections are given for best and worst cases in Table 5-38. A summary plot is shown in Figure 5-23.

5.5 RESULTS OF MARKET/REVENUE ANALYSES FOR SELECTED PRODUCTS IN UNITED STATES ONLY

As discussed earlier, market analyses for product initiatives were substantially different in that more generalized assumptions were necessary due to the scope of the unknowns. As shown in the following sections, projected sales in generic markets were assessed for penetration by an improved product from space using least case/best case assumptions. It is important to realize that these analyses were made in order to get some data on what the future potential might be. As this implies, the expected answer was anticipated to be nothing more than a "ballpark" number. Thus no claims are made relative to the viability of any specific product called out here. For purposes of program analyses (as discussed later) it is felt that the results of this market survey work is at least indicative of scale. The literature survey conducted during the compilation of candidates (discussed in Section 3) reflects a strong theoretical basis for improvements in all products specifically addressed here. With a sufficient reduction in launch costs to Low Earth Orbit (LEO), say $5 to $50 per pound, it is quite probable that these market projections will (in the aggregate) prove much too conservative.

5.5.1 Drugs and Pharmaceuticals

The following data was used to extrapolate the total drug market and sale of new drugs in the 2000 to 2010 time period.

TABLE 5-38.

REVENUE FROM ENERGY MONITOR

	Circuit miles	Saturation	User coils	Fee	Least Case Revenue	Best Case Revenue
1990	400K	20%(50%) (.1)	4K	$365	$1.5M	$2.9M
1991	410K	40%	8.2K		3.0M	6.0M
1992	420K	60%	12.6K		4.6M	9.2M
1993	430K	80%	17.2K		6.3M	12.6M
1994	440K	100%	22K		8.0M	16.0M
1995	450K		22.5K		8.2M	16.4M
1996	460K		23K		8.4M	16.8M
1997	470K		23.5K		8.6M	17.2M
1998	480K		24K		8.8M	17.6M
1999	490K		24.5K		8.9M	17.8M
2000	500K		25K		9.1M	18.2M
2001	510K		25.5K		9.3M	18.6M
2002	520K		26K		9.5M	19.0M
2003	530K		26.5K		9.7M	19.4M
2004	540K		27K		9.8M	19.6M
2005	550K		27.5K		10.0M	20.0M
2006	560K		28K		10.2M	20.4M
2007	570K		28.5K		10.4M	20.8M
2008	580K		29K		10.6M	21.2M
2009	590K		29.5K		10.8M	21.6M
2010	600K		30K		10.9M	21.8M

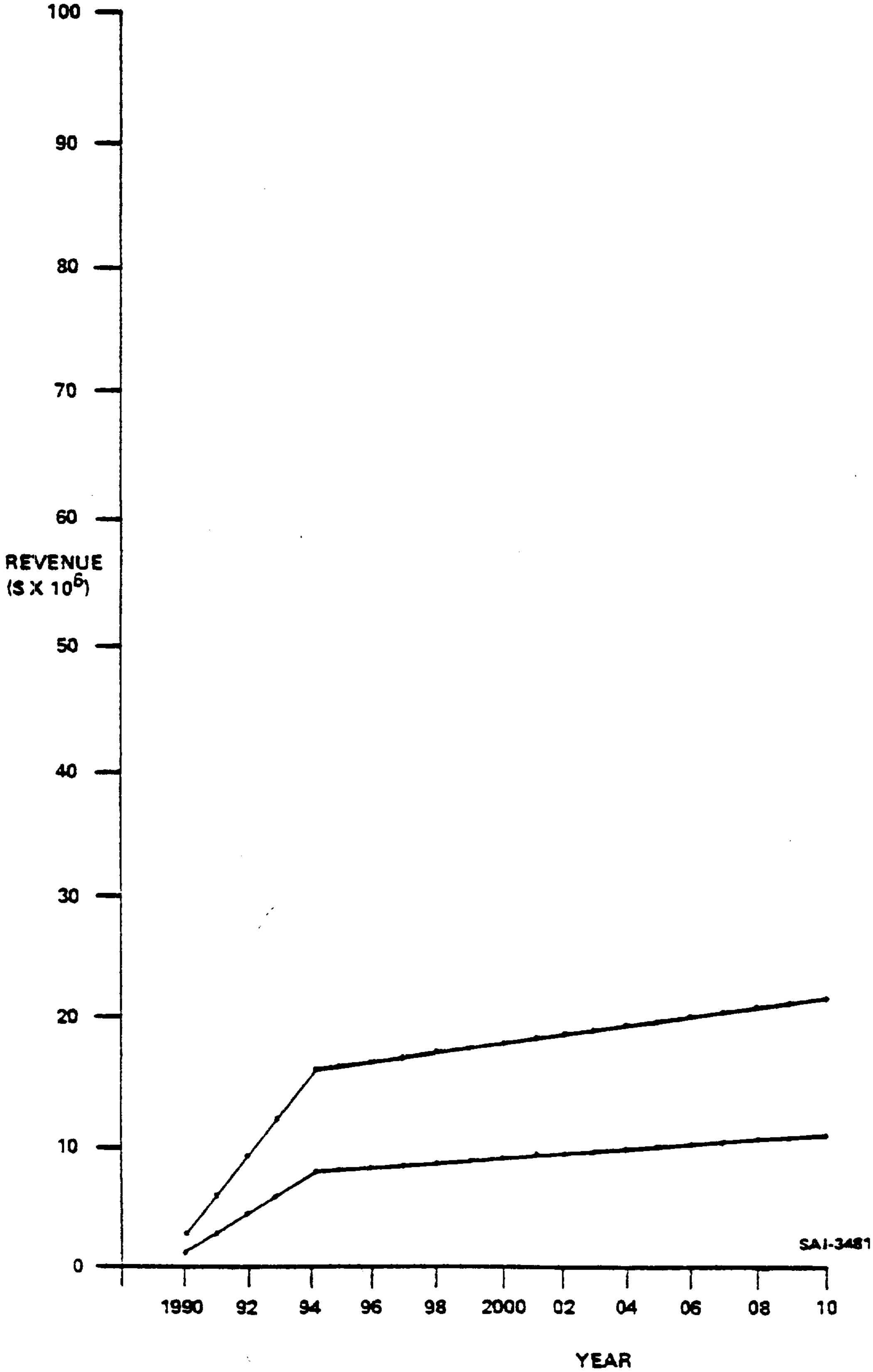


Figure 5-23. Revenue From Energy Monitor. (User Fee Only)

Sales of New Drugs			Drug Industry Shipments	
1975	1980		1975	1985
\$335(10^6)	\$1700(10^6)		\$10.4B	\$23B

\$1.7B is approximately 10% of drug industry for 1980. 10% using 1990 forecast is \$2.3B. Assume total market only doubles by 2000 to \$46B then new drugs would be about \$4.6B that year. 1% would thus be \$46,000,000/year sales or about twice Grumman urokinase projection for 1990. This estimate is probably much too conservative considering the reduced transportation and operating costs resulting from activities within those programs where these products occur. Isoenzyme kit sales from BUS (GE) predict about \$55M in sales for year 2000. Although it is purely arbitrary, it appears reasonable (given the data) to assume that a minimum a \$50M (1976 \$) per year market will exist for D&P in 2000 A.D. unless no process proves viable. The market for the various programs may then be assumed as multiples of 1% of the new D&P market. In the most aggressive future scenarios/programs it seems reasonable to assume that 25% of the new D&P market is captured by space processing in the 2000 to 2010 time period. That market projection amounts to about \$1,150M.

5.5.2 Semiconductor Electronic Materials

Skylab experiments in crystal growing in zero-gravity have proved that it is possible to grow large crystals with a minimum number of imperfections. This crystal-growing capability of the zero-gravity environment, plus the ability to fabricate very large thin films and produce high-purity materials can be added to the space capability of producing potential new semiconductors.

Linear extrapolation of the current semiconductor market growth rate projects a \$12,700,000,000 market in 2000. Because of the very low density of such semiconductor materials as silicon and gallium, semiconductor materials have a very high cost per pound ranging from \$250 to \$500 per pound. The Year 2000 market equates to 250,000 to 500,000 pounds of silicon per year at that date.

It appears quite likely that on-line semiconductor materials processing in orbit could begin as early as 1985 if early experiments prove out and improved products result as anticipated. An overly conservative estimate would target space semiconductor material as capturing at least 1% of the market which would grow from about $500,000 in 1985 to $1,270,000,000 by the year 2000. Early 1985 - 1990 applications will be for high value electronics systems that will justify the high cost of early space-made semiconductor materials.

5.5.3 High Strength Magnets

The capability to manufacture directionally-solidified materials in orbital weightlessness holds promise of permitting the space manufacture of cobalt/rare-earth (CORE) magnets. Such super magnets would possess very cohesive magnetic fields and would allow the construction of electrical equipment of reduced size and weight.

The market for magnets indicates an acceptable price of $500 per pound for high-quality magnetic materials. Even at a price of $750 per pound in the late 1980 time period, the market for space-produced CORE magnets is estimated at $13,700,000 per year with an 18-month penetration to 1% of the market by about 1988. By the year 2000, the total market has grown to $20,000,000 on the low side and $100,000,000 on the high side.

Hard data on CORE magnetic material produced in orbit may indicate improved performance capabilities that might tend to increase their market share.

5.5.4 Superconducting Materials

A fine-particle superconductor material with transition temperature greater than the hydrogen liquefaction temperature could have substantial impact in electrical generation and transmission technology and economics. No estimate of the line losses which might be recouped by the use of superconducting cables has ever been made . . . and perhaps cannot be made until more hard data is available.

An identified use for liquid hydrogen superconductors of some interest has been located in direct current power generation and transmission. Such superconductors, if orbital experimentation in the early 1980's proves out, could possibly eliminate a substantial number of the power transformers projected for use in the year 2000. The total annual market for power and distribution transformers is projected at:

1976: $1,200,000,000
1985: $2,376,000,000
2000: $4,140,000,000

The maximum revenue could be expected where superconductor costs approximately equalled replaced transformer costs and where gained efficiencies were the primary motivator. Maximum revenue also assumes that all added capacity in 2000 made use of liquid hydrogen superconductors. If only 115 Kv and 161 Kv systems were replaced, then about 62.2% or $2,592,000,000 would be maximum revenue.

There is only promising theoretical data that would tend to support the possibility of manufacturing a liquid hydrogen temperature superconductor in orbital facilities. Hard data must come from experiments in the 1980's. However, even if highly speculative, the potential for this product suggests that efforts be made to obtain the hard data. The market for electrical equipment such as this is certainly bound to continue its growth pattern through the early years of the following century.

5.5.5 Fiber Optics

A strong possibility exists for fabricating very high quality optical glasses in weightlessness. There is even Skylab and Apollo-Soyuz data that would indicate the probability of new and better types of optical materials formed in orbital facilities. If so, their use in fiber optical systems could greatly improve the characteristics of these systems.

Phenomenal annual growth rates in excess of 50% per year have been forecast for fiber optics systems. The fiber optics cable market alone is forecast as:

1975: less than $1,000,000
1980: $35,000,000
1990: $358,000,000
2000: $2,100,000,000 (assuming slower growth rate in the 1990-2000 decade.)

If improved fiber optical materials can be fabricated in orbit, a mere 1% penetration of the 1990 market would be $3,580,000 growing to $21,000,000 in 2000. A 10% penetration ($210,000,000) by the year 2000 was assumed in most scenarios.

5.5.6 Metallics

Research experiments already conducted in the Apollo flights, Skylab, and the Apollo-Soyuz mission indicate that the weightless or zero-gravity conditions of earth orbital space may permit the fabrication of totally new types of alloys that cannot be made in the one-gravity environment of the earth's surface. The data is encouraging. Experimentation continues utilizing the several minutes of zero-g available during special vertical rocket flights. Shuttle-SpaceLab flights starting in 1981 will permit researchers to accompany their experiments into space. Most of the alloys under consideration are in the family of immiscible materials, high-purity materials, and directionally-solidified materials. Materials that will not mix under one-gravity conditions because of density differences can be made to mix, it is believed, in weightlessness. The zero-gravity conditions of orbital flight will also permit the fabrication of high-purity materials made without coming into contact with any container. Directionally-solidified.

Three products in this area were examined as representative potentials: perishable cutting tools, bearing materials, and jewelry.

5.5.7 Perishable Cutting Tools

Good perishable cutting tools (PCT's) exhibit the sort of cost characteristics amenable to consideration for space processing -- $200 to $500 per pound. Generally, the harder the PCT material, the higher the cost. A tool made of a harder alloy manufactured in orbit and having longer life and/or a faster cutting speed would have a market at a competitive price. When down-time and lost production costs are also considered, especially in plants using an increasing amount of numerically-controlled machines, costs appear to be even more competitive for space-made cutting tool alloys.

The market for space-produced PCT's is strongly sensitive to transportation costs and to the degree of improvement of physical properties attainable through orbital manufacturing.

Hard physical data on such PCT alloys is not yet available. But the potential market indicates that this product area is one that should be subjected to further R&D to obtain such data.

The existing and projected PCT market is:

1976: $1,040,000,000
1985: $2,600,000,000
2000: $5,600,000,000

Carbide tools represent about 50% of this market.

A small improvement in PCT hardness, lifetime, or cutting speed would certainly be expected to capture at least 5% of this total market within twenty years. PCT's with the highest performance now hold 5% of the total market. With the anticipated reduction in transportation costs possible after 1990, the maximum market penetration by the year 2000 could possibly attain 50% of the total market. A reasonable worst case and best case figure for the market for space-produced PCT's in 2000 would be $280,000,000 to $2,800,000,000.

Although hard data is not yet in hand, this product area appears even more attractive because of the possibility that minimal, unmanned, automated orbital production facilities could be built, requiring only occasional visits to remove the completed product, make adjustments and repairs, and re-stock the raw material supplies.

5.5.8 New Bearing Materials

Wear is perhaps the greatest bearing problem. Balls, rollers, races, and inserts are the items subjected to wear. Additional desired bearing material characteristics are corrosion resistance, very low creep, high temperature capability, and lubricity.

Initial experiments in alloying metals in orbit and the potential capability for producing directionally-solidified materials offer promise of new and improved bearings.

It is very early yet to say what the outcome of projected experiments in this area might be.

However, the total market projections for ball and roller bearings are as follows:

1976: $2,375,000,000
1985: $4,620,000,000
2000: $6,900,000,000

If projected experiments yield affirmative data, the best market projections that can be made at this time is an assumption of capturing from 1% to 10% of the market, giving gross revenues of space-manufactured bearing materials in 2000 of $69,000,000 to $690,000,000.

5.5.9 Jewelry

Every trade route in Europe and Asia was established to fulfil a market desire for a luxury -- silk, myhrr, ambergris, amber, to name but a few. Luxury items can command an arbitrarily high value dependent to some extent upon the scarcity of the item.

The glamor and retained assurance of value will continue to make jewelry and precious metals items that are marketable.

There appear to be alloys that can be made in space that cannot be made on Earth because of the space conditions of zero-gravity, high vacuum, and wide temperature ranges. These alloys do not have to possess beauty or utility. Nor do they have to have exceptional physical characteristics. They must be unique, special, readily identified, and scarce.

The projected total market for jewelry is:
1975: $1,540,000,000
1976: $1,720,000,000
1985: $3,470,000,000
2000: $5,220,000,000

The glamour and uniqueness of a piece of jewelry made from a space alloy could capture from 1% to 10% of the 2000 market, giving a market of $52,200,000 to $522,000,000. Such jewelry could be an early space product because of its high value per unit weight and small quantity. 1% of the 1985 market would amount to $34,700,000.

5.5.10 Cumulative Revenue for Products

The cumulative revenues anticipated over the time span of 1990 to 2010 for all products surveyed are given in Table 5-39. Also shown is the estimate of total market cumulative in the same time period and the assumed penetrations as a percent of annual market in 1990 and 2010. The Cumulative Space Segment is then the integral of all captured market inclusive in the time period.

In all cases where non-zero percentages occur in 1990 it was assumed that a shuttle derivative launch vehicle with per pound costs to LEO of $100 to $150 will become available about 1987. All 2010 percentages assume the cost goals mentioned earlier ($5 to $50 per pound to LEO) are achieved in the 1990s.

5.6 RESULTS OF MARKET/REVENUE ANALYSES FOR PEOPLE IN SPACE ACTIVITIES

To the technologist who has suffered the agonies associated with keeping one, two or three people alive and well in space, the prospect of providing life support for hundreds or thousands is sometimes staggering. The results of this study indicate, however, that space industrialization will bring the world to that very situation. Economics will demand both economical access and maximum practical stay times for the work crews. Once low cost access has been achieved, those industries related to recreation and entertainment for people in space will undoubtedly emerge.

The market analyses presented here were conducted to determine the revenue potentials relative to the other three industry categories. The scale of these revenue potentials is a direct function of the cost of transportation and habitation assumed, as reflected in the analyses. Even at very low cost ($25/pound or less to LEO) and high traffic volume it does not appear that these activities will be revenue producers on the scale of the other industry initiatives. The importance of the ultimate impact of People in Space should not be underestimated, however, based on the revenue potential.

TABLE 5-39. CUMULATIVE REVENUES FOR PRODUCTS

PRODUCT	CUMULATIVE TOTAL MARKET (IN 10^9 $)	PENETRATION (1990 – 2010)	CUMULATIVE SPACE SEGMENT (IN 10^9 $)
DRUGS & PHARMACEUTICALS			
New Drugs	$ 92B	1%, 10% 1%, 25%	$ 6.4B 15.4
ELECTRONICS			
Semiconductors	254.5	1/2%, 2% 1/2%, 10%	3.8 17.5
ELECTRICALS			
Magnets (w/Electric Cars)	200	1%, 2% 1%, 10%	3.7 17.3
Magnets (w/o Electric Cars)	20	1% ,2% 1%, 10%	0.3 1.3
Superconductors			
Mkt. for Power Transformers	83		
Power Trans. & LH_2 Super Conductor	47.8	*	16.5
OPTICALS			
Fiber Optics	42	1/2%, 2% 1/2%, 10%	0.8 3.9
STRUCTURAL MATERIALS			
Perishable Cutting Tools	112	0, 5% 0, 50%	3.8 38.0
Bearings	138	0, 2% 0, 10%	1.7 8.4
Jewelry	104.4	1/2%, 2% 1/2%, 10%	1.5 6.6

*No penetration in 1990. In 2010, superconductors are in 115 KV and 161 KV systems, representing 62.2% of total market, at 50% value of replaced transformers.

The possibility of personal involvement in space has intrigued people (the young in particular) for several decades, with periodic heightening evidenced by popular press, movies, etc. This intrigue led to advocacy groups (spurred by individuals) which seized opportunity in the thirties and again in the fifties. Each step brought these advocates closer to their own personal dreams of the first hand experience. The technological and economic indicators examined in this study show that the current generations under age forty will be the first to realize the fulfillment of that dream on a large scale. This is not going to be overlooked, especially with the attention anticipated as a result of space shuttle orbital flight testing.

5.6.1 Space Tourism

As long as launch-to-orbit costs remain on the order of $150 to $300 per pound, there will be few tourists to orbit. For instance, a cost of $150 per pound gives a prohibitive per person cost of $26,250 (assuming 175 pounds per person to orbit). This cost precludes the development of any mass tourist market. When cost of delivery to orbit reaches $25 per pound, that will mark the beginning of volume traffic. For this would place the average ticket price at roughly $4000 - comparable to a present-day world cruise. This could occur between 1990 and 2000.

As costs decline, the market for tourists to space will be roughly as price-sensitive as the tourist market on earth. That is, volume of traffic will increase as price per pound (i.e., total ticket price) declines. This means that relatively large numbers of tourists in space will require a launch vehicle other than the Shuttle . . . a DC-3 of space, for instance, which can carry 20 to 30 people to orbit per flight, or a payload of 5000 to 8000 pounds. For economy and simplicity of operation, the vehicle could be single stage to orbit, vertical takeoff/horizontal landing, with a gross liftoff weight of 400,000 pounds.

A follow-on vehicle could lower cost of transportation to around $5 per pound - giving a ticket price of less than $1000. Such a vehicle would carry 500 passengers per flight, with two flights per week, at an average payload of 87,500 pounds.

A best case situation for space tourism assumes that the market does not grow gradually, but is sufficiently well promoted in advance of the entry date of lower priced transport that all seats are filled on every flight (100% load factor). An example of this situation is given in Table 5-40 (best case), with cost of transport declining from $200 in 1982 to $5 per pound in 2000. Concurrently, annual passenger volume increases from 50 in 1982 to 50,000 in 2000.

A worst case situation, shown in Table 5-41 (Least Case), shows a gradual increase in passenger volume, starting in the year 1990 with costs at $25/lb, and with costs declining to $10/lb in 2000, and to $5/lb in 2010.

A summary plot is shown in Figure 5-24.

5.6.2 Space Hotel

Several studies have shown that a 1500 to 10000 person capacity hotel in LEO can profit at a per person-day charge of $80 to $100. This of course depends on the nature of the hotel and the number of persons traveling to orbit. For without a relatively inexpensive place to stay (say less than $1000 per person-day), there would likely not be a significant number of people traveling to orbit. Yet without a significant number of tourists traveling to orbit, there is no economic justification for a space hotel.

One driver of numbers of people (tourists) to LEO is the cost of transport. As this cost goes down, more and more people would be willing to take an orbital trip, even without an orbital facility to provide long term comforts. As a first step in the tourist to space process, we would likely see provisions for stays in orbit of up to several days in the transport vehicle itself.

In one transport scenario, as cost goes down from $25/lb to $5/lb, number of passengers increases from 5000 per year to 50000 per year. If we assume an average one week per person stay, then this implies a need for a 100 person capacity hotel with 5000 people per year; and a 1000 person capacity hotel with 50000 per year. Any hotel smaller than 100 person capacity would seem to be both too small for extended tourist stays, and uneconomical in terms of the charge per person day.

TABLE 5-40. REVENUE FROM SPACE TOURISM (BEST CASE)

	$/lb	Passengers	Total Weight	Revenue
1980	$400	--- (200 lb)	---	---
1981	400	---	---	---
1982	200	50	10K lbs	$2M
1983	200	50	10K	2M
1984	200	50	10K	2M
1985	100	500	100K	10M
1986	100	500	100K	10M
1987	100	500	100K	10M
1988	100	500	100K	10M
1989	100	500	100K	10M
1990	25	5000	1000K	25M
1991	25	5000	1000K	25M
1992	25	5000	1000K	25M
1993	25	5000	1000K	25M
1994	25	5000	1000K	25M
1995	25	5000	1000K	25M
1996	25	5000	1000K	25M
1997	25	5000	1000K	25M
1998	25	5000	1000K	25M
1999	25	5000	1000K	25M
2000	5	50000	10000K	50M
2001	5	50000	10000K	50M
2002	5	50000	10000K	50M
2003	5	50000	10000K	50M
2004	5	50000	10000K	50M
2005	5	50000	10000K	50M
2006	5	50000	10000K	50M
2007	5	50000	10000K	50M
2008	5	50000	10000K	50M
2009	5	50000	10000K	50M
2010	5	50000	10000K	50M

5-41. REVENUE BY YEAR FROM SPACE TOURISM (LEAST CASE)

	$/lb	Passengers		Total Weight	Revenue
1980	400	---	(200lb)	---	---
1981	400	---		---	---
1982	400	---		---	---
1983	400	---		---	---
1984	400	---		---	---
1985	400	---		---	---
1986	400	---		---	---
1987	400	---		---	---
1988	400	---		---	---
1989	400	---		---	---
1990	25	100		20K	500K
1991	25	250		50K	1M
1992	25	500		100K	2M
1993	25	1000		200K	5M
1994	25	2000		400K	10M
1995	25	3000		600K	15M
1996	25	4000		800K	20M
1997	25	4500		900K	22M
1998	25	5000		1000K	25M
1999	25	5500		1100K	27M
2000	10	6500		1300K	13M
2001	10	7500		1500K	15M
2002	10	9000		1800K	18M
2003	10	11000		2200K	22M
2004	10	13000		2600K	26M
2005	10	15000		3000K	30M
2006	10	17000		3400K	34M
2007	10	19000		3800K	38M
2008	10	21000		4200K	42M
2009	10	22000		4400K	44M
2010	5	23000		4600K	22M
2011	5	25000		5000K	25M
2012	5	27000		5400K	27M
2013	5	30000		6000K	30M
2014	5	33000		6600K	33M

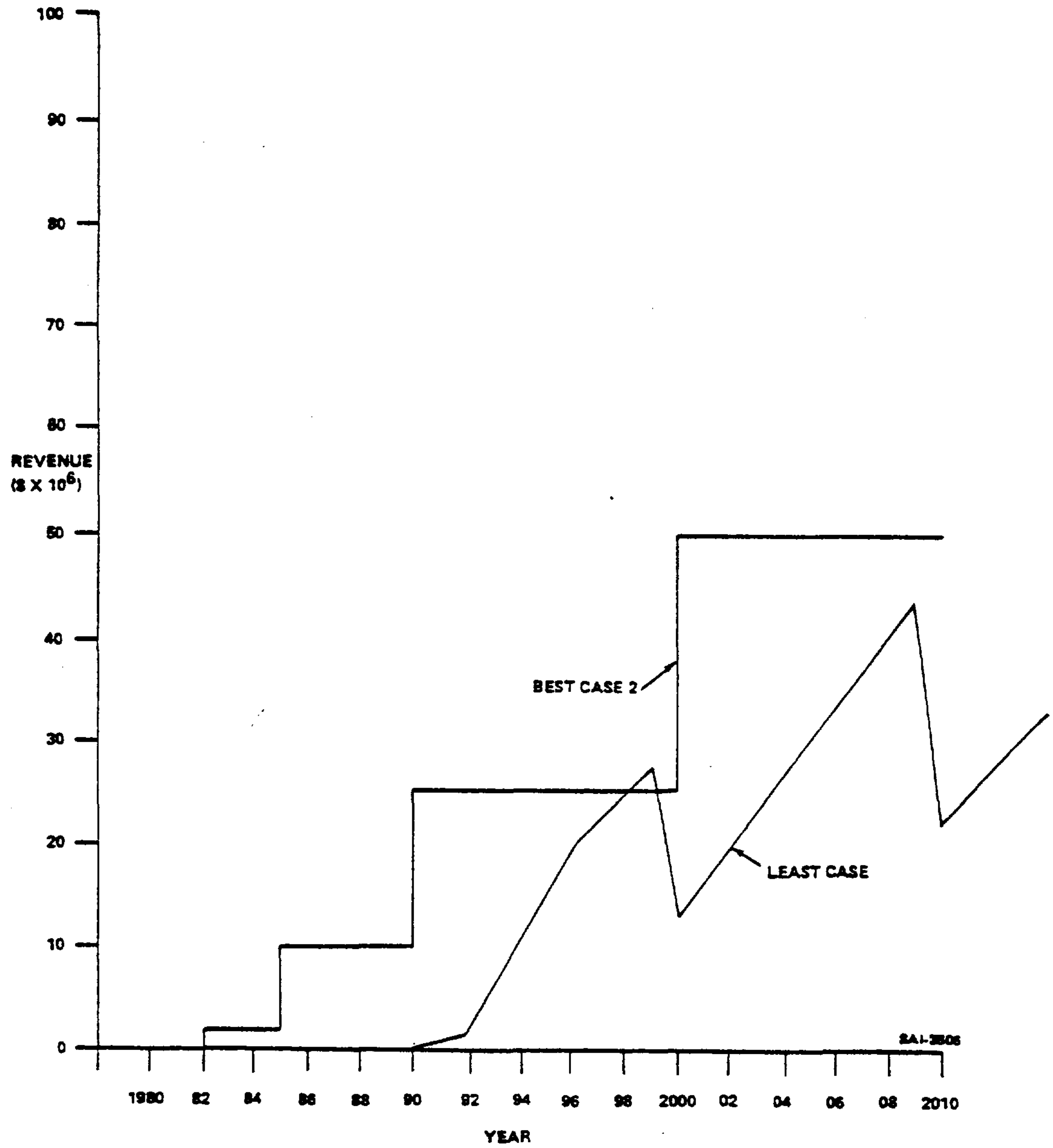


Figure 5-24. Revenue From Space Tourism

As a possible scenario, then, assume the traffic model given in the Least Case and Best Case of Space Tourism (Market Potential). Then assume that 75% of those traveling to LEO will stay in a hotel an average of one week. Cost to the 100 person hotel will be $500 per person day (average 3500 per week, compared to approximately $5000 for the flight at $25 per pound). As occupancy pushes 100%, assume new modules are added on to meet the need. In the Best Case, in which there are quantum jumps of people to orbit, assume a 100 person hotel in 1995, followed discretely by a 1000 person hotel as the capacity is warranted (2000). Cost per day at the 1000 person hotel would be $200 per day - roughly twice the cost of staying at an expensive Hilton on Earth. In the Least Case, assume cost per person day drops $25 each year as increasing volume warrant expansion, and to attract the increased volume.

Market revenue projections for best case and worst case are given in Table 5-42.

5.6.3 Entertainment

Entertainment in orbit will need two elements before it can be economically successful: a place to entertain, and people to entertain. Professional entertainment in orbit must await an in-orbit facility for housing large numbers of people. It is unlikely that professional entertainment could be afforded before a significant number of people were in place to view the entertainment. Before large numbers of people, we could likely assume that the workers in orbit would find ways of entertaining themselves. But this would produce little or no revenue.

Assume therefore a direct tie in of entertainment with emplacement of orbital hotel facilities. Revenue could come from two sources: paying guests and television royalties. There are several policies on paying guests which could be followed: any activities outside the rental of a room could be considered an extra charge - to offset the high cost of transportation. On the other hand, when a guest pays upwards of $500 per day for a hotel room - no matter where it is - he expects something more than just a room. For the purpose of this analysis, then, assume that until the space hotel is large enough to house 1000 people (concomitantly

244

TABLE 5-42. REVENUE FROM SPACE HOTEL

(Least Case)

	Population	Rate of stay	User group	Daily avg	Fee	Revenue
2000	6500	75%	4875	94	$500	$17.1M
2001	7500		5625	108	475	18.7M
2002	9000		6750	130	450	21.3M
2003	11000		8250	159	425	24.7M
2004	13000		9750	187	400	27.4M
2005	15000		11250	216	375	29.6M
2006	17000		12750	245	350	31.3M
2007	19000		14250	274	325	32.5M
2008	21000		15750	303	300	33.2M
2009	22000		16500	317	275	31.8M
2010	23000		17250	332	250	30.3M

(Best Case)

1995	5000	75%	3750	72	$500	$13.2M
1996						
1997						
1998						
1999						
2000	50000		37500	721	$200	$52.6M
2005						
2010						

bringing the cost per day down to $200 or less), that entertainment in orbit will be an added inducement for people to stay at the space hotel. However, we can assume that television royalties could help pay for transportation and other fees for the entertainers.

As one way of viewing the situation then let's assume that in the space hotel (Least Case) the only direct revenue is from TV royalties, and that for the first five years or so, a network pays $1M for the rights to one or two exclusive videotapings per year. Since there will be relatively few people involved in the entertainment (which could consist of dancing, acrobatics, stage shows, magic, etc.), there would not likely be as much on-going interest as in a sports spectacular when many people are involved. After the fifth year, we might assume a live show put on weekly or bi-weekly from orbit. The fee might be reduced on a per week basis to a number such as $100,000 per week for the right to produce, but could result in increased revenue to the space facility.

A similar situation would hold for the space hotel (Best Case), except that in the fifth year we would have a 1000 person capacity hotel. At this point, prices would be sufficiently low ($200 per day) to begin charging admission - or applying a certain portion from over-priced refreshments to revenue for the entertainment. Assume then that $10 per person revenue is derived from each hotel guest (Best Case) for entertainment once the 1000 person facility is in place, in addition to the abovementioned TV royalties.

Market revenue projections for best case and worst case are given in Table 5-43. A summary plot is shown in Figure 5-25.

5.6.4 Movies

Technologically available in 1985, movies produced in space would represent a quality improvement over films of the same genre produced at earth-bound movie sets.

While it would be technologically feasible to produce at least parts of movies in space by 1985, using the Shuttle, economic factors might delay entry until cost of transport were significantly reduced. Typically, a film

TABLE 5-43. REVENUE FROM SPACE ENTERTAINMENT

(Least Case)

	TV Royalties	Frequency of showing	TV Revenue
2000	$1M	1/yr	$1M
2001	1M	1/yr	1M
2002	1M	1/yr	1M
2003	1M	2/yr	2M
2004	1M	2/yr	2M
2005	100K	25/yr	2.5M
2006	100K	25/yr	2.5M
2007	100K	25/yr	2.5M
2008	100K	50/yr	5.0M
2009	100K	50/yr	5.0M
2010	100K	50/yr	5.0M

(Best Case)

	Population	Cover charge	Cover revenue	TV royalties	TV revenue	Total rev.
1995	3750	---	---	$1M	$1M	$1M
1996				1M	1M	1M
1997				1M	1M	1M
1998				1M	2M	2M
1999				1M	2M	2M
2000	37500	$10	$375K	100K	2.5M	2.9M
2001				100K	2.5M	2.9M
2002				100K	2.5M	2.9M
2003				100K	5.0M	5.4M
2004				100K	5.0M	5.4M
2005				100K	5.0M	5.4M
2010				100K	5.0M	5.4M

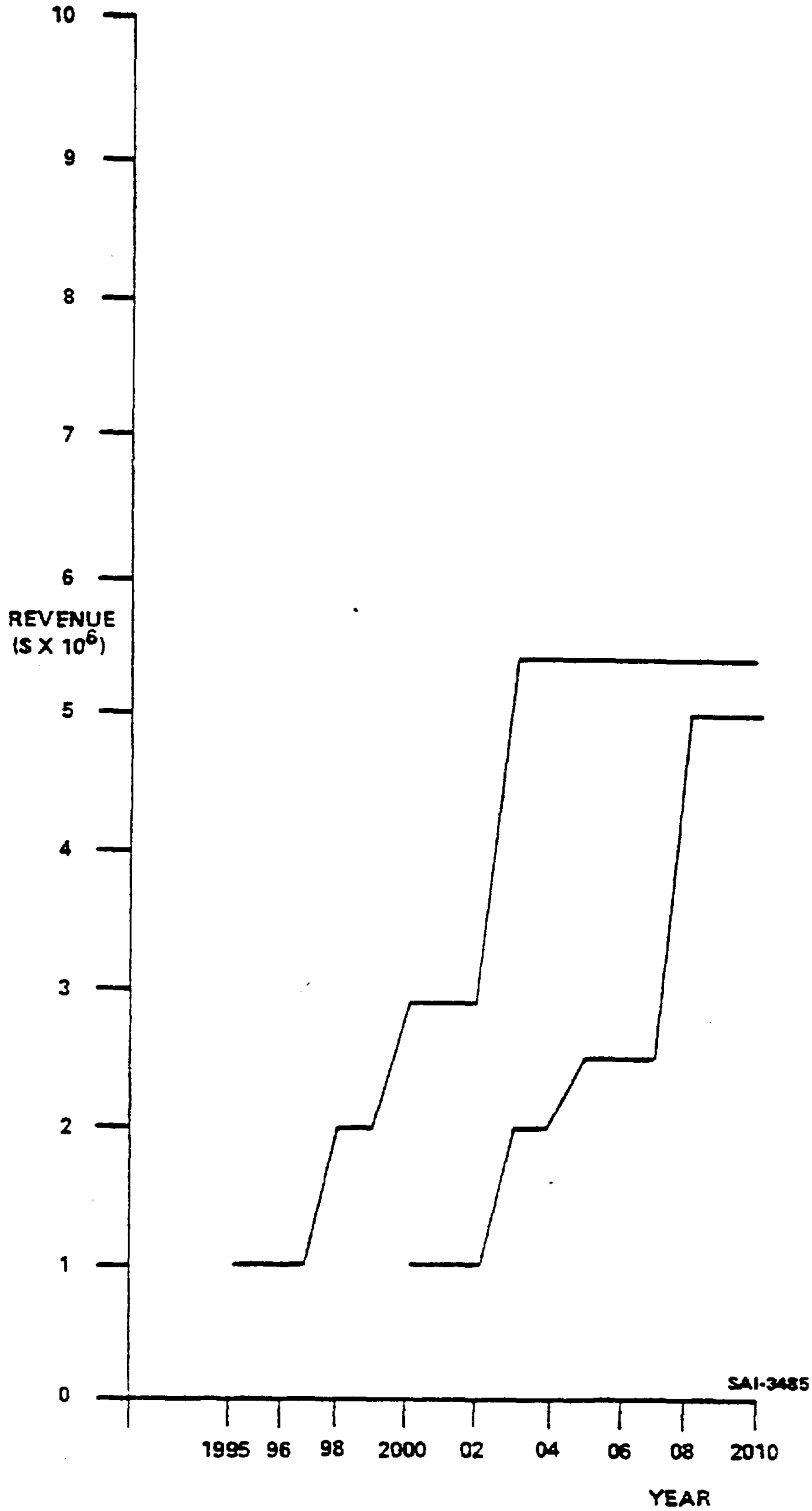


Figure 5-25. Revenue From Space Entertainment

must gross 2 1/2 times its cost of production to break even. With a single Shuttle flight costing roughly $20 million, to say nothing of other costs, the film produced using the Shuttle would have to gross $50 million to break even. Yet only the top few revenue producers in all movie history have ever grossed that amount. Anticipated vehicle developments by 1990 might allow sufficiently reduced cost to motivate the investment. But the chief operative factor here is that unless it is economically advantageous to produce the film in space, producers will use the craftsmanship of earth-based set makers - who produced excellent simulations in the movies 2001 and Star Wars. Aside from minor film clips of earth from space, therefore, assume a high delay barrier entry for major film production in space of 10 years.

End user of this product would be the average movie goer - who spends anywhere from $3 to $5 per ticket. This price may inflate somewhat, but should not contribute significantly to overly large revenues. Primary market would be the United States - an advanced society. The product would satisfy an advanced need - entertainment. This means it is selling into an uncertain market which is dependent on a number of factors over and above anticipated population levels. Final acceptance of each movie is dependent on many factors over and above production in space. Therefore only an average revenue per film can be assumed.

While it does not make sense to speak of a level of saturation, it is useful to assess the likely number of films to be produced over the given period. Currently, 150-200 of all types of films are produced per year. This is down by about 50% from several decades ago. About half of these are produced by major film companies. Of these, very few are of the science fiction or future science genre. Typically, one major science fiction film has been produced every five years, over the last twenty years or so. This includes such films as Destination Moon, 2001, and Star Wars. In the future, as space becomes more a domain of normal workings, there may be more films on the subject. For this analysis, assume 2 minor films per year (as TV - gross $5 million), and one major film every five years (gross $20 million) the first ten years. As cost of transportation decline, the number of films produced will rise. Therefore over the next five years, assume three minor films per year, and two major films.

Market Revenue projections are given in Table 5-44, and a summary plot is shown in Figure 5-26.

5.6.5 Entertainment/Sports

Like standard evening entertainment in orbit, sports entertainment in orbit must await a place in which to entertain, and people to entertain with the sport. Further, because of the uniqueness of the environment, and because sport techniques are shaped very much by the environment, it would take quite a bit of experimenting before a sport was defined which would be sufficiently unique yet suitable to the environment of space that professional teams would participate. That is, while there could be a good deal of sport and play activity in an orbital facility by the guests, some time would elapse after emplacement of the facility before any on-going revenue-producing situation would be defined.

Assume there would be insufficient volume in a 100 person capacity hotel for any revenue producing sport, but that a 1000 person hotel could sustain a sport equivalent to tennis or jai-lai. While the hotel would be considered an environment - just as Aspen or Forest Hills is an environment - still to make best use of the uniqueness of the environment, a number of professionals would have to spend a considerable amount of time practicing in the space hotel facility before there could be any worthwhile matches. Even then, it would seem that, like soccer in this country, spectator enthusiasm might grow slowly at best, particularly considering the spectators' unfamiliarity with the environment. Most sport would likely be classed as entertainment at first, rather than sport per se, and would be viewed with interest on an occasional basis only.

Consider then that sport is practiced only after a 1000 person facility is in place, and that at least five years must elapse before any professionals would attempt the circuit. Then likely revenue sources would be admission, and TV royalties.

Assume two major events per year the first five years of professional sports, with TV royalties of $1M per event, and admission charge of $50 per person.

TABLE 5-44.

ANTICIPATED REVENUE FROM SPACE MOVIES

	Minor films	Major Films	Revenues
1995	2	---	$10M
1996	2	---	$10M
1997	2	---	$10M
1998	2	---	$10M
1999	2	1	$30M
2000	2	---	$10M
2001	2	---	$10M
2002	2	---	$10M
2003	2	---	$10M
2004	2	1	$30M
2005	3	---	$15M
2006	3	---	$15M
2007	3	1	$35M
2008	3	---	$15M
2009	3	---	$15M
2010	3	1	$35M

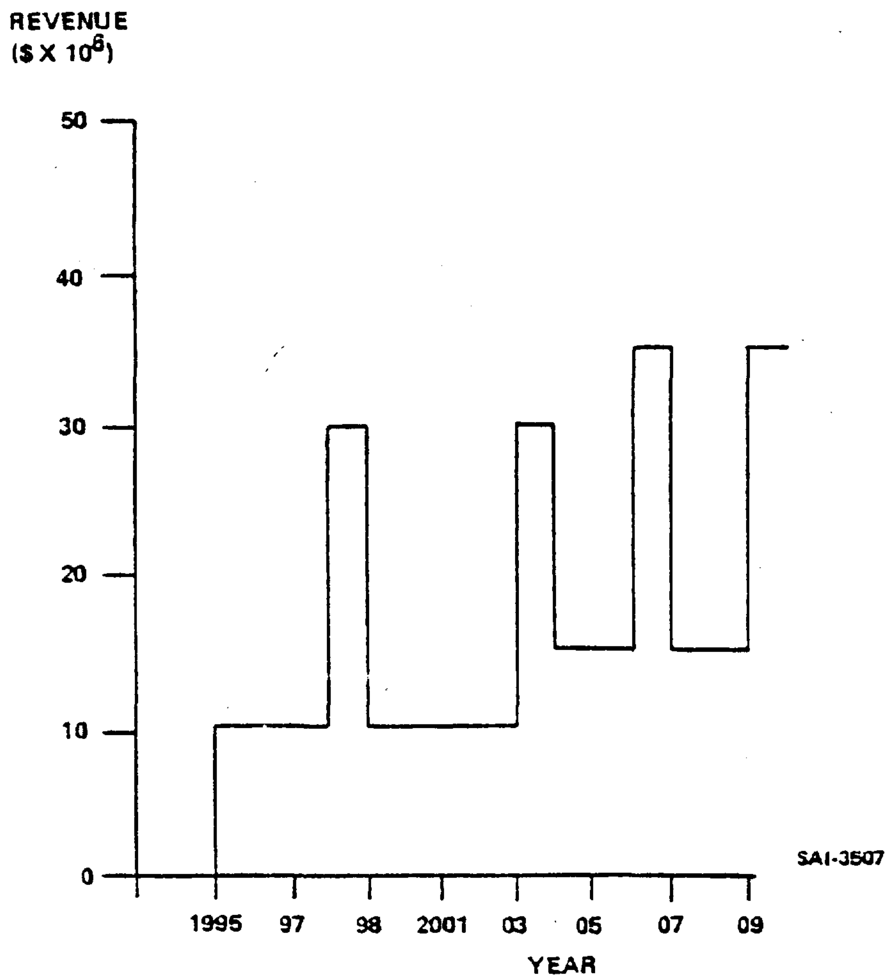


Figure 5-26. Space Movies Revenue by Year

(Least Case)

No revenue before 2010

(Best Case)

	Population/week	Admission fee		Revenue	TV Royalties	Total Revenue
2005	721	$50	(x2)	$72K	$2M	$2.1M
2010						$2.1M

5.7 RESULTS OF CURSORY INTERNATIONAL MARKET/REVENUE ANALYSES

Potential international markets were analyzed and associated revenues estimated for several industry opportunities. Specifically examined were Portable Telephone, Electronic Mail, Ocean Resources and Solar Power. The objective was to obtain some information indicative of these potential markets for comparison to the United States. The lack of both a good numerical data base and personal insight by the investigator makes these examinations more uncertain. The assumptions required by the methodology described earlier depend rather heavily on both sources.

The assumptions made and data used in the market/revenue analysis seemed to yield very reasonable results. Inaccuracies will most probably lean toward the conservative side, underestimating the true market potential. A considerable amount of work remains to be done to get a better estimate of these markets as well as obtain insight into many others.

5.7.1 Portable Telephone (International)

As indicated in the domestic analysis, this communication device would allow citizens to communicate direct person-to-person through a multi-channel switching satellite, and the user can call and be called from any location. Such a system could be available technologically in 1985.

Portable telephones satisfy needs ranging from fundamental to peripheral. The need for on-the-spot communications in business and professional activities is evidenced by the rapid growth (in the US) of pocket pagers. Satisfaction of more peripheral needs is evidenced by the rapid growth (in the US) of CB radios. This implies a widespread use of portable telephones, with a wide spread of needs being met by the device.

To determine how many of these potential users would be actual users, what revenues they would generate through unit sales and call fees, and the time phasing of the revenues, several assumptions have been made. It is assumed that the primary market is Europe - using present day population figures are assumptions concerning the user universe (calculators as an example) and market saturation (using the telephone as an analogy).

At the higher price levels, the universe of users/buyers would likely be limited to professional and businessmen. This is precisely what happened with calculators and pagers: for 2 to 5 years, the marketing approach was toward the professional and businessman. As costs declined and these markets became saturated, the overall market was expanded to the entire population - resulting in the present situation of sophisticated electronic devices being purchased by school children. Thus the potential universe of buyers will be assumed to include the entire population of Europe age 16 and over, over the course of the product's life.

In 1973, there were 88.9 million phones in the major countries of Europe, serving a population of roughly 318.4 million. This implies a 35% saturation of market of communications instruments can be attained. Further, during the period 1970-1973, phones were being added at the approximate rate of 1% per year. This implies a growing market. However, since the competing form of communications is in place; since other forms of communication will be needed to carry transmissions other than voice; and since improved techniques such as optical fibers may vastly improve reception quality of in-place units - which themselves may be made mobile once broad-band transmission is made available - then the ultimate saturation of portable telephones may ideally reach 10% of the potential universe of buyers in the assumed period (1995-2010). A lower band could be 1% overall. Since Europe is made up of numerous political units, some countries may choose not to allow portable telephones - still giving a 10% to 25% market potential in those countries that do, but bringing down the overall potential for all Europe.

Analogous products would be the telephone, hand calculators, digital watches, and CB radio. Calculators, when first introduced, were priced in the neighborhood of $350 (to the end user). Similar functioning calculators can now be purchased for $10 to $30 - although addition of features has kept the price spread between $10 and $300. Average low selling price may be assumed to be around $30. Digital watches originally sold for $100 to $300, but are now selling in the neighborhood of $20 to $100, with higher quality watches remaining the higher price brackets. CB radios are following a similar pricing trend. We may therefore assume an average price spread of $300 down to $30, from first sale to the average price near market saturation.

Political and financial roadblocks may give a delay of up to 10 years before implementation. Not only are there precedent setting delays in the establishment of international communications systems (ref: marine and aeronautical communications), but in Europe, the phone companies are owned and operated by the State. A portable telephone system would bypass the middleman (the State), hence pose difficulties in the transition period. Further, many new frequency bands would have to be allocated, requiring either extensive restructuring of the existing frequency allocation system, or opening new channels.

The product has a comparable to lower price than existing person-to-person communication methods; is much more flexible in use; and requires little change of method by the end user. However, resistance to change by competing products implies some stretchout. It should be noted that the portable telephone will likely be a supplemental device, rather than a replacement device. Assume a Medium stretchout (5 years) before growth phase.

The product appears to be analogous to calculators, digital watches and color television in favorable reception by the end user. While the number of people ultimately desiring the product may be high, the complexity of producing such a large volume and then making such a complex system operational may imply a moderate track (20 years) to ultimate saturation. This is in line with the saturation rate of color televisions.

With ideal saturation coming in 20 years, and a medium stretchout from resistance to change factors, 10% of the saturation level will come in 11 years after entry (30% (20 years) + 5 years). The final 10% will take 6 years.

Population assumptions are derived from the UN Statistics Yearbook (1974), with the proportion of 16 and over (75%) coming from the Series II US projected population (Dept. of Commerce).

Finally, while product lifetime can be high, the product appears to have a high potential for incremental marketing improvements, similar to calculators and CB radios. This implies a high (10%) replacement level.

The following tables are applicable to this analysis:

Table 5-45 shows the number of telephones in each country.

Table 5-46 shows unit sales and cumulative sales as a function of population.

Table 5-47 shows replacement sales and resultant total sales units.

Table 5-48 shows best case and worst case $ sales (revenues).

Table 5-49 shows average monthly bill as a function of calls per person per day.

5.7.2 Electronic Mail (International)

In many European countries, the mail is handled quite efficiently. Though the cost may be somewhat more than in the US, delivery times are typically quite short. One reason for this could be the smaller areas over which the European postal services must deliver. In any case, it does not seem likely that an already efficient system would invest large amounts to provide somewhat better delivery time - as would be the case with electronic mail.

On the other hand, countries of great expanse and less efficient services could profit from an electronic mail service. For the purpose of this analysis, we will take five countries of varying stages of development, assume a constant set of base conditions, and show a potential range of markets in each. The five countries will be:

TABLE 5-45.

Telephones

	#,1973	/100	1973 pop.	change/yr
Austria	1.8M	24.6	7.5M	0.6%
Belgium	2.5	25.7	9.7	0.4
Denmark	2.0	40.0	5.0	0.6
Finland	1.5	32.9	4.6	0.4
France	11.3	21.7	52.1	0.9
Germany	17.8	28.7	62.0	0.7
Italy	12.6	22.9	54.9	0.8
Netherlands	4.3	32.0	13.4	1.0
Norway	1.3	32.9	4.0	0.7
Spain	6.3	18.1	34.8	1.1
Sweden	4.8	59.4	8.1	0.4
Switzerland	3.6	56.0	6.4	1.3
UK	19.1	34.0	55.9	0.3
Japan	38.7	35.7	108.3	1.3

TABLE 5-46.

14.	Population	Level Saturation		Unit sales/Cum sales	
1995	363M	(0.91%)(10%)=.09%		.33M	.33M
1996	365	1.80	.18	.3	.7
1997	367	2.70	.27	.3	1.0
1998	370	3.6	.36	.3	1.3
1999	372	4.5	.45	.4	1.7
2000	374	5.5	.55	.3	2.0
2001	376	6.4	.64	.4	2.4
2002	379	7.3	.73	.4	2.8
2003	381	8.2	.82	.3	3.1
2004	383	9.1	.91	.4	3.5
2005	385	10.0	1.0	.3	3.8
2006	388	20.0	2.0	4.0	7.8
2007	390	30.0	3.0	3.9	11.7
2008	392	40.0	4.0	4.0	15.7
2009	395	50.0	5.0	4.0	19.7
2010	397	60.0	6.0	4.1	23.8

TABLE 5-47.

15.	New purchases	Replacement	Total sales
1995	.3M	---	.3M
1996	.3	---	.3M
1997	.3	---	.3
1998	.3	---	.3
1999	.4	---	.4
2000	.3	---	.3
2001	.4	---	.4
2002	.4	---	.4
2003	.3	---	.3
2004	.4	---	.4
2005	.3	---	.3
2006	4.0	.8	4.8
2007	3.9	1.2	5.1
2008	4.0	1.6	5.6
2009	4.0	2.0	6.0
2010	4.1	2.4	6.5

TABLE 5-48.

(Best Case)

15.	Unit sales	Cost/unit	$ sales	Calls/yr	Cost/call	Call sales
1995	.3M	$300	$90M	29M	$3.00	$87.6M
1996	.3	220	66	109	2.20	240
1997	.3	180	54	182	1.80	328
1998	.3	160	48	292	1.60	467
1999	.4	143	57	438	1.43	626
2000	.3	131	39	584	1.31	765
2001	.4	122	49	803	1.22	980
2002	.4	116	46	1131	1.16	1312
2003	.3	109	33	1350	1.09	1471
2004	.4	103	41	1642	1.03	1691
2005	.3	98	29	1934	.98	1895
2006	4.8	70	336	4270	.70	2989
2007	5.1	56	286	6825	.56	3822
2008	5.6	48	269	9745	.48	4678
2009	6.0	43	258	12957	.43	5571
2010	6.5	39	253	16498	.39	6434

(Least Case)

	Unit $ Sales	Call Sales
1995	$9.0M	$8.8M
1996	6.6	24.0
1997	5.4	32.8
1998	4.8	46.7
1999	5.7	62.6
2000	3.9	76.5
2001	4.9	98.0
2002	4.6	131.2
2003	3.3	147.1
2004	4.1	169.1
2005	2.9	189.5
2006	33.6	298.9
2007	28.6	382.2
2008	26.9	467.8
2009	25.8	557.1
2010	25.3	643.4

TABLE 5-49.

ASSUMED RATE OF CALLS

	Calls/Person/Day	Average Monthly Bill
1995	.25	$22.50
1996	.40	26.40
1997	.5	27.00
1998	.6	28.80
1999	.7	30.03
2000	.8	31.44
2001	.9	32.94
2002	1.1	38.28
2003	1.2	39.24
2004	1.3	40.17
2005	1.4	41.16
2006	1.5	31.50
2007	1.6	26.88
2008	1.7	24.48
2009	1.8	23.22
2010	1.9	22.23

Brazil
Indonesia
India
Canada
Japan

Each has an extensive area to contend with, though mail volumes vary greatly - from 149 million pieces per year in Indonesia to 13 billion pieces per year in Japan. While mail volume in Brazil, Canada and Japan is increasing at 3 to 6% per year, volume in Indonesia and India is steady - perhaps reflecting both an economic malaise and an inefficient system not conducive to letter writing. Though volume may be holding steady now, the assumption will be that if and when a satellite service is initiated in India and Indonesia, the state of the economy and the efficiency of the mail system will have improved to a point where they will have mail volume increases of roughly 3% per year.

The basic 1975 volumes and annual rates of increase are as follows:

Brazil	627M	20M	3%
Indonesia	149M		
India	6700M		
Canada	5000M	300M	6%
Japan	13100M	500M	4%
(US	87700M	2000M	2%)

Each country will be assumed to have a 3% growth rate in mail volume by the time of initiation of satellite mail.

In analyzing this satellite service, we will use the following assumptions.

- As with the US, 60% of all mail volume is first class, hence amenable to transmission via satellite.
- Fifty percent of the mail volume is between major population centers, hence is most likely to be involved in an electronic mail service.
- Transmission charge per sheet will be 10 cents, with an average of 2 sheets per letter.
- 10% of major city mail volume to 50% of all mail volume will use the service (first class).
- Saturation in each country will be reached in 10 years.

- Electronic mail service in the US could be operational by 1990. We can assume service for other nations could start at roughly the same time, and that there's an equal probability of starting before the US as after. Thus we assume all service begin in 1990.

Tables 5-50 through 5-54 indicate the respective potential revenues from such a service in Brazil, India, Indonesia, Canada, and Japan.

5.7.3 Ocean Resources (International)

In the years 1938 to 1968, the World's fish catch increased considerably.

Fish Catch in Top Ten Countries (million metric tons)

	1938	1948	1958	1968
Peru	.02	.08	.6	10.5
Japan	3.7	2.5	5.2	8.7
China	---	---	3.3	5.8
USSR	1.5	1.5	2.6	6.1
Norway	1.1	1.4	1.8	2.8
US	2.3	2.4	2.8	2.4
Canada	.8	1.1	1.0	1.5
India	---	---	1.1	1.5
Spain	.4	.5	.8	1.5
S. Africa	.1	.2	.6	2.2
World Total	21	20	31.7	64.3

Of this, 6/7 is ocean caught, the remainder is fresh water fish.

Much of the increase in the last decade has likely been due to the use of sophisticated electronic gear for detecting schools of fish.

As a rough approximation, assume the average catch is valued at $200 per metric ton, or 10¢ per pound. One measure of propensity to pay for an ocean resources service would be the value of the catch involved.

One way of efficiently mapping this resource is to use a satellite to measure temperature and emissivity differences in surface water, caused by schools of fish, currents, and plankton concentrations. These would be detected by the differences in self-emission in the long-wave infra-red. 100 foot resolution could be attained over all ocean surfaces every 12 hours. Sensitivity of up to 0.002 degrees could be achieved.

TABLE 5-50.
INTERNATIONAL REVENUE FROM ELECTRONIC MAIL

(Brazil)

	Base volume	1st class sheets	Saturation	User mail	Cost	Least case Revenue	Best Case Revenue
1990	977M	1172M	3.3%(10%)	3.9M	10¢	$0.4M	$3.9M
1991	1006M	1207M	6.7%	8.1M		0.8M	8.1M
1992	1036M	1243M	10%	12.4M		1.2M	12.4M
1993	1067M	1280M	30%	38.4M		3.8M	38.4M
1994	1099M	1319M	50%	65.9M		6.6M	65.9M
1995	1132M	1358M	70%	95.1M		9.5M	95.1M
1996	1166M	1399M	90%	125.9M		12.6M	125.9M
1997	1201M	1441M	93.3%	134.4M		13.4M	134.4M
1998	1237M	1484M	96.7%	143.5M		14.3M	143.5M
1999	1274M	1529M	100%	152.9M		15.3M	152.9M
2000	1313M	1576M		157.6M		15.8M	157.6M
2001	1352M	1622M		162.2M		16.2M	162.2M
2002	1393M	1672M		167.2M		16.7M	167.2M
2003	1434M	1721M		172.1M		17.2M	172.1M
2004	1477M	1772M		177.2M		17.7M	177.2M
2005	1522M	1826M		182.6M		18.3M	182.6M
2006	1567M	1880M		188.0M		18.8M	188.0M
2007	1614M	1937M		193.7M		19.4M	193.7M
2008	1663M	1996M		199.6M		20.0M	199.6M
2009	1713M	2056M		205.6M		20.6M	205.6M
2010	1764M	2117M		211.7M		21.2M	211.7M

TABLE 5-51.

(India)

	Base volume	1st class sheets	Saturation	User mail	Cost	Least case revenue	Best case revenue
1990	7000M	8400M	3.3%(10%)	27.7M	10¢	$2.8M	$27.7M
1991	7210M	8652M	6.7%	58.0M		5.8M	58.0M
1992	7426M	8911M	10%	89.1M		8.9M	89.1M
1993	7649M	9179M	30%	275.4M		27.5M	275.4M
1994	7878M	9454M	50%	472.7M		47.3M	472.7M
1995	8115M	9738M	70%	681.7M		68.2M	681.7M
1996	8358M	10030M	90%	902.7M		90.3M	902.7M
1997	8609M	10331M	93.3%	963.9M		96.4M	963.9M
1998	8867M	10640M	96.7%	1028.9M		102.9M	1028.9M
1999	9133M	10960M	100%	1096.0M		109.6M	1096.0M
2000	9407M	11288M		1128.8M		112.9M	1128.8M
2001	9690M	11628M		1162.8M		116.3M	1162.8M
2002	9980M	11976M		1197.6M		119.8M	1197.6M
2003	10280M	12336M		1233.6M		123.4M	1233.6M
2004	10588M	12706M		1270.6M		127.1M	1270.6M
2005	10906M	13087M		1308.7M		130.9M	1308.7M
2006	11233M	13480M		1348.0M		134.8M	1348.0M
2007	11570M	13884M		1388.4M		138.8M	1388.4M
2008	11917M	14300M		1430.0M		143.0M	1430.0M
2009	12274M	14729M		1472.9M		147.3M	1472.9M
2010	12643M	15172M		1517.2M		151.7M	1517.2M

TABLE 5-52

(Indonesia)

1990	200M	240M	3.3%(10%)	0.8M	10¢	$0.1M	$0.8M
1991	206M	247M	6.7%	1.6M		0.2M	1.6M
1992	212M	254M	10%	2.5M		0.2M	2.5M
1993	218M	262M	30%	7.9M		0.8M	7.9M
1994	225M	270M	50%	13.5M		1.3M	13.5M
1995	232M	278M	70%	19.5M		1.9M	19.5M
1996	239M	287M	90%	25.8M		2.6M	25.8M
1997	246M	295M	93.3%	27.5M		2.7M	27.5M
1998	253M	304M	96.7%	29.4M		2.9M	29.4M
1999	261M	313M	100%	31.3M		3.1M	31.3M
2000	269M	323M		32.3M		3.2M	32.3M
2001	277M	332M		33.2M		3.3M	33.2M
2002	285M	342M		34.2M		3.4M	34.2M
2003	294M	353M		35.3M		3.5M	35.3M
2004	302M	362M		36.2M		3.6M	36.2M
2005	311M	373M		37.3M		3.7M	37.3M
2006	321M	385M		38.5M		3.8M	38.5M
2007	330M	396M		39.6M		4.0M	39.6M
2008	340M	408M		40.8M		4.1M	40.8M
2009	351M	421M		42.1M		4.2M	42.1M
2010	361M	433M		43.3M		4.3M	43.3M

TABLE 5-53.

(Canada)

	Base volume	1st class sheets	Saturation	User mail	Cost	Least case revenue	Best case revenue
1990	7790M	9348M	3.3%(10%)	30.8M	10¢	$3.1M	$30.8M
1991	8023M	9628M	6.7%	64.5M		6.4M	64.5M
1992	8264M	9917M	10%	99.2M		9.9M	99.2M
1993	8512M	10214M	30%	306.4M		30.6M	306.4M
1994	8767M	10520M	50%	526.0M		52.6M	526.0M
1995	9030M	10836M	70%	758.5M		75.8M	758.5M
1996	9301M	11161M	90%	1004.5M		100.4M	1004.5M
1997	9580M	11496M	93.3%	1072.6M		107.3M	1072.6M
1998	9868M	11842M	96.7%	1145.2M		114.5M	1145.2M
1999	10164M	12197M	100%	1219.7M		122.0M	1219.7M
2000	10469M	12563M		1256.3M		125.6M	1256.3M
2001	10783M	12940M		1294.0M		129.4M	1294.0M
2002	11106M	13327M		1332.7M		133.3M	1332.7M
2003	11440M	13728M		1372.8M		137.3M	1372,8M
2004	11783M	14140M		1414.0M		141.4M	1414.0M
2005	12136M	14563M		1456.3M		145.6M	1456.3M
2006	12500M	15000M		1500.0M		150.0M	1500.0M
2007	12875M	15450M		1545.0M		154.5M	1545.0M
2008	13262M	15914M		1591.4M		159.1M	1591.4M
2009	13659M	16391M		1639.1M		163.9M	1639.1M
2010	14069M	16883M		1688.3M		168.8M	1688.3M

TABLE 5-54.

(Japan)

1990	20409M	24491M	3.3%(10%)	80.8M 10¢	$8.1M	$80.8M
1991	21022M	25226M	6.7%	169.0M	16.9M	169.0M
1992	21652M	25982M	10%	259.8M	26.0M	259.8M
1993	22302M	26762M	30%	802.9M	80.3M	802.9M
1994	22971M	27565M	50%	1378.3M	137.8M	1378.3M
1995	23660M	28392M	70%	1987.4M	198.7M	1987.4M
1996	24370M	29244M	90%	2632.0M	263.2M	2632.0M
1997	25101M	30121M	93.3%	2810.3M	281.0M	2810.3M
1998	25854M	31025M	96.7%	3000.1M	300.0M	3000.1M
1999	26629M	31955M	100%	3195.5M	319.5M	3195.5M
2000	27428M	32914M		3291.4M	329.1M	3291.4M
2001	28251M	33901M		3390.1M	339.0M	3390.1M
2002	29099M	34919M		3491.9M	349.2M	3491.9M
2003	29972M	35966M		3596.6M	359.7M	3596.6M
2004	30871M	37045M		3704.5M	370.4M	3704.5M
2005	31797M	38156M		3815.6M	381.6M	3815.6M
2006	32751M	39301M		3930.1M	393.0M	3930.1M
2007	33733M	40480M		4048.0M	404.8M	4048.0M
2008	34745M	41694M		4169.4M	416.9M	4169.4M
2009	35788M	42946M		4294.6M	429.5M	4294.6M
2010	36861M	44233M		4423.3M	442.3M	4423.3M

There are several consequences arising from use of a service which pinpoints likely areas where large concentrations of fish may be located. One is the ability of fishing fleets to catch more fish than would otherwise be the case. The other is the ability of fishing fleets to catch their fish more efficiently - gaining a given catch in a shorter period of time with less searching. Thus there can be added income and cost savings resulting from this service.

Likely buyers of a satellite service could include any of the top ten countries listed, though Russia and China could be expected to subscribe to their own service. (US was treated in a separate study.) Within the different countries are different levels of fishing industry: the large-scale highly sophisticated fishing fleets, and the more fragmented individual fishing vessels.

We will assume that while most of the world's fishing vessels are small and individually owned, up to 50% and more of the world's fish catch is made by the large sophisticated fishing fleets. (This is partially indicated by the large increase in catch between 1958 and 1968 - a period when sophisticated fishing trawlers became quite common in several countries.) Nonetheless, even the smaller vessels appear to be taking on electronic gear in some parts of the world, hence an ocean resources service could find users among both the larger and the smaller fishing fleets.

In this analysis, the following assumptions will be made:

- The standard base of unsophisticated (non-electronic) fishing will remain constant at 20 million metric tons per year. This was the approximate yearly catch before electronic techniques entered the scene.

- The world fish catch will increase at 35M metric tons per decade, with 1/7 of this coming from fresh water fish farming.

- Saturation of an ocean resources service would be limited by lack of background data and by the number of analyses . . . each fish species would be identified by a particular "signature" of ocean temperature, color, etc., which would require extensive research before operational readiness of a system. Thus it could take 20 years before final saturation of the industry with the service (assume 5% per year).

- 25% - 75% of the free world/non-US sophisticated ocean fish catch is the ultimate penetration of this service. Some fish will not be prone to analysis from space sensors; some fish companies will see little incremental value to the service.

- Cost of the service as a user's fee would represent an equivalent of 0.5% - 2% of the value of the fish catch of the users. This cost would include receipt of raw data and analysis. While some of the larger ships could have their own analysts on board to speed up the process and thereby cut lead time over other vessels, most subscribers would likely rely on a central source for the processed information.

- US, USSR, China and other communist bloc countries represent 25% of the world's fish catch, and will not be treated as potential market in this analysis.

- Earliest service will be available in the US in 1985, in the rest of the world by 1990.

- While present indications are that the world's fish stock may be depleting through overfishing, ways will be found to prevent this and to actually stimulate the increase in number of fish. At least one of the method of increasing fish stock will use the ocean resources information to identify ideal conditions for various species of fish.

Market revenue projections are given in Tables 5-55 and 5-56.

5.7.4 Solar Power (International)

Most projections show energy demand rising rapidly over the next 30 years, while energy supplies become less and less able to meet the demand. As a result, Solar Power Satellites (representing one possible solution to the energy problem) appear to have an unlimited growth potential.

International demand for energy has been growing as rapidly as US demand over the last 50 years, and both have been increasing at a linearly logarithmic rate, doubling every decade. If there were to be an unlimited supply of Solar Power Satellites with relatively cheap energy, the question is how much of the resultant power would be sold to off-shore countries, and how much kept in the US.

TABLE 5-55. REVENUE FROM INTERNATIONAL OCEAN RESOURCES.

(Least Case)

	Fish catch	Ocean catch	Sophisticated	Free World Universe	Saturation
1990	140M tons	120M tons	106M tons	79M tons	5% (25%)
1995	157M	134M	120M	90M	30%
2000	175M	150M	136M	102M	55%
2005	192M	164M	150M	112M	80%
2010	210M	180M	166M	124M	100%

	User group	Value	User Fee	Revenue
1990	1.0M tons	$197M	0.5%	$1.0M
1995	6.7M	1350M		6.7M
2000	14.0M	2805M		14.0M
2005	22.4M	4480M		22.4M
2010	31.0M	6200M		31.0M

TABLE 5-56.

(Best Case)

	Free World Universe	Saturation	User group	Value	User fee	Revenue
1990	79M tons	5% (75%)	3.0M tons	$592M	2.0%	$11.8M
1995	90M	30%	20.2M	4050M		81.0M
2000	102M	55%	42.1M	8415M		168.3M
2005	112M	80%	67.2M	13440M		268.8M
2010	124M	100%	93.0M	18600M		372.0M

As the accompanying figures indicate, worldwide capacity for energy (outside the US) has generally been 1.5 times that of the US. This trend is expected to continue for the next 30 years.

POWER GENERATION (Kw-Hr x 10^{12})

	US	World	(World - US)
1920	.05	.12	.07
1930	.10	.25	.15
1940	.20	.5	.3
1950	.4	1.0	.6
1960	.8	2.0	1.2
1970	1.6	4.0	2.4
1980	3.2	8.0	4.8
1990	6.4	16.0	9.6
2000	12.8	32.0	19.2
2010	25.6	64.0	38.4

If the international energy capacity listed, roughly 45% belongs to Communist bloc countries (i.e., USSR, China, East Germany, Czechoslovakia, etc.). This means that projecting at the same rate of increase for East and West - the non-communist countries will have projected capacities (as a response to projected demands) at roughly 80% of the US capacity.

When it comes to exporting the power versus keeping the power for domestic use, political considerations would certainly play as important a role as economic considerations. In a severe energy shortage situation, it's unlikely that the US would sell significant amounts of solar power after spending tens of billions on development. On the other hand, in a world desperately willing to pay for energy, this could be a means of satisfying external political demands and at the same time generate income for repayment of the massive debt expected to come from the program. Pricing would then become a major element of consideration - all the more important since energy rates appear to be a good deal higher in countries (especially underdeveloped countries) outside the US. Yet if the US were to sell energy at rates significantly higher than domestic rates, this would result in political repercussions as well, though it's uncertain what if anything could be done about it.

The other major consideration is export of energy to Communist bloc countries. Not only is there a question of whether or not we should, but there's also a question of whether they'd accept the power if offered. All indications are that while the Soviet Union is indeed attempting to broaden its ties with the West, it has a vast resource of potential energy supplies to draw on. The Eastern European block would likely follow the Soviet Union for strategic reasons, with policy being dictated by Moscow. China could be more amenable to heavy input of cheap power, as it continues to strive for industrial equality with the more advanced countries.

For preliminary assessment purposes, then, make the following assumptions:

- The O'Neill and Glaser figures for power plant production in space (given in an earlier analysis: Solar Power) are limiting figures, representing the most that can be done in a given time period with facilities anticipated.
- First five years of solar power will be used solely by the US (1996-2000).
- Communist bloc countries will take a distant fourth in priority of distribution behind developed friendly countries and underdeveloped countries. Distribution to communist bloc countries will come after 2010 (after the relevant time period).
- Beginning in 2001, 1/3 of the power generated by solar power satellites will be distributed to off-shore customers, though only whole systems are considered. There will be no fractional transfer of power from any given satellite system.
- Pricing will be roughly comparable to that projected by O'Neill and Glaser, with a slight markup on each: 13 mills for the O'Neill concept, 33 mills for the Glaser concept. These prices allow more equitable payment for development costs, yet aren't so different from US figures as to provide fuel for political antagonism.
- Power is converted with an 85% conversion at the ground-base rectenna.
- 100% of available solar power is bought.

The following Tables 5-57 and 5-58, indicate potential revenue resulting from off-shore sale of solar power and the effect on revenues from domestic sales.

TABLE 5-57. REVENUE FROM DOMESTIC AND INTERNATIONAL SOLAR POWER.

(Glaser)

	SSPS in use	US use	US cost	US revenue	Off-shore use	Off-shore cost	Off-shore revenue
1996	1 (5GW)	1	27mill	$1005M			
1997	3	3		3016M			
1998	5	5		5026M			
1999	7	7		7036M			
2000	9	9		9047M			
2001	13	9		9047M	4	33mill	$4914M
2002	17	12		12062M	5		6143M
2003	21	14		14073M	7		8600M
2004	25	17		17088M	8		9829M
2005	29	20		20104M	9		11057M
2006	33	22		22115M	11		13514M
2007	37	25		25130M	12		14743M
2008	41	28		28146M	13		15972M
2009	45	30		30156M	15		18429M
2010	49	33		33172M	16		19657M

(O Neill)

1996	1 (10GW)	1	11.5	$856M			
1997	2	2	11.0	1638M			
1998	3	3	10.7	2390M			
1999	4	4	10.5	3127M			
2000	5	5	10.3	3835M			
2001	7	5	9.8	3648M	2	13mill	$1936M
2002	9	6	9.5	4244M	3		2904M
2003	12	8	9.1	5421M	4		3872M
2004	15	10	8.9	6627M	5		4840M
2005	19	13	8.6	8325M	6		5808M
2006	26	18	8.1	10856M	8		7744M
2007	34	23	7.8	13358M	11		10468M
2008	42	28	7.5	15637M	14		13552M
2009	51	34	7.3	18481M	17		16456M
2010	60	40	7.1	21147M	20		19360M

TABLE 5-58.

	Total Glaser	Total O Neill
1996	$1005M	$856M
1997	3016M	1638M
1998	5026M	2390M
1999	7036M	3127M
2000	9047M	3835M
2001	13961M	5584M
2002	18205M	7148M
2003	22673M	9293M
2004	26917M	11467M
2005	31161M	14133M
2006	35269M	18600M
2007	39873M	24006M
2008	44118M	29189M
2009	48585M	34937M
2010	52829M	40507M

5.8 AGGREGATION OF MARKET POTENTIAL

One conclusion quickly drawn from the data presented in previous sections is that very large single opportunity revenues are possible in several areas. It follows that aggregates of these potential (or expanded) industries will represent even greater possibilities.

As indicated in each market analysis the flow of revenues initiates and evolves based on several assumptions including best case/least case for total market potential at saturation. Thus the actual revenues which might be anticipated in the time period of this study will depend substantially on the background scenarios previously presented. For purposes of analyzing far and near term implications of Space Industrialization the time frame of initiation and rate of growth of each industry was adjusted during the analysis. This will be discussed further in the section on program formulation and analysis.

Although the more exact figures will depend on such specifics as future scenarios and programmatics, it is worthwhile to summarize revenue projections. This will allow interpretation by the reader of the possible significance of SI in the 1980 - 2010 time period. Summary data are presented in Tables 5-59 through 5-62 for revenues (best case) using the time scales presented in each analysis. This timing is considered to correspond roughly to the baseline scenario. As noted, all revenues calculated are additive to current SI revenues which total about one billion dollars per year in 1978.

The relative value of each market area (Information Services, Energy, Products and People) as a function of time is presented in Figure 5-27. A more aggressive scenario (implying more aggressive SI programs) basically accelerates the revenue flow and adds more minor initiatives. A scenario without SPS eliminates that portion of the summary and inhibits other activities in the Information Services and Products industries. In the opinion of the SAI study team, given no "surprises", no substantial foreign challenges in space, etc., we can expect Space Industrialization to evolve as depicted in Figure 5-27.

TABLE 5-59. PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED INFORMATION SERVICES INITIATIVES (1977 DOLLARS)

	POTENTIAL REVENUES (in Millions of Dollars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
INFORMATION SERVICES		
Wrist Radio (General Use Initiated 1990)	20,000	100,000
Teleconferencing	9,000	90,000
National Information Services	6,000	40,000
Electronic Mail	9,000	90,000
Disaster Communications Set	30	600
Advanced TV Broadcast	2,000	8,000
Vehicle Inspection	300	4,000
Global Search and Rescue	50	300
Nuclear Fuel Locators	3	40
Ocean Resources	2	50
Transportation Services (Equipment Sales)	70	400
Rail Anti-Collision System	40	600
Personal Navigation Sets (Equipment Sales)	100	400
Vehicle/Package Locator	300	5,000
Voting/Polling Wrist Set	40	200
	~$47B/Year	~$340 BILLION

TABLE 5-60. PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED ENERGY INITIATIVES (1977 DOLLARS)

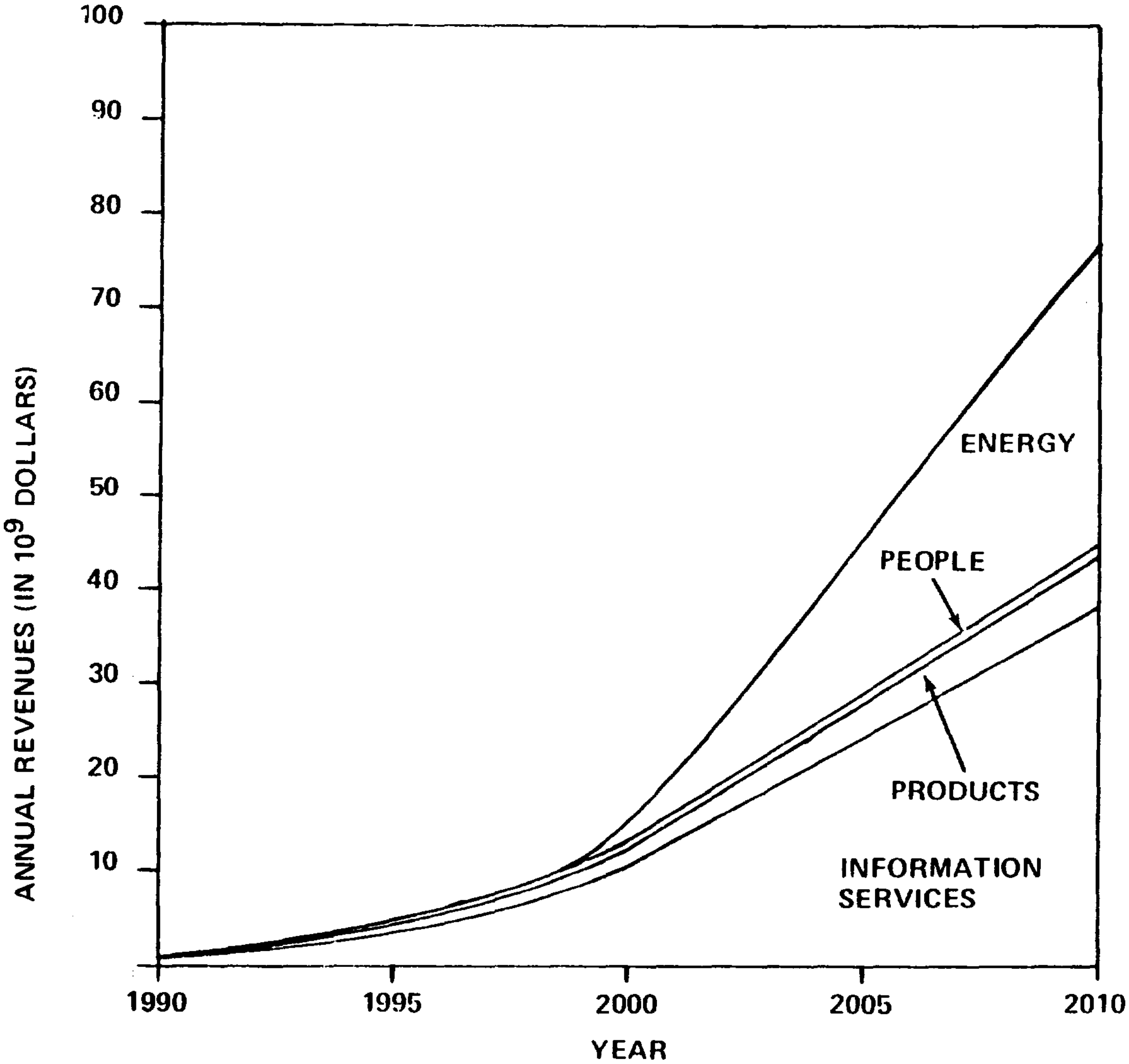
	POTENTIAL REVENUES (in Millions of Dolars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
ENERGY		
Solar Power Satellite (First SAT in 1996)		
49 5GW at 27 MILS/KWH	50,000	300,000
60 10GW at 11.5 MILS/KWH → 7.1 MILS/KWH	30,000	200,000
60 10GW at 27 MILS/KWH	100,000	600,000
Urban Night Illuminator	200	2,000
Nuclear Waste Disposal	1,000	3,000
	~$30 – $100 B	~$200 – $600 B

TABLE 5-61. PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED PRODUCTS (1977 DOLLARS)

PRODUCTS	POTENTIAL REVENUES (in Millions of Dolars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
Drugs and Pharmaceuticals	600	7,000
Electronics		
Semiconductors	2,000	20,000
Electrical		
Magnets	300	4,000
Superconductor (generating only)	2,000	20,000
Optical		
Fiber Optics	80	800
Special Metals		
Perishable Cutting Tools	800	8,000
Bearings and Bushings	200	2,000
Jewelry	100	2,000
	~$6B/YR	~$64 BILLION

TABLE 5-62. PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED PEOPLE INITIATIVES (1977 DOLLARS)

PEOPLE IN SPACE	POTENTIAL REVENUES (in Millions of Dolars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
Space Tourism	50	900
Space Hotel	50	600
	~ $100 M/YR	~ $1.5 BILLION



Note: All values shown are additive to the present (1977) revenues of approximately one billion dollars per year. All figures are in 1977 dollars.

Figure 5-27. Project Revenues for Space Industry Activities Assuming the Baseline Scenario for Terrestrial Background

Inherent to this prediction is a period of capability and technology development in the 1980s leading to expanded exploitation and utilization in the 1990s and intensive growth beyond the year 2000. The resulting interpretation from this is that revenues will approximately double from 1980 to 1990. A very rapid growth in revenue then ensues as technology and hardware development efforts in the eighties come on line in the 1990 to 1995 time period. Although new technologies (particularly in power, structures and transportation) are emerging, the activities settle basically into an implementation and expansion phase with doubling time for revenues becoming approximately five years until the end of the time period of interest.

There appear to be no "natural laws" or technological barriers which would limit revenue growth to the level indicated. Strong response to a foreign challenge or a heavy entrepreneurial initiative in the near future (early eighties) could result in more rapid growth. Potential revenues well over 100 billion (1977) dollars per year appear feasible with technology and development effort acceleration and aggressive marketing.

6. SPACE INDUSTRY PROGRAM DERIVATION AND ANALYSIS

The results of the work described in previous sections (Terrestrial Background, Opportunities and Markets) provided the basic information necessary to map out probable courses of future programs. Space Industrialization by definition consists of a multitude of development or operational programs occurring simultaneously or in series. In the first part (Part 1) of this study, the totality of programs was referred to as a "program" for convenience. That terminology has been maintained in this volume in order to distinguish these "program" analyses from the work in Part 2 of the study. In Part 2, SAI and Rockwell Int. agreed to change the semantics so that the word "Plan" represented the totality of programs.

The flow and interrelationship of various tasks from which programs were derived and analyzed is shown on Figure 6-1 which also summarizes the grouping of eleven scenarios into six programs. The philosophy of this grouping will be discussed in the next section.

6.1 DERIVATION OF SPACE INDUSTRIALIZATION PROGRAMS FROM THE BACKGROUND SCENARIOS (1980 - 2010)

6.1.1 Program Generation Philosophy

Historical analogies which we examined in the course of developing the background scenarios for Space Industrialization strongly suggest that new technological and economic systems are seldom "pushed" by the urgent needs or requirements of society, business, or government, unless those needs are directly related to military necessities. What seems to be the case, instead, is that the social, political, and economic background at any given time create a climate in which new systems can be forecefully and successfully advocated by enthusiasts or special interests. From this perspective, it is easy enough to recognize a variety of *opportunities for the advocacy of specific space programs* at various times in each of the eleven alternative futures we have previously described in the background scenarios. Due allowances, of course, must be made for the levels of technology likely to be available or attainable at any given time in any particular scenario.

CONSOLIDATION 11 SCENARIOS → 6 PROGRAMS	
Foreign Challenge Commitment to Space Longevity Breakthrough	Upside
Cooling of N. Hemisphere	Climatic Crisis
Space Entrepreneurs	Commercial
Baseline Critical Materials Shortage Ecological Catastrophes	Baseline
Energy Breakthrough	No SPS
Disenchantment with Space Collapse of Debt Structure	Downside

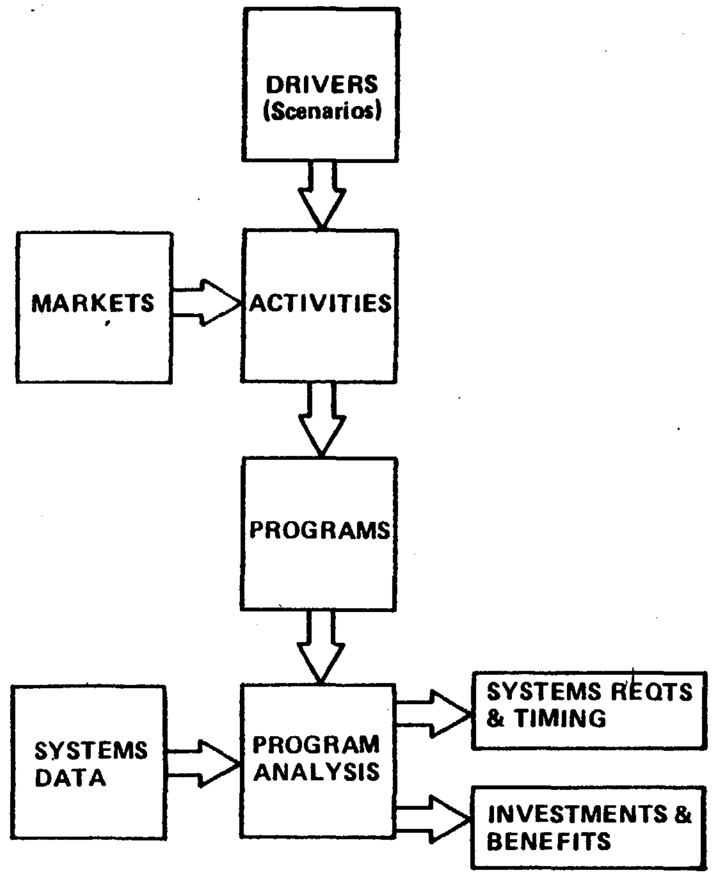


Figure 6-1. Summary of Space Industry Programs Derived and the Steps to Their Derivation and Analysis

In this manner, preliminary programs were sketched out for each of the eleven background scenarios. In several cases, larger elements occurring in one of the eleven preliminary programs also occurred in another program with only small differences in timing or expected scale of activity. This has allowed us to reduce the original eleven programs to just six alternative programs for Space Industrialization over the period 1980 to 2010. The programs and the corresponding scenarios from which they were derived are shown in the following table:

SPACE INDUSTRIALIZATION PROGRAM	BACKGROUND SCENARIOS
Baseline	Baseline Critical Minerals Shortages Ecological Catastrophies
Upside	Commitment to Space Challenge of Foreign Space Advances Longevity Breakthrough
Commercial	Space Entrepreneurs
Climatic Crisis	Cooling of Northern Hemisphere
Cheap Terrestrial Energy	Energy Breakthrough
Downside	Disenchantment with Space Economic Collapse

The hypothetical programs we have developed reflect our considered collective judgment of what kinds of space activities are likely to be economically and politically viable in the assumed contexts of the background scenarios. Like the scenarios themselves, these programs should not be interpreted as attempts to forecast the future but rather as explorations of plausible alternatives which can be used to provide reasonable guidelines for long-range planning. This kind of exploration can serve to identify stepping stones which are common to a multitude of alternative futures and to identify systems which are likely to be much more dependent on external contingencies, requiring more careful attention to the course of events.

6.1.2 Methodology for Generating Programs

For each of the six groups of alternative future scenarios, specific programs for industrializing space were derived using the following procedure. First, individual elements of each scenario, identified as having potentially causal bearing on space industrial activity (called "space drivers"), were extracted and assembled in rough chronological order as shown at the top of Figure 6-2. It is stressed that the exactness in the order shown is not intended to be precise nor to associate each driver with a specific year, but is merely dictated by visual presentation constraints. Obviously there will be overlaps and uncertainties. The drivers shown for Program 1 ("Baseline") are assumed as the starting basis for all other programs, and the drivers shown for those programs are intended as modifiers to the baseline array.

Second, each driver is associated with the Space Industrialization activity for which it is potentially causal. As implied by the arrows from drivers to activities, drivers are assumed to precede chronologically the initiation of activities, which are shown for various locations (i.e. LEO = low Earth orbit; HEO = high Earth orbit; L = Lunar surface; A = asteroid; M = Mars).

Third, the various phases of each activity are associated with the supporting system(s) necessary for their respective implementation. The supporting systems are also represented in terms of their location requirements. Lines connecting certain supporting systems indicate in a general way how one system may establish the technological base for and lead to a subsequent or more advanced system. This procedure thus generates six alternate qualitative and time-phased programs in sufficient detail to be later quantified in accordance with quantitative needs and markets determined elsewhere in the study.

6.1.3 Baseline Program (Figure 6-3)

The Baseline Scenario; the Critical Minerals Shortages Scenario; and the Ecological Catastrophies Scenario all resulted preliminary programs which had more commonality than differences. The

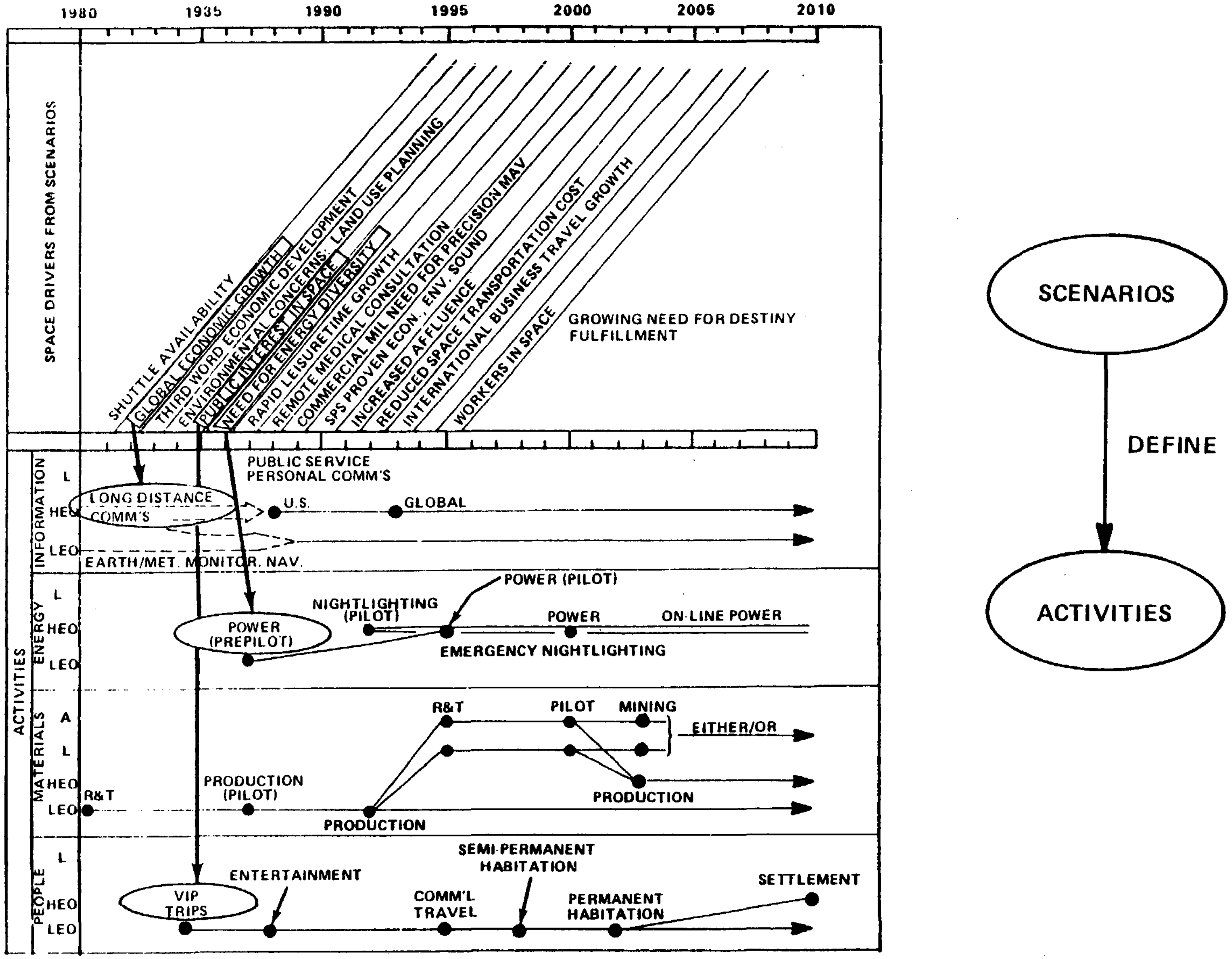


Figure 6-2. Example of the Generation of Activities by Consideration of Causal Drivers From Terrestrial Background Scenarios

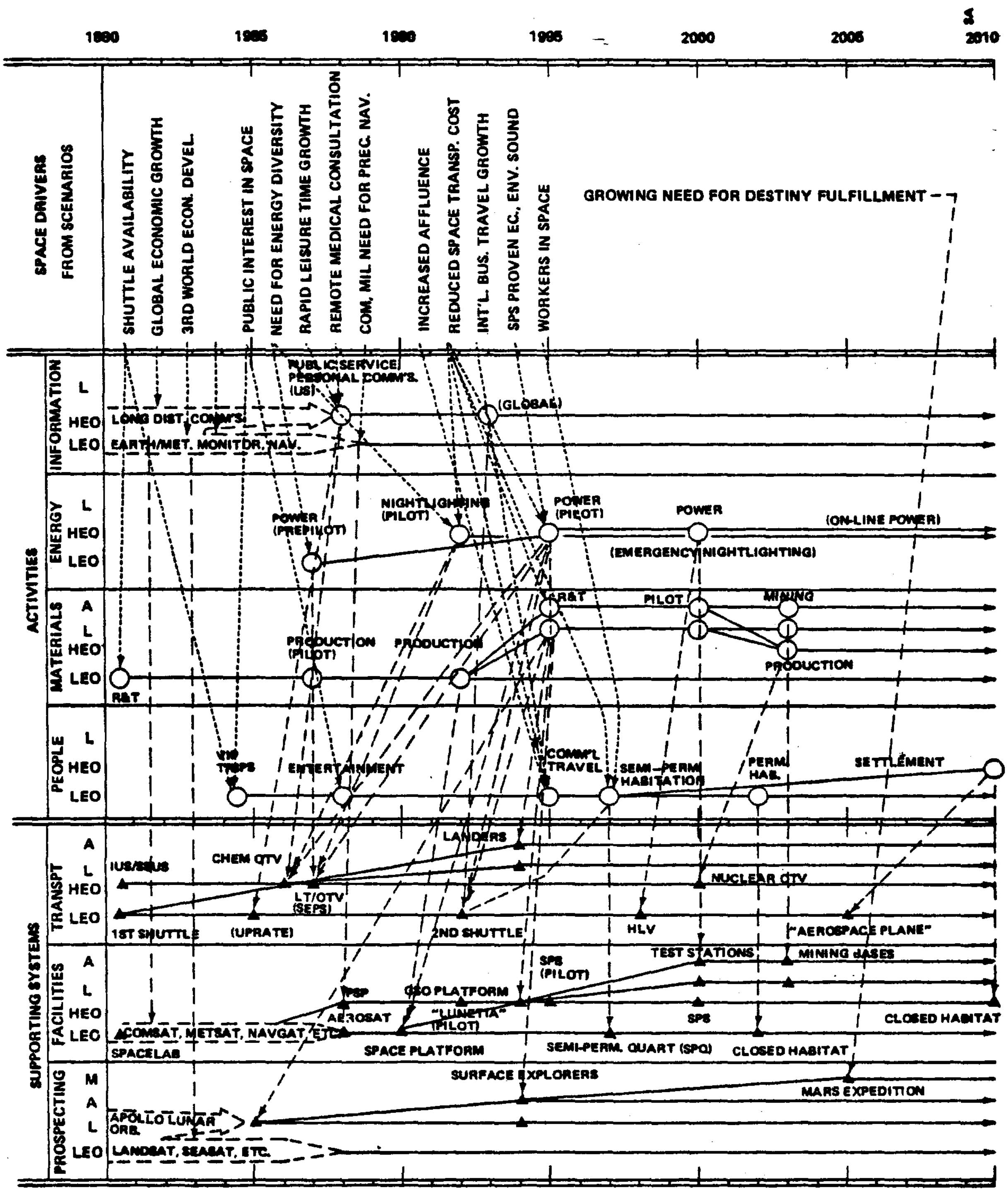


Figure 6-3. Program 1: Baseline

principal differences between the programs for the latter two scenarios and the baseline case were the emphasis on certain types of Earth-monitoring satellites, navigation satellites, and geolocation satellites; and reinforcement of the desire for greater diversification of major energy sources for the industrialized nations, strengthening the case for Solar Power Satellites.

During the 1980's, some reasonable expansion (perhaps 50% growth in constant dollars) could be expected for NASA funding over the decade. Several factors would contribute to the political force needed to increase space appropriations, including the growth of the "Star Trek" and "Star Wars" voting blocs; the visibility of the Shuttle/Spacelab program; continued U.S./Soviet competition, especially in the wake of significant new Soviet space systems yet to come; and the development of new space technology and new space missions by the military. Political opposition to the space program on the other hand, would arise from the continuing rise of Social Security and other welfare costs as National Health Care is implemented and as the elderly fraction of the population increases.

Specific factors which we believe would result in specific activities in space are given below.

6.1.3.1 Information

Earth Monitoring. During the early 1980's, the use of Landsat-type satellites to assess crop inventories for major U. S. export crops would help devise U.S. farm policy and U.S. export policy, with forecasts for the U.S., Canada, the U.S.S.R., Australia, and possibly some Third World countries as well. Pollution monitoring activities would also come into play, especially for the oceans as international shipping regulations are tightened. Landsat use for Third World economic development would be marketed through such international agencies as the World Bank. Satellite photographs would also come into play during the late 1980's for regional land-use planning by governmental agencies at federal, regional, state, and supra-local levels.

Communications Satellites. Continued economic growth around the world will require constantly expanding communications capacity, both in the transoceanic and in the domestic markets. In the United States, relocation of business offices from large cities and suburbs to small towns scattered throughout the country (as a consequence of mounting tax and insurance rates in larger cities and of the rural renaissance movement) will also require rapid expansion of telecommunications circuits and, to some extent, of electronic mail.

Personal Communications. The Bekey concept of a personal "wrist telephone" would be likely to succeed in the late 1980's due to continued economic growth, the desire for increased and diversified leisure-time activities, and the need for remote medical consultation as part of a nationwide system of regional emergency and trauma centers developed under National Health Care, especially in rural areas where ambulance (either conventional or airborne) personnel would require reliable mobile communications with the emergency center.

Global Public Service Platform. Continued economic growth around the world and the information and communication needs of economic development programs in the Third World would provide a ready market for a global system of Public Service Platforms incorporating direct TV broadcast, two-way voice, sensor polling, and (possibly) two-way video capabilities during the 1990's.

Navigation Satellites. During the early 1980's, increased regulation of international shipping, combined with the military need for precision navigation capabilities around the globe, will provide the impetus for deployment of satellite-based navigation systems of increasing precision and coverage. In the late 1980's, the availability of more sophisticated electronic hardware and of the ability to deploy much larger satellites will make possible navigation satellites for aeronautical purposes. Increased air transportation facilities around the world would rapidly take advantage of the improved precision and reliability of such a system.

6.1.3.2 Energy

Pre-Pilot for Solar Electric Propulsion System (SEPS). By the mid-1980's, the need for greater diversification of energy sources for the future needs of the industrialized nations will be clear even at the grass-roots political level. Difficulties with coal (including the scarcity of mine workers and the environmental damages associated with coal mining and burning) are likely to stimulate much more serious interest in "clean" energy systems, including Solar Power Satellites. Budgetary constraints, however, would not be likely to permit commitment on a large scale program in that time frame. In combination with a program to develop Orbital Transfer Vehicles, however, a small-scale (perhaps 25kW) solar-electric based propulsion system would be feasible, testing LEO to GSO transfer as well as microwave transmission from Earth through the atmosphere to space in an "upside down" test.

Pilot Solar Power Satellite; Pilot Night Illumination Satellite. Even if a pilot fusion power plant had been successful, a pilot SPS and a pilot NIS should be politically feasible programs in the 1990's because of the need for energy diversification and because of the likely very high capital costs of fusion powerplants. The Night Illumination Satellite would also be used for emergency lighting needs around the world, providing a boost to U.S. prestige abroad whenever used in disaster relief abroad (e.g., after earthquakes, tropical storms, or floods).

Solar Power Satellite Program. Assuming the SPS pilot program had been successful, a moderate scale program to provide electricity from space for the U.S. would be likely during the first decade of the twenty-first century. Such a system, deployed as an adjunct to fusion, fission, coal, and natural gas, would also be favored by public pressure to shut down "dirty" powerplants, wells, and mines before completion of their full economic lifecycle, especially in veiw of the expectation that the capital costs for SPS based on nonterrestrial mining are likely to be favorable in comparison with fusion powerplants or breeder reactors.

6.1.3.3 Products

Shuttle/Spacelab. Given the assumptions of the Baseline scenario, the Shuttle/Spacelab experiments on zero-gravity materials processing can be expected to proceed as presently planned. In the course of these experiments, one or more specific products are likely to prove economically viable. Industrial research laboratories will then be likely to buy space on Shuttle flights for their own experiments and for pilot production tests.

LEO Platform. Based on the successes of the Spacelab and Long Duration Exposure Facility (LDEF) programs, a modest life-support platform in LEO for use of technicians operating small production plants launched by the Shuttle would be highly likely in the mid-1980's, with gradual growth in total production of zero-gravity processed materials through the late 1980's. The Platform would also gain support as a stepping stone for the Personal Communications system and as a base for development of assembly techniques for large structures.

Extraterrestrial Materials. During the first decade of the twenty-first century, the decision to proceed with a Solar Power Satellite program would provide the green light for mining of extraterrestrial materials. Scientific instrument packages to examine asteroids and comets and to provide detailed lunar mapping would have provided the information needed to proceed with high confidence. After about 2010, importing of some metals (such as nickel) to the Earth may be economically advantageous, particularly if the asteroid mining option were selected.

6.1.3.4 People in Space

VIP Trips. Successful operation of the Shuttle during the early 1980's will almost inevitably result in Shuttle flights by a handful of VIP's (newspaper, radio, and television reporters and commentators; perhaps some diplomats or politicians; perhaps some illustrious artists, writers, poets, or composers) during the mid-1980's. Both the general public interest in the Shuttle and the desire to enhance U.S. prestige abroad would contribute to the decision to proceed with this program, and would provide positive reinforcement for the entire space program, sustaining and perhaps accelerating increases in NASA budgets.

Entertainment. The availability of the Shuttle (especially after its safety and reliability had been demonstrated graphically by a few trips), together with the growing requirement for leisure-time activities, would stimulate use of the Shuttle and of the LEO platform for commercial entertainment in the forms of television and motion picture productions with "on location" filming in space. This, too, would have strong positive reinforcement for the entire space program.

LEO Semi-Permanent Quarters. During the 1990's, facilities for a growing number of workers in LEO who must spend longer and longer periods of time on station will create a need for more satisfactory quarters than have been afforded by systems such as Skylab. Such quarters may not provide full Earth-normal gravity but may provide at least partial gravity simply to make daily activities more convenient than in weightlessness, even if zero-gravity proves to have no severe long-term medical effects.

Commercial Travel and Tourism. Significantly reduced costs of launch to LEO could be expected by the early 1990's following development of a second-generation Shuttle or Single-Stage-to-Orbit vehicle. Besides reducing the cost of transporting workers into space, such vehicles would also open the door for a limited number of fare-paying passengers who wished to go on even a brief excursion into space. Used as a Global Transportation System to reduce travel times far more than even hypersonic transports could be expected to do, such a system would soon develop a sizable market among multinational corporation executives. After Semi-Permanent Quarters were established, expansion of tourism could be expected, and some space workers might pay for their spouses to occasionally accompany them into orbit for a few days. All of these factors would be intensified by continued rise of affluence.

Medical Facilities. As the number of workers in LEO increases enough to justify Semi-Permanent Quarters, some medical facilities or clinics would become necessary for emergency treatment of industrial injuries. The presence of several qualified medical personnel and of medical equipment would justify some studies of possible reduced-gravity therapies. As tourism to LEO increases and as the tolerance of the general public to launch conditions is established, the use of these facilities for treatment of some special conditions after 2000 is very likely.

Recreation. Once the number of workers in LEO is large enough to justify Semi-Permanent Quarters, the workers will very likely develop new recreations and games using existing facilities in space. Tourists will inevitably participate in these activities as well during the 1990's. Once mining and fabrication with extraterrestrial materials are underway after 2000, construction of dedicated recreational facilities will be almost inevitable.

Permanent Settlements. Full-scale permanent settlements with at least some degree of self-sufficiency in food supply would result after about 2000 simply from the increasing labor force in space. The growth of various kinds of plants in reduced gravity would have been tested by hobbyists among the workers in LEO (if not as part of a formal research program) during the previous decade or more, permitting some definition of the problems of space farms.

Mars Expedition. Sustained expansion of human activities in space over two decades after initial Shuttle operation would lead to a widespread public belief in the "manifest destiny" of the human species in space. By the turn of the century, economic growth and public interest would provide sufficient support for a scientific expedition to Mars. Using the permanent settlements as a staging base, such an expedition would be vastly easier than if the entire expedition had to be mounted from the surface of the Earth.

6.1.4 Upside Program (Figure 6-4)

The needs and opportunities of the Commitment to Space scenario; the Challenge of Foreign Space Advances scenario; and the Longevity Breakthrough scenario all tend to drive the space program at a generally accelerated pace in comparison with the scenarios from which the Surprise-Free program was derived. In the three scenarios presently under construction, economic growth continues or is even accelerated. Such economic growth is likely to be a political prerequisite for the types and scales of space endeavors projected below, although the total-space program costs in this optimistic program are not extravagantly greater than the Surprise-Free program.

Since most of the needs and opportunities for advocacy postulated in the Baseline scenario will also be present in the three scenarios

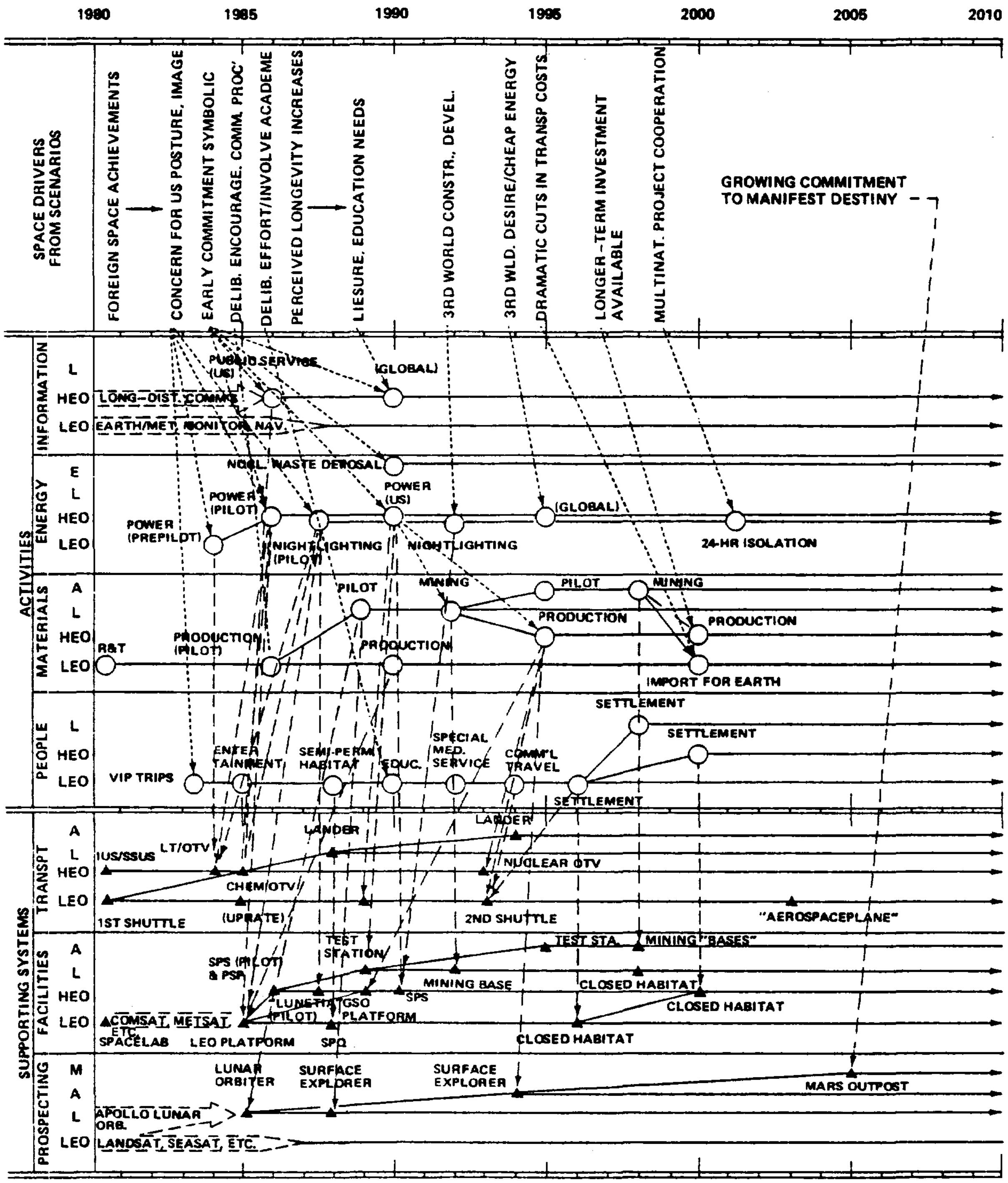


Figure 6-4. Program 2: Upside

considered here, the motivations for programs which were described above in connection with the Surprise-Free program will also apply here. Rather than repeating all of those here, the discussion below will focus on additional opportunities presented by the alternative scenarios. In many cases, technological readiness will be the limiting factor in this accelerated program for Space Industrialization. We have been careful to consider research and development lead times in all six alternative programs, but especially in this fast-paced program.

6.1.4.1 Information

Earth Monitoring. In order to enhance sagging U.S. prestige abroad and to provide an early and visible symbol of U.S. commitment to the use of space technology for the improvement of the human condition throughout the world (rather than for blatantly military purposes), deployment of satellites for the assessment of Earth resources, for pollution monitoring, and for meteorological observation and forecasting would be accelerated in the 1980's, with a great deal more publicity than has characterized such activities in the 1970's.

Communications Satellites. Although the rate of deployment of satellites for use in conjunction with highly visible economic development programs in the Third World would be somewhat accelerated in comparison to the Surprise-Free program, no major differences would be expected between this program and the Surprise-Free program.

Personal Communications. Increased leisure time resulting from a longevity breakthrough and increased awareness of space in any of the scenarios considered here would tend to hasten market penetration by portable telephones, accelerating expansion of the system in comparison to the Surprise-Free program.

Global Public Service Platforms. Availability of the first Public Service Platform would create new opportunities for educational programs on a commercial basis. The desire to enhance U.S. prestige abroad by the development of educational broadcasts geared to rural needs in Third World countries in conjunction with economic development programs would provide a further stimulus to expansion of such satellites into a global network more rapidly than in the case of the Surprise-Free Program.

6.1.4.2 Energy

Pre-Pilot for SEPS. Commitment to a more vigorous space program and to expanded geosynchronous capabilities would require the development of a variety of orbital transfer capabilities, including Solar Electric Propulsion Systems. Thus the early deployment of a SEPS pre-pilot unit to test out self-powered orbital transfer of large satellites and to simultaneously test microwave energy transmission from Earth orbit to the ground would be likely, even before the difficulties of meeting national energy needs by heavy reliance on coal lead to widespread recognition of the need for diversification of our energy sources.

Pilot Solar Power Satellite; Pilot Night Illumination Satellite. The desire to maintain technological leadership in space and to enhance U.S. prestige abroad would provide strong incentives for early pilot programs in both of these areas. Pilot systems for either program could be placed in relatively low orbits to minimize costs while demonstrating feasibility and enhancing our national image.

Solar Power Satellite Program. The success of international participation in communications satellites used to support economic development programs, combined with the availability of larger payload vehicles developed for the deployment of large communications satellites, would provide motivation and financial backing for an SPS program. Accelerated economic growth in the Third World would provide additional wide-based international support for this new energy alternative.

Night Illumination Satellite Program. Success of the pilot NIS would encourage further deployment of these satellites, especially for Third World nations whose economic development has been accelerated by satellite communications. The rapid growth of very large cities at rates so fast as to exceed logistical capabilities to install conventional street lighting systems would provide an international market for night lighting for public safety. In the Commitment to Space scenario, an international NIS program might well become a joint U.S. and U.S.S.R. venture during the mid-1990's.

6.1.4.3 Products

Pilot Materials Processing Plants. -In the event of a serious national commitment to space or in response to major foreign advances in space, deliberate incentives for business and industry to exploit the Shuttle/Spacelab capabilities could be expected. Such incentives would lead to more rapid and widespread participation of the business community in space, particularly in materials processing in zero-gravity.

Materials Production. Success of the pilot processing plants, continued economic growth, and deliberate governmental incentives would result in rapid expansion from pilot plants to full scale production in LEO.

Extraterrestrial Materials. Success of the Solar Power Satellite pilot program would focus serious attention on extraterrestrial materials as a component of a full-scale SPS program. Use of expanded Earth launch system capabilities developed for other purposes would allow deployment of a small scale prospecting and mining operations on the Moon and among the Earth-crossing asteroids during the early 1990's.

Manufacturing for Earth. Expansion of extraterrestrial mining beyond the immediate needs of the SPS program, combined with 15 years of experience in zero-gravity materials processing, would result in some manufacture of goods for use on Earth from extraterrestrial materials after the turn of the century, especially in the light of falling costs for surface-to-LEO transportation.

6.1.4.4 People in Space

VIP Trips. Compared to the Surprise-Free program, VIP trips aboard the Shuttle might be accelerated by two or three years in order to demonstrate U.S. commitment to space and/or U.S. superiority in space technology.

LEO Semi-Permanent Quarters. The acceleration of large-scale activities in space would necessitate larger numbers of workers in space, advancing deployment of Semi-Permanent Quarters by a few years relative to the Surprise-Free program. Although an upgraded Shuttle would reduce transportation costs to LEO significantly, economics would still provide adequate motivation for the establishment of such quarters, perhaps using the Space Shuttle external tanks for pressure hulls.

Commercial Travel and Tourism. Although the Semi-Permanent Quarters in LEO occur much earlier in this program than in the Surprise-Free program, tourism into space on a commercial basis must still await the development of reduced cost human-rated transportation systems. Once a second-generation Shuttle or Single-Stage-to-Orbit vehicle becomes operational, however, it would be exploited for Global Transportation and for space tourism much more rapidly in this program because of the accelerated economic growth expected in the underlying scenarios and because of heightened public interest in space.

Education. In order to deliberately foster academic involvement in a vigorous national space program, grants could be awarded for specialized postdoctoral research in orbit. Significant scientific benefits could be realized at modest incremental cost by using the existing Semi-Permanent Quarters for this purpose.

Mars Outpost. Because of the expanded scale of activities in this program as contrasted with the Surprise-Free program, the initial Mars expedition would be scaled up in size to establish a permanent outpost on Mars, although it would not be occupied full time until sometime after 2010. Growing belief in "manifest destiny" would contribute to the motivations for this undertaking, as would longevity breakthroughs and accelerated economic growth.

6.1.5 Commercial Program (Figure 6-5)

This program corresponds to the Space Entrepreneurs scenario. Continuation of governmental funding for space activities at an approximately constant level would probably preclude large scale space ventures in the public sector, but would allow private entrepreneurs to take advantage of those opportunities for profit which can still be found in space in the Shuttle era. In its earlier stages, this program is somewhat more conservative and less willing to take risks than is the Surprise-Free program.

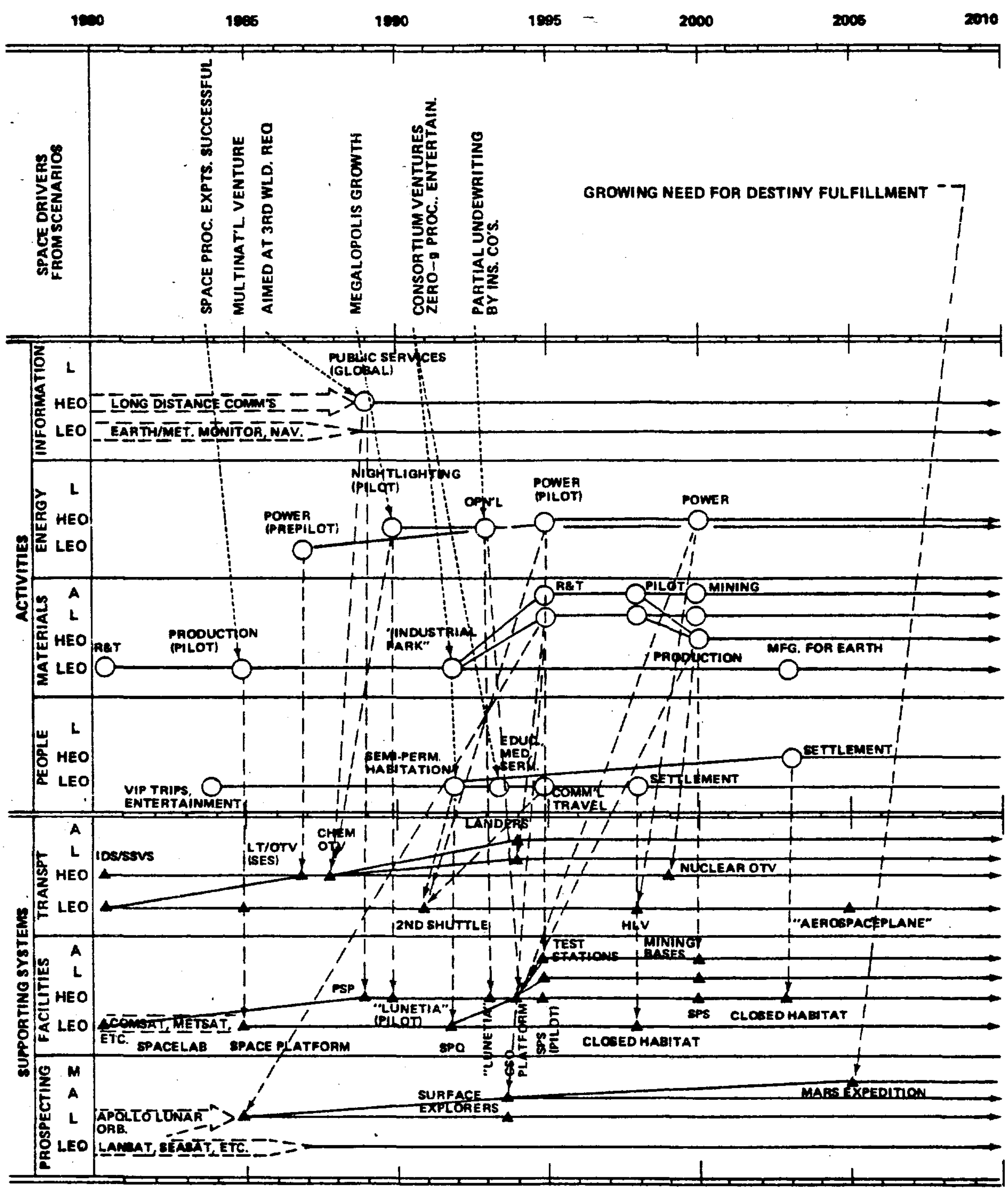


Figure 6-5. Program 3: Commercial

Later, however, as new transportation and supporting systems are developed for specific commercial purposes, they are likely to be exploited for new uses more rapidly than might be the case in a purely governmentally operated program. Thus the later stages of the program expand dramatically, albeit in directions different from the Surprise-Free or the Upside Programs.

6.1.5.1 Information

Communications. Given continued economic growth around the world and continued growth of large multinational corporations, the already lucrative satellite communications industry can be expected to grow still more rapidly during the 1980's. The advent of more flexible, less expensive mini-computer systems will create new opportunities for commercial datalink services via satellites, with extensive utilization by multinational corporations for internal corporate communications between far-flung offices. Extension of these services to electronic fund transfers and to some electronic mail would follow rapidly.

Earth Monitoring. Weather satellites, Earth resources satellites, and pollution monitoring satellites would continue as governmental agency projects. The advent of advanced minicomputer systems, however, may transform the analysis of Landsat-type multispectral images into a rapid and inexpensive means of prospecting for resources, and commercialization of such analysis services appears likely in the mid-to late-1980's.

Personal Communications; Global Public Services Platform. The formation of new companies, including some of multinational character, to exploit the new opportunities for profit in space would provide a mechanism for spreading the development and capital costs for a global PSP system incorporating the personal communications "wrist telephone" system during the late 1980's. International development agencies and multinational corporations would become large customers for such services. Such projects would make rapid and early use of orbital assembly techniques for large space structures developed in the public sector.

6.1.5.2 Energy

Pre-Pilot SEPS. As discussed below, greater private participation in materials processing experiments and pilot production testing would free up some NASA resources for a more thorough pre-pilot SEPS program than in the Surprise-Free Program, in response to growing recognition of the need for diversification of energy sources and of the future needs for interorbital transportation. Because of the long-term, high-risk nature of this project, it is likely to remain in the public sector until the technical risks have been appreciably reduced.

Night Illumination Satellite. The growth of megalopolitan areas around the world provides an opportunity for a commercial enterprise to provide street illumination by contract. Suitable selection of orbits would allow one satellite to be shared by up to about ten megalopolitan areas around the world. A pilot NIS could be deployed from the Shuttle during the late 1980's; its use in disaster relief would provide highly visible advertisement of the system and bring about insurance industry participation in a full-scale system, both because of the reduction of damages after a disaster made possible by accelerated rescue and relief and also by reduction of claims in industrialized nations for losses by burglary, arson, and muggings in large urban areas.

Solar Power Satellite. Assuming reasonable reduction of technical risks made possible by the pre-pilot SEPS efforts, a joint venture by government and the utilities industry to deploy a pilot SPS in the mid-1990's would seem likely, making use of the second-generation Shuttle-type vehicles likely to have become operational by the late 1980's to support extensive space processing (see below). Many of the facilities developed for the materials processing and NIS systems would make the costs of deploying an operational SPS system (based on nonterrestrial mining) quite reasonable and modest by this time.

6.1.5.3 Products

Shuttle/Spacelab. Assuming that funding for the Shuttle/Spacelab programs is adequate, it is reasonable to expect that a number of specific processes or products which can be performed or produced in zero-g will be identified in the early 1980's. Provided red tape is minimized, rapid entry of private industry into space manufacturing could be expected, with pilot production experiments aboard the Shuttle and an uprated Shuttle in the mid-1980's.

"Industrial Park". Rapid expansion of space processing by numerous new space companies would provide sufficient economic base for a consortium of space companies to develop, deploy, and operate basic facilities in LEO for materials processing plants. Such an "industrial park" would provide power, heat rejection, communications, and strongback services to individual users, as well as basic living quarters for workers. Such a combined facility would provide economies of scale and reduce the "front-end" capital costs for small users, allowing more space companies to participate than would be the case if each had to provide its own complete system.

Nonterrestrial Mining. The success of the Night Illumination and pre-pilot SEPS programs would justify public investment in the development work needed to begin nonterrestrial mining of the Moon and/or the Earth-crossing asteroids, especially in an environment in which both business and labor have become strongly pro-space and which stock issues for the new space companies have provided the glamor issues needed for a sustained stock market boom. Several years of experience with the life-support systems of the Semi-Permanent Quarters attached to the "industrial park" would have demonstrated the feasibility of deep-space habitation in an industrial context, reducing the technical risks of such an approach to SPS. Full scale mining operations by the turn of the century would be privately funded and operated by a consortium of space companies.

Manufacturing for Earth. Early in the first decade of the twenty-first century, the existence of nonterrestrial mining, of extensive space processing experience, and of living quarters in space would make the additional cost of beginning to manufacture selected products for Earth from the nonterrestrial raw materials quite low. Such possibilities would soon be exploited by several of the space companies.

6.1.5.4 People in Space

VIP Trips, Entertainment. At the earliest possible opportunity for VIP trips aboard the Space Shuttle, commercial television and movie producers can be expected to exploit the Shuttle for documentary films, special effects, and "on location" sequences for dramatic purposes, provided only that bureaucratic obstacles can be minimized. Besides stimulating public interest and support for space programs in the public sector, these would also serve to bring the new opportunities for profit to the attention of the business sector, contributing to the successful commercialization of space processing aboard the Shuttle.

Semi-Permanent Quarters. The growth of production facilities and profits in zero-gravity would result, as we have seen, in strong pressures for an "industrial park" in LEO. Semi-permanent quarters for workers would be an important adjunct to such a common facility by the beginning of the 1990's. The growing number of workers in space and of production facilities would also induce the larger space companies to participate with the government in the development of a second-generation Shuttle-type vehicle, whose operation would facilitate construction and operation of the semi-permanent quarters.

Education and Medical Services. The existence of living quarters in LEO and of growing numbers of workers would lead, as in the Surprise-Free Program, to some medical services in LEO and, as in the Upside Program, to some advanced postdoctoral research and education in LEO, most likely funded by the public sector.

Commercial Travel and Tourism. With private participation in the development of the second-generation Shuttle-type vehicle, exploitation of its capabilities as a Global Transportation system and for space tourism would be rapid.

6.1.6 Climatic Crisis (Cooling - Figure 6-6)

This program is primarily implemented by the public sector in response to the climatic crisis of a significant and fairly rapid cooling of the Northern Hemisphere. Perception of the crisis in the mid-1980's would result from consistently lower-than-projected agricultural yields; significantly colder and longer winters; and more serious shortages of energy for heating. Governmental response when it finally came, would have the mental set of fighting a war, with major programs undertaken quickly with little concern for cutting corners on expenses.

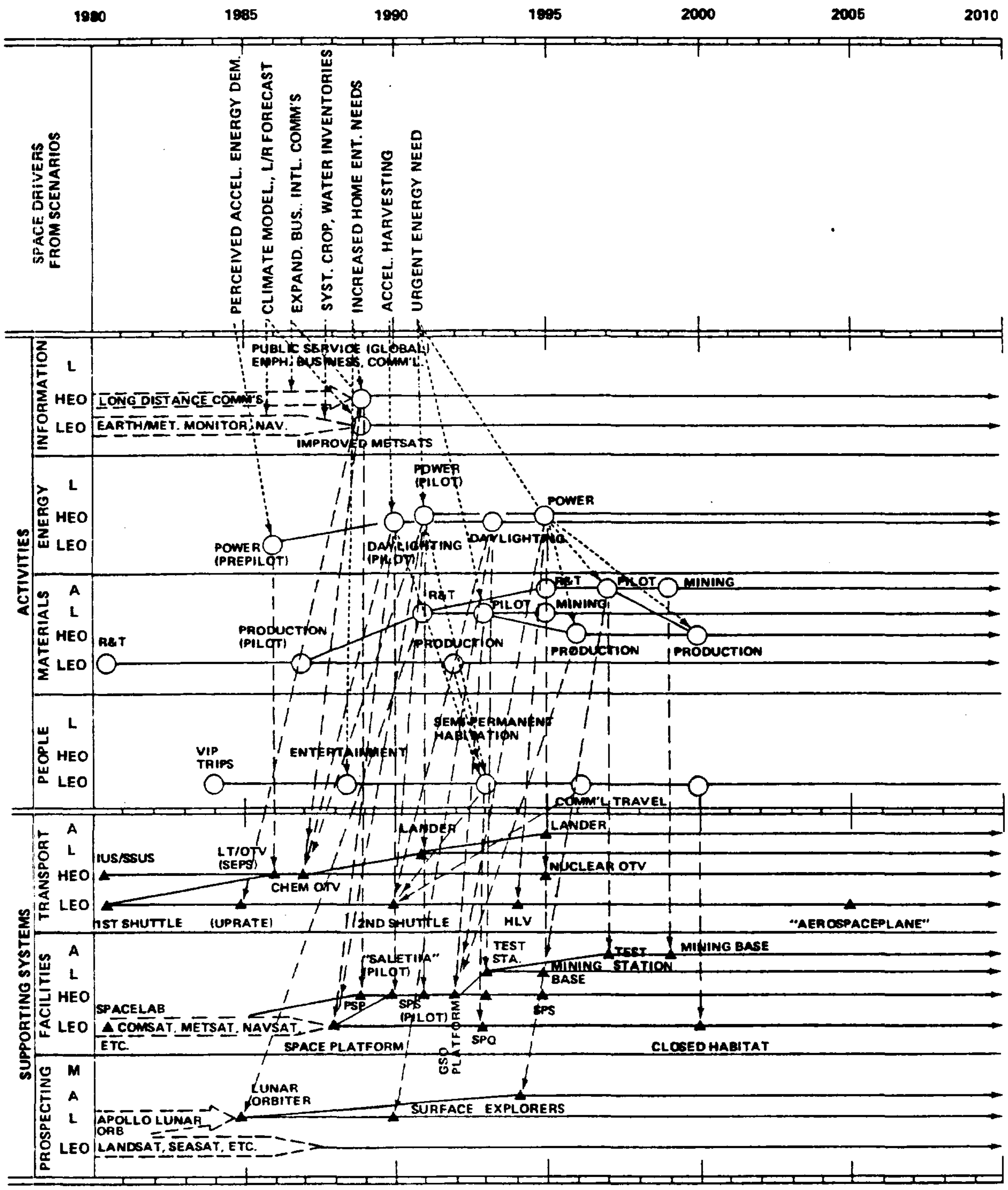


Figure 6-6. Program 4: Climatic Crisis (Cooling)

6.1.6.1 Information

Earth Monitoring. Expansion of meteorological satellites geared to more thorough understanding of the Earth's atmosphere would be the first, rapidly implemented element of the program. Satellites to monitor solar luminosity would also be included for the first time. The first steps would be taken to integrate weather data collected by satellite into a weather forecasting computer system with real-time data collection. Landsat-type satellites would find rapidly expanded utilization for crop forecasting on a global basis, with or without the cooperation of other nations. These satellites would also be used to continually update water inventories for the major agricultural areas of the world.

Communications. With rapid shifts in crop production around the world, the need for communications by international shipping, multinational corporations, and international development and relief organizations would grow rapidly. In North America, energy shortages in the winter months would stimulate demand for personal communications and more home entertainment. These demands would lead rapidly to the implementation of a global Public Service Platform system, helping reduce U.S. petroleum imports.

6.1.6.2 Energy

Pre-Pilot for Solar Power Satellite. The perception of an accelerated increase in energy demand at a time when agricultural exports were decreasing would provide a strong incentive for rapid exploration of the SPS concept in the mid-1980's.

Pilot for SPS. Success of the pre-pilot program, combined with five or six more years of worsening climate, would lend a sense of urgency to the SPS program, with deployment of a pilot SPS (ground built and launched) early in the 1990's. Simultaneously, lunar surface explorers would be deployed to identify optimal mining sites.

SPS Program. The combination of continually accelerating demand for energy and of promising theoretical studies on deliberate climate modification would provide the go-ahead for a full-scale SPS program based on lunar mining and for initial prospecting among the Earth-crossing asteroids.

Pilot Daylighting Satellite. Because of the rapidly shortening growing season, a pilot program to develop large reflectors to extend daytime-levels of solar insolation in areas threatened by frost at critical times (e.g., shortly after sprouting or shortly before the crops are ready for harvesting) or in areas where extended daylight hours are needed to complete harvesting operations before the arrival of major storms would be viable.

Full-Scale Daylighting Program. Success of the pilot program, combined with promising theoretical studies of deliberate weather modification, would justify a rapid go-ahead for a full-scale program deploying a few dozen Daylighting Satellites for use globally as needed. This program would also make use of nonterrestrial materials as soon as they became available.

6.1.6.3 Products

Pilot Processing. While the climatic crisis does not affect the space program in the early 1980's, so that materials processing experiments aboard the Shuttle and Spacelab proceed as in the Surprise-Free Program, the acceleration in the mid-1980's of deployment of communications and monitoring satellites could be expected to compete for space aboard the Shuttle, leading to some delays in beginning pilot plant operations. By the late 1980's, though, expansion of launch capabilities for other purposes would allow this area to catch up to the Surprise-Free Program, with full-scale production in the early 1990's.

Nonterrestrial Mining. The necessity for very rapid expansion of energy sources by way of an SPS program would require nonterrestrial mining to begin at the earliest date, first with lunar mining in the mid-1990's; then from Earth-crossing asteroids near the end of the 1990's.

6.1.6.4 People in Space

VIP Trips. Motivation for these would not have changed in the early 1980's from those given in the Surprise-Free program. During the late 1980's, however, the accelerated growth of demand for home entertainment (both for energy conservation and to avoid personal exposure to more severe winter weather) would result in continuation of these flights for a longer period.

Entertainment. The prolongation of VIP trips (as compared to the Surprise-Free Program) would grow into active entertainment activities for terrestrial audiences, with greater activity than in the Surprise-Free case.

Semi-Permanent Habitation. The deployment of power satellites and daylighting satellites in the early 1990's would result inevitably in some facilities for habitation in space of a fairly significant scale.

Commercial Travel and Tourism. The expansion of the number of workers in space, coupled with the availability of advanced, low-cost launch vehicles to support the power satellite program, would result in the deployment of a Global Transportation system and in paying space tourists in the mid- to late-1990's.

Permanent Settlements. Large-scale expansion of the number of workers in space by the turn of the century (primarily for the SPS program)would lead to the enlargement and elaboration of Semi-Permanent Quarters into permanent settlements.

6.1.7 Cheap Terrestrial Energy (No SPS - Figure 6-7)

Since the masses of systems in space are so vastly much larger for Solar Power Satellites than for anything else yet considered in space, the presence or absence of an SPS program has enormous impact on the entire space program's shape and scope. In the Energy Breakthrough Scenario, we postulated a major breakthrough in the economic application of a new solar-based terrestrial energy technology, but any other energy technology which proves to be inexpensive and abundant would have similar effects.

6.1.7.1 Information

Until the proliferation of the new energy source during the late 1980's, little difference could be expected in space industries dealing with information. Proliferation of cheap energy around the globe, however, would soon lead to acceleration of economic growth worldwide, resulting in rapidly expanding demand for communications services. The deployment of large Public Service Platforms would thus be accelerated, extending personal communications and similar services to worldwide scale by the early 1990's.

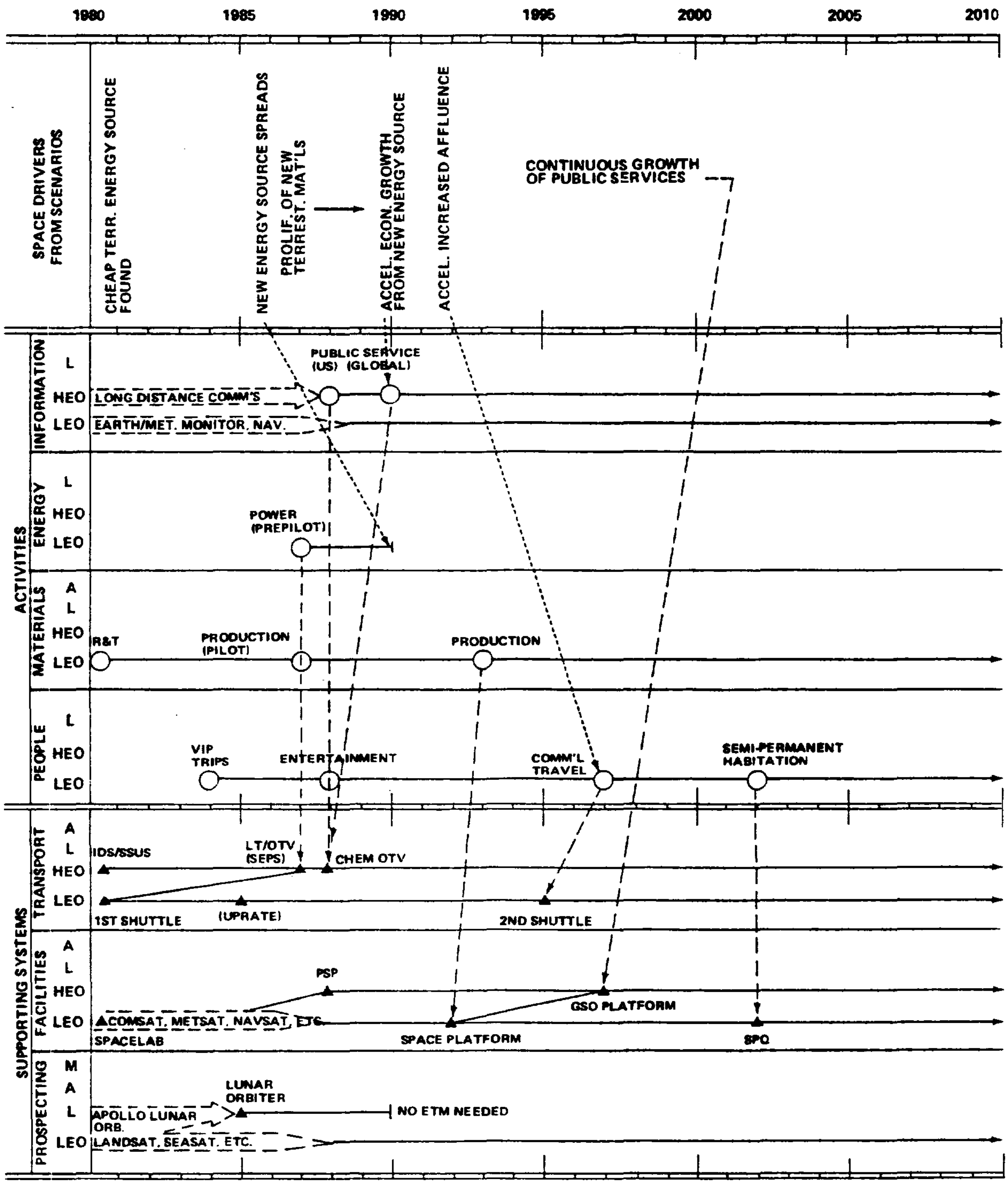


Figure 6-7. Program 5: Terrestrial Energy Breakthrough (No SPS)

6.1.7.2 Energy

Pre-Pilot for SEPS. Concern about energy sources during the early 1980's would justify a pre-pilot SEPS program, just as in the Surprise-Free Program. But the success of the new terrestrial technology would in all likelihood prevent further investments in space energy systems, regardless of the success of the SEPS program.

6.1.7.3 Products

No significant differences could be expected in the materials processing area throughout the 1980's. Acceleration of economic growth, however, would lead to expansion of orbital production during the early 1990's, while the absence of an SPS program thereafter would preclude importation of products manufactured in space from nonterrestrial sources.

6.1.7.4 People in Space

Commercial Travel and Tourism. Without an SPS program, the deployment of post-Shuttle vehicles would be delayed until the mid-1990's, so that Global Transportation and tourism to LEO would not occur until nearly the end of the century, at significantly reduced scales, especially in the absence of Semi-Permanent Quarters until after the turn of the century.

Semi-Permanent Quarters. Although the absence of an SPS program significantly reduces the number of workers in space, maintenance of communications satellites would grow sufficiently to justify establishment of semi-permanent habitation facilities shortly after the turn of the century. Little need for permanent settlements would then result until beyond the time-frame of this study.

6.1.8 Downside Program (Figure 6-8)

This pessimistic program is based on the Disenchantment with Space and the Economic Collapse Scenarios. In the former case, although the economy is sufficiently vigorous to support a space program comparable to the present NASA budget, public perceptions of so-called "human needs" and of the "expense" of space result in very small appropriations for space. In the latter case, economic constraints are so evident (and real) that

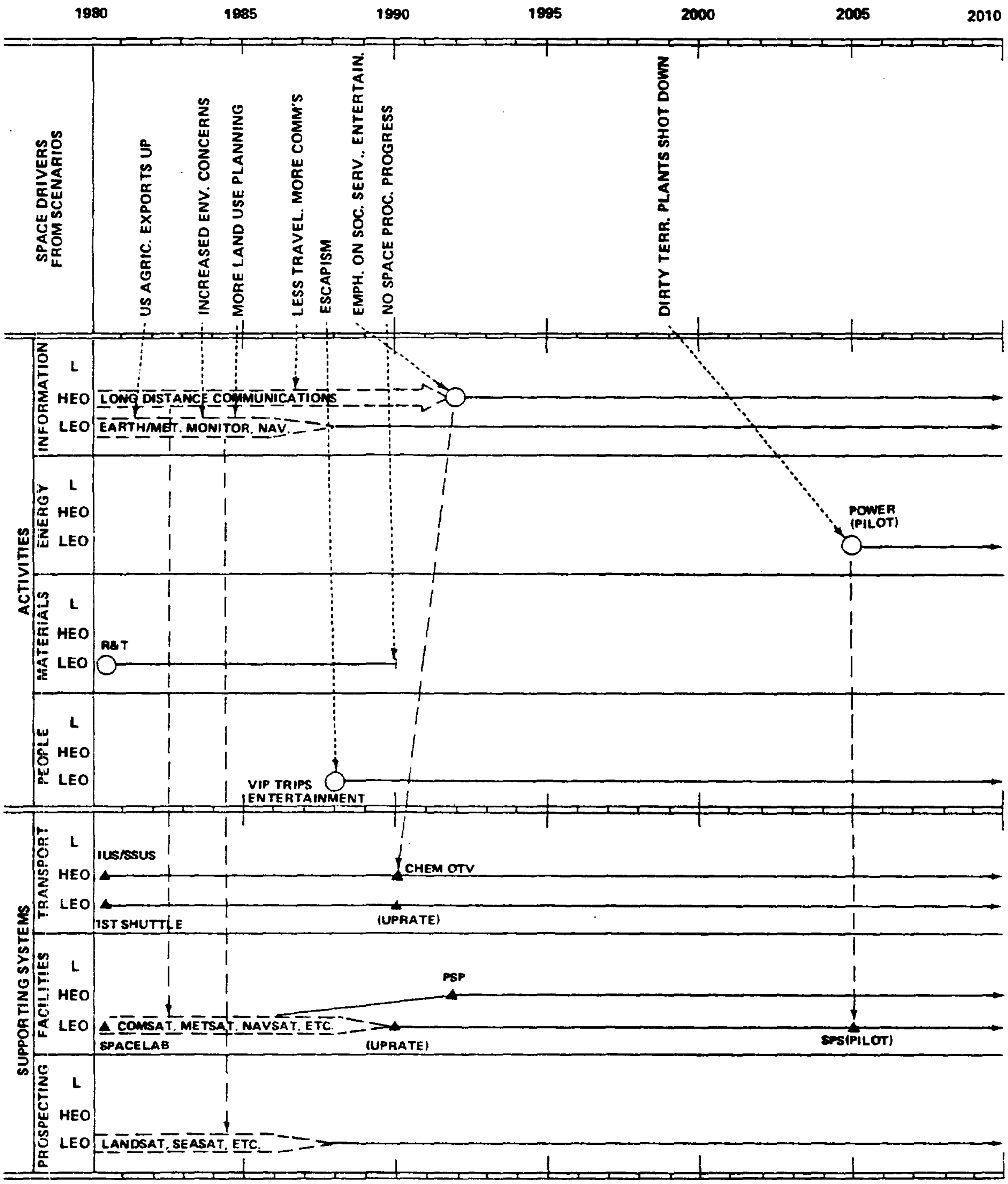


Figure 6-8. Program 6: Downside

only space programs directly applicable to "human needs" can continue in the public sector, and virtually all space ventures are considered too risky in a shaken and uncertain private sector.

6.1.8.1 Information

Communications. Communications satellites would be expected to continue to be profitable in either of the scenarios considered here. In the economic collapse case, business would rely more heavily on long distance electronic communications in preference to travel. In the disenchantment with space case, the governmental emphasis on human services would contribute modestly to increased demand for electronic communications.

Earth Observation and Monitoring. Expansion of U.S. agricultural exports, increased federal and state land use planning, and greater concern for the environment would all contribute to more extensive use of Earth monitoring and observing satellites.

Public Service Platform. The emphasis in the mid- to late- 1980's on social welfare programs would favor deployment of PSP's providing governmental agencies with datalink channels, electronic mail and (perhaps) two-way video teleconference capabilities. Direct television broadcast would respond to the increased needs for home entertainment, especially in an economic depression.

6.1.8.2 Energy

In an anti-space political atmosphere, the development of Solar Power Satellites or of Night Illumination Satellites would not be viable for the next two decades or more. With only limited expansion of communications satellites in geosynchronous orbit, development of Solar Electric Propulsion Systems for orbital transfer missions would also be unlikely, further reducing the likelihood of programs in the energy field. Diminished demand for energy resulting from the economic depression, however, would result in the abandonment of large numbers of "dirty" powerplants during the 1990's prior to completion of their normal lifetime. Economic recovery after the turn of the century would reawaken interest in environmentally clean sources of power, making a pilot SPS program possible in the first decade of the twenty-first century.

6.1.8.3 Products

With limited funding for the Shuttle/Spacelab program, few if any commercially viable materials processing application would be identified in the zero-g environment. Combined with the economic downturn, this entire area could be expected to dry up by the late 1980's.

6.1.8.4 People in Space

VIP Trips; Entertainment. As long as some Shuttle flights continued, some interest in the space program would remain, so that a few VIP trips in the late 1980's would be likely, especially in the interest of providing some escapist entertainment in the midst of a depression. Other nations (except, perhaps, for the U.S.S.R.) would not be likely to develop or maintain a manned capability in space in the face of a worldwide depression.

6.2 ANALYSIS OF SPACE INDUSTRIALIZATION PROGRAMS (1980 - 2010)

6.2.1 Program Analysis Methodology

An assessment of the program costs, system requirements and technology requirements was desired prior to entering Part 2 of the study. Comparison of the six programs presented in the last section resulted in the following observations. The Commercial, Climatic Crisis and Upside programs were similar to the Baseline except in timing and magnitude of most major space activities. The Downside program presupposes a number of failures in will and planning and is of little positive interest. The largest single swinger between the most likely programs was the SPS.

To scope future costs, impacts and requirements within reasonable effort three programs were thus selected for detailed analysis. These were the Baseline, No SPS and Upside Programs. The general analysis methodology is summarized in Figure 6-9. The procedure was to take the general programs as presented in Section 6.1 and adjust specific timing and scale according to guidelines from the scenarios and market data. In some cases several initiatives were lumped into a single system for purposes of simplifying costing and scheduling. A platform approach to developing the communications initiatives was assumed with one basic

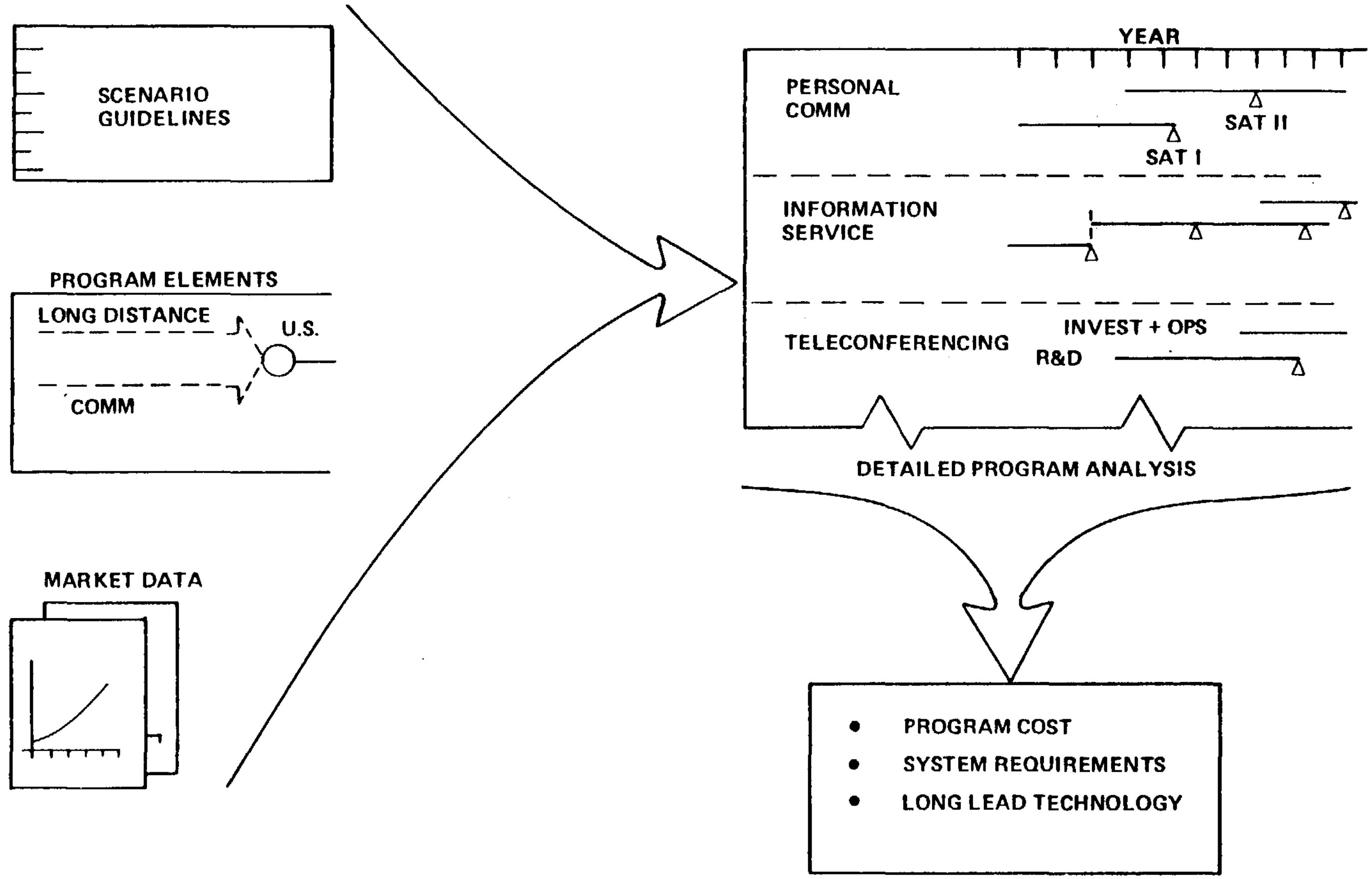


Figure 6-9. Generalized Methodology for Detailed Analysis of Program

platform serving development needs for most initiatives in the eighties and early nineties.

Introduction and growth of the various Information Services leads to requirements for very large platforms in the nineties and beyond corresponding to the market projections presented previously. This turned out to be the largest single set of industry initiatives in terms of power and structures other than SPS and light reflectors. Lumped parameters from the Aerospace New Initiatives Study (Bekey) were used to estimate both the cost and schedule for these Information Services requirements. The parameter varied was number of channels required for the various services. Mass and power were assumed to be linear functions of channel requirements near the design points presented in the Aerospace study.

6.2.2 Non-SPS Power Requirements

To better understand the general nature of the power requirements being dictated by the markets, two initiatives were broken down to step-wise growth needs in orbital mass and power. These were the Portable Telephone and Teleconferencing (Baseline Program, US markets only). The results of that examination is presented in Figure 6-10. The implementing steps can take many forms, the largest being assumed here was one megawatt (1.0 MW). This indicates that for all initiatives a Payload Service Platform of the mid to late nineties will be of the 1 to 10 megawatt size. The power required by the Products Manufacturing Modules are on the same order for markets projected during this time period.

The highly aggressive Upside Program accelerates these requirements in time and increases the rate of growth near the turn of the century. A thorough analysis to identify the levels and rates relative to power requirements was not pursued. However, it seems reasonable to anticipate optimal steps in excess of 10 MW each by the year 2000 could be utilized.

6.2.3 Summary Program Schedule and Cost Estimates

The estimates of investments required and relative timing for industry hardware development and production and support element development and operation are summarized in Figures 6-11 (Baseline Program), 6-12 (No

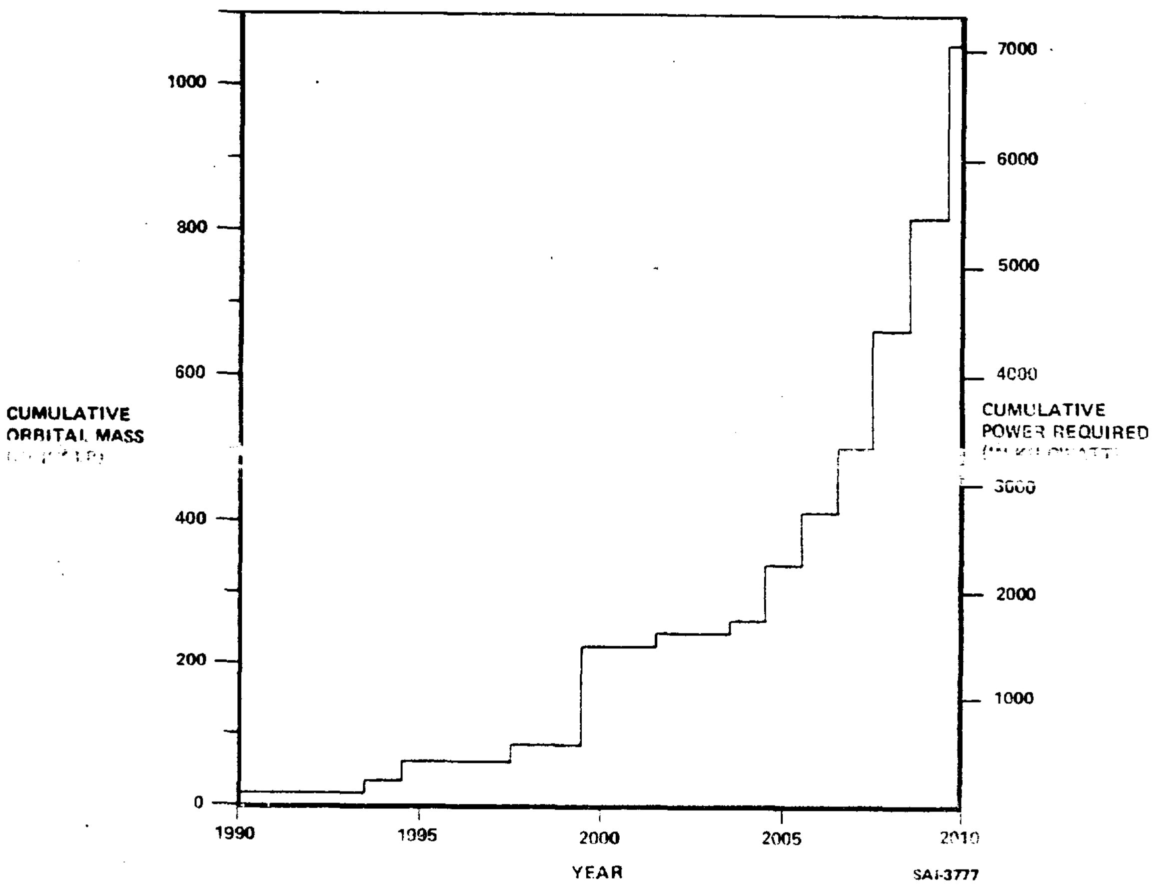


Figure 6- 10. An Example of the Mass and Power Requirements at Geosynchronous Orbit Generated by Two Initiatives Only; Portable Telephone and Teleconferencing

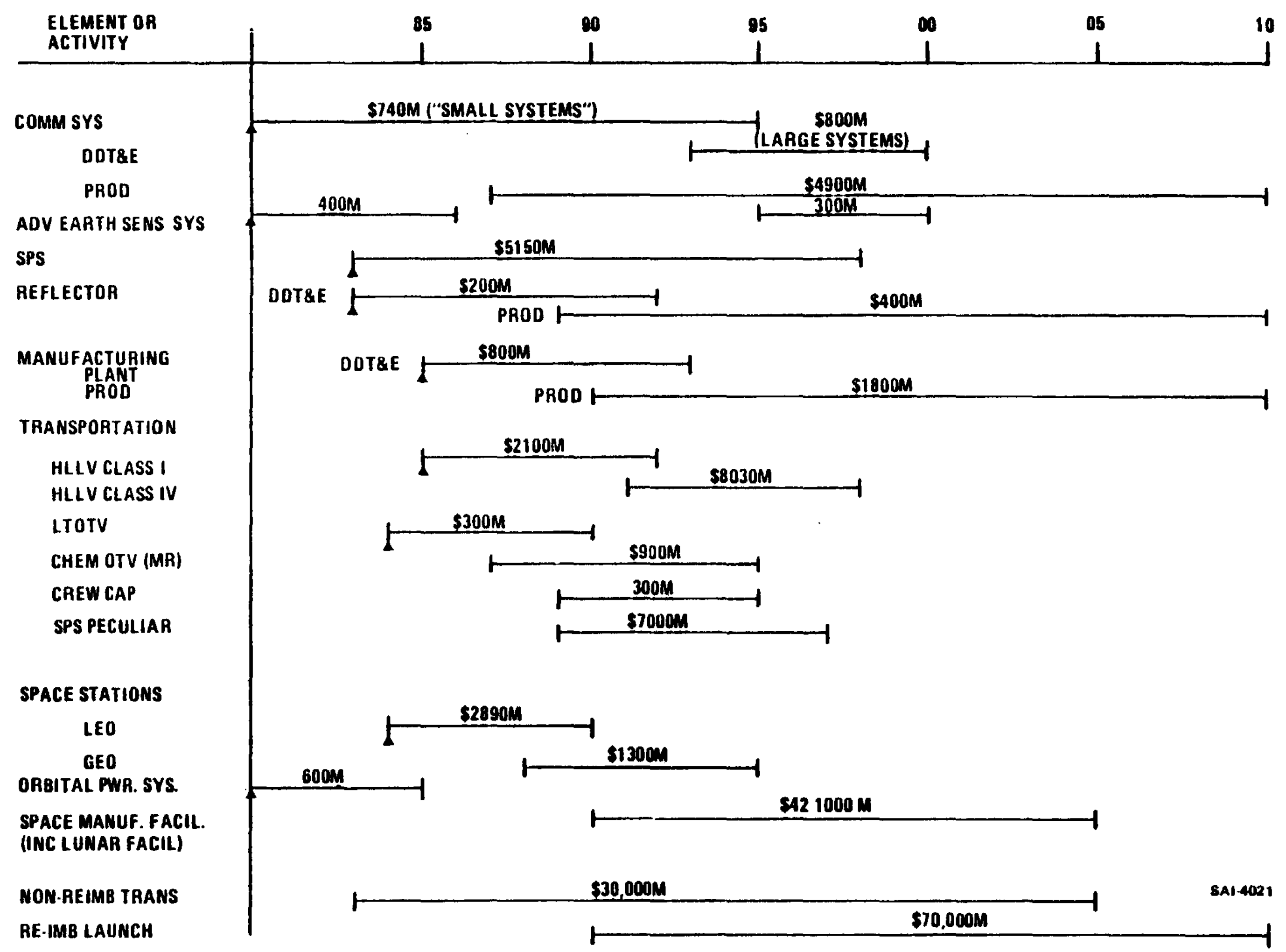


Figure 6-11. Baseline Program Schedule & Cost

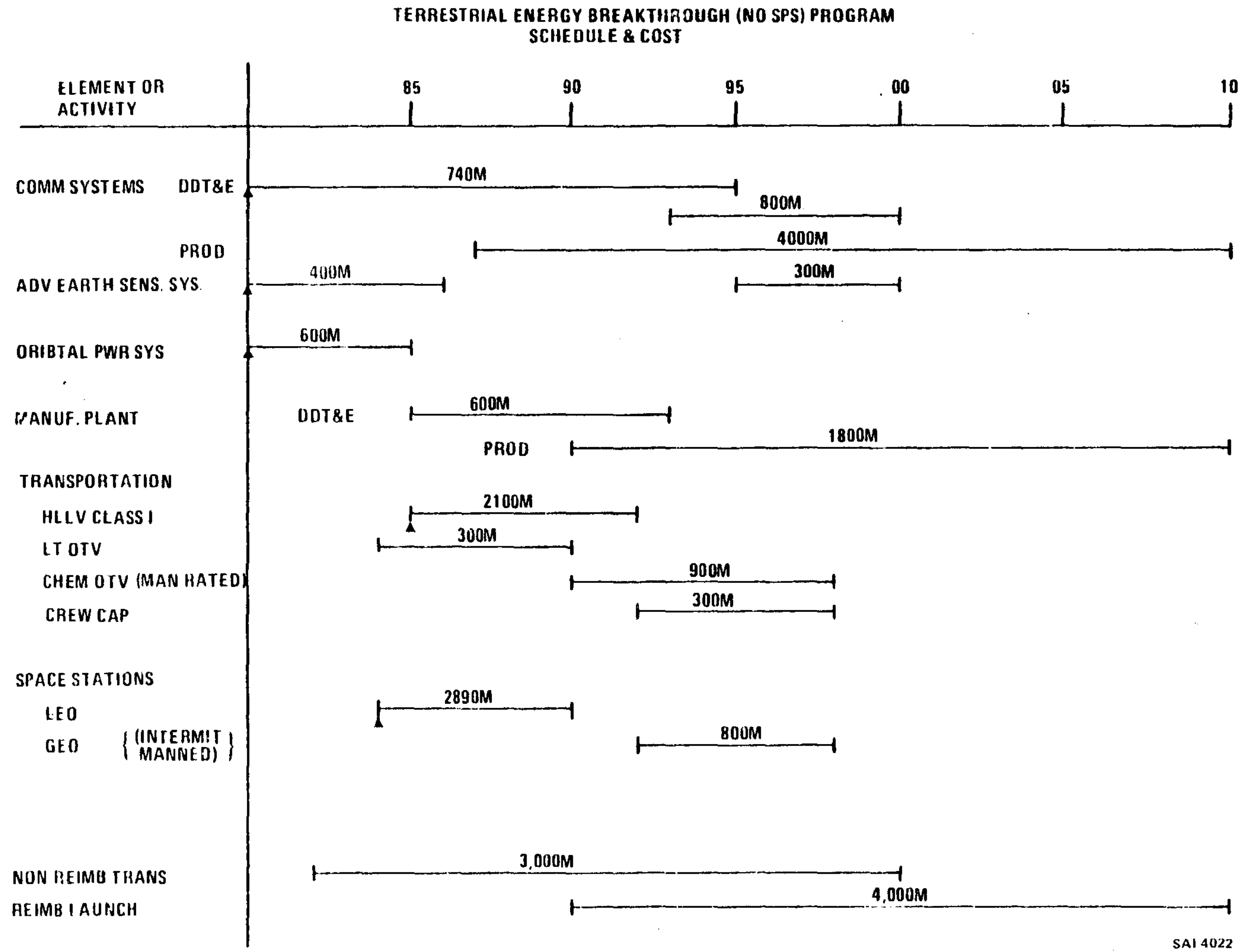


Figure 6-12. Terrestrial Energy Breakthrough (No SPS) Program Schedule and Cost

SPS Program) and 6-13 (Upside Program). These data plus the projected revenues associated with these investments provided the basis for a portion of the economic impact assessment reported in Volume 3 of this report.

A comparison of annual revenues and expenditures and cumulative revenues and expenditures was made for both the Baseline and No SPS programs where required funding included DDT&E for systems and production and launch of the hardware. Revenue predictions came from the market surveys conducted. The comparison is presented in Figure 6-14 and 6-15. A full definition of all operations and ground segment costs were not addressed. All DDT&E was assumed to be paid for by public funding, whereas profit making production hardware and launches were assumed to be commercial. This allows certain implications and conclusions to be drawn on these programs. Particularly, it is noted that the SPS, which required substantial early funding, will tend to push the total program break-even into the 2010 time period with return on investment (ROI) delayed until afterwards. This is not unexpected since the SPS would by necessity be a long payback investment. The cross-hatched area represents SPS revenues in Figure 6-14. The direct effect of the SPS including extraterrestrial material acquisition, etc. can be seen by comparison of the figures. As indicated on Figure 6-15, information systems look highly attractive for good ROI and early payback. Peak funding would appear to be less than $2 billion.

6.2.4 Program Analysis Observations

An overview of observations for each activity focuses on the major advantages for space, the major technical hurdles and the possible timing as indicated on Figure 6-16. Information activities have already begun with communications, observations and navigation industries. However, by the mid 1980's, significantly larger systems could begin operation and expansion would then proceed rapidly. The information systems utilize the view and access offered by orbiting the Earth. The major technical hurdles to their implementation are their size and power requirements as well as the need for extensive data processing to be conducted in space (so called "complexity inversion"). The very large steps and numbers of systems in

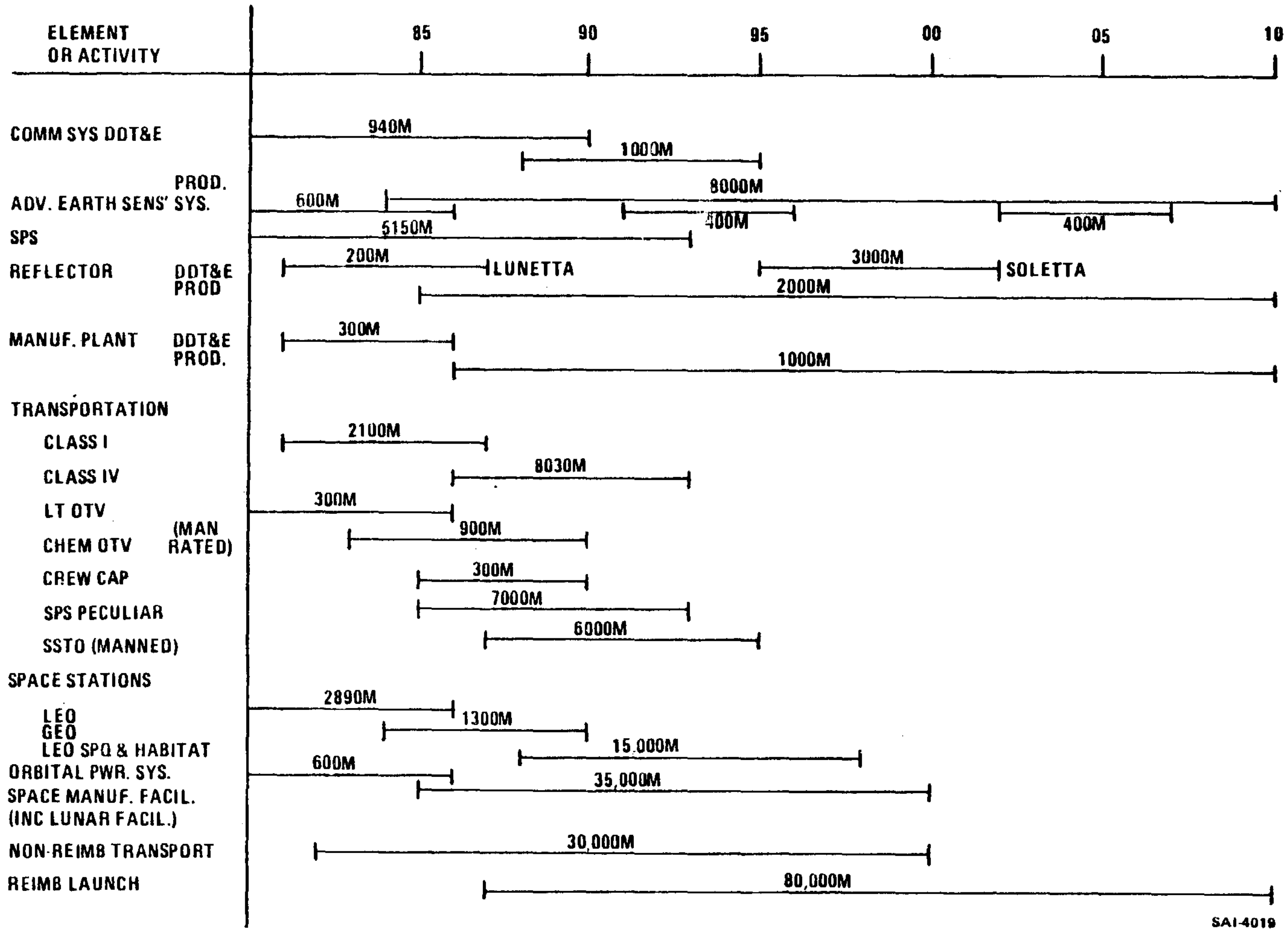


Figure 6-13. Upside Program Schedule & Cost

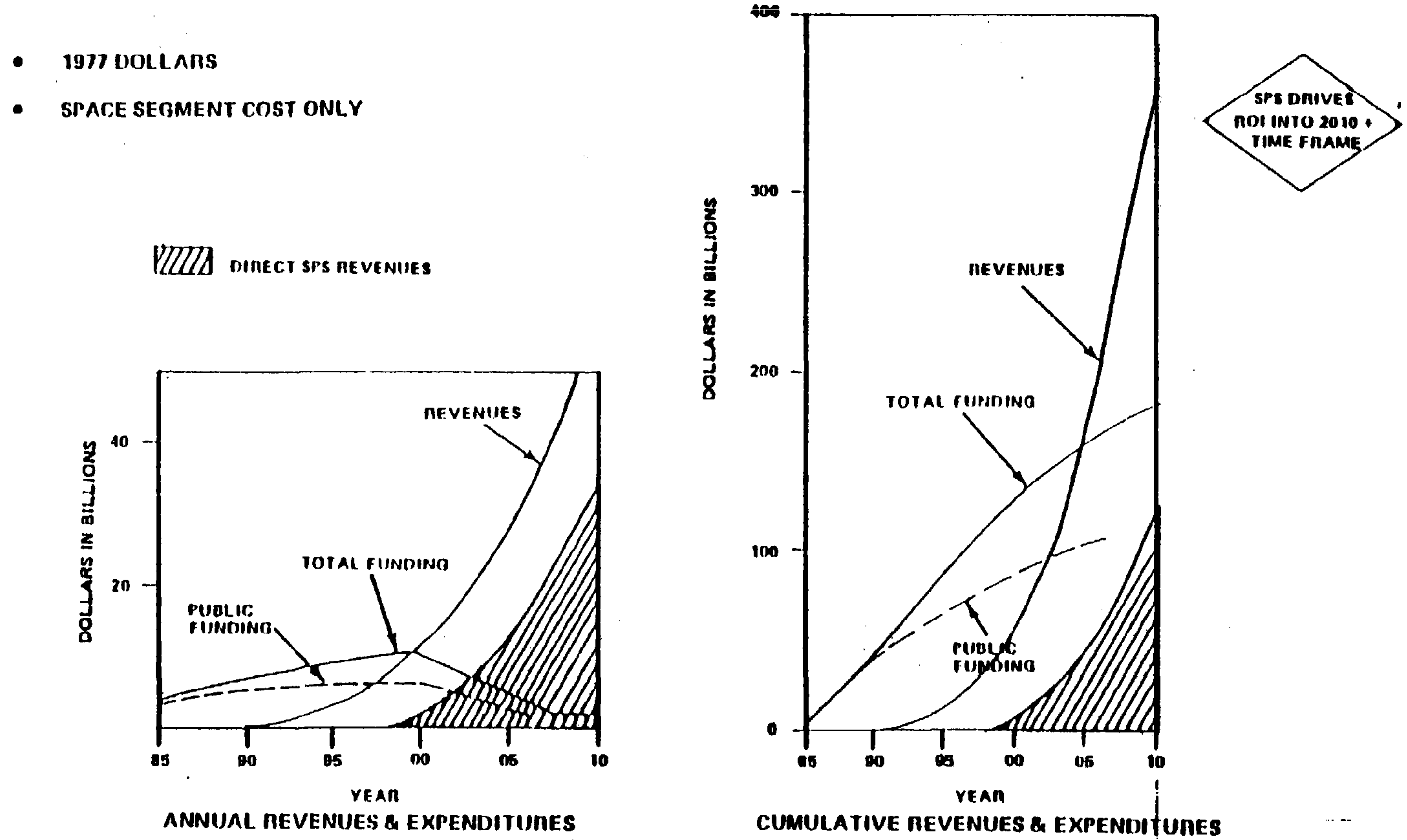


Figure 6-14. Comparisons of Annual and Cumulative Revenues and Expenditures for the Baseline Program

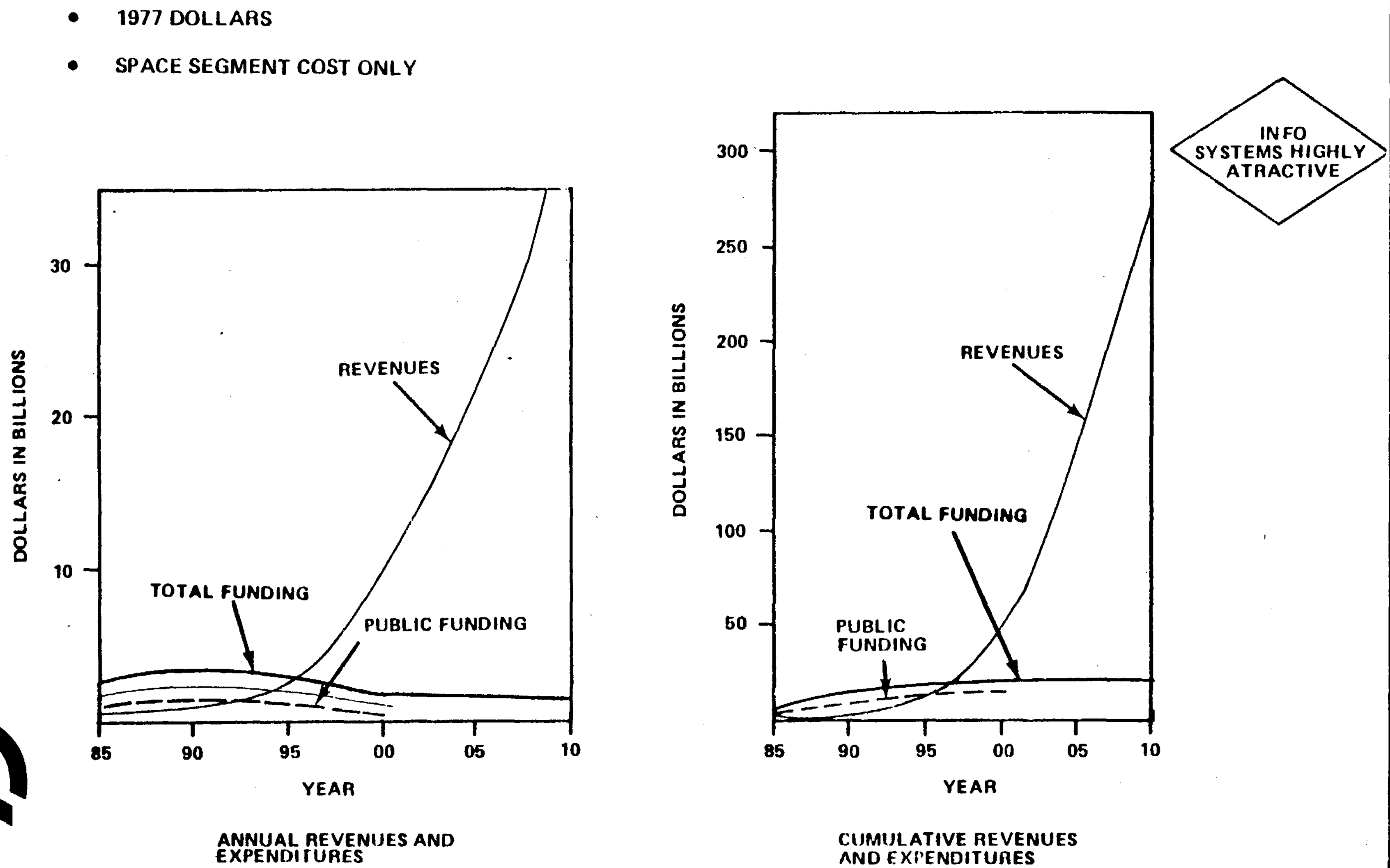


Figure 6-15. Comparisons of Annual and Cumulative Revenues and Expenditures for the No SPS Program

ACTIVITY	INFORMATION	ENERGY	MATERIALS	PEOPLE
MAJOR SPACE ADVANTAGE	• VIEW • ACCESS	• SOLAR FLUX	• LOW 'G' HIGH VAC • HIGH VAC	• UNIQUENESS
MAJOR TECHNICAL HURDLES	• SIZE 10–100 METER ANTENNA • POWER 21 KW -- 10,000 KW • DATA PROC • TRANSPORT COST (OPERATIONS)	• SIZE/MASS OF SYSTEM ~ 10^4 MW ~ 10^5 TONS ~ $\$10^{10}$ • TRANSPORT COST $<$ \$20/LB LEO • ENVIRONMENT ISSUES	• PROOF OF THEORY • PRODUCTION DEVELOPMENT HUNDREDS OF POUNDS PER DAY • POWER 10 KW – 10,000 KW CONTINUOUS • TRANSPORT COST $<$ \$100/LB LEO	• TRANSPORT COST \$25/LB OR LESS • HABITATION
TIMING FOR SIGNIFICANT REVENUES	• PRESENT $>$ \$1000 M/YR • 1985 + RAPID EXPANSION	• 1996 +	• 1987 +	• 1990 +

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Figure 6-16. A Summary of Qualitative and Quantitative Observations Drawn From the Programs Analysis operation will require economical maintenance activities in GEO, implying economical transportation.

Energy activities rely mainly on the solar flux. The major technical hurdles are due to the size and mass of the systems, which leads to a requirement for lower transportation costs. Additionally, environmental issues may present significant barriers for their implementation. The timing for energy activities is viewed as after the late 1990's.

Product activities take advantage primarily of the reduced gravity and high vacuum available in orbit. In addition to demonstration of techniques, product activities will require significant power and low cost transportation. These are envisioned to begin during the late 1980's in, perhaps, commercial batch quantities. To become the substantial revenue producer envisioned in the nineties, transport cost must be reduced to \$5 - \$50/pound to LEO.

People activities in space use the uniqueness of space. The major technical hurdles are transportation cost and, for large scale activities, habitation facilities. These activities should be viable starting in the 1990's.

A series of recommendations drawn from these observations and other segments of this report volume are presented in the section on Recommendations in Volume 3.

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