

Satellite Power System (SPS) Financial/Management Scenarios

October 1978

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U.S. Department of Energy
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DOE/NASA
Satellite Power System
Concept Development
and
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EXECUTIVE SUMMARY

In this white paper, the major factors involved in the evaluation of the Satellite Power System's (SPS) feasibility and in SPS financing and management are presented. Areas for further research are also enumerated.

The financial attractiveness of any project depends primarily upon the relationship between its anticipated reward and expected risk. Cash flow analyses under several assumptions produced preliminary "best estimate" returns on investment ranging between four and fifteen percent for the SPS.

Project downside risk at this time is considered high. Numerous factors including satellite malfunction and interference, and potential international repercussions threaten the project. Opportunity costs associated with alternative methods of power generation have not been analyzed sufficiently. Finally, cost overruns may be particularly large. Nevertheless, it is premature to conclude that the SPS is not feasible. Several steps can be taken to materially reduce the risks, and these are reviewed in the white paper.

Financing and management requirements for the SPS will differ markedly at each of its three stages of growth--research and development, start-up, and maturity. It is clear, however, that the U.S. government (and perhaps a consortium of governments) will need to finance and manage the project during the first two (and perhaps all three) stages.

The private sector, nevertheless, will participate from the beginning in the roles of suppliers and contractors. As such, they will form an important part of the SPS organizational pyramid. Administering this dynamic pyramid and representing the SPS in its relationships with its external environment present a supreme challenge to the practice of management.

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I. INTRODUCTION

The objective of this white paper is to assess the potential feasibility and advantages of alternative SPS financing and management scenerios. This was accomplished through (1) a search of the relevant literature (see bibliography), (2) interviews and discussions with financial, government, and academic professionals¹, and (3) the development and implementation of original cash flow and return on investment models based upon the current NASA preliminary costing estimates.

The paper is divided into three major sections dealing with financial analysis, finance and management, and areas for further research. The separation of finance and management was done to facilitate exposition of the subject matter. In practice, the two are closely interrelated.

The author is indebted to a large number of people who gave willingly of their time and ideas to this study. Most of them are acknowledged as sources in the bibliography. Planning Research Corporation personnel encouraged and assisted the author in many ways, and gratitude for this help is hereby acknowledged. Mr. Lawrence S. Campbell, Dr. T. Stephen Cheston, and Mr. Michael A. G. Michaud reviewed the first draft and their comments were most helpful.

II. FINANCING: THE RISK/REWARD TRADEOFF

The financial attractiveness of the SPS concept will depend primarily on the relationship between its anticipated rewards and expected risk as compared with other power generation alternatives. Reward or benefit can be expressed as a percentage return on investment (internal rate of return). Risk can be expressed qualitatively in words or quantitatively by a number of methods. In this section both returns and risks are discussed under a variety of scenerios.

RETURNS

A number of estimates of SPS project returns have been made over the past few years using a variety of revenue and cost data and assumptions.² The data used in this white paper were developed in consultation with NASA, using the Planning Research Corporation's computer model. All statistics are expressed in constant dollars of 1977.

Exhibit II-1 shows preliminary estimates of research and development costs spread over the years 1981 to 1999. The total cost of \$76 billion will be allocated among three phases: technology development and verification; design, development, test and evaluation; and the construction of a working prototype. Exhibit II-2 displays a breakdown of the capital preliminary estimate for investment expenditures required to build one complete five gigawatt SPS. Nearly half the estimated \$12 billion capital requirement is expended on the satellite portion of the system. Capital replacement expenditures currently are expected to be \$138 million per year for each SPS. Annual operations and maintenance costs could amount to approximately \$17 million per system. Property taxes and insurance on the rectenna are estimated at \$82 million annually per system.

Exhibit II-1

SATELLITE POWER SYSTEM
 PRELIMINARY ESTIMATE
 RESEARCH AND DEVELOPMENT COST: 1981-1999
 (\$ Billions, 1977)

	<u>Technology Development & Verification</u>	<u>Design, Develop- ment, Test & Evaluation</u>	<u>First 5-GW Unit</u>	<u>Total Development Cost</u>
	Years 1-9 (1981-1990)	Years 7-16 (1988-1998)	Years 14-17 (1996-1999)	
Satellite		\$10.242	\$ 6.457	
Ground Station	\$ 3.009	.682	3.927	
Assembly & Support		13.103	7.132	
Transportation	1.891	13.943	10.618	
Management and Systems Engineering & Integration	--	--	1.407	
Contingency	--	--	<u>3.813</u>	
TOTAL	\$4.900	\$37.970	\$33.354	\$76.224

Source: NASA

Exhibit II-2

SATELLITE POWER SYSTEM
 PRELIMINARY ESTIMATE
 CAPITAL INVESTMENT REQUIRED
 PER SYSTEM
 (\$ Billions, 1977)

<u>Component</u>	<u>Investment Required</u>	<u>Percent of Total</u>
Satellite		
Solar Cell Blankets	\$ 2.086	17%
Antenna System	2.174	18
Other	<u>.989</u>	<u>8</u>
Total Satellite	5.249	43
Ground Station	3.319	29
Assembly & Support	.382	3
Transportation	1.386	12
Management & Systems	.517	4
Engineering & Integration		
Contingency	<u>1.105</u>	<u>9</u>
TOTAL	11.958	100

Source: NASA

The Assumptions and the Returns

In developing cash flow estimates based on these figures, some rather conservative assumptions were made. It was assumed that the SPS would shoulder a state and federal income tax burden of 50 percent of profits. Currently, this tax can be partially avoided by the ten percent investment tax credit; and payment can be partially delayed by accelerated depreciation methods. However, it was assumed that by the year 2000, a less liberal tax climate would prevail. Thus, the investment tax credit used here is only five percent and straight line depreciation is assumed.

Revenues based upon a charge of \$.04 per kilowatt hour were assumed since \$.04 was the average U.S. price in 1977. At that price, each five gigawatt system would produce \$1.6 billion in revenues annually. Two systems per year will be placed in operation between the years 2000 and 2029.

Also, a system life of 30 years was assumed. According to some engineers, it would be as reasonable to select a 40 year life. Finally, it was assumed that the five gigawatt satellite to be placed in orbit during the research and development phase will not produce revenues.

Two net cash flows were developed. The first included the research and development costs shown in Exhibit II-1, while the second did not. Net cash flow is the difference between cash inflow from revenues and cash outflow occasioned by operating costs, the purchase of plant and equipment, and so on. In some years (particularly at the beginning), net cash flow will be negative; while in others, it will be positive.

The rationale for including research and development is obvious. The rationale for excluding it is perhaps less so. However, it can be argued that at least some, and perhaps all, of the \$76 billion spent to develop the first SPS will result in many applications above and beyond the immediate one of providing power. To burden the SPS project with the total research and

development costs would be to understate the benefits derived from its implementation.

An internal rate of return (IRR) was calculated for each net cash flow estimate. The IRR is a rate of return that equates the present value of cash inflows from a project to the present value of its cash outflows. Given the initial (conservative) assumptions, the actual IRR for the project when research and development is included is four percent. The actual IRR for the project when research and development is excluded is six percent.

These IRR figures represent the actual returns that would be realized from the specific project given the assumptions associated with the cash flows. Although they are "actual" they are not strictly comparable to one another for two reasons.

In the first place, the cash flow that includes research and development was discounted to the "present" point of 1981, since the first expenditure occurs then. When research and development is excluded, the "present" becomes 1996. Secondly, the amount and timing of investment required differs between the alternatives. Comparison requires either the investment required (cost) or the return (benefit) to be the same for all alternatives.

To be strictly comparable, the "research and development excluded" cash flow alternative should have added to it the cash flows from a project expending funds at a pace and amount equal to the SPS research and development expenditures. Furthermore, the new project's cash outflow should begin in 1981. In this way, both alternatives would be compared on the basis of an equal cash outflow (investment required) over a similar time period. On the other hand, such a comparison is totally unrealistic and illogical.

It should be stated again, as well, that the data used in these cash flow calculations (and reflected in the IRRs) are expressed in constant 1977

dollars. If inflation was built into the numbers, the return on investment would be higher than otherwise because a compound inflation rate would be applied to a cash flow which is negative at first and positive later on. In other words, an inflated positive net cash flow later on in the project's life would be combined with a less inflated negative net cash flow earlier in the project's life. In interpreting this discounted cash flow data, care must be taken to compare the IRRs with interest rates which do not contain provisions for inflation. And today, published interest rates are highly inflated.

Returns Under Relaxed Assumptions

The returns on the SPS, although low under the conservative assumptions, change for the better when some of them are relaxed. Consider the assumption of a \$.04 per kilowatt hour price. That price can be compared with a 1977 average price paid by residential electricity users in the U.S. of \$.0376, up from \$.0321 in 1976. On a regional basis, however, residential prices vary dramatically. In 1976, for example, a customer in the Pacific Northwest paid \$.015 per kilowatt hour, while a resident in the Northeast paid \$.048.³

Furthermore, recent history has witnessed a dramatic increase in prices of electricity and raw materials used in the production of energy. Over the past five years, the cost of electricity has increased at an average annual rate of 11.2 percent. Since 1969, prices have nearly doubled.⁴ The following tabulation in Exhibit II-3 shows the price changes for three raw materials over the past few years adjusted for inflation and expressed in 1975 dollars.

Given these data, and assuming that the demand for power will continue to increase while its availability continues to decline, a price of \$.10 per kilowatt hour in 1977 constant dollars by the year 2000 A.D. is not unreasonable. A price of \$.10 per kilowatt hour yields an actual IRR of ten percent

with research and development included. When the return was calculated without research and development, the actual return at the "present" date of 1996 was 15 percent.

Exhibit II-3

PRICES OF RAW MATERIALS
(1975 \$)

<u>Year</u>	<u>Crude Oil¹ Per Barrel</u>	<u>Natural Gas at Wellhead Per 1000 Cu.Ft.</u>	<u>Coal Per Ton</u>
1970	\$ 4.39	\$.24	\$ 8.72
1971	4.44	.24	9.37
1972	4.26	.24	9.75
1973	4.74	.26	10.26
1974	9.69	.33	17.22
1975	10.00	.45	19.24
1976	10.03	--	19.02

1. Average of wellhead domestic crude and CIF value of imported crude.

Source: Bureau of Mines, FEA "Energy in Focus: Basic Data," May, 1977.

Clearly, there is significant improvement when \$.10 per kilowatt hour is used. Some care must be taken, however, in comparing the returns of the \$.04 assumption with those of the \$.10 assumption because, again, the investment bases are different. For example, the "\$.10, research and development included" assumption requires a smaller total cash outflow or investment spread over a shorter time period from 1996 onward than the "\$.04, research and development included" assumption. Presumably the extra funds unused in the "\$.10, research and development included" alternative could be earning a return elsewhere. To exclude this return would be to compare the alternatives unfairly.

Another set of assumptions which may be relaxed are those having to do with income and property taxes and rectenna insurance. Some public utilities are owned by the government and do not pay taxes. Also, the government is large enough to self-insure. If the original conservative assumptions are used except that the SPS project does not pay taxes and insurance, the actual IRR is seven percent when research and development is included. If research and development is excluded, actual IRR is ten percent. Again, the caveat about comparisons of IRR should be noted.

Finally, it was stated earlier that the expected life of each SPS was 30 years, but that a 40 year life is a reasonable assumption. If 40 years is assumed (other things remaining the same), the actual IRR is five percent with research and development included, and six percent without.

RISK

Risk has been defined as the "variability of possible returns emanating from the project."⁵ Upside risk refers to the high side of the variation. Major factors contributing to upside risk--40 year satellite life, \$.10/KWH price, and tax exemption--were identified and incorporated into the earlier analysis. Downside risk refers to the low side of the variation, and it is this element of decision that plays a major role in project financing.

Risk can be measured by developing cash flows based upon pessimistic cost or revenue assumptions. Another, more intuitive, definition or measure of risk is the payback or payoff period--the length of time before the investment is repaid. The longer the time period involved, the less certain the investor is of a return because the events and conditions which influence this return are further into the future and are thereby less predictable (other things being equal).

In order to comprehend the risk involved, a literature review was undertaken, a number of financial professionals were interviewed, and meetings were held with NASA/Marshall Space Flight Center personnel.⁶ In this section the major causal factors influencing downside risk which were uncovered in the literature review and discussions are presented. Then, a quantitative evaluation of risk using cash flows and payoff periods is displayed and its interpretation discussed.

Cause and Effect Relationships: Qualitative Evaluation

Variations in project returns are caused by future events and conditions impinging upon the project. This is why a purely quantitative analysis of risk is insufficient. Quantitative analysis neither causes risk, nor will it eliminate risk. The only way downside risk can be limited is by understanding the nature of relevant events and conditions and taking specific actions to deal with them. Those interviewed for this report noted several events and conditions which they believed could contribute substantially to the downside risk in the SPS cash flow. These fall naturally into four general categories.

The first is insurance risk, and refers to those disasters which might occur from the malfunctioning of the satellite or interference with it. A second category of downside risk is related to the first and involves international repercussions from U.S. entry into the SPS field. The possibility of attack and destruction of one or more satellites by a foreign power is a possibility.

International agreements will need to be worked out because the microwave beam and possibly the satellites will violate the "air space" of other countries. These negotiations may fail or be stalled for indefinite periods, making the SPS infeasible.

Finally, the SPS can be perceived easily by other nations as a sophisticated weapons systems. Microwave beams themselves can damage body tissue. Furthermore, the platforms in space which house the solar blankets could also be mounts for powerful lasers or launch platforms for other weapons.

It is not difficult to view the SPS as a platform for a modern day sword of Damocles which would hang over the world, capable of falling almost anywhere on command from a control system located in a remote place--on earth, under the earth (or ocean), on the moon, or elsewhere in space. This perception is likely to be widely held and is not conducive to trust among nations. And the very threat itself will make necessary some kind of agreement among the principal nations on earth if the SPS is to work.

Dr. T. Stephen Cheston⁷ describes a third category of risk as "the unpredictable nature of U.S. political behavior toward projects of this kind and scope." He elaborates as follows:

A large investment in a single new energy generation idea, especially one that is space-based, requires a critical mass of sustained national will. U.S. history, however, is replete with examples where national will has changed radically in a short period of time; e.g., in 1961 the U.S. was able to mobilize enough will to commit \$20 billion for Apollo while in 1971 it had great difficulty committing only \$5.6 billion to Shuttle (the amount was actually far less when converted into 1961 dollars). Vietnam, and the subconscious linkages (rightly or wrongly) of space to it in popular perceptions was partially responsible for the dramatic decline in the national interest in space projects. A reverse of this was the Eisenhower administration rejecting proposals for low cost U.S. space projects before Sputnik; thereafter government space officials were offered open checkbooks. A single dramatic event or emerging social processes can coalesce to shift public opinion radically on a long-range, high-cost project such as SPS.

The fourth category of downside risk is technological and has two aspects. The first involves opportunity costs, while the second involves engineering project costs.

Opportunity costs are those benefits foregone by selecting one alternative over another or others. If the "best" alternative is selected, there

are no opportunity costs. This present analysis shows no comparisons of the project costs of alternative methods of generating an amount of power equal to the SPS project.

Thus, a way or ways may now exist to produce enough power to satisfy U.S. needs in the next century at a lower cost than the SPS. Or, the means to produce lower cost power may be discovered and developed in the future. Coal, shale, power from the ocean are all possibilities.

Furthermore, alternative methods for providing solar power from space may be overlooked when, in fact, they represent a less expensive alternative. Proponents of space colonization point to a way to build the SPS using lunar materials which may prove to be less expensive than terrestrial methods.⁸

Also, it is clear that the engineering costs on the SPS project itself are far from firm. Without probing too deeply into the technical aspects of SPS, these three major areas of potential variation in cost are noted:

Space Transportation. The major questions in this field revolve around operating time and cost. Is it possible to fly the number of missions necessary in the length of time proposed? The cost to transport a kilogram in the Space Shuttle is now between \$600 and \$1000. It will be necessary to transport a kilogram into LEO at a cost of about \$30. Can this be done? Can the proposed ion thrusters move the solar array to GEO cheaply and safely? The heavy lift launch vehicle has never been built, nor have the ion thrusters been perfected.

Solar Cells. At this time photovoltaic arrays are very expensive. The cost of a terrestrial array is somewhere between \$10,000 and \$15,000 per kilowatt. This cost must drop to about \$500 per kilowatt and the array must be lightweight and radiation resistant. Space rated solar cells have never been produced in quantity, much less in the enormous volume needed to blanket an SPS satellite structure.

Orbital Construction and Assembly. The satellite involves a large number of parts which must be assembled into a huge structure in a relatively short period of time--perhaps 90 days or less--if the schedule is to be maintained. This operation has never been performed before. Can it be done for the amount budgeted?

Quantitative Evaluation

The impact of the first three categories of risk--insurance, international repercussions and U.S. political behavior--are very difficult to quantify. Opportunity cost comparisons are beyond the scope of this paper. However, it is possible to estimate the quantitative impact of risk associated with engineering costs on the project.

Exhibit II-4 shows the preliminary estimates of capital investment required per satellite under high, low, and best estimate forecasts of cost behavior. The lowest and highest costs have been calculated as percentages of the best estimate so that percentage variation may be shown. As indicated earlier, solar cell blankets have considerable cost risk associated with them. In Exhibit II-4, the highest reasonable estimate of \$6.3 billion for the blankets is 300 percent above the best estimate. Transportation shows a high risk also, while the ground station is much less risky in terms of cost.

Exhibit II-5 shows optimistic, pessimistic, and best estimate cash flows for the SPS given the original conservative assumptions. Cumulative net cash flow is shown in the Exhibit, i.e., annual net cash flows were cumulated and the summed figures were plotted on the chart.

The negative net cash flows, when added, show the total investment required for the entire operational phase of the 60 satellite SPS program excluding research and development. In the best estimate case, the cumulative net cash flow reaches a low in the year 2011, and indicates a need for \$183 billion in capital. That investment is returned by the year 2026, when the curve crosses the horizontal axis on the chart. The payback period, therefore, is (2026-1996) or 30 years from the time of the initial investment in 1996.

Exhibit II-4

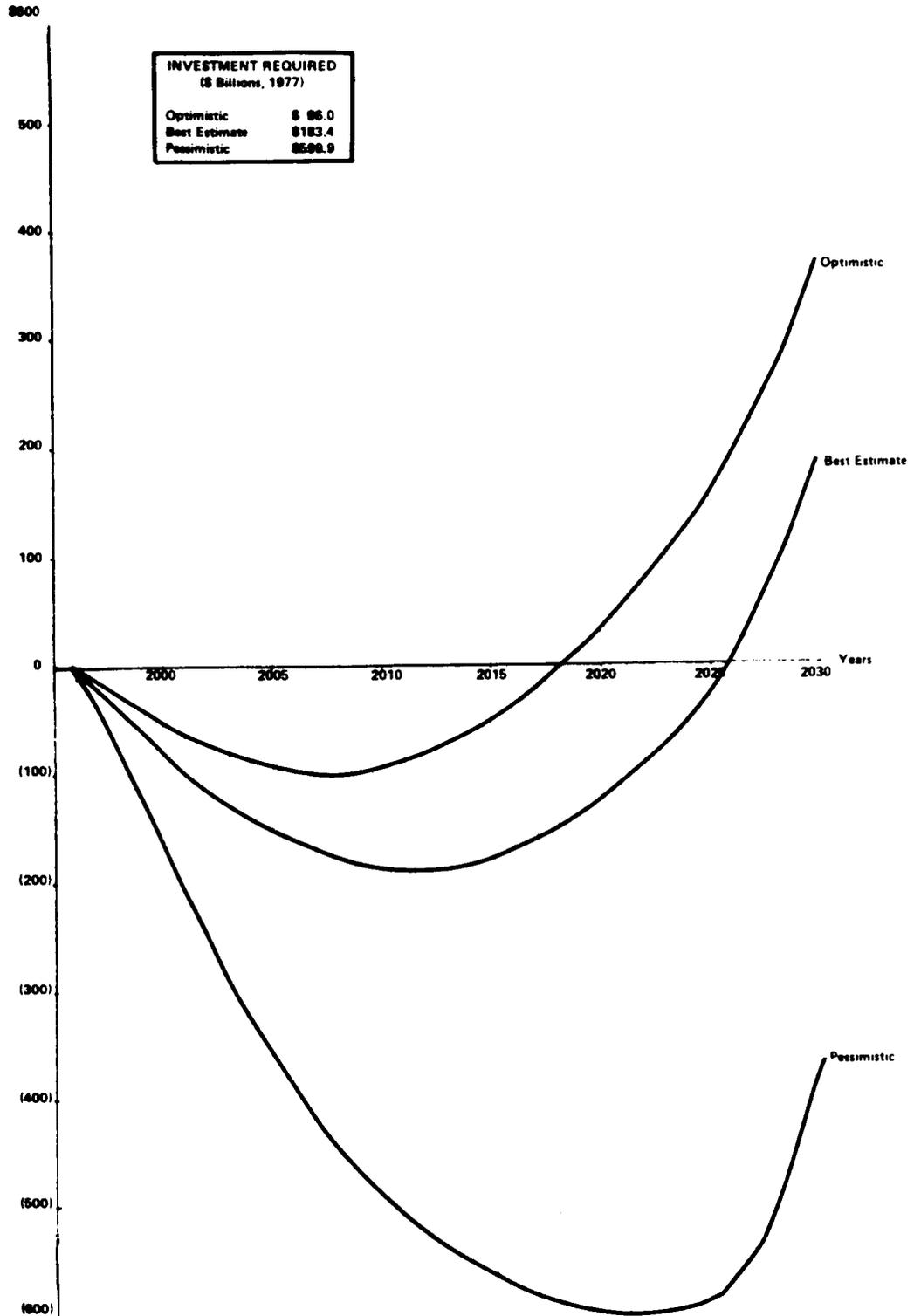
SATELLITE POWER SYSTEM
 CAPITAL INVESTMENT REQUIRED PER SYSTEM
 ALTERNATIVE SCENERIOS
 (\$ Billions, 1977)

	<u>Lowest Reasonable Estimate</u>	<u>Best Estimate</u>	<u>Highest Reasonable Estimate</u>	<u>Lowest as a % of Best Estimate</u>	<u>Highest as a % of Best Estimate</u>
Satellite					
Solar Cell Blankets	\$1.0	\$2.1	\$6.3	48%	300%
Antenna System	1.1	2.2	4.3	50	195
Other	<u>.8</u>	<u>1.0</u>	<u>1.3</u>	80	130
TOTAL SATELLITE	2.9	5.3	11.9	55	225
Ground Station	2.8	3.3	4.3	85	130
Assembly & Support	.2	.4	.8	50	200
Transportation	1.0	1.4	3.5	71	250
Management and Systems					
Engineering & Integration	.4	.5	1.0	80	200
Contingency	<u>.7</u>	<u>1.1</u>	<u>2.5</u>	64	227
TOTAL	8.0	12.0	24.0	67	200

Source: NASA. Based in part on studies by Johnson Space Center/Boeing and ECON.

Exhibit II-5

SATELLITE POWER SYSTEM
CUMULATIVE NET CASH FLOWS
OPTIMISTIC, BEST ESTIMATE, AND PESSIMISTIC
AT \$0.04/KWH
(\$ Billions, 1977)



In the optimistic case, \$96 billion is needed before the net cash flow turns positive in 2008. Payback of the investment in the optimistic case occurs in 2018, a 22-year payoff period. The pessimistic net cash flow does not turn positive until the year 2021 after almost \$600 billion investment is expended. Payback of the investment is not shown on the chart, but occurs in the year 2038. Thus, the payback period spans 42 years.

The cash flow analysis for the 40 year satellite life scenerio is the same as that for the original assumption up to the year 2030. Best estimate and pessimistic cash flows for the \$.10 per kilowatt hour and tax exempt scenerios are displayed in Exhibits II-6 and II-7. The improvements in these cash flows as a result of changing the assumptions is evident.

Evaluation of Risk and Return

Great care must be taken in the interpretation of the risk/return trade-off for the SPS presented in this paper. The term risk has been used in a general sense as variation in cash flow. In fact, however, risk consists in the occurrence or nonoccurrence of events and states of nature which affect the cash flow:⁹

Usually, information about the occurrence or continuation of the many events and conditions that influence a given project's cash flow can be categorized as certain (or practically certain), risky, uncertain, or unknown. The effects of these variables on the cash flow can be categorized in the same way.

An event or condition (or effect on cash flow) is certain if its probability of occurrence is 1.0--or very close to 1.0--and the decision maker is absolutely confident that this probability is correct. A risky event is one that has a probability of occurrence of less than 1.0. However, the decision maker is completely confident that the probability assigned, whatever it be, is the correct one.

An uncertain event or condition (or effect on cash flow) is characterized by a probability of occurrence below 1.0 and something less than absolute confidence in the accuracy of the probability figure. Those events that are totally unanticipated--hence have no probability assigned to them--are designated as unknown.

Exhibit II-6

SATELLITE POWER SYSTEM
CUMULATIVE NET CASH FLOWS
BEST ESTIMATE AND PESSIMISTIC
AT \$.10/KWH
(\$ Billions, 1977)

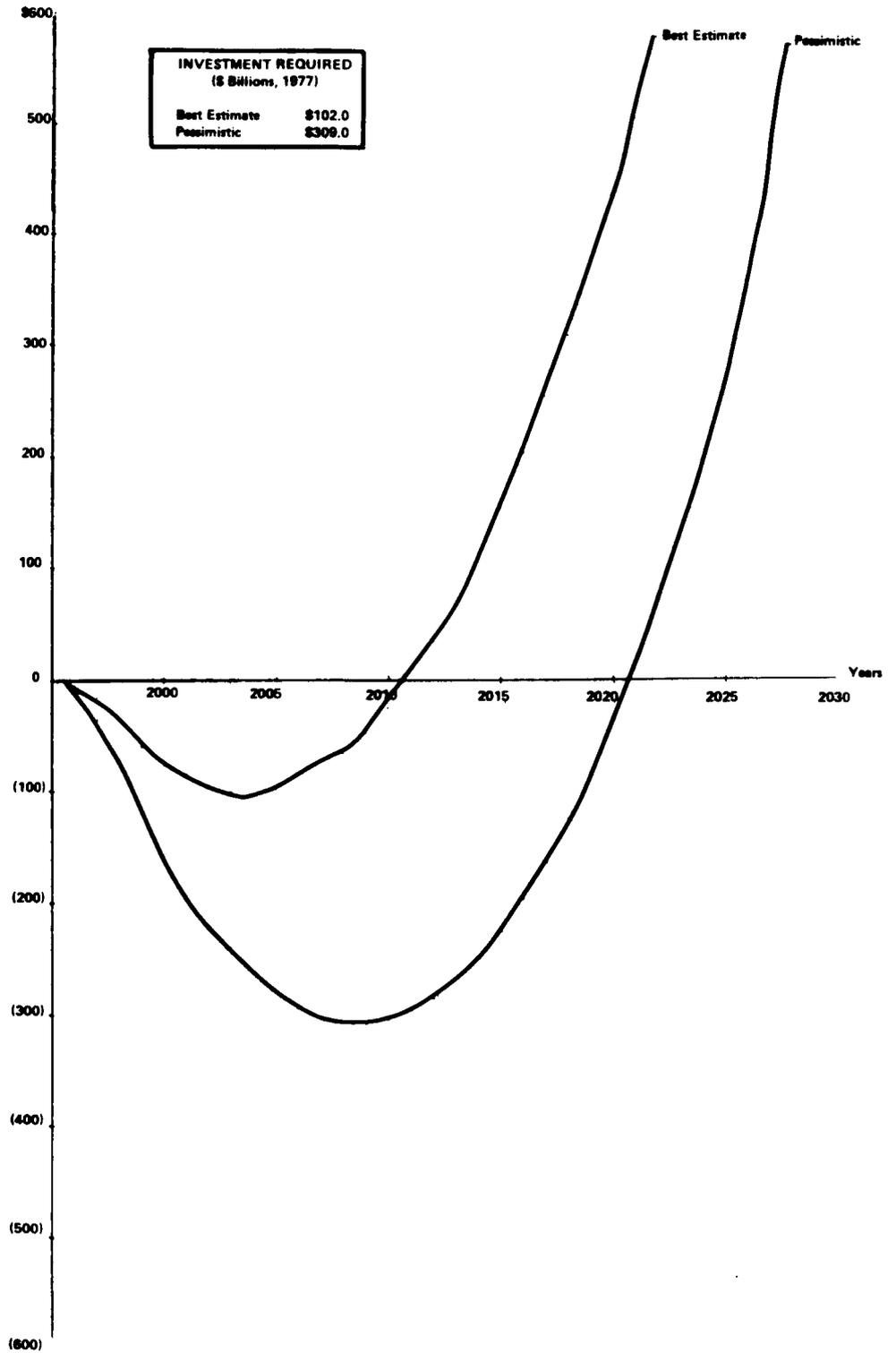
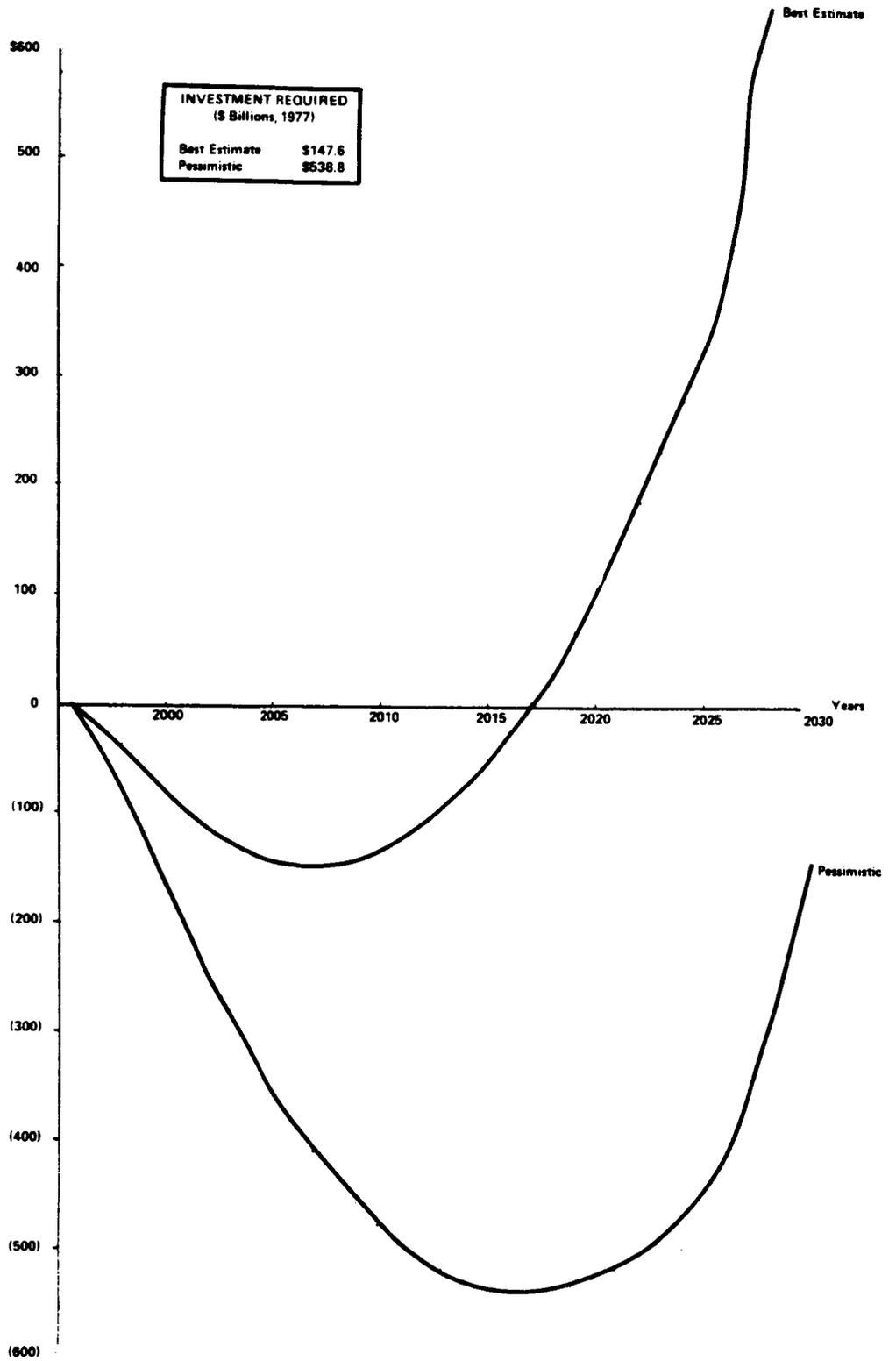


Exhibit II-7

SATELLITE POWER SYSTEM
CUMULATIVE NET CASH FLOWS:
BEST ESTIMATE AND PESSIMISTIC
AT \$04/KWH
NO TAXES/INSURANCE
(\$ Billions, 1977)



The Event/Effect Matrix shown in Exhibit II-8 illustrates the point. If it were possible to enumerate all the events and states of nature that will affect the SPS cash flow; and if one could estimate and then assign a 100 percent correct probability to the state of nature of each event and condition, and to the monetary effect each would have on cash flow; then analytical techniques designed for certain risky environments could be applied to the SPS.

To the extent that uncertainty prevails, scientific risk analysis becomes less useful. To the extent that relevant events or conditions and/or their effects are unknown, a purely scientific analytical approach is illogical.

As a practical matter, all investment projects are characterized entirely by uncertainty and the unknown because the future is uncertain and unknown. The SPS is particularly difficult to analyze because (1) so many of the events and conditions which affect it are unknown or highly uncertain and (2) the interaction among the events and conditions is uncertain and/or unknown.

A number of factors, such as the political and social issues, are qualitative and subjective in nature. The time spans involved are great, making even the identification of causal variables difficult. The project is of unparalleled magnitude in space technology.

Furthermore, the interaction among certain events and conditions give rise to concurrency, a term which "refers to the simultaneous and interrelated development of two or more components of a given project. The words "and interrelated" have been emphasized because any continuing project eventually reaches the point where all its various components are not only under simultaneous development, but are experiencing interrelated development."¹⁰

Concurrency, according to students of the subject, is a previously overlooked cause of cost overruns in high technology projects. Problems in

Exhibit II-8

EVENT/EFFECT MATRIX

Effects of Events on Returns	Events or Conditions Which Are			Unknown
	Known	Risky (Probabilistic)	Uncertain	
Known	Events certain; their effects known	Events probabilistic; their effects known	Probability of events uncertain; their effects known	Not possible
Risky (Probabilistic)	Events certain; their effects are probabilistically	Events and their effects probabilistically certain	Probability of events uncertain; probability of effects uncertain	Not possible
Uncertain	Events certain; their effects uncertain	Events probabilistic; their effects uncertain	Probability of events and effects uncertain	Not possible
Unknown	Events certain; their effects unknown	Events probabilistic; their effects unknown	Probability of events uncertain; effects unknown	Events and their effects unknown

Source: California Management Review, Winter 1976, p. 76.

the development of one component cause unanticipated delays and difficulties in the development of related components and of the project as a whole. Hence, large cost overruns occur. Because so many interrelated components of the SPS will be developed at the same time, the research and development portion of this project and possibly its operations are prime candidates for overruns due to concurrency.

In conclusion, while all of the factors discussed in this section argue for great care in the interpretation of the existing estimates, there is no reason to conclude that the project is infeasible because of risk or a low initial return on investment. Neither is there reason to believe that it will be impossible to include a credible financial risk/return analysis in the final decision matrix.

A better conclusion would be that the financial case for the SPS is yet to be made, but that there is insufficient evidence to reject SPS as economically infeasible. Hence there is a great need to reduce the level of uncertainty and the unknown in the project before a final go/no go decision is made. How this may be done is a subject for further research and is discussed in Section IV of this white paper.

III. PROJECT FINANCE AND MANAGEMENT

The financing and management of any economic organization are inextricably intertwined for at least two reasons. First, the financial success of an enterprise is absolutely dependent upon the talents of management personnel, and upon the way in which the management function is structured in relation to the external and internal environment of the organization. Those who finance new ventures consider competent management as the most important single ingredient for success and will not finance a "second rate" management team.

Secondly, the finance function is a part of the management function. The financial manager is normally responsible for obtaining funds from external sources and monitoring their use in the firm. His management roles in planning and control are well accepted, and the organizational structure of the SPS must reflect these roles.

Furthermore, as the SPS evolves from an ever more complex research and development entity to a growing and finally mature operating business, its financial and management character and requirements will evolve together. In this section, SPS finance and management scenerios are examined at three stages of development--research and development, start up and early growth, and maturity. The Tennessee Valley Authority and COMSAT Corporation are presented as precedent models which may provide guidance to SPS planners.

FINANCING

Financing requirements for the SPS differ markedly at each of the three stages of SPS development. It follows that financing arrangements present differing challenges at each stage.

Research and Development

The financing requirements for the 17 year research and development effort are shown in Exhibit III-1 by phase. During the first six years of the project, annual requirements will remain below \$1 billion. Over the next seven years, they should not exceed \$6.5 billion. During the final four years, requirements will range from \$8.3 to \$11.3 billion.

Exhibit III-1

SATELLITE POWER SYSTEM
RESEARCH AND DEVELOPMENT
ANNUAL INVESTMENT REQUIRED
(\$ Billions, 1977)

<u>Year</u>	<u>Technology Development and Verification</u>	<u>Design Development, Test and Evaluation</u>	<u>First Unit</u>	<u>Total</u>
1	\$.2			\$.2
2	.5			.5
3	.8			.8
4	.9			.9
5	.9			.9
6	.7			.7
7	.5	\$ 1.2		1.7
8	.2	3.5		3.7
9		5.3		5.3
10		6.3		6.3
11		6.5		6.5
12		5.9		5.9
13		4.7		4.7
14		3.0	\$8.3	11.3
15		1.4	8.3	9.7
16		.2	8.3	8.5
17			8.3	8.3

Source: NASA

There is general agreement among those surveyed that the federal government (or perhaps a consortium of national governments) must underwrite all or the major portion of the research and development for the SPS. The dollar amounts, especially in the later years, are too large for the private sector in

this country to shoulder. Last year, for example, research and development spending in the private sector approximated only \$20 billion. The three leaders--General Motors, Ford, and IBM--spent only \$1.5, \$1.2, and \$1.1 billion respectively on their entire programs. After these companies, spending dropped rapidly. For example, the tenth largest expenditure for research and development was \$280 million, invested by IT&T.¹¹

In addition, the analysis in Section II of this paper shows the risk to be very high, the payoff period long, and the conservative best estimate of return to be rather low at this point in time. These attributes make the investment less than attractive to the private sector because the economic objectives of most major business firms are those of a good return, and steady growth in earnings per share and sales. It may be possible to engage in some cooperative research and development with private industry, especially if the results could be immediately beneficial in a related field in which the private firms were interested. The potential even here, however, may not be great.

The federal government's economic objectives, however, are different. They include (1) growth as measured by changes in the Gross National Product (GNP), (2) "full" employment as indicated by the Full Employment Act of 1947, (3) stability in the general price level, and (4) balance in the nation's international balance of payments.

To the extent that research and development on the SPS employs resources unutilized or underutilized in the economy, the program will contribute to a non-inflationary increase in GNP and employment. And since government and private investment have a multiplier effect on GNP, growth in the economy should be greater than the amount of the investment in research and development.

The end product of the research--a functioning SPS project--would have a potentially great impact on this nation's balance of trade. The balance of trade or net exports measures the difference between imports and exports and is a major element in the balance of payments. Exhibit III-2 displays the trade balance over the years 1973-1977.

Exhibit III-2

BALANCE OF TRADE: 1973-1977
(\$ Billions, 1977)

<u>Component</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
Exports	101.6	137.9	147.3	162.9	174.7
Imports	94.4	131.9	126.9	155.1	185.6
Net Exports	7.2	6.0	20.4	7.8	(10.9)

Source: Division of Research and Statistics, Federal Reserve System
Flow of Funds, 1-78.

An operational SPS network would greatly reduce U.S. reliance on foreign sources of power, thereby reducing imports. It could also represent a valuable resource that could be sold to countries in the rest of the world, thereby increasing exports. As such, it could help solve a problem with which this country must deal for as long as it remains a nation.

If the federal government chooses to finance the SPS research and development, two scenerios may be envisioned. First, the U.S. government may act alone. Secondly, it may seek some funding from other countries.

If the latter course is chosen, knowhow and trade secrets will have to be shared. And other countries may want to participate in construction of SPS systems. Hence, the opportunity for the U.S. to improve its economic positions--especially its balance of payments position--will be limited. On the

other hand, the project will be a drain on those of our resources which are employable in other functions; and if it fails, this country will pay the total price.

A further point should be considered. If a foreign country wishes to delay the implementation of the SPS, its best strategy could be to join the international organization and obstruct from within.

Start-Up

Since four years are required to build an SPS, start-up operations must begin at least four years before revenues are generated. The early and large capital investments, coupled with the relatively low returns from the few systems initially in operation, cause the first ten years of the project to be ones of heavy cash outflow. Exhibit III-3 displays the cash situation over the first ten years, which have been (arbitrarily) classified as the start-up years. The original conservative best estimate calculations from Section II have been used.

Exhibit III-3

SATELLITE POWER SYSTEM
ANNUAL NET CASH FLOW
(\$ Billions, 1977)

<u>Year</u>	<u>Net Cash Flow</u>	<u>Year</u>	<u>Net Cash Flow</u>
1	\$(6.0)	6	\$(18.5)
2	(12.0)	7	(16.0)
3	(18.0)	8	(13.3)
4	(24.2)	9	(10.5)
5	(20.9)	10	(9.5)

Source: NASA

According to those interviewed for this white paper, the U.S. government or a consortium of governments will probably be the only available

sources of finance for all or most of these ten years. The main reason underlying private investor reluctance to participate will be risk.

It seems reasonable to suppose that national and international political and social repercussions from the SPS will not be fully clear until the project has been in actual operation for a few years. Further, the technological and financial risks cannot be reduced to a minimum until the systems perform for some time.

Private sector companies are not capable of assuming the extent of risk that will be present in the start-up period. Much of the private capital for longer term investment is mobilized through large institutions such as insurance companies, banks, pension funds and the like. These organizations are precluded from large risks by government regulations and by the narrow range between their cost of money and the usual returns they can expect.

Undistributed profits of corporations constitute another major source of long-term investment capital. Usually, however, these funds are plowed back into their respective companies because the firms' long-range strategies call for them to invest in products and services closely allied to their present product lines.

Furthermore, large and high-risk investments endanger the capital structure of any firm, whether in the field of energy or not. Consider the following rough estimate of an electric utility company's capital cost as shown in Exhibit III-4. The cost of debt is assumed to be nine percent, but the calculation reflects deduction of a corporate income tax of 50 percent.

The weighted average cost of capital is 9.2 percent. If this figure is adjusted downward by, say, four to five percent to reflect the expectations about inflation built into it, real capital cost amounts to four to five percent. This cost includes a small amount (perhaps under three percent) to encourage suppliers of funds to invest rather than consume.

Exhibit III-4

HYPOTHETICAL ELECTRIC COMPANY, INC.
COST OF CAPITAL CALCULATION

<u>Capital Structure</u>	<u>Percent of Total</u>	<u>After Tax Cost*</u>	<u>Weighted Cost of Capital*</u>
Debt	50%	4.5%	.0225
Preferred Stock	10	9.5	.0095
Common Stock and Retained Earnings	40	15.0	<u>.0600</u>
TOTAL			.0920

*Not adjusted for inflation

The remaining one to two plus percent defines the average amount of risk capital suppliers expect the Hypothetical Electric Company to take. And this percentage is similarly low among all major U.S. corporations. For this reason, executives of large corporations are sometimes willing to invest hundreds of thousands and even millions in a highly risky venture with a high potential payoff; but they will not invest hundreds of millions or billions in a risky venture, even if the possible payoff appears to be enormous.

Nevertheless, funds will exist in the late 1990s and early 2000s to invest in SPS, if the investment vehicles are government guaranteed. In 1977, \$340.5 billion was raised in U.S. long and short term credit markets.¹² Corporations' cash flows totalled \$135.9 billion that year,¹³ and investment in plant and equipment amounted to \$137.0 billion.¹⁴ Public utilities spent approximately \$26.1 billion for new plant and equipment during 1977.¹⁵

According to a study published by the Edison Electric Institute,¹⁶ the real GNP will double between 1980 and the year 2000. If all the figures mentioned in the above paragraph were doubled to (roughly) indicate their future values in 1977 dollars, it is evident that the economy can deal with the negative cash flows generated by the SPS start-up.

Maturity

At some point after start-up, it may become feasible for private companies to invest in all or a part of one or more systems. The Rockwell International Study,¹⁷ based in part on conversations with Southern California Edison Corporation, postulated a situation whereby an SPS satellite would be owned and operated by the government, while the rectenna would be owned and operated by a consortium of private companies.

Consortia exist now for similar purposes. For example, the Washington Power Supply Corporation consists of 126 public and private utilities investing over \$4 billion in two nuclear plants. It is being financed by bonds at the rate of \$600 to \$800 million per year.

Some of those interviewed for this white paper suggested that, in addition, the larger non-power companies making extensive use of energy may wish to participate to ensure a source of supply. Large aluminum companies are one example.

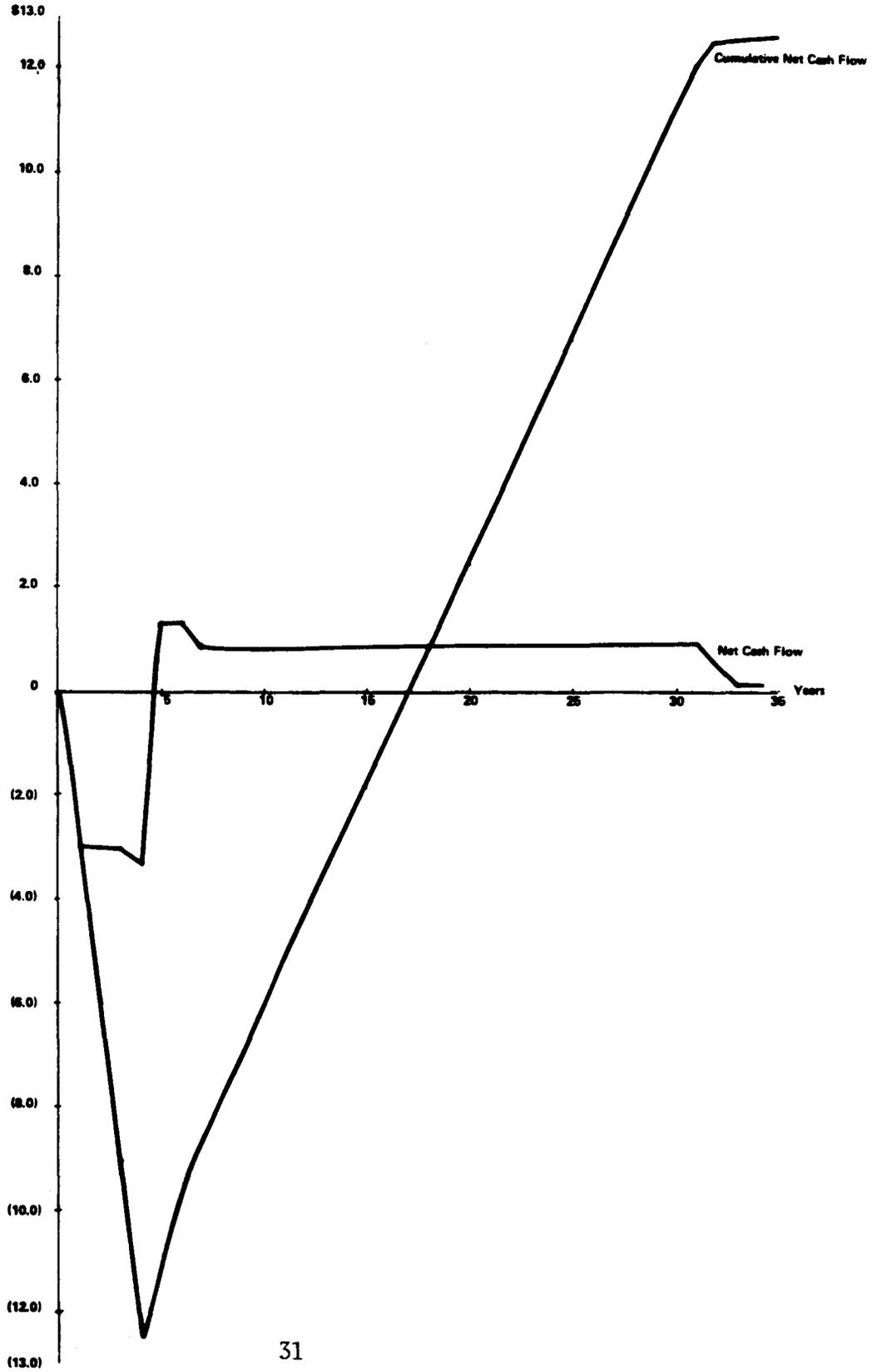
Nevertheless, financing a complete SPS from the private marketplace may represent a supreme challenge to the financial community even in, say, 2010 when the U.S. economy could be three times its current size. To explain this view more fully, some perspective is necessary.

Based upon the NASA best estimate data, a \$12 billion SPS will be built over four years, necessitating a cash outflow for construction of \$3 billion per year. As Exhibit III-5 indicates, total investment will slightly exceed \$12 billion, and will not be fully recovered until 17 years later.

Three billion dollars per year per system is a large sum, if capital must be mobilized by private means. A typical public utility common stock placement today is around \$50 to \$75 million. Few common stock offerings in any industry exceed \$100 million--the recent offering of two million shares of Phillip Morris at \$66 per share being a rare exception.

Exhibit III-5

SATELLITE POWER SYSTEM
CASH FLOWS AT \$.04/KWH
(\$ Billions, 1977)



The recent corporate debt financing of \$250 million by General Motors is considered very large by today's standards. The largest tax exempt bond issue in memory was \$440 million according to one expert in the field. The Washington Power Supply Corporation example, then, is apparently an exception.

These figures are meant only to suggest that new ways or new combinations of old ways of private financing will need to be devised if the private sector is to participate in any meaningful way in SPS financing. This holds even if the figures are tripled to represent real growth in the economy over the next 25-30 years.

One such new scenerio would be for government to finance an SPS and then to sell or lease all or part of it to a private venture with payment over an extended period--say, 10 to 30 years. Another would be a joint venture partnership between government and industry with each providing some cash and resources, the amounts to be determined through negotiation.

On the other hand, why involve the private sector at all? The government has taken all the risk in development of the SPS. Why should private enterprise now step in at project maturity and reap the profits?

There is no firm evidence now that private sector management would do a better job than managers on the payroll of a public corporation. As one author points out: "Examples can be adduced to support a case for either side of the argument. . . . No conclusion is justified."¹⁸ And there is no evidence that decentralized management by private enterprise of individual SPS units would be more efficient than centralized management of the total system.

Moreover, there is ample precedent for government or public enterprises of this kind. The government developed the Alaska Railroad, pioneered crop

insurance, and began providing rural electricity because the private sector saw little profit in these ventures. The government financed the Panama Canal and river developments because of their high initial costs and great risks. And it has stepped in for purposes of resource conservation to preserve the nation's grazing lands and forests and to provide irrigation. The government developed atomic energy at great economic risk and manages its use in defense because the national security role outweighed pure economic considerations.¹⁹

In short, a strong case can be made for excluding the private sector. But there are counter arguments; and here are three:

First, if great economic profits are to be reaped from the SPS at maturity, and the private sector is to be involved, the federal government as the representative of the people who took the development risks can ensure that the people enjoy the benefits in one of two ways: (1) regulatory agencies could limit the profits of the enterprise by regulating the price, and (2) the government could license the technology to industry, charging a fee that would limit the profit of private entrepreneurs.

Second, the U.S. developed under a tradition of free enterprise, hampered as little as possible by government "interference." This tradition is still a strong one in the minds of the U.S. citizenry.

Third, public corporations in this country--with the exception of the TVA, the Federal Reserve Board and the Federal Deposit Insurance Corporation--are subject to Civil Service. And all public corporations must have their administrative expenses (a key area) approved by Congress and the Bureau of the Budget. They are not free of political control, and political control may sooner or later corrupt economic efficiency.²⁰ Lord Acton's famous admonition about power tending to corrupt and absolute power tending to corrupt absolutely may be worth keeping in mind.

In any case, the question in one important sense is not whether the SPS is financed and owned by government or private enterprise. Private enterprise will in fact constitute the major portion of the SPS totality unless the government enters the subcomponent manufacturing and fabrication business in an unprecedented way. And even if private enterprise were to own the entire system eventually, it would be regulated by the government in the public interest.

As Exhibit III-6 illustrates, the entire system at each stage consists of a vast number of contractors, subcontractors and suppliers in a large and complex hierarchy. The satellite, rectenna, transportation, and assembly portions of the SPS which have appeared as costing elements of the system represent only the tip of the iceberg or pyramid. While it is true that the tip of the pyramid regulates and controls the remainder, it is also true that the tip is limited, directed and shaped by the base upon which it rests.

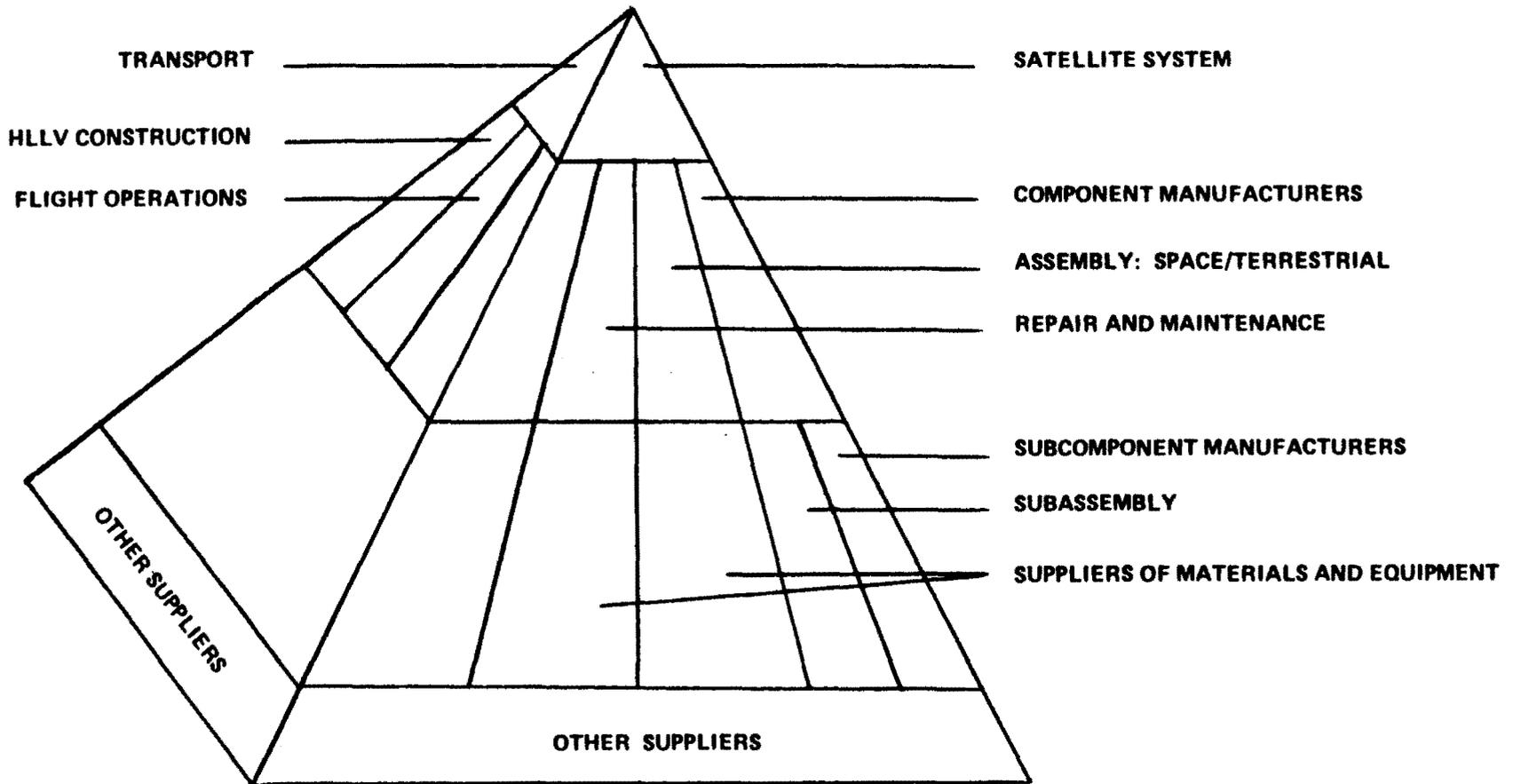
MANAGEMENT

The key to successful management of the SPS project will be the ability of its executives at each stage of SPS development (1) to relate the entire SPS pyramid to the external environment, and (2) to relate the tip of the pyramid to its remainder. Role models now exist suggesting that favorable external relationships can be developed on a national and international scale. The Tennessee Valley Authority and COMSAT Corporation are two which are briefly reviewed here. Then, the questions of internal organizational management and design are considered.

The External Environment

TVA was organized in 1933 as an independent government owned corporation which was, in the words of President Roosevelt, "charged with the broadest duty of planning for the proper use, conservation, and development

Exhibit III-6
SPS MANAGEMENT HIERARCHY
AN ILLUSTRATION



of the natural resources of the Tennessee River drainage basin and its adjoining territory. . . ."21 This was seen as a unified and systematic regional program with headquarters located in the area so that interaction with state and local agencies, businessmen, and farmers could be facilitated.

Today it is involved in a variety of activities including the provision of over 100 billion kilowatt hours of electricity per year, water management, agricultural and chemical development, and research. TVA is funded by the federal government, but its Office of Power has been self-supporting from electricity revenues.²² An organizational bulletin is appended to this paper.

Communications Satellite Corporation (COMSAT) was incorporated in 1963 to carry out the congressional mandate to establish, along with other participating countries, a commercial communications satellite system which would span the globe. The company was capitalized through the sale of \$200 million in common stock on the public market in 1964.²³

In August, 1964, the International Telecommunications Satellite Organization (INTELSAT) was formed as a joint venture among 19 countries. By August, 1977, 98 countries had joined. Each signatory to the operating agreement may own an investment share in INTELSAT that equals its percentage of system use. Shares may be traded among signatories.

COMSAT owned about 25 percent of INTELSAT as of December, 1977, and is the largest shareholder. COMSAT also provides operational and technical services to INTELSAT under a management contract.

COMSAT General, a wholly owned subsidiary, provides maritime satellite communications through its MARISAT system and is a partner in Satellite Business Systems which is developing an all-digital domestic satellite system. COMSAT General also leases capacity of its COMSTAR satellites to AT&T for U.S. domestic communications.²⁴

In-depth analyses of the management of these and other models (both successful and unsuccessful) is beyond the scope of this white paper. It seems clear, however, that TVA and COMSAT have maintained good relationships with their external publics because they perform vital services, are well managed, and take pains to maintain a good image. In the case of COMSAT/INTELSAT, furthermore, voting power in the international body is exercised on the basis of financial participation through share ownership. And ownership is open to all who use the system.

The Internal Environment

The objective of the SPS research and development stage will be to place a five gigawatt system in operation in 17 years given a budget. This is a unique, one time effort and the functional organization that undertakes it will either disband altogether or change dramatically when the objective is reached. The task is complex, dynamic, and interdisciplinary. The basic orientation is scientific.

At start-up, most of this will change. The objectives will be (1) to establish domestic and international markets for electrical power, and (possibly) markets for SPS units, and (2) to produce, install and (possibly) manage SPS units in response to the demand. This is a continuing, often repetitive effort requiring an entrepreneurial spirit. Survival and rapid growth will be key issues. The basic orientation will be towards marketing.

As the project matures, the objectives will remain the same, but the emphasis will move somewhat away from marketing towards production. Problems of control and budgeting will replace those of survival and rapid growth as the key issues. Functions and tasks will vary only slightly over time, but will remain complex and technical. Entrepreneurial management will give way to a more steady state managerial style, and the environment will become more predictable.

It is clear that the type of organization structure and management style appropriate for one stage will not do for another. Furthermore, the organizational structure best suited for the overall organization of one (or all) SPS units should not be duplicated in exact detail at every level and functional area in the pyramidal organization. Obviously, the research and development department should not be structured exactly like the overall company, nor should it resemble the organization that manufactures solar power cells, or the one that fabricates satellites in space. None of these will look exactly alike.

In developing an organization, it is important to observe that structure will vary depending upon how objectives and policies are set. If objectives and policies are established on high in great detail for each functional unit, the organization is centralized. If broad strategy is established at the top, but the responsibility for setting goals and policies consistent with the strategy is centered at lower levels, the organization is decentralized.

Obviously, centralization is a matter of degree rather than kind. However, smaller companies and divisions of larger companies with a relatively small number of products tend to be more centralized than large diversified companies with many product lines. The TVA organizational structure described in the appendix appears to be decentralized, at least at the higher levels.

Structure also depends upon the nature of the work and how it is carried out. When job descriptions and procedures necessary to perform and carry out tasks are detailed, concrete and inclusive; and when line officers see themselves as decision makers who issue instructions; a formal structure is being defined. Behavior tends to be task-oriented and formal. This type of organization most closely resembles the rational bureaucracy invented by

the military and is found most often in companies where the technology is not complex.

At the other extreme is the informal organization, where leadership is based on knowledge or a specialized skill. This type of management has been termed democratic or ad hoc. It may be found in scientific laboratories or elsewhere where those who do the work also coordinate with others and integrate their work with that of other units.

At its extreme, informal management envisions a continuously changing technology and job structure, where planning is performed by anyone with the relevant knowledge to do so. The term often associated with this form is team management.

Between the extremes of formal and informal is a type of structure termed project management, which involves one or more individuals developing a team to perform a task or function within the framework of the larger organization. The project manager uses resources from several functional departments in a centralized organization to produce and market a unique product on a one-time-only basis. He cuts across the normal organizational structure and develops strong lateral working relationships. This form is often found in the construction industry, for example.

The matrix organization is found in less centralized companies, and it functions like project management. However, relationships across the organizational structure are generally less formal and lasting. Aerospace companies typically use this form of organization on their contract work.²⁵

The relationships between goal setting and the way work is carried out is displayed in Exhibit III-7. While it is not feasible at this point to design a structure or structures for SPS, it is nonetheless possible to make some brief generalizations to relate the foregoing to the SPS project.

Exhibit III-7

Setting of Objectives and Policies

<u>Organization of Work</u>	<u>Setting of Objectives and Policies</u>	
	<u>Centralized</u>	<u>Decentralized</u>
Formal	Rational or Mechanistic	Structurally Decentralized*
Mixed	Project Management	Matrix Management
Informal	Democratic	Team or Group Management

*Referred to in small organizational units as "operating job enrichment" or "horizontal job enlargement," and in large organizations and companies as profit center decentralization.

It is very likely that the federal government will sponsor the research and development of the SPS--at least the technology development and verification portion. Furthermore, it is unlikely that the one government agency in charge will be either willing or able to do much of the actual work itself. Hence, one can envision a relatively small government coordinating group at the top of a research and development pyramid.

This coordinating group will be controlling a decentralized organization made up of other government units and private organizations which appear capable of meeting its strategic goals. Most of the units it will contract with will be organized along matrix/group management or project/democratic lines, depending upon the size of the subcontracting organization. (A large subcontractor such as a major aerospace firm is more likely to be decentralized and therefore to use a matrix approach.)

When and if the SPS becomes operational and mature, there are many forms it may take. For example, four separate entities may be created that operate semiautonomously, providing (1) transportation, which is purchased by (2) a satellite manufacturing company whose sales and service are handled

by (3) a management firm selling to (4) individual or group owners of rectenna farms.

Or, the entire SPS project could be owned or managed by a government or multinational government agency. In this case, the organization may be structurally decentralized at the higher levels. Alternatively, it may be more efficient (at least initially) to treat each SPS as a project, using project management techniques across such functional specialities as transportation, satellite construction, rectenna construction, and operations and maintenance.

The system, or parts of it, might later be transferred to private hands through a lease or buyout arrangement over time. In such case, the government would act as a regulatory body and the organization structure would change again.

How ownership and management develops in practice over the life of the SPS project will depend to a great extent on several factors. One is the political/social realities of the SPS. Will other nations permit the U.S. to build and operate it alone? Does the U.S. government deem it politically desirable to work with other countries? Will political pressure force the project partially or completely into private hands, or will the reverse occur?

Another factor is the stage of development of the project, whether research and development, start-up, or maturity. What will be the public/private mix in the SPS pyramid at each developmental stage? How will the pyramid itself and each element in it be structured, organized and financed?

A third is the quality and nature of project leadership at each stage. A strong leader can exert considerable influence on the goals, organization structure, and international position of the project.

A fourth factor--closely related to the others--is the overall organizational design of the program.

Definitive answers to these and other related questions must await further research. Some of the directions this research should take is the subject of the following section.

IV. FURTHER RESEARCH

Further research in the finance/management scenerio area should have as its objectives (1) reducing uncertainty and unknowns in the SPS project as a whole, and (2) planning for the research and development stage of the project, particularly its technology development and verification phase. The first objective is necessary as a continuing part of overall project feasibility analysis.

The second objective is required for success in meeting stage one objectives and must be completed before a go/no go decision is made on the technology development and verification phase of the SPS project in 1980. Otherwise, if a go decision is made, unnecessary delays for planning will be introduced into the system.

REDUCING UNCERTAINTY AND UNKNOWNNS

Reducing finance and management uncertainty and unknowns in the overall SPS project involves (1) identifying and evaluating the events and conditions which may effect the project, (2) estimating their impact on project cash flow and on management, and (3) determining what steps may be taken at what cost to counter undesirable events and conditions and to take advantage of oportune ones. The following research projects will help reduce uncertainty and unknowns.

Industry Analyses

Cost analyses have been done on the various components of the SPS pyramid to provide initial cost inputs for project feasibility analyses. And a detailed work breakdown structure has been established to describe the system.²⁶

The next step is to examine in more detail the industries and companies which will be contractors, subcontractors and suppliers to the system. The purpose of the examination should be:

1. To identify the industries and the companies in each industry that will supply the goods and services needed for each of the three phases of SPS development and to identify their position in the organizational pyramids for each phase.
2. To identify potential bottlenecks in the system. Can the companies currently in each industry identified in (1) supply the requisite goods and services on time at the expected price? If the price is found to be higher or lower than expected, how will this affect overall SPS financial feasibility? Do these companies have a ready availability of sufficient labor and raw materials? Will more plant capacity be needed? Will more managers need to be trained? Can expansion be financed out of retained earnings or will prepayments and additional private or public financing be required?
3. To recommend steps that can be taken now and in the future to eliminate the potential bottlenecks. This should include an analysis of concurrency potential and recommendations for system redundancy to limit the risk of concurrency.
4. To provide a competitive analysis for product selection in cases where more than one company can provide an essential good or service.
5. To recommend the most efficient and effective organizational structures at each point within the organizational pyramid at each phase of SPS development. An intensive review of the experience of such organizations as COMSAT Corporation and TVA would be helpful in making these recommendations.

These studies should be performed in considerable detail in 1979 for the research and development phase of the project, since they would be of immediate value in the event of a decision to begin work on the SPS in 1980. Sufficient information must be gathered by 1980 for the other two phases (start-up and maturity) to provide a further in-depth look at SPS economic feasibility and to determine what must be done now to ensure achievement of objectives 17 plus years from now.

One approach to these studies would be to identify the key government agencies, firms, and industries involved, and then to prepare investment memoranda or business venture proposals for each product or service where expansion or new product development is necessary. These proposals would describe the new venture or expansion, present a plan for its implementation, and show its feasibility by means of cash flow and risk analyses. At some point a political/economic evaluation would have to be made to determine whether the product or service should be provided by private industry or the government.

A standard approach to competitive analysis is a matrix showing competitors across the top and selection criteria such as cost, quality, design characteristics, delivery schedules, and so on down the side. Such an approach could be modified for SPS purposes.

These analyses, done for each stage of SPS project development, can be brought together in constructing effective and efficient organizational frameworks or SPS pyramids. These pyramids may then be examined for economic and political feasibility.

Analyses of Alternative Systems

A major risk of the SPS is the opportunity cost if it is selected when in fact an alternative system would deliver the same amount of power at a lower cost while meeting all other constraints. Currently, studies are being undertaken to evaluate non-SPS power systems including wind, power from the ocean, and so on.

Opportunity cost would also be incurred if the approach taken to SPS development was more expensive than a known alternative. For example, in Section II it was noted that recent studies have indicated that the manufacture of SPS units at a moon based space manufacturing facility from lunar

materials is technically feasible, and that it is logistically feasible to implement it. Financial and economic analyses currently in progress may show a higher return on investment and a shorter payback period for this alternative compared with the one analyzed in this white paper.

To minimize the risk of incurring substantial opportunity cost, alternatives should be compared on a common set of criteria and constraints. Externalities associated with each alternative should be included in the analysis.

The first step in developing such an analysis would be to establish a common set of criteria, constraints, and ground rules against which each alternative can be measured. These might be weighted if weighting appears feasible and useful. Then, data for each alternative would be cast into the established criteria/constraints framework and compared, taking into account externalities. Finally, the best approaches would be selected and tradeoffs made among criteria, constraints and externalities where appropriate. In this way a proper mix of power alternatives for the period 2000AD and beyond may be developed.

Sensitivity Analysis

The cash flow and return on investment analyses showed that SPS project attractiveness was particularly sensitive to three factors above and beyond variances in system cost:

1. Whether the enterprise would be subject to taxes.
2. Whether the SPS project should be expected to show a return on its research and development costs as well as its operations.
3. Radical changes in the real price of electricity. (An increase from \$.04 to \$.10 per kilowatt hour was tested.)

The first two factors have political as well as economic implications which should be examined. The benefits and disbenefits of including taxes and research and development costs should be enumerated and analyzed, and recommendations made.

An in-depth analysis and forecast of power pricing over the years 2000 to 2060 should be made under several applicable alternative scenerios. These estimates should be introduced into the continuing feasibility analysis of the project.

Finally, a search should be made for other conditions and events which will effect SPS project cash flow. These should be tested in a cash flow model on a basis consistent with the others.

RESEARCH AND DEVELOPMENT MANAGEMENT

The industry analyses research project recommended earlier in this section will provide data for the structuring of the SPS organizational pyramid at each stage of project development. This "bottom up" approach is essential for good organizational design as well as for planning and feasibility analysis.

However, the research and development phase of the project cannot await the results of this study before beginning a systematic search for competent management talent to direct and control the project. Furthermore, the structure of the organization itself will reflect the style of its chief executive officer and his associates. A "top down" approach to executive selection and to selection (or creation) of an administrative agency should begin immediately.

The first step should be to define the functions and the tasks and subtasks to be carried out by the SPS research and development administrative structure. The output of each task and subtask should be defined as

carefully as possible, and the user of the output and his requirements identified. This will keep unnecessary reports and other activities to a minimum. When the tasks are known, an estimated budget for each function can be developed.

At the same time, functions can be grouped according to their similarities. Individual functions and groups of functions will form the organization structure and the basis for selection of management personnel. In effect, the functions become job descriptions.²⁷

For each job description, a set of personal requirements including education, experience, and so on should be developed. These requirements may be divided into mandatory and non-mandatory, and even weighted if desired. In addition, for each job description, a set of personality characteristics should be developed. The job description, personal requirements and personality characteristic sets become the profile used to seek qualified candidates for each position.

Researchers in this study should work closely with those doing the research and development industry analyses so that the "top down" approach will mesh with the "bottom up" approach. In this way, correct structuring for coordination and control of the research and development pyramid may be assured.

Researchers also must work very closely with DOE officials responsible for the project. The SPS project management team, when selected, will be working with these officials and they will have an important input into executive selection.

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ORGANIZATION OF THE TENNESSEE VALLEY AUTHORITY

The Board of Directors approved the following statement of organization for the Tennessee Valley Authority to be effective January 4, 1976. It supersedes the organization statement effective July 1, 1975.

The Board of Directors, under the TVA Act, is vested with all the powers of the Corporation. The Board establishes general policies and programs; reviews and appraises progress and results; approves projects and specific items which are of major importance, involve important external relations, or otherwise require Board approval; approves the annual budget; and establishes the basic organization through which programs and policies are executed.

The General Counsel advises the Board on legal matters. He, or the representative he designates to act in his absence, serves as Secretary to the Corporation.

The General Manager is the principal TVA administrative officer. He serves as liaison between the Board and the offices and divisions in the handling of matters of Board concern, and is responsible for coordinating the execution of programs, policies, and decisions which the Board of Directors approves or adopts. He brings before the Board matters which require its consideration or approval; assists the Board in presenting the TVA budget to the Office of Management and Budget and to Congress; affirms to the Board the adequacy of staff coordination and contribution in matters presented for its consideration, including judgments relating to broad public consequences, social and economic effects, and planning and program direction; interprets the Board's instructions to the offices and divisions; originates or approves administrative controls to ensure integrated execution of the total TVA program; and reports to the Board on overall efficiency, effectiveness, and economy of TVA operations.

The General Manager assigns duties and makes delegations to the TVA offices, divisions, and staffs in their execution of programs and policies which the Board of Directors adopts, subject to such controls as it may establish. He reviews and approves major TVA management methods, major organization changes within offices and divisions, and major staff appointments, and recommends to the Board basic changes in the TVA organization. He is responsible for ensuring that appropriate matters are presented in coordinated form to the Board at the proper time and that the Board has pertinent related information. He provides for the formal definition and communication of TVA programs, policies, procedures, and continuing delegations of authority and responsibility.

The Office of the General Manager includes the Planning Staff, the Budget Staff, the Information Office, the Equal Employment Opportunity Staff, the Washington Office, the Power Financing Officer, and such other assistants as the General Manager may require to perform specialized duties or to aid him in expediting, coordinating, and disposing of current business. The functions of the above groups are set out in the Organization Bulletin, "Office of the General Manager" (I GENERAL MANAGER).

I TVA

The Division of Finance formulates, recommends, administers, and evaluates policies related to accounting, auditing, financial reporting, and the handling of TVA funds; establishes systems of accounting and internal control, including accounting controls over TVA property and other assets; develops related instructions and procedures; and advises and assists on matters pertaining to these functions. It performs accounting and administrative work for the TVA Retirement System.

The Division of Law handles all litigation, legal proceedings, claims, and other legal problems relating to TVA's activities; advises and assists on legislative matters in which TVA has an interest; gives legal advice, opinions, and assistance; and prepares or approves and construes all documents affecting TVA's legal relationships.

The Division of Personnel formulates, recommends, administers, and evaluates policies in the field of personnel administration, including those related to recruitment, selection, classification, compensation, and training of personnel, union-management relations, organization, administrative relations, personnel management information, and related aspects of personnel administration; conducts negotiations with unions representing employees; develops personnel standards and procedures; and advises and assists in the handling and execution of matters and actions related to TVA personnel administration.

* The Division of Property and Services develops, recommends, and carries out plans, policies, and activities related to acquisition, transfer, and disposal of real property; administration of TVA lands not managed by program divisions; operation and upkeep of dam reservations; site planning and landscape architectural services; property protection and law enforcement; and visitor information at appropriate TVA properties. It provides specialized services on TVA lands and reservations for other programs when in the interest of efficiency and economy. It formulates, recommends, administers, and evaluates policies related to the provision of computing and systems development services; transportation services; coordination of nonmilitary defense measures, employee housing assistance, and offices services, and analyses of office systems; and develops related standards and procedures, and advises and assists in their application and use.

The Division of Purchasing formulates, recommends, administers, and evaluates policies relating to the procurement, shipping, transfer, and disposal of equipment, materials, supplies, and services, except personal services; and issues instructions and advises and assists on matters related to the application of these policies.

The Office of Agricultural and Chemical Development formulates, recommends, and carries out plans, policies, and programs for research in and development of experimental new and improved forms of fertilizers and processes for their manufacture; for testing and demonstrating the value and best methods of fertilizer use as an aid to soil and water conservation and to improved use of agricultural and related resources; for developing, operating, and maintaining facilities to serve as a national laboratory for the dual purposes of research in chemistry and chemical engineering in the development and production of experimental fertilizers and the design and testing of improved manufacturing processes, and for the production and provision of basic chemical materials and services in the munitions field essential to national defense; for readjustment of agricultural areas affected by TVA operations; and for related activities having to do with the management and use of agricultural resources and with national defense.

*Revision

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The Office of Engineering Design and Construction participates in the planning and provides or obtains the architectural treatment, engineering design, and construction of all permanent structures and permanent engineering works which are authorized to be built in the TVA program, in accordance with the requirements determined by the offices and divisions having program responsibilities for such structures and works, except for power transmission, distribution, and communication facilities and switchhouses at substations not adjacent to generating stations; and provides other engineering, architectural, and construction services as feasible and economical.

The Division of Environmental Planning recommends, develops, coordinates, and carries out programs and activities related to TVA's interests in environmental quality of the region. It reviews and evaluates the environmental impact of programs and activities proposed and carried out by other offices and divisions and provides technical guidance and assistance as needed to assure that appropriate environmental protection features are planned and implemented. It conducts field monitoring and environmental quality studies and investigations at TVA installations. It provides environmental data and technical assistance to state and local agencies. It coordinates and administers environmental research and demonstration projects carried out by TVA in cooperation with other agencies and organizations. It serves as TVA's liaison with other governmental agencies concerned with environmental planning and protection. In collaboration with other divisions, it develops and applies programs to assess and control potential hazards in the work environment of TVA employees.

The Division of Medical Services develops, recommends, and executes plans and policies related to the health of employees and of the public affected by TVA activities, and to TVA's interests in community health education and health planning. It participates in medical research and development activities, demonstrations, and other cooperative activities with Federal, state, and local agencies and other organizations.

The Office of Power develops, recommends, and appraises objectives, plans, policies, and programs, and carries out approved policies, programs, and activities for the generation, transmission, and utilization of electric power; forecasts future needs of the power program and plans means and methods of meeting those needs; and cooperates with other TVA organizations in carrying out TVA's multiple-purpose programs involving power activities.

The Office of Tributary Area Development administers TVA's interests in comprehensive activities designed to obtain maximum economic progress in tributary areas of the Tennessee Valley region. It works with state and Federal agencies and with local governmental and citizen groups in organizing for, planning, and carrying out unified resource development programs in individual areas. It administers contracts for related studies and demonstrations. It coordinates the participation of other TVA offices and divisions in all stages of tributary area planning and development.

*The Division of Forestry, Fisheries, and Wildlife Development formulates, recommends, and conducts investigative and development programs in forestry, fisheries, and wildlife, directed toward maximum sustained production and use of these resources for their contribution to the regional economy and environment. It plans and administers Land

*Revision

I TVA

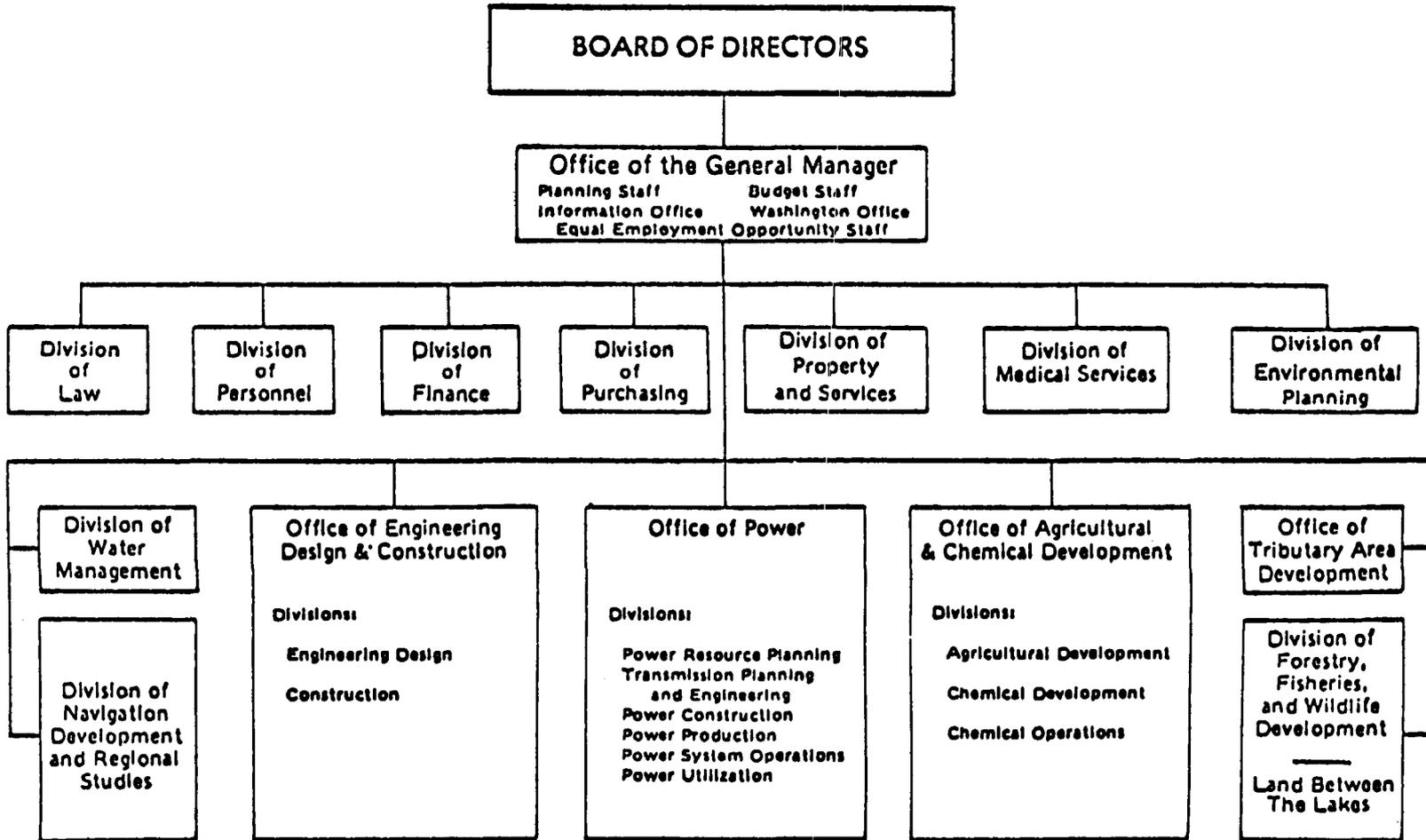
Between The Lakes to demonstrate social, economic, and other benefits in unified development and management of these and other natural resources for large-scale outdoor recreation and environmental education uses. It develops, recommends, coordinates, and carries out plans, policies, and activities related to development of Valley recreation resources. It maintains cooperative relationships with Federal, state, and other appropriate agencies and industries concerned with these resources.

The Division of Navigation Development and Regional Studies develops, recommends, and carries out plans, policies, and programs for the navigation engineering development of the Tennessee River system and for its full and effective use in development of the region; conducts studies and research and advises and assists the General Manager, offices, and divisions on social, economic, and governmental relationships, and regional planning problems and opportunities of importance to development of the region; and performs related activities.

The Division of Water Management provides a comprehensive program of water resources management in the Tennessee Valley region which includes flood damage abatement and the scheduling of releases from all TVA-owned and TVA-operated reservoirs in accordance with the TVA Act, taking into consideration all essential objectives of water resources management such as flood control, navigation, power production, water quality management, water supply, and recreation. It provides specialized services which include the development and operation of environmental monitoring systems, engineering geologic investigations, land approvals, topographic mapping, engineering surveying, engineering laboratory research and testing, and hydrologic and hydraulic research activities.

ORGANIZATION OF THE TENNESSEE VALLEY AUTHORITY

JANUARY 4, 1976



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	Chattanooga, TN	" 615-755-3011	FTS 8-854-3011	Zip 37401
	Muscle Shoals, AL	" 205-383-4631	FTS 8-872-8631	Zip 35660

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Chairman	S. David Freeman, Knoxville, TN
Director	Vacant
Director	Vacant

ADMINISTRATIVE STAFF

Acting General Manager	H. N. Stroud - Knoxville, TN
Assistant to the General Manager (Planning, Budget and Systems)	
Chief, Planning Staff	John S. Barron " "
Chief, Budget Staff	David A. Patterson " "
Director of Information	David T. Shereda " "
Power Financing Officer	John Van Mol, Jr. " "
Washington Representative	James R. Durall, Chattanooga, TN
Director of Equal Employment Opportunity	Lawrence L. Calvert, Washington, DC
	George White, Knoxville, TN
General Counsel	Herbert S. Sanger, Jr., Knoxville, TN
Comptroller	Willard R. Stinson " "
Director of Personnel	Robert J. Betts " "
Director of Property and Services	John S. Rozek " "
Director of Purchasing	James L. Williams, Jr., Chattanooga
Director of Forestry, Fisheries, and Wildlife Development	Thomas H. Ripley, Norris, TN
Manager of Land Between The Lakes	Frank R. Holland, Golden Pond, KY
Director of Navigation Development and Regional Studies	Minard I. Foster, Knoxville, TN
Director of Tributary Area Development	H. Peter Claussen " "
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Acting Director of Environmental Planning	Harry G. Moore, Chattanooga, TN
Medical Director	Robert L. Craig, M.D. " "
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Director of Construction	Horace H. Mull " "
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Assistant Manager of Power	Jack E. Gilleland " "
Manager of Power Operations	E. Floyd Thomas " "
Manager of Power Planning	H. G. Parris " "
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Director of Power Construction	Joe Neal Benson " "
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Director of Power Resource Planning	James P. Darling " "
Director of Power System Operations	John P. DeLong " "
Director of Power Utilization	Albert O. Daniels " "
Director of Transmission Planning and Engineering	Frank W. Smith " "