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ECON INCORPORATED

(NASA-CR-162388) THE REQUIREMENTS AND FEASIBILITY OF BUSINESS PLANNING IN THE OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS (ECON, Inc., Princeton, N. J.) 265 p HC A12/MF A01 CSCL 12B G3/66

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THE REQUIREMENTS AND FEASIBILITY OF BUSINESS PLANNING IN THE OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

Prepared for

National Aeronautics and Space Administration
Office of Space and Terrestrial Applications
Washington, DC

Prepared by

ECON, Inc.
900 State Road
Princeton, NJ 08540

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March 22, 1979

NOTE OF TRANSMITTAL

This study examines the desirability and feasibility of applying strategic business planning techniques, developed and commonly used in the private sector of the economy, to certain programs in the Office of Space and Terrestrial Applications, of the National Aeronautics and Space Administration.

The Principal Investigators for this study and the authors of this report were Mr. Joel S. Greenberg and Mr. B. P. Miller. Ms. Celia Drumheller and Mr. Gregg Fawkes assisted in the review of the programs that could be candidates for business planning.

The NASA Technical Officer for this study was Dr. Irvin D. Reid, Technology Transfer Division, Office of Space and Terrestrial Applications. While many members of the staff of the Office of Space and Terrestrial Applications provided input data to this study, the authors are particularly indebted to Dr. Reid for his guidance and careful review of the many drafts of this report.

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Director, Techno-Economic Analyses

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ABSTRACT

Strategic business planning is widely used in the private sector to anticipate and support the decisions that must be made by management as a corporate program proceeds through the stages of RD&D, production and sales. This study examines the feasibility of applying strategic business planning techniques that have been developed and used in the private sector to the planning of certain projects within the NASA Office of Space and Terrestrial Applications. The study examines the methods of strategic business planning that are currently in use in the private sector. The typical contents of a private sector strategic business plan and the techniques commonly used to develop the contents of the plan are described, along with modifications needed to apply these concepts to public sector projects. The current long-range planning process in the Office of Space and Terrestrial Applications is reviewed, and program initiatives that might be candidates for the use of strategic business planning techniques are identified. In order to more fully illustrate the information requirements of a strategic business plan for a NASA program, a sample business plan is prepared for a hypothetical program--The Operational Earth Resources Satellite program. The study concludes that it is both desirable and feasible to apply many of the methodologies used for strategic business planning in the private sector to certain RD&D programs in the Office of Space and Terrestrial Applications. Specific actions to improve the capability within the Office of Space and Terrestrial Applications to perform strategic business planning are recommended.

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1. INTRODUCTION

The National Aeronautics and Space Administration (NASA) is engaged in research, development and demonstration (RD&D) in aeronautics and space technology and systems, as well in the operation of the space transportation system. As a major part of NASA, the Office of Space and Terrestial Applications (OSTA) plans and manages that part of the NASA RD&D program that is concerned with the practical and beneficial application of space systems and technologies. While some of the RD&D performed by OSTA is basic or general, much of it is intended to demonstrate the technical or economic feasibility of using technology or systems developed by OSTA in a manner that could provide economic or social benefits to the United States as a nation and to the taxpayers that provide the funds for this RD&D.

In fulfillment of this responsibility, OSTA has performed RD&D on technologies and systems for the observation of the atmosphere, oceans and land masses to provide information that could be used to improve environmental forecasting and the management of the earth's resources. This RD&D has resulted in operational environmental satellite systems, such as TIROS and SMS/GOES, and development and demonstration satellite systems such as LANDSAT and SEASAT. The desirability of operational versions of these latter two satellite systems is currently being studied by NASA and other federal agencies. Similiarly, OSTA has performed RD&D on space communications technologies and systems, and operational communications satellite systems now are used for both domestic and international trunking communications. In recent years, OSTA has also become increasingly involved in RD&D to use the environment of space to perform

materials processing operations and produce materials products that cannot be made in facilities on the surface of the earth. Space materials processing has yet to attain operational status.

Under the ground rules that have been used since the estalishment of NASA in 1958, OSTA does not operate the systems that are supported or derived from its RD&D. These systems are operated by other federal agencies or by organizations in the private sector, and OSTA continues to perform RD&D to enhance and extend the capabilities of these systems. The operational environmental satellite systems are operated by the National Oceanographic and Atmospheric Administration (NOAA), while the operational communications satellite systems are operated by the COMSAT Corporation and by various communications common carriers in the private sector. Thus, in these applications, the results of NASA RD&D have been successfully transferred, in the first instance to another federal agency and in the second instance to the private sector. If the present and future RD&D performed by OSTA is successful, and the benefits of the resulting systems can be demonstrated, it is likely that this process of technology transfer from OSTA to other federal agencies and the private sector will continue.

The history of the OSTA applications satellite programs supports the fact that the time required to progress from NASA-sponsored RD&D to an operational system upwards from five years. The TIROS program had its inception in 1958 and the first operational TIROS flew in 1965. Communications satellite research began in the early 1960s and the first operational commercial communications satellite flew in 1965. RD&D in support of earth resources observations began in 1968 and in 1979 the LANDSAT program is still considered to be operating in a demonstration phase. RD&D in support of ocean observations begain in 1973 and an operational demonstration of a National Oceanic Satellite System is now planned

for 1985. In each of these programs, the time period from the beginning of federally-sponsored RD&D to the beginning of operations is a minimum of about five years. It is interesting to note that the two applications in which technology transfer has successfully taken place, namely environmental observations and satellite communications, both occurred about 15 years ago and both required five to seven years from RD&D to operations. NASA-sponsored RD&D has continued in support of both of these applications, and the process of technology transfer from NASA to the user organizations has also continued. On the other hand, it is clear that earth and ocean observations and space materials processing, will require ten to 15 years to progress from the inception of RD&D to the onset of operations. It is not the purpose of this study to examine the reasons for the time required for technology transfer in each of these applications areas. However, it is apparent that NASA is involved in long-range efforts in each of these applications areas that could extend into the five to ten year range. The planning in support of these long-range efforts must consider the full spectrum of activities ranging from research through demonstration of an operational capability in order to facilitate user acceptance and successful transfer of the RD&D sponsored by OSTA to the user organization.

It is interesting to look for the motiviating force behind RD&D sponsored by OSTA. Is the RD&D motivated by "technology-push"; i.e., by the desire of NASA scientists and engineers to extend the state-of-the-art? Or, is the RD&D motivated by user needs? It is likely that both motivating factors are behind the OSTA RD&D program. In some cases, a perceptive scientist or engineer may see the possible application of a new technology and push its development. In other cases, other public or private sector organizations may recognize the need for RD&D to demonstrate technical feasibility and reduce the financial risk of

development of an operational system. Although some of the RD&D undertaken by OSTA is not intended to lead to operational systems but is meant to contribute to the continuing flow of new technology, it can be safely assumed that an important part of the RD&D performed by OSTA is intended to affect decisions made by other public or private sector organizations concerning the implementation of operational systems. It is with this latter part of the OSTA RD&D program that this study is concerned. Furthermore, unless the work sponsored by OSTA is basic research, it should be possible to identify the expected recipient of the operational technology or system, the real or perceived need for the RD&D, and to quantify the improvement that the RD&D will produce if it is successful.

What is the relationship of RD&D and business planning? The normal cycle of mangement in any organization can be viewed as a feedback loop. Requirements, capabilites and expected results combine to form the basis for a plan. The plan is implemented and results are obtained. The results are measured and the measurements are used as a basis for replanning. Thus, a plan is not a static management tool. It is a dynamic management tool that must be periodically updated on the basis of the results obtained in its implementation, and changing requirements, capabilities, goals and constraints. Business planning is an attempt to understand and anticipate the critical decisions to be made in the progression from research to operations, and to provide in a formal and structured manner the information need to support decision making. Two types of business planning are generally recognized; namely, strategic planning and operational planning. Strategic (or long range) planning is concerned with the implementation of the long-range goals and objectives of the organization and most often involves activities that span a number of years. Operational (or tactical) planning supports near term and day-to-day operations. This study is limited to the consideration of

strategic business planning, and specifically to the feasibility of using strategic business planning concepts developed in the private sector to improve the management of the RD&D performed by OSTA.

When one proposes to consider the feasibility of using management and analysis concepts that have been developed and successfully used in the private sector of the economy to improve the management of work performed in the public sector, it is important to examine the two sectors for similarities and differences that could affect the transferability of the concepts.

This study is concerned with that part of the OSTA RD&D program that is intended to influence decisions by other agencies or organizations, public or private, concerning the implementation of operational systems. This influence may stem from the demonstration of technical feasibility, or it may be the result of reduced cost, performance or schedule uncertainty and risk. The value of this RD&D can be described in terms of its potential impact upon decisions to implement operational systems or business ventures. That part of the RD&D performed by OSTA that is intended to support the development and operation of these systems should be responsive to the needs of the organizations that will eventually operate these systems. In effect, these needs constitute the demand for a large part of the RD&D performed by OSTA. When an operational system is implemented, the results of the RD&D are transferred from OSTA to the organization charged with the responsibility for operating the system. To a great extent, this division of management responsibility for RD&D and operations parallels other situations encountered in both the public and priate sectors. For example, in the public sector, both the Departments of Energy and Transportation perform RD&D that is largely intended for transfer to the private sector. With the exception of the air traffic control system, neither the the Departments of Energy

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nor Transportation operate the systems that are based upon their RD&D. In the private sector, it is the general rule that RD&D is performed in an organizational segment that is managed separately from the operational, production or sales parts of the organization. In the private sector where the organizational coupling between RD&D and production is provided by a Vice President and corporate staff personnel, strategic planning is used to tie the RD&D to corporate business objectives, and to facilitate the transfer from RD&D to production, sales and operations. A significant difference between the management of RD&D performed by OSTA and RD&D performed in the private sector is that an interagency or intersector transfer of the results is necessary in order to successfully implement an operational system. This need for an interagency or intersector transfer of results is a management encumbrance that is not often encountered in the private sector. Because of this additional interface, the development of the requirements for RD&D, as well as the planning and implementation of the transfer process, is more complex in the case of OSTA than in the private sector.

If the organization and management of RD&D in OSTA is essentially similar in concept to that encountered in the other federal agencies and the private sector, is there a difference in the nature and content of the RD&D performed by OSTA in comparison to the private sector? Investment by the federal government in RD&D has certain features which distinguish it from other investment activities. One of the most pervasive differences is technical uncertainty, which in turn introduces a large element of cost uncertainty in federal RD&D. A second distinguishing characteristic is that federal RD&D programs often have political and other intangible benefits that are difficult to translate into monetary terms that are used to assess private sector RD&D. A difficulty often encountered in evaluating federal RD&D programs is that there is no actual or potential market to impute

through the price mechanism economic values reflecting the independent preferences of private citizens.* The latter difference is most often encountered in OSTA RD&D programs that deal with the collection, processing and dissemination of information such as atmospheric, earth and ocean observations, and less often encountered in RD&D pertaining to communications and space materials processing. The comparison of RD&D performed by OSTA with private sector RD&D is complicated by the fact that at least in the area of atmospheric, earth and ocean observations, there is no similar private sector RD&D on a scale comparable to that performed by OSTA; however, in the communications and materials processing applications there is a long history of substantial private sector RD&D that differs mainly in the dimension of uncertainty from the RD&D performed by OSTA. Thus, at least the communications and materials processing applications are similar in content and nature to RD&D performed in the private sector. A similar judgment on RD&D performed by OSTA in support of atmospheric, earth and ocean observations must await further study.

A third area of comparison between RD&D performed by OSTA and private sector RD&D is that of accountability and measurement. The marketplace is the forum of accountability in the private sector. If the prodcuts or services provided by a private sector organization are not competitive, the firm will suffer when a purchaser expresses his preference for the products of a competitor. RD&D is one of several ways open to a firm to maintain its competitive edge. If the RD&D performed by a firm is not relevant to the needs of the firm in the marketplace, the firm will, at a minimum, forego the opportunity to improve or maintain its market share and in the long run will not be competitive. Government agencies that perform RD&D should be as accountable for the relevance and relationship of

*Measuring Benefits of Government Investments, Robert Dorfman, Editor, The Brookings Institute.

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their RD&D to national needs and objectives as private sector research and development establishments are for the relationship of their RD&D to the business objectives of the corporation that they serve; however, in the case of public sector RD&D the function of the marketplace is replaced by an allocation decision made by the Congress, agencies such as OMB, GAO and OTA, and NASA management in the case of OSTA. If a federal agency that is engaged in the type of RD&D that is performed by OSTA cannot point to the concrete practical benefits of its RD&D program, it is possible that the public and Congress may lose faith in the agency and its programs and cut back on funding.

The performance measures commonly used in the private sector to evaluate the desirability of proposed RD&D in support of a business venture are measures such as cash flow, profit, return on assets, return on investment and payback period.* What is the measure that should be used to evaluate proposed public sector RD&D in support of a decision to implement an operational system, or to impact the timing or rate of implementation of an operational system, or the design characteristics of the system? Clearly, the profit-oriented measures of desirability for a private sector project cannot be applied to the public sector. However, for public sector projects, benefit-cost analysis is closely analogous to the methods of investment project appraisal used in the private sector. The major difference is that in the public sector estimates of social value that broadly include all factors attributable to the project, both measurable and non-measurable, are used in place of estimates of sales value when appropriate.

In summary, many of the RD&D projects performed by OSTA are similar in nature, organization, content and applicability of concepts of measurement and

*A Glossary of Commonly Used Economic and Financial Terms is provided in Appendix E.

accountability to RD&D performed in the private sector. The purpose of this study is to examine the feasibility of using strategic planning techniques that have been developed and successfully used in the private sector to improve the management of RD&D projects conducted by OSTA. Those RD&D projects performed by OSTA that are intended to influence decisions by other federal agencies or the private sector concerning the operational use of technology or systems developed and demonstrated by OSTA are considered to be the likely candidates for the beneficial use of strategic planning techniques. The following sections of this report attempt to provide a bridge between strategic business planning as it is used in the private sector and planning as it has been performed in OSTA.

2. THE REQUIREMENT FOR BUSINESS PLANNING IN THE PUBLIC SECTOR

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2. THE REQUIREMENT FOR BUSINESS PLANNING IN THE PUBLIC SECTOR

Formalized planning is now an established fact in both the private and the public sectors. What has brought about this interest is formal planning? It is probably due to the realization that without a formal planning process in an era of rapid technological obsolescence, unanticipated events (such as premature failure of major system components, introduction of competitive products or services, changes in regulatory constraints, etc.) could occur that may prove detrimental to the organization. The formal planning process, it is hoped, will diminish the likelihood of occurrence of these unanticipated events or, as a minimum, make it easier to cope with other events when they do occur. If pressed, most managers would probably claim that managing and planning are virtually synonymous. Up to a point this is, of course, true, but actual planning, in many situations, tends to be intuitive, sporadic and unsystematic. What is needed, in practice, is a consciously systematic approach that reflects a determination to start from basic considerations such as corporate or organizational goals, to make decisions on the basis of facts, and to test the plan or hypothesis in action.

The planning process is concerned with decisions pertaining to the commitment of resources to achieve current and long-term goals and objectives. The goals and objectives include both financial and nonfinancial considerations. Typically in the private sector these include return-on-investment, earnings per share, sales volume, diversification, employment level, community relations and other broad considerations. The objective of the planning process is to select a strategy, that is a specific plan, from amongst the various devised alternatives, which can achieve the stated goals and objectives. It is also an objective of the

planning process to see that the selected plan is implemented, that periodic reviews are conducted to see that the plan is being carried out, and that remedial action is taken as found to be necessary. It cannot be emphasized too strongly that planning must be viewed as a continuous and ongoing process with constant review of objectives, goals and selected strategies. Planning results in the road map to the future. The plan requires constant modification and updating in the face of changes in constraints (budget, environmental concerns, relative importance of objectives, etc.) and results of research and development efforts. Planning is not a static but a dynamic process.

There are many benefits to be reaped from instituting a formal approach to planning (as will be developed in the following pages). It forces decision makers to think ahead and anticipate problems before they occur. It provides a detailed forecast and plan that makes it easier to discover why the action taken did not produce the expected results. It forces a detailed thinking through of the problem and solutions, uncovering areas of assumptions, knowledge and uncertainty. The material developed as part of the planning process can usually play a major role in the evaluation, justification, and resource allocation processes of projects (which are incorporated in the plan). In addition, detailed planning of this kind enables a manager to delegate responsibility with more confidence. Within the framework of the plan, a subordinate can be given a fair amount of autonomy and independence, while his superior on the other hand retains general control.

Planning is therefore seen as an integral part of the management process. Planning, and more specifically, corporate planning, has been associated with the review of strategy. Peter Drucker defines corporate planning as a "continuous process of making entrepreneurial decisions systematically, and with the best possible knowledge of their futurity; organizing systematically the effort needed to

carry out these decisions; and measuring the results against expectations through organized systematic feedback." Corporate planning has come to mean a systematic approach to decision making.

Benefits anticipated by organizations from the introduction of formal planning procedures include:

1. Improvements in coordination between divisions
2. Achievement of successful diversification
3. Ensuring the rational allocation of resources
4. Anticipation of technological changes.

Corporate planning is a philosophy of change. It is not so much a battery of techniques and systems as it is a style of management. Consequently the main benefits of planning derive from a continuing dialogue about the future of the organization, between top management and middle management, between line and staff, and between the divisions and headquarters staff.

A distinction needs to be drawn between operational planning, which is planning in support of near-term and day-to-day operations, and strategic planning, which is a systematic process for guiding the future development of an enterprise. Operational planning is performed within the framework established as a result of strategic planning. The most important elements in strategic planning are the long-term goals set by top management and the plans to achieve those goals in a thorough and systematic way. The planning to achieve the goals is sometimes referred to as tactical planning. Strategic planning helps, on the one hand, to anticipate and reduce the adverse influences of a rapidly changing business environment and, on the other, to take advantage of opportunities occurring in the environment. This approach includes the following elements:

1. Setting company objectives

2. Appraising the enterprise's resources and capabilities

3. Analyzing trends in the commercial, technological, social and political environment

4. Assessing alternative paths open to the business and defining strategies for future development and growth

5. Producing detailed operational plans, programs and budgets

6. Evaluating performance against clear criteria in the light of the goals, strategies and plans established.

The process has three important characteristics: First, it is concerned with the development of integrated plans for the total enterprise, not simply planning for a particular department or division; second, it emphasizes long-term "strategic" considerations as opposed to short-term "operational" ones; third, it envisages the establishment of formal procedures for strategic planning, which will exist in parallel with the short-term budgeting operations.

Managers in an enterprise have to operate in two decision-making systems at the same time. They make "operating decisions" that relate the buying, producing, selling and distributing goods and services, and improving the efficiency with which resources are used in this process. They also make "strategic decisions," which are concerned with effecting major changes in the "linkages" between the enterprise and its environment. A fundamental problem for management is to ensure that strategic issues are not neglected owing to the pressure of the day-to-day operation.

Three levels of strategic decisions are discernable (see Table 2.1): at the corporate level, the investment decision; at the divisional level, the resource allocation decision, and at the unit level, the implementation decision.* The

*This is not to say that these same decisions are not made at other levels in the organization, but that these are the dominant issues at the specified levels.

TABLE 2.1 EXAMPLES OF STRATEGIC DECISIONS

LEVEL	TYPE OF DECISION	EXAMPLE
CORPORATE	INVESTMENT	• ACQUISITION • NEW BUSINESS AREA • MAJOR FACILITIES
DIVISION	RESOURCE ALLOCATION	• APPLIED RESEARCH PROJECTS • ADDITION TO PRODUCT LINE
UNIT	IMPLEMENTATION	• ADDITION OF ANOTHER SHIFT • SELECTION OF SPECIFIC PRODUCTION EQUIPMENT MIX

investment decision concerns the investment of resources in the near term to produce benefits in the longer term. Resource allocation decisions are concerned with the allocation of scarce resources so as to maximize benefits in a resource constrained environment. Implementation decisions are concerned with the day-to-day decisions that must be made in order to get the job done.

In this study the possible use of business planning techniques is examined for OSTA decisions concerning (1) the evaluation, comparison, selection and justification of new initiatives, (2) the formulation and justification of an R&D portfolio when resources are constrained, and (3) program implementation. The following paragraphs are limited to first, a general discussion of business planning in the private sector concerned with investment decisions; second, business planning applied to the public sector is considered and is limited to decisions concerning the evaluation, comparison, selection and justification of new initiatives; third, the elements of a business plan for OSTA new initiatives are considered.

The following pages deal with planning in a somewhat restricted sense in that the process of setting goals and objectives is not considered. It is assumed in the following that a set of goals and objectives exists and that the major area of concern is the evaluation, comparison, selection and justification of new investment opportunities in a resource constrained environment, in such a manner that the stated goals and objectives are likely to be achieved. As will be developed in the following pages, private sector business planning, in general, is concerned with selecting that set of investments that maximizes the value of the firm whereas the public sector business planning should be concerned with selecting that set of investments that maximizes the net societal benefits. The value of the firm may be measured in terms of the present value of the future projected cash flow of the firm. Net societal benefits may be measured in terms of the present value of the

change in consumer's surplus and producers' surplus that is the result of the public sector investment, less the present value of the investment. Often, the change in the consumer's surplus and producers' surplus can only be achieved through changes in private sector implementation (i.e., investment) decisions concerning new ventures that are the direct result of public sector investment in R&D and/or incentive programs. For example, new initiatives in communications may lead to private sector business ventures that provide new and/or improved communication services. The public sector benefits depend upon whether or not and the rate at which the private sector will provide the new and/or improved communication services. Thus, the evaluation of the benefits of a new communications initiative must consider the private sector response to the new initiative. This implies the need for the public sector to analyze the private sector business ventures that may result from the new initiative. In the event that the return-on-investment perceived by the private sector is inadequate for private sector investment but anticipated public sector benefits are large,* the communications initiative may not be desirable from the perspective of the private sector unless coupled with other actions. These other actions may take the form of public sector incentives for the private sector which are of sufficient magnitude to achieve the desired private sector investment that will in turn produce the anticipated net (i.e., taking

*For example, large benefits may result from the reduction of mortality rates due to improved communications in emergency medical services, but these benefits may not be adequately reflected in the pricing of communication services. The pricing, reflecting the cost savings of the communications in the emergency medical applications, may be inadequate to generate necessary private sector return on investment. Note that the private sector sees a cash flow made up of the costs of providing the service and the fees paid by the users of the service. On the other hand, the public sector benefits accrue from the reduced mortality rates as well as any reduction in the costs of the new and/or improved communications.

into account the cost of the incentives) public sector benefits. Thus, it is not uncommon for public sector planning to encompass many of the aspects of private sector business planning since the planning and evaluation of private sector business ventures is an integral part of public sector planning.

2.1 Business Planning in the Private Sector

A major part of business planning in the private sector is concerned with the evaluation, comparison, selection and justification of new initiatives or ventures. A business venture is considered in the following discussion to be any undertaking which requires an investment of resources in the near term with the anticipation of rewards in the longer term. Thus, applied research, development and demonstration projects undertaken with the objective of creating new products and/or services are considered as ventures as are capital expenditures for plant and equipment replacement. Also considered as ventures are expenditures to increase production capacity in response to anticipated increases in demand. Basic research projects, that is, research undertaken with the intent of extending knowledge into new areas which offer the opportunity for making choices that would not otherwise be possible, do not fall into this classification since the opportunities which will be created (and the resulting benefits) in the future cannot be identified in the present. The following paragraphs summarize typical business planning approaches used by the private sector to evaluate, compare, select and justify new ventures. First, a number of definitions and measures of the value of a venture are discussed. The elements of a business plan are then described as are typical analyses performed in support of the business plan.

2.1.1 Definitions and Measures of Venture Worth

A number of measures or criteria that describe investment or venture worth are in common use today. Some of the more popular of these which also have

application to public sector planning are payback period, net present value, discounted rate of return (also referred to as discounted return on investment and internal rate of return), simple rate of return and benefit-cost ratio. In a survey of capital budgeting practices, Fremgen has shown that rate of reurn and payback period criteria are the most commonly used measures in business firms.*

The evaluation of new business ventures by the private sector is concerned with establishing quantitative values of these and other performance measures. To accomplish this, it is necessary to determine sales potential and profit potential.** Their determination is based upon delineating R&D, operating, engineering, manufacturing and other costs and expenditures.

Profit is the difference between revenue and expenses:

$$\text{Profit} = (1 - \text{Tax Rate}) * (\text{Revenue} - \Sigma\text{Expenses} - \text{Depreciation Expense})$$

A typical pro forma income statement (profit and loss projection) is illustrated in Table 2.2. As illustrated by this table, revenue, expenses and profit are forecasted on an annual basis over the period of concern to the planner. Capital expenditures are not explicitly included in the profit computation but occur only indirectly (and in any one year only partially) through depreciation expense. Cash flow, on the other hand, reflects the flow of funds through the business entity. The cash flow computation includes the magnitude and timing of the inflow and outflow of funds. The cash flow equation is:

$$\text{Cash Flow} = \text{Profit} + \text{Depreciation} + \text{Change in Payables} - \text{Change in Inventory} - \text{Change in Receivables} - \text{Capital Expenditures.}$$

*Fremgen, J.M., A Survey of Capital Budgeting Practices in Business Firms and Military Activities, Naval Post Graduate School, Report No. NPS-55FM72101A, October 11, 1972.

**DuPont Guide to Venture Analysis: A Framework for Venture Planning, E. I. DuPont de Nemours and Company, 1976; Pessemier, E. A., New Product Decisions: An Analytic Approach, McGraw-Hill, 1966.

TABLE 2.2 TYPICAL PRO FORMA INCOME STATEMENT (THOUSANDS OF DOLLARS)

ITEM	YEARS 1	2	3	4	5	6	7	8	9	10
INITIAL PRODUCT LINE	-	-	1965	5784	8838	8427	8211	6379	5700	5000
OTHER PRODUCT LINE	-	-	-	-	1965	5784	10803	14211	19014	21000
SERVICE INCOME (U.S.SALES)	-	-	90	374	895	1575	2468	3426	4568	6000
TOTAL INCOME	-	-	2055	6158	11698	15786	21482	24016	29282	32000
MFG.COSTS (INCL. AMORT.& DEPR.)	-	-	1032	2460	4447	5516	7260	7610	9189	11000
COST OF SERVICE (INCL.INSTALLATION & WARRANTY	-	-	75	301	715	1207	1874	2539	3414	4000
ENGINEERING EXPENSE	-	-	482	615	1170	1580	2150	2400	2900	3200
COST OF SALES	-	-	1589	3376	6332	8303	11284	12549	15503	18200
GROSS MARGIN										
K$	-	-	466	2782	5366	7483	10198	11467	13779	13800
% OF SALES	-	-	23%	45%	46%	47%	47%	48%	47%	43%
START-UP COSTS	236	482	-	-	-	-	-	-	-	-
G & A EXPENSES	203	385	717	1393	1710	2142	2553	2710	3141	3300
PRETAX PROFIT (LOSS)	(439)	(867)	(251)	1389	3656	5341	7645	8757	10638	10500
AFTER TAX PROFIT (LOSS)	(439)	(867)	(251)	1389	1912	2671	3823	4379	5419	5345

This includes after-tax profit, depreciation, increase in payables, decrease in inventories, decrease in receivables, etc., as cash inflows (sources of funds); and losses, capital expenditures, decrease in payables, increase in inventories, increase in receivables, etc., as cash outflows (uses of funds). It should be noted that cash flow (which includes profit and loss as a component), and not profit, is the important determinant of the value of a venture. Profit is an accounting artifact--*cash flow is a basic measure; a profitable business venture may fail because of cash flow problems. The significance of profit, however, cannot be overlooked, since it is a key consideration when evaluating the availability of funds from the financial community. (Stock prices are normally measured in terms of price-earnings ratio.) A simplified profit and cash flow computation is illustrated in Figure 2.1.

Figure 2.2 illustrates a typical private sector investment analysis in terms of profit, cash flow and indebtedness. Indebtedness is the negative of the cumulative cash flow to date and is positive as long as the cumulative cash outflow exceeds the cumulative cash inflow. Point A, the point where indebtedness passes through zero, is termed the payback period and is the point in time when the total cash inflow first equals the total cash outflow. Point B is the time at which the cash flow becomes positive. Point C represents the point of maximum indebtedness or the maximum requirement for funds for the investment opportunity.

Private sector investment or implementation of technology developed by government R&D funding depends to a large extent on the values of A, B and C and other criteria (yet to be discussed) such as net present value, internal rate of return and other considerations. Since public sector benefits, in many instances,

*It depends upon the choice of depreciation method, captializing or expensing R&D expenditures and other accounting decisions.

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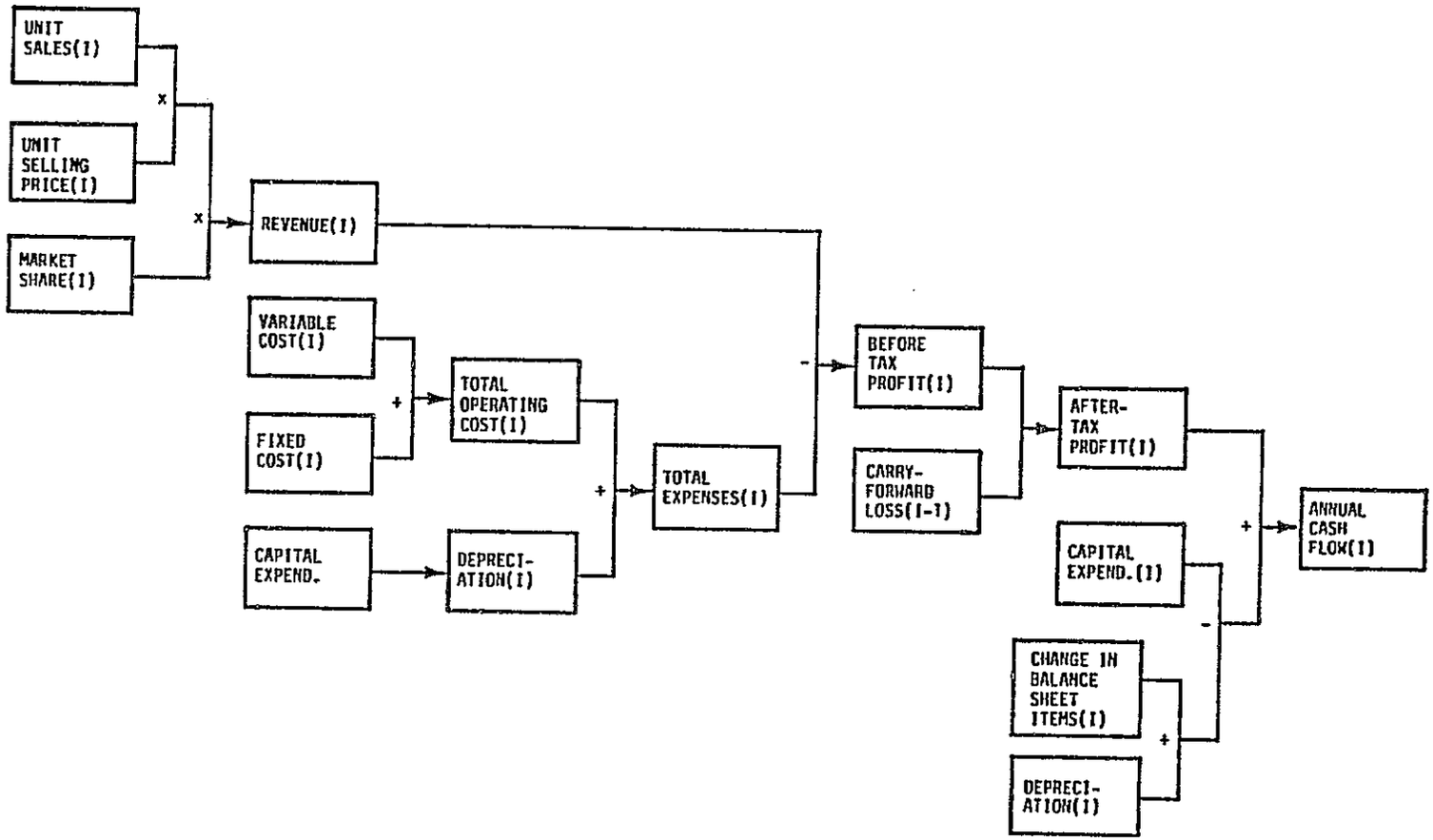

FIGURE 2.1 SIMPLIFIED PROFIT AND CASH FLOW COMPUTATION

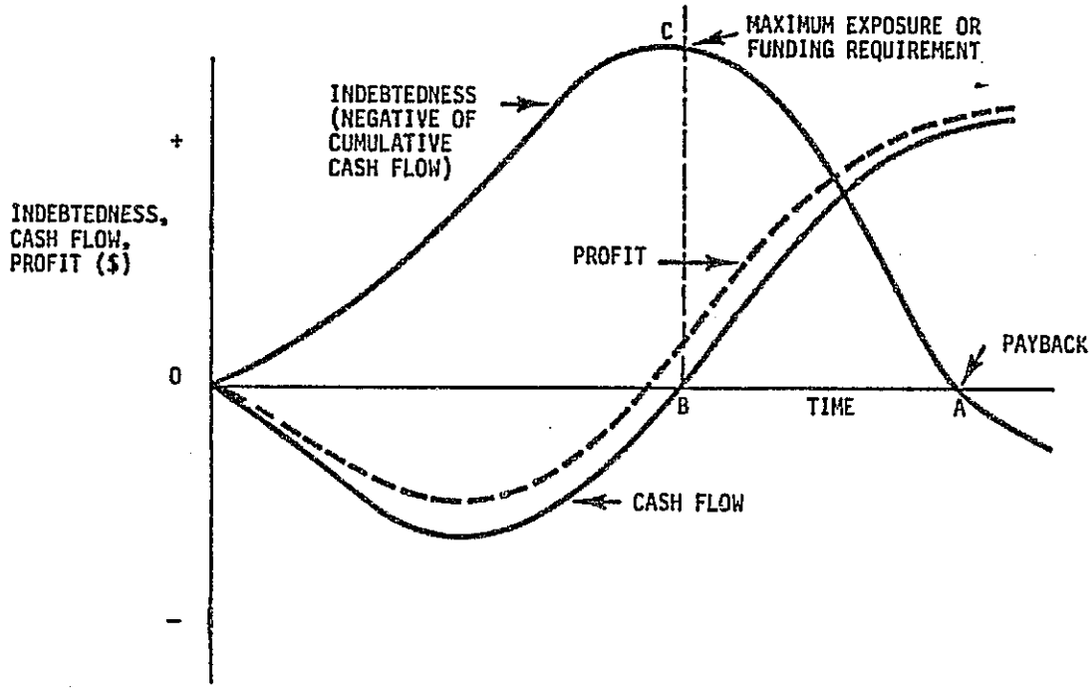

FIGURE 2.2 TYPICAL PATTERN OF PROFIT, CASH FLOW AND INDEBTEDNESS

depend upon private sector investment decisions, the likelihood of private sector implementation (investment) and the rate of implementation must be evaluated in terms of factors such as the above in combination with explicit risk considerations. In general, both the likelihood and the rate of implementation are related to the values of A, B and C and their probability distributions. The viability of a venture depends on many factors and is influenced significantly by the potential sources of capital and what investors consider as significant. Many large corporations rely heavily on present value concepts and quantitative measures of risk. Some venture capitalists are concerned with their maximum exposure, the first profitable year and payback period, while others establish a value (used in their investment decision) of K times the profit in the fourth year. Thus, part of the private sector venture analysis is an assessment of the various likely sources of funds and an evaluation of the likelihood of obtaining the necessary funds in terms of the investor's criteria and other investment alternatives.

Net present value (NPV) analysis seeks to adjust cash flows (both costs, the negative cash flows, and benefits, the positive cash flows) occurring in different future time periods in a manner so as to eliminate time as a parameter. The adjustment process, known as discounting, establishes a present or "now" value of the future cash flows. The rationale behind the adjustment is that a dollar received in the future is worth less than a dollar today, since a dollar in hand today could be used to improve one's status today rather than at some point in the future. The computational mechanism is to reduce the cash flow occurring in a particular future period by a discount factor such that the discounted amount is that which, if invested at the discount rate from the present to the corresponding future time, would be equal to the unadjusted value. In the mathematical sense, this process is the complement of compounded interest on a savings account; although, in the economic sense, discounting is a very different concept. The net present value is given by

$$NPV = \sum_{i=1}^{N} \frac{CF_i}{(1+r/100)^i}$$

where CF_i represents the cash flow in the ith time period, N is the planning horizon, and r is the discount rate (%) or cost of capital. An interpretation of the net present value of an investment is that it represents the maximum sum of money that an investor with an adjusted (for inflation) cost of capital equal to r would be willing to pay so as to have the opportunity to invest. It represents the value of the project over and above all costs associated with funding the project including interest expenses paid at the cost of capital (r). A positive NPV indicates a return in excess of the project cost plus the cost of capital. In theory, all projects having NPV > 0 should be undertaken. Those projects with NPV < 0 should

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not be undertaken, and for those projects with NPV = 0, the choice (i.e., undertake or not undertake) is immaterial. The previous statements, of course, are true in a world of certainty and in the absenceof budget constraints.

The internal rate of return (IRR) or discounted rate of return of a project is that discount rate at which NPV = 0. The net present value and associated internal rates of return of two projects are illustrated in Figure 2.3. The internal rate of return represents the maximum rate of return which might be paid on funds borrowed to make the investment. The IRR computation, which can be performed by computing the net present value at several different discount rates and graphically establishing that rate which yields NPV = 0, attempts to avoid the issue of determining what is the correct discount rate. Each project has its associated

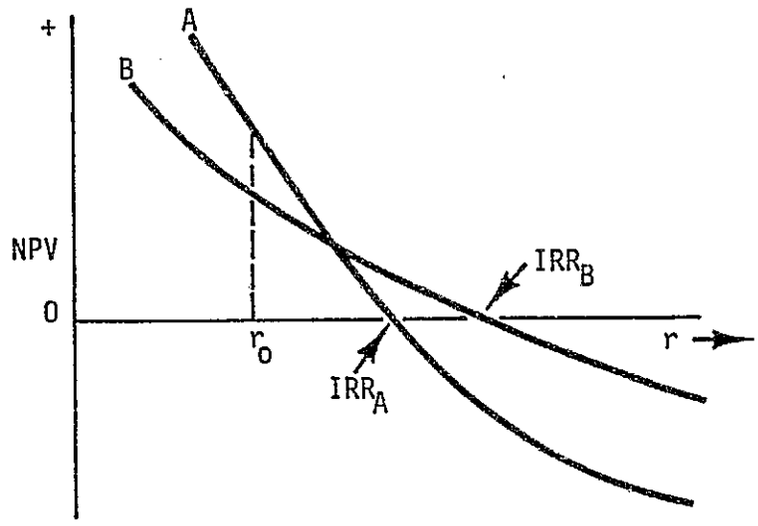

FIGURE 2.3 NET PRESENT VALUE AND INTERNAL RATE OF RETURN

discount rate. When using IRR as an investment criteria, projects should be undertaken as long as the IRR exceeds a predetermined cutoff value. Projects are undertaken in descending order from the one with the highest IRR until the available resources are exhausted, or the cutoff rate of return is reached. The cutoff rate of return would be the same discount rate used in the NPV equations. Note that even though the IRR approach tries to avoid the determination of discount rate (the cutoff value in this case), its determination cannot be completely avoided.*

In theory, all projects which yield net present values greater than zero or internal rates of return greater than the cost of capital should be undertaken. Budget constraints should not be considered since the firm could borrow additional funds and still be better off.** In theory, this process could be continued until either (1) there are no further worthwhile projects to undertake or (2) the effect of borrowing the additional funds causes the cost of capital to rise to the point where there are no further projects to undertake which yield (a) net present values greater than zero or (b) internal rates of return greater than the cost of capital.

In practice, a somewhat different approach is usually taken. It is generally assumed that the cost of capital or discount rate is unaffected by the project selection process and that constraints do exist. This introduces a conflict in the project selection by rank ordering according to different criteria. This conflict is

*The use of internal rate of return may be further complicated when a project has a cash flow projection that cyclically alternates between positive and negative values (this is not an infrequent occurence). In this situation, the internal rate of return may have multiple real values leading to decision maker confusion.

**In the public sector, all projects with NPV's greater than zero should be undertaken since this implies societal benefits that would be foregone if the project were not undertaken.

illustrated in Figure 2.3 where the NPV of Projects A and B is illustrated in terms of discount rate r. The cost of capital is illustrated as r_0. At this cost of capital, the NPV of Project A exceeds that of Project B, and according to the NPV criteria, Project A ranks ahead of Project B. On the other hand, the internal rate of return of Project B exceeds that of Project A (both exceed r_0). Therefore, according to IRR criteria, Project B ranks ahead of Project A. In general, it can be seen that the mix of projects selected will depend upon the criteria used for ranking. This conflict, of course, can be resolved by considering all projects simultaneously and determining that portfolio which maximizes the net present value of benefits of the entire portfolio within specified cost constraints.

The present value index represents the ratio of the present value of the cash receipts divided by the present value of the cash outlays. The discount rate used is the same as that used in determining the net present value. The present value index is also referred to as the benefit-cost ratio. The benefit/cost ratio (B/C) is often used in various forms by government organizations particularly at the federal level. The benefit/cost ratio expresses the ratio of net present value of benefits to the present value of costs incurred to achieve the benefits. The benefits and costs are those perceived by the public at large and may differ significantly (because, for example, the lack of a pricing mechanism) from those observed by the private sector. Mathematically, it is expressed as:

$$B/C = NPV/PVC$$

where PVC is the present value of cost. From the perspective of the public sector projects should be undertaken if B/C is greater than 0. It is commonplace to rank projects according to B/C ratios and, when resource constraints are imposed, select those projects with the highest B/C ratios.

Finally, simple rate of return, often called the accounting rate of return, is the expected average annual net income from an investment divided by either the initial amount of that investment or the average investment over the life of the project.

The previously defined measures of investment worth are important because they significantly influence investment decisions. It is quite normal for firms to establish threshold values for the criteria which must be exceeded if the venture is to be entered into. For example, a firm might specify that if a venture is to be considered further, it must have a return on investment in excess of 20 percent and a payback period of less than five years. Sometimes these threshold criteria are adjusted to "compensate" for the perceived risk associated with the venture.

In combination with the investment criteria, other factors or criteria are also considered. Typically, these are as indicated in Table 2.3. Some of these criteria are considered prior to the detailed financial assessment of the venture. For example, if the perspective venture is not compatible with the firm's current strategy and long-range plan, it may not be considered further. On the other hand, there may be no need to consider detailed safety considerations unless the venture meets the firm's financial objectives.

Other criteria are considered for other situations. For example, Fremgen indicates that business decision makers place greatest emphasis on the discounted rate of return and the incremental cash flow when evaluating mutually exclusive alternative investments. In a similar situation, military decision makers rely upon payback period as the criteria. When alternative capital investments are ranked, business decision makers use rate of return or payback period, while military decision makers most often use payback period. Nonfinancial considerations are also important to both private and public sector decision makers. As shown in

TABLE 2.3 CRITERIA COMMONLY USED IN SELECTING R&D PROJECTS

CORPORATE OBJECTIVES AND STRATEGY

1. IS IT COMPATIBLE WITH THE COMPANY'S CURRENT STRATEGY AND LONG RANGE PLAN?
2. IS ITS POTENTIAL SUCH THAT A CHANGE IN THE CURRENT STRATEGY IS WARRANTED?
3. IS IT CONSISTENT WITH THE COMPANY "IMAGE"?

RESEARCH AND DEVELOPMENT

1. IS IT CONSISTENT WITH THE COMPANY"S R&D STRATEGY?
2. IS ITS POTENTIAL SUCH THAT A CHANGE IN THE R&D IS WARRANTED?
3. PROBABILITY OF TECHNICAL SUCCESS.
4. THE PATENT POSITION.
5. DEVELOPMENT TIME AND COST--UNIQUE ESTIMATES CAN BE MISLEADING & THE PROBABILITIES OF VARIOUS OUTCOMES SHOULD BE ASSESSED.
6. AVAILABILITY OF R&D SKILLS AND EFFORTS.
7. EFFECT UPON OTHER PROJECTS.
8. POSSIBLE FUTURE DEVELOPMENTS OF THE PRODUCT & FUTURE APPLICATIONS FOR ANY NEW TECHNOLOGY GENERATED.

PRODUCTION

1. NEW PROCESSES INVOLVED
2. REQUIREMENTS FOR ADDITIONAL FACILITIES.
3. AVAILABILITY OF RAW MATERIAL.
4. MANUFACTURING SAFETY.
5. AVAILABILITY OF MANU. PERSONNEL - NUMBERS AND SKILLS.
6. VALUE ADDED IN PRODUCTION.

MARKETING

1. TOTAL SIZE OF THE MARKET.
2. ESTIMATED MARKET SHARE.
3. 1 AND 2 INDICATE THE LIKELY VOLUME OF THE SALES FOR THE COMPANY. CONSIDERATIONS NEED TO BE GIVEN TO THE QUESTION WHETHER THERE ARE ADVANTAGES IN HAVING SEVERAL MAJOR NEW PRODUCTS RATHER THAN A LARGER NUMBER OF SMALLER PROJECTS. THE LATTER WILL ABSORB MORE SCARCE MANAGEMENT EFFORT BUT WILL MIN+ IMIZE THE EFFECTS OF A FAILURE.
4. ESTIMATED PRODUCT LIFE.
5. PROBABILITY OF COMMERCIAL SUCCESS.
6. TIME SCALE AND RELATIONSHIP TO CURRENT PLANS.
7. EFFECT UPON CURRENT PRODUCTS.
8. PRICING AND CUSTOMER ACCEPTANCE.
9. COMPETITION.
10. COMPATIBILITY WITH EXISTING DISTRIBUTION CHANNELS.

FINANCE

1. CAPITAL INVESTMENT REQUIRED.
2. REVENUE EXPENSE DURING THE DEVELOPMENT PHASE.
3. AVAILABILITY OF FINANCE FOR 1 AND 2.
4. EFFECT UPON OTHER PROJECTS REQUIRING FINANCE.
5. POTENTIAL ANNUAL CASH FLOW.
6. PROFIT MARGINS.
7. TIME TO BREAK EVEN & MAXIMUM NEGATIVE CASH FLOW.
8. DOES IT MEET THE COMPANY'S INVESTMENT CRITERIA?

SOURCE: TAYLOR, B. AND J. R. SPARKES, EDITORS, CORPORATE STRATEGY AND PLANNING, JOHN WILEY & SONS, 1977.

Table 2.4, safety is often an important consideration to private sector decision makers while support of existing programs is important to military decision makers.*

2.1.2 The Elements of a Business Plan

Planning within a firm is a continuing process requiring updating as new information is obtained. Planning is also a continuing process since a firm, in order to survive, must constantly introduce new products and/or services. These may be developed internally within the firm through R&D groups or they may be acquired externally. In either case, it is necessary to evaluate the possible resulting products and/or services in terms of the business potential that might result relative to the investment required, the risks involved, and other possible investment alternatives. The normal situation is that of having resource constraints with possible business opportunities requiring resources in excess of the constraints--hence, a comparison and selection of alternatives is necessary. The planning, evaluation, comparison and selection of alternatives requires many questions be answered requiring the conduct of a venture analysis. It should be noted that the role of the business planner (i.e., the entrepreneur) is to answer these questions and to develop a credible, rational and defensible business plan that conveys to management (i.e., the investors) all of the pertinent facts regarding the venture. The table of contents of a typical business plan might read as follows:

1. Summary
2. Background
3. Description and Relevance of the Venture
4. The Market

*Fremgen, J.M., A Survey of Capital Budgeting Practices in Business Firms and Military Activities, Naval Post Graduate School, Report No. NPS-55FM72101A, October 11, 1972.

TABLE 2.4 NONFINANCIAL JUSTIFICATIONS OF CAPITAL INVESTMENTS

	BUSINESS RESPONDENTS		MILITARY RESPONDENTS	
	NO.	%	NO.	%
RESPONDENTS THAT DO ACCEPT NONFINANCIAL JUSTIFICATION FOR INVESTMENTS	172	97%	51	73%
REASONS CONSIDERED ACCEPTABLE AS NONFINANCIAL JUSTIFICATION:				
SAFETY OF EMPLOYEES OR THE PUBLIC	162	92%	31	44%
NECESSITY OF MAINTAINING EXISTING PROGRAMS OR PRODUCT LINES	139	79%	45	64%
EMPLOYEES' CONVENIENCE OR COMFORT	136	77%	20	29%
SOCIAL CONCERN OR ENHANCED COMMUNITY RELATIONS	122	69%	19	27%
POLLUTION CONTROL	17	10%		
LEGAL REQUIREMENTS	13	7%		
UNMEASURED LONG-TERM POTENTIAL (E.G., RESEARCH AND DEVELOPMENT PROJECTS)	9	5%		
CONTRACTUAL COMMITMENTS	3	2%		
PROTECTION OF PROPERTY	2	1%		

SOURCE: FREMGEN, J.M., A SURVEY OF CAPITAL BUDGETING PRACTICES IN BUSINESS FIRMS AND MILITARY ACTIVITIES, NAVAL POST GRADUATE SCHOOL, REPORT NO. NPS-55FM72101A, 11 OCTOBER 1972.

5. Products/Services Description

6. Patent Position

7. Competition

8. Sales Forecast

9. Business Plan

   - R&D
   - Engineering
   - Manufacturing
   - Marketing
   - Promotion

10. Organization (key personnel, skills, availability, etc.)

11. Financial Analysis

    - Manufacturing Costs
    - Income Projection
    - Cash Flow Projection

12. Risk Analysis

The Summary presents a concise statement of the need, a description of the venture, the pertinent market characteristics, the product and/or services that will be offered. The summary also indicates the magnitude of the venture in terms of unit sales and dollar sales, maximum investment required, etc. It also presents a summary of the key performance parameters such as first profitable year, NPV, payback period, rate of return on investment, and other measures that must exceed cutoff criteria and which are deemed of primary importance to decision makers.

The Background indicates pertinent facts regarding what has already transpired and why the venture is now being considered. Such aspects as status of previously initiated research and development, previous attempts to obtain funding

for the venture, source of impetus for the current venture analysis and plan, etc., are described.

The Description and Relevance of the Venture indicates the basic form of the venture, the rationale that led to this form, and the relationship of the venture to the overall goals and objectives of the firm. For example, the venture may be concerned with the expansion into a new business area which is indicated by the corporate strategy as being an attractive area for expansion. The product line may be based upon developments which have taken place outside the firm and a licensing arrangement is necessary and possible. The firm may have the necessary development and manufacturing capability but does not have access to the market. Thus, the venture is based upon marketing through another firm which has the appropriate distribution channels. The relevance of the venture to the stated goals and objectives of the firm can be described by indicating its effect on each of the stated goals and objectives of the firm. For example, if the stated goals are to achieve increased earnings per share and decreased energy consumption, the contribution of the venture to earnings per share and energy consumption should be indicated.

The Market section presents a detailed characterization of the marketplace and the existing and anticipated trends. The number of potential purchasers is indicated and segmented according to pertinent attributes. The anticipated impact of the products and/or services upon the market are described. Also described are factors that may impact the rate and magnitude of market penetration (for example, union reaction and response) and actions that might be taken to improve the rate and magnitude of market penetration.

The Products/Services Description section details the attributes of the products and/or services which will be offered. It also describes how the specific

attributes were established (for example, as a result of cooperative analyses of several firms operations with and without the proposed products and/or services) and the importance of the key attributes in satisfying user needs. The initial product line is described in detal with following (in the future) product lines outlined and described in lesser detail.

The Patent Position section describes the anticipated patent position of the firm and the impact of changes in the anticipated position upon the desirability of the business venture. The Competition section indicates who the likely competition will be and their strengths and weaknesses. It also indicates the dominant competitive forces currently in existence and what new competitive forces might develop (for example, where might competitive technology be developed).

The Sales Forecast indicates the number of units of the products and/or services that may be sold as a function of time and selling price. The sales forecast includes both original sales and replacement sales for both the initial and following product lines. The sales forecast also indicates those market segments or firms which are considered as innovative and will therefore be responsible for a large number of early sales. The sales forecast serves as a major input to the various elements of the business plan and the financial analyses. Since the sales forecast is of such importance, a useful technique is described in Section 2.1.3 and a sales forecast employing this technique is presented in Appendix A.

The Business Plan consists of the Research and Development (R&D) Plan, the Engineering Plan, the Manufacturing Plan, the Marketing Plan and the Promotion Plan. These are all integrated together to form the coherent business plan. The R&D Plan is concerned with the details of the R&D required to support the business venture. The plan includes consideration of manpower requirements (skills, etc.), costs and space requirements, all as a function of time. The

Engineering Plan is concerned with the product or service related engineering support. This includes the consideration of manpower, costs and space requirements as a function of time. It also delineates the basic philosophy which will be followed concerning engineering and production prototype equipments and their costs. The Manufacturing Plan is concerned with all of the details of manufacturing a sufficient number of units to meet market forecasts and inventory requirements. If capital constraints impose a production limitation, this will be described. Both the Manufacturing and Engineering Plans will describe their appropriate sales support functions such as initial service support, training and spare parts. The Marketing Plan delineates the strategy with respect to extensive versus intensive market strategies, pricing policies, the number of salesmen required as a function of time, the creation of a service organization, sales force productivity, etc. The Promotion Plan considers the integrated advertising and promotion approach required to accomplish the market objectives.

The Organization Plan establishes the overall management structure of the organization required to support the business venture. Key personnel are indicated and the number of persons required as a function of time is indicated as a function of skill type and availability.

The Financial Plan places all of the previous plans and analyses into perspective through a financial structure. Manufacturing costs are established as a function of time. The final results of the Financial Plan are summarized in the form of pro forma income and cash flow projections. Quantitative values are also established for all key performance criteria used by decision makers to evaluate the desirability of the proposed business venture. These may include the determination of net present value, rate of return on investment, benefit-cost ratio, payback period, return on assets, and others.

Risk Analysis, though concerned with financial analysis, because of its relative importance is considered separately. Risk analysis is the explicit and quantitative consideration of those market, cost and performance uncertainties that can have a significant impact upon investment decisions. The risk analysis presents the results of a formal procedure whereby quantitative estimates of uncertainty associated with basic input quantities are converted to risk profiles of financial results. The analysis allows the decision makers to see the quantitative level of risk that they are facing in terms of the specific ranges of uncertainty facing the venture analysts and planners. The areas of uncertainty include basic elements of cost, capital expenditures, performance and market. Market uncertainties may be due to lack of knowledge of user decision making characteristics, uncertainties in market share due to the patent situation and competitive reactions, uncertainties in magnitude of total market due to uncertainties associated with government regulation and incentive programs, etc. The risk is conveyed to the decision makers in terms of the chance that the pertinent evaluation criteria thresholds will be exceeded by different amounts. Thus, decisions can be made having explicit indication of the chance that budgets will be exceeded, payback period threshold criteria will be exceeded, etc.

2.1.3 Typical Analyses in Support of the Business Plan

In the following paragraphs, four areas, namely Market Forecasting, Risk Analysis, Mathematical Modeling and Portfolio Selection, are discussed briefly. These areas have been selected for closer examination because of their importance in business evaluation and planning and because of the potential use of the techniques in public sector planning.

Market Forecasting*

Market forecasting is concerned with estimating the number of units of a product or service which will be purchased as a function of time. Techniques employed for market forecasting range from econometrics to intuition. A procedure which has been used successfully on a number of occasions is illustrated in Figure 2.4 and is applicable when purchase decisions are based upon economic considerations (typically industrial type goods and conservation products that are acquired because of cost savings considerations). The procedure, illustrated by an example in Appendix A, is based on an analysis of the user needs, economics (in terms of the costs associated with a new product) and acquisition decisions (in terms of user economics). The starting point of a market forecast is market segmentation which is accomplished in terms of pertinent attributes such as geography, income levels, production levels, solar insolation, etc. For each market segment, the number of potential users or installations is established in terms of the size of the installation or production level or energy consumption (1). For each market segment, it is also possible to establish the payback period (payback period is used since many purchasing or acquisition decisions still place great emphasis on this measure) in terms of the specific product (2). The product specification includes cost (purchase price, maintenance cost and fuel or other operating costs) and capability. The payback period is determined by evaluating the user cash flow pattern with and without the new product or system (that is, an analysis which establishes the value in use). The payback period is thus a function of tax

*Market forecasting is an important element of public sector planning and evaluation since the benefits which may result from a new initiative will normally depend upon the number of purchasers or users of the resulting goods and/or services. For example, benefits from improved communications for emergency medical servcies will depend upon the number of emergency medical service districts that acquire terminals and related equipments.

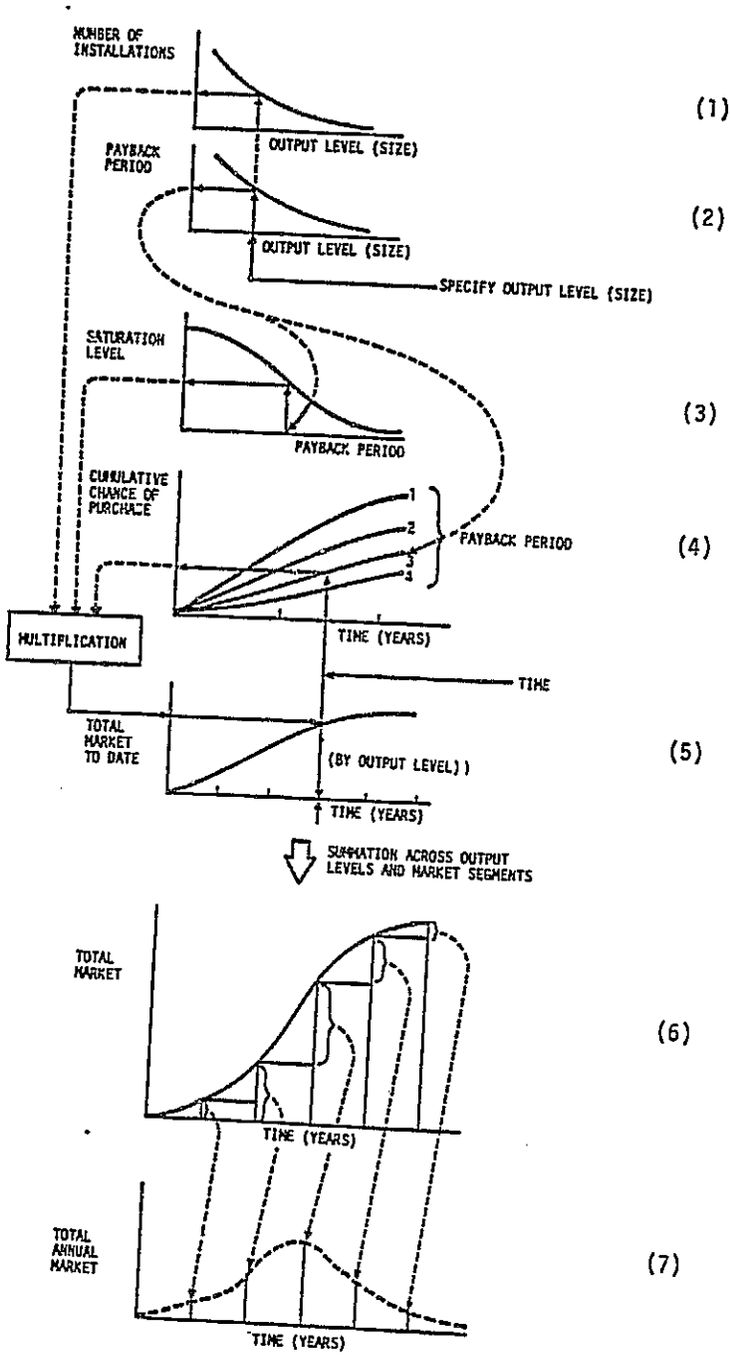

FIGURE 2.4 A TYPICAL MARKET ESTIMATION PROCEDURE

incentive, government cost sharing and other incentive forms. Thus, the specification of an output level or size will yield a payback period (2) and the number of installations which have this payback period (1). It is necessary to make subjective assessments of "saturation level" (3) and "cumulative chance of purchase" (4) based upon experience with similar products and/or industry purchase patterns. Saturation level is defined as the fraction of the potential users which will ultimately acquire the new product or service. Both are considered to be functions of payback period and can be established in terms of user community, historical purchase decisions or analysis of technology diffusion rates.

Figure 2.4 illustrates how the market forecast is accomplished once these estimates are made. A specific output level or size is selected. This results in the determination of payback period (2) and the number of installations (1) having this payback period. The payback period is used to enter the saturation level (3) and cumulative chance of purchase (4) curves. Number of installations multiplied by saturation level and cumulative chance of purchase (as a function of time) yields the total market to date (5). Repeating the process for different output levels and summing across the results yields the total market to date (6). The total annual market (7) is obtained directly from the cumulative market data. It is obvious that pricing policy will influence the market as will performance capability (which, in turn, may affect cost and pricing policy) and incentive projects. If, as a result of using the previously described market forecasts together with a conventional deterministic financial analysis, the business looks promising, a risk analysis is often performed.

Risk Analysis

Risk analysis has been used by business organizations to improve decisions which are concerned with the current use of funds in the hope of future rewards.

Risk analysis techniques have been used by a large number of organizations in both the public and private sectors. Risk and decision analysis have been used by NASA to evaluate the investment required to develop the space solar power station and to establish the likelihood that the cost of electrical energy from the space power station will be less than that from terrestrial power sources.* Risk analysis has been used by DOE to evaluate the desirability of developing and thence using nuclear power supplies (in lieu of solar power supplies) for DOD space missions.**

The private sector has used risk analysis to improve decisions concerned with new product introduction, new business investment, lease versus buy, the addition of production facilities, new plant investments, R&D program formulation, etc. RCA used risk analysis techniques to help make their decision to enter the domestic communication satellite business. Johnson & Johnson used risk analysis techniques to evaluate the desirability of entering several overseas pharmaceutical businesses. Florida Power & Light used risk analysis to evaluate the cost/risk associated with new fossil fuel power plants. DuPont uses risk analysis to evaluate capital expenditure requests. Mobil uses risk analysis in both the design engineering and financial areas to evaluate performance and cost risk, respectively. Standard Oil of Indiana used risk analysis to evaluate the risk associated with construction costs for transportation facilities in the arctic for an oil joint venture. These and other applications and users of risk analysis are summarized in Table 2.5.

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*Assessment of Economic Factors Affecting the Satelllite Power System, ECON, Inc., December 15, 1978.

**A Benefit/Cost Analysis of Nuclear Power Applied to the GPS Mission, ECON, Inc., September 30, 1976.

TABLE 2.5 TYPICAL RISK ANALYSIS USERS & USES

TYPICAL USERS	TYPICAL USES
• FLORIDA POWER & LIGHT	• FACILITY ADDITION ANALYSIS • NUCLEAR POWER PLANT OVERHAUL ANALYSIS • ANALYSIS OF LARGE CAPITAL OUTLAYS
• FMC	• PLANT EXPANSION ANALYSIS • ANALYSIS OF LARGE CAPITAL EXPENDITURES
• STD. OIL OF INDIANA	• ANALYSIS OF GAS REFINING PLANT • ARCTIC CONSTRUCTION COST ANALYSIS • ANALYSIS OF ADDITION OF TRANSPORTATION FACILITY • BUILDING DESIGN ANALYSIS
• ALLIED CHEMICAL	• ANALYSIS OF PLANT EXPANSION • BUSINESS TERMINATION ANALYSIS • COMPARISON OF COMPETITIVE MANU. COSTS
• GULF	• ANALYSIS OF WORLDWIDE MOVEMENT OF CRUDE OIL • ANALYSIS OF SOURCES & DEMAND FOR CRUDE • TANKER SUPPLY & DEMAND ANALYSIS
• KODAK	• PRODUCT CONTROL ANALYSIS • INVENTORY CONTROL (LOW ORDER RATES)
• PPG INDUSTRIES	• EXPANSION ANALYSIS • CAPITAL EXPENDITURE ANALYSIS
• JOHNSON & JOHNSON	• ANALYSIS & COMPARISON OF NEW PRODUCT ALTERNATIVES • NEW BUSINESS ANALYSIS
• NABISCO	• NEW PRODUCT INTRODUCTION ANALYSIS

For those organizations that use it, risk analysis is most likely to be used to evaluate ventures which require investments on the order of tens of millions of dollars; risk analysis is often used to evaluate ventures which entail investments on the order of millions of dollars, and is sometimes used to evaluate ventures which require investments on the order of hundreds of thousands of dollars. It is also likely that specific risk analysis models will be developed to evaluate the larger investments whereas simpler and standard models will be used to evaluate the smaller investments.

Risk analysis* is a formal procedure whereby quantitative estimates of uncertainty associated with basic input quantities are converted to risk profiles of performance data as indicated in Figure 2.5. Risk analysis is an important element of public sector planning and evaluation for the following reasons: (1) the risk dimension is important when new initiatives are being considered (and must be compared) that incorporate systems which are in different stages of research, development and use, and (2) when public sector new initiatives are undertaken with the intent of affecting private sector investment decisions that depend upon risk considerations.

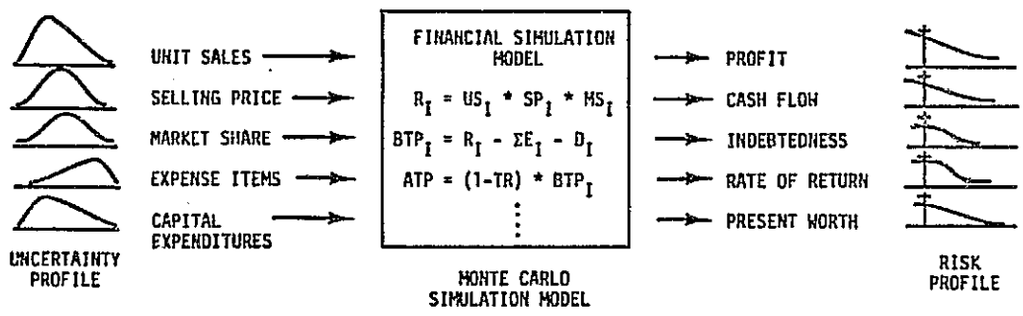
Basic input data consists of deterministic data and probabilistic data. Examples of deterministic data are the number of time periods to be considered, the discount rates, tax rates, etc. The probabilistic data consist of the probability density functions, hereafter referred to as "uncertainty profiles", associated with

*Hertz, D., Investment Policies That Pay Off, Harvard Business Review, January-February 1968; Van Horne, J., Capital Budgeting Decisions Involving Combinations of Risky Investments, Management Science, Volume 13, No. 2, October 1966; Edelman, F. and J. S. Greenberg, Venture Analysis: An Assessment of Uncertainty and Risk, Management: A Book of Readings, edited by H. Koontz and C. O'Donnell, McGraw-Hill, 1972; Greenberg, J. S., Risk Analysis, Astronautics/Aeronautics, November 1974; Greenberg, J. S., An Assessment of Risk Models, ECON, Inc., Princeton, New Jersey, March 1978 (for DOE).

the variables whose values cannot be predicted or known exactly in advance. The uncertainty profiles thus are subjective estimates which describe the range of uncertianty and the form (shape) of the uncertainty. Typical uncertainty variables are unit sales, selling price, market share, expense items, capital expenditures and others.

These data are input to a financial simulation model which is of the complexity necessary to adequately represent the real world situation being evaluated. The model indicated in Figure 2.5 states that revenue (in the Ith time period) is equal to the product of unit sales, selling price and market share; before-tax profit is equal to revenue less the sum of all expense items less the depreciation expense; after-tax profit is one minus the tax rate multiplied by the before-tax profit.

The risk analysis is performed by random sampling of the input data (according to the weighting of the uncertainty profiles), performing the computations contained within the simulation model, saving the results and thence



R = REVENUE
US = UNIT SALES
SP = SELLING PRICE
MS = MARKET SHARE
BTP = BEFORE TAX PROFIT
E = EXPENSES
D = DEPRECIATION EXPENSE
ATP = AFTER TAX PROFIT
TR = TAX RATE
I = TIME PERIOD

FIGURE 2.5 RISK ANALYSIS CONCEPT

repeating the process. This process is repeated a large number of times (Monte Carlo) until a reasonable set of histograms can be developed from the saved output data. These histograms are thence manipulated into the desired graphical or other summary form so as to indicate the variability of pertinent performance measures such as profit, cash flow, indebtedness (negative of the cumulative cash flow to date), rate of return and present worth. A convenient form of displaying the performance measures is that of "risk profiles" which indicate the chance of the performance measure exceeding specific levels (i.e., the complementary cumulative probability distribution).

The characteristics of a typical risk model are summarized in Figure 2.6. One of the uses of the results of risk analysis is to characterize ventures from the points of view of expected values and standard deviations where the standard deviation is a measure of variability or risk. This is illustrated in Figure 2.7 in terms of return on investment. The risk analysis develops the probability distribution of return on investment from which the risk, σ , and expected value, m, are obtained. These may be plotted as in Figure 2.7 where each venture shows up as a point in the m-σ space. It can be seen that venture 3 is preferable to 4, that venture 1 is preferable to 2, 2 is preferable to 4 and that 1 is preferable to 3. Thus, a frontier can be established of the best possible ventures. The attention of management is then quickly focused on the best alternatives and they can then select that set, of alternatives to receive funding exercising their risk avoidance preferences.

Mathematical Modeling

Modeling is a sophisticated combination of art and science. Models are computational procedures designed to help the decision maker and his staff predict and evaluate the consequences of proposed alternatives. In some cases, the model

UNCERTAINTY VARIABLES (PDF)

- VALUE OF EACH CAPITAL EXPENDITURE ITEM
- DEVELOPMENT DURATION (TIME TO START OF SALES)
- MULTIPLE EXPENSE ITEMS (BY YEAR)

- TOTAL COST OF SALES (BY YEAR)
- TOTAL REVENUE (BY YEAR)

OR

- UNIT COST OF SALES (BY PRODUCT & YEAR)
- UNIT SALES (BY PRODUCT & YEAR)
- SELLING PRICES (BY PRODUCT & YEAR)
- MARKET SHARE (BY PRODUCT & YEAR)

MODEL STRUCTURE

- MULTIPLE TIME PERIODS CONSIDERED
- TRENDS CONSIDERED FOR FOLLOWING TIME PERIODS
- LARGE NUMBER OF STORED UNCERTAINTY PROFILES
- MULTIPLE PRODUCTS
- DEMAND-PRICE RELATIONSHIPS (BY PRODUCT)
- PRODUCT INTER-RELATIONSHIPS
- MANUFACTURING COST-QUANTITY RELATIONSHIPS (BY PRODUCT)
- MULTIPLE CAPITAL EXPENDITURE ITEMS
- CHOICE OF DEPRECIATION METHOD (BY EXPENDITURE)
- CAPITAL EXPENDITURE DETERMINATION BY PRODUCTION REQUIREMENTS
- CONSIDERATION OF INITIAL CORPORATE POSITION
- FLEXIBLE TAX STRUCTURE
- FINANCIAL COMPUTATIONS FOR DIFFERENT BUSINESS SITUATIONS
    - PART OF EXISTING CORPORATION
    - PARTNERSHIP LEADING TO A CORPORATION
    - SEPARATE CORPORATION (START-UP)

RISK PROFILES (PDF)

- REVENUE
- EXPENSES
- CAPITAL EXPENDITURES
- PROFIT
- CASH FLOW
- CUMULATIVE CASH FLOW (INDEBTEDNESS)
- RETURN ON ASSETS
- PRESENT WORTH (MULTIPLE DISCOUNT RATES)
- PAYBACK PERIOD

FIGURE 2.6 CHARACTERISTICS OF ECON'S RISK MODEL

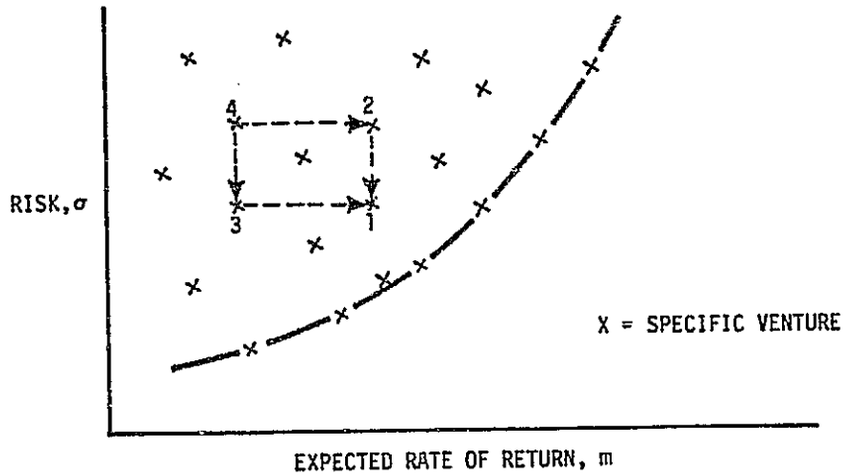


FIGURE 2.7 COMPARISON OF ALTERNATIVES INCORPORATING THE RISK DIMENSION

includes procedures for computing the optimal alternatives. Models are valuable in supporting those decisions which must be made in relation to complex and changing situations where even informed judgment will not necessarily lead to the best possible results.

A model is a way of abstracting the real world so that not only the static picture of the world is obtained, but also the dynamic (time) interrelationships are represented. The art of model building is in translating a perception of the world into the essential relationships and variables and thus into a model which is tractable and, hopefully, computationally manageable. In the model, the variables represent parameters which may be specified through input data or computed based upon the interaction of input data with the established relationships. The relationships in the form of equations or constraints are the stated procedures for computing the value of certain variables given values of others; sometimes for computing variables at a future time given the values at the present time.

In nearly all models, it is found that the variables can be classed as follows:

1. Controllable Variables: These are variables whose values can be determined by the decision process (for example, the determination of the specific set of projects which, if funded, would maximize the specified value function).

2. Uncontrolled Variables: These are variables which are not under the control of the decision maker, but are the result of actions of others or results of other processes (for example, the time of failure of a component). With any uncontrolled variable, there is a degree of uncertainty: The estimates are never exact. Sometimes the estimates are sufficiently accurate and have a sufficiently small amount of variation so that specific values may be assumed. This leads to what are called "deterministic models" where the uncontrolled variables are assumed to be determined exactly. When the uncontrolled variables are considered to have ranges of uncertainty, they must be represented as statistical quantities and probabilitistic or stochastic models result.

3. Results or Output Variables: These are variables which characterize the results of the processes (for example, total annual cost of a specific operation).

4. Utility or Value Variables: These are variables which represent the decision maker's utility or value of the results of the process.

The model builder in a particular situation must first identify the variables of importance and then construct relationships (equations or computational processes) that interconnect the variables. In the most ideal case, this work is facilitated by two sorts of theory: (1) theories about the physical and behavioral phenomenon in the situation derived from physical, physiological and social research and (2) theories about the structure of the specific management process derived from operations research work. The theoretical results, if available, indicate to the model builder what are the most important variables, the relationships between them (in precise, computationally-feasible form) and procedures that can be used to find the decision (controllable) values which will give the greatest utility.

All modeling processes allow present and future values of operating or result variables to be computed. Some allow the utility optimizing controllable values to be computed. The latter is known as optimization and the former is called prediction.

The basic types of models available to an analyst can be classified by the manner in which they are expressed: descriptive, physical, symbolic and procedural. Descriptive models (which are expressed in native language) have many limitations, perhaps the greatest being that the method of prediction is usually internal and thus cannot be communicated or easily replicated. The advantage of descriptive models is that the cost of making predictions is extremely low; therefore they are the most commonly used models for decision making. Physical models range from floor plan layouts to complicated aircraft wind tunnel models. If optimization is to be performed using physical models, the method of optimizing is to search among alternative designs by varying performance characteristics and other variables and searching for that combination which maximizes a specific objective function.

Decision analysis has made major progress by the use of symbolic models. These models employ concise mathematical symbols to describe the status of variables in the system and to describe the way in which variables change and interact. Predictions or optimal solutions are obtained from these symbolic representations by means of mathematical, computational and logical procedures called deductive methods. The fourth model type is referred to as procedural, however, it is generally referred to as simulation. The model is actually a procedure expressed in precise symbols; the term simulation refers to the method by which the model is used to make predictions. A simulation is a model of some situation in which the elements of the situation are represented by arithmetic and logical relationships and processes that can be manipulated (on a computer) to predict the dynamic properties of the system. In contrast to symbolic models, the problems usually attacked by simulation procedures do not lend themselves to solution by standard computational techniques.

Models may serve different purposes in relation to specific analyses. Models are usually used to answer "what if" questions of two types: (1) "What if we set the decision variables at certain values (e.g., what if we selected a specific subset of R&D projects)?" and (2) "What if an uncontrollable takes on a different value?".

As has been pointed out, the ideal model normally has two aspects or parts, the first part representing the real world and allowing the prediction of how that world might unfold (given certain assumptions about both uncontrollable input and about the decisions for controllable variables). The second part then selects from the feasible range of controllable variable values the particular ones that optimize or give the most desirable results. Some models accomplish both aspects and are called optimizing models. Other models contain only the predictive process.

In deterministic models, it is assumed that the exact values of all variables can be computed and values of all parameters are known. In a probabilistic model, at least some variables or parameters have an unpredictable randomness and must be represented as statistical variables. If the model is dynamic, it might be termed stochastic, i.e., the model includes random variables that depend on some parameters, and often vary as a function of time. The class of models referred to as "risk analysis" models are stochastic models. Most decision making situations require a model which represents situations which change over time. Thus most models are dynamic in the sense that time is explicitly represented and the variables change with simulated time as they would in the real world.

The following discussions center upon simulation, econometric, input/output, mathematical programming and decision tree models which are the most commonly used policy-decision-supporting models.

In simulation, the analyst programs a computer directly to represent the situation under study. The only limitation to the simulations that can be modeled

are those which the analyst imposes upon himself because he lacks an understanding of the relationships within the real situation. In the most basic form of simulation, time is represented as discrete points. The world is viewed as a series of snapshots with the program computing the changes between the snapshots. The time interval can be any size (minutes, years, decades) or even unequal. The computations can represent any change, large or small. One of the most difficult aspects of a simulation model is to determine its validity. Since the model may be prepared on a basis of one analyst's understanding of the important relationships, its validity may be more uncertain than models which are based on more widely understood and acceptable relationships. Simulation models have been used in the planning process and range from simple financial planning models to complex corporate planning models for new business ventures and simulate manufacturing, market, and other processes involving multiple interdependent products in multiple interrelated markets being supplied by multiple interrelated divisions of a firm.*

Econometric models are, in a sense, simulations in which most of the key variables and most of the relationships between them are derived from economic theory. The other difference is that econometricians usually insist that the parameters in the model be derived from carefully designed, statistical estimating procedures which use past economic data as a basis. This fact on one hand tends to increase the model's validity, but on the other limits the scope since economic historical data is readily available only for certain aggregate phenomena.

Econometric models have been developed to study the behavior of various economic units in the activities of producing, exchanging and consuming economic goods. Economic units are households, firms, government, etc. Macroeconomic

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*Greenberg, J. S., A Corporate Planning Model for a New Business Venture, 1971 Winter Simulation Conference Record, December 8-10, 1971.

models are economic models that concentrate on various groups of economic units using aggregative measures such as national income, total employment and the price level. Each of these economic units may have definite motives such as maximizing satisfaction or maximizing profits. Macroeconomic models examine how the interactions of various sectors with different behavior patterns determine the aggregate of magnitudes of total economy. Some macroeconomic models go even further and explore the possibilities of influencing the aggregates to attain desired goals by public policy actions. Input/output models are based upon a table which shows the relationship in dollar terms between the inputs and outputs of each sector of the economy. It is a highly structured form of an econometric model. The entries in the table show, for example, how much of the output of the steel industry is used by the automobile manufacturing industry and how much of its output is used in transportation services that are used by the steel and other industries. Also shown are the ultimate demands, inventory accumulation, export, government and private purchases and capital formation. Inputs in forms of payments from such sources into the economy are also represented. The input-output models are useful for evaluating the impact of changes in one segment of the economy on all other segments of the economy.

Mathematical programming models are highly structured, unlike simulation, and are generally applicable only in well-defined cases where resources are allocated to predefined programs or activities. Mathematical programming is used to solve maximization and minimization problems in which constraints are imposed on the decision maker. It is necessary to specify an objective function, the value of which is to be maximized or minimized within a specific set of constraints. A typical problem when mathematical programming techniques are applicable is in the selection of a subset of R&D projects from amongst a larger set which cannot

all be undertaken because of resource constraints. The objective is to maximize the value of the R&D program within the budget constraints. The use of mathematical programming techniques will be discussed in a following section with particular emphasis upon the R&D portfolio problem.

Decision trees are a simple form of simulation which is structured by aggregating future activities into major decisions and their consequences. The model represents only three basic variables: (1) the probability of each of the possible consequences of decisions, (2) the cost, and (3) the benefit, usually measured in dollars of each possible consequence. The purpose of a "tree" is to estimate the expected or probable value of taking each of several alternatives at intermediate decision points. A tree can incorporate estimates of the immediate and future costs that will arise because of the decisions and of the consequences of future decisions.

A decision tree may be looked at as an overall model of the possible consequences of a decision.* Other, more detailed models would be used to obtain the estimates of the probabilities, the costs and the possible benefit from each of the alternatives. The costs and benefits may be probabilistic quantities resulting in the marriage of risk analysis and decision analysis techniques.** The main mathematical process used in the decision is Bayesian statistics. Initially, subjective estimates are made of the probabilities of various consequences. Then the Bayesian statistical method*** is used to get more refined estimates of the probability of the combination of sequences of activities. This gives a net estimate

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*Magee, J. F., Decision Trees for Decision Making, Harvard Business Review, July 1964; How to Use Decision Trees in Capital Investment, Harvard Business Review, September 1964.

**Hazelrigg, G. A., Satellite Solar Power--Will It Pay Off?, New Options in Energy Technology, AIAA, 1977.

***See for example, Chernoff, H. and L.E. Moses, Elementary Decision Theory, John Wiley & Sons, 1965.

of benefit by computing the probable total benefit minus the total probable cost of each alternative.

One of the main uses of this analysis is to help determine the value of additional information about a situation. The main assumptions in use of decision trees is that the future can be summarized by a sequence of activities followed by decisions and that the alternative consequences of each decision can be identified. It also assumes that the required data can be estimated.

The previous discussion is summarized in Table 2.6 where various typical decisions are indicated. The types or forms of models used to help evaluate these decisions are indicated as well as the method of estimating the parameters, the basic deductive theory and the method of computation. All of the previously described model forms and techniques are in common use in the private sector as well as in the public sector.

R&D Portfolio Selection

R&D portfolio selection is concerned with selecting a subset of R&D projects which will receive funding from amongst a larger set of proposed projects. The selection process is brought about by resource constraints wherein all proposed projects cannot be funded. The objective of the portfolio selection is to select that subset of R&D projects, within the resource constraints, that maximize the organizations net benefits. Much use has been made of mathematical programming models to assist decision makers in this area.* Research in this area was performed for OAST and an R&D project selection system implemented and demonstrated.** The following paragraphs describe the general R&D portfolio

*Baker, N. R., R&D Project Selection Models: An Assessment, IEEE Trans. on Eng. Mgt., Volume EM-21, Nol 4, November 1974; Martino, J., M. J. Cetron and L. Roepcke, The Selection of R&D Program Content--Survey of Quantitative Methods, IEEE Trans. on Eng. Mgt., Volume EM-14, March 1967.

**Greenberg, J. S. and G. A. Hazelrigg, Jr., Research on the Problem of Efficient R&T Program Formulation Under Conditions of Uncertainty and Risk, Princeton University, Report AMS-1268, April 30, 1976.

TABLE 2.6 DECISION AREA AND SUPPORTING MODEL FEATURES

DECISION OR STUDY AREA	EXAMPLE	MODEL FORMS	METHOD OF ESTIMATING PARAMETERS	BASIC DEDUCTIVE THEORY	METHOD OF COMPUTING PREDICTIONS
ESTABLISHMENT OF INCENTIVES, CONSTRAINTS OR REGULATIONS	IMPOSE OR REMOVE A LIMIT ON THE PRICE THAT CAN BE CHARGED FOR NATURAL GAS (AT WELL HEAD)	ECONOMETRICS INPUT/OUTPUT	STATISTICAL METHODS STATISTICAL METHODS	ECONOMETRIC SUPPLY/DEMAND AND SIMULTANEOUS EQUATIONS AND CALCULUS, MATRIX ALGEBRA	COMPUTER COMPUTER (MANUAL IN SIMPLE CASES)
APPROVAL AND INTIATION OF PROGRAMS OR PROJECTS	START A NEW BUSINESS IN THE AREA OF SATELLITE COMMUNICATIONS; PASS LEGISLATION FOR A HEALTH INSURANCE SUBSIDY TO PEOPLE	SIMULATION	MAY BE SIMPLE "GUESSTIMATES" OR FORMAL STATISTICAL METHODS	(NONE)	COMPUTER
ALLOCATION OF RESOURCES TO PROGRAMS	R&D PROJECT SELECTION	MATHEMATICAL PROGRAMMING (LINEAR OR NON-LINEAR SIMULATION)	MAY BE FORMAL OR INFORMAL	"SIMPLEX" METHOD, VARIOUS SPECIAL METHODS. (NONE)	COMPUTER COMPUTER
FORECAST OVERALL TRENDS TO PINPOINT PROBLEMS & SUGGEST POSSIBLE SOLUTIONS	FORECAST POLLUTION LEVELS IN A REGION	SIMULATION	USUALLY FORMAL STATISTICAL METHODS	(NONE)	COMPUTER

selection problem and use the model developed for OAST to illustrate the basic mathematical techniques that are employed.

Simultaneous consideration of many multi-attributed R&D projects is a task which requires rather complex reasoning capabilities. When the number of candidate projects becomes large, comprehensively enumerating all the options can itself become an unwieldy job. Methods employing automatic data processing can then be valuable tools for the decision maker, providing accurate, optimal selections, but only according to the attributes which the portfolio selection model has been designed to consider. It should always be remembered that mathematical models are tools that provide information to the decision maker; the tools should not make the decisions. The tools should be used by the decision maker to evaluate what has to be given up if he selects a project set that differs from the optimum as determined by the tools. The decision maker can then proceed with his choice or modify it.

The portfolio selection model must contain an optimization routine which selects, out of the set of candidate project portfolios which satisfy budget constraints, that portfolio which provides the greatest measure of worth. Such a model must also select only whole projects and not partial ones and must be able to consider projects which are mutually exclusive (e.g., a project in coal gasification can be planned for completion in 15 years, while a different option will be the same project in 10 years; the model must be able to recognize that these are mutually exclusive alternatives so that both projects aren't selected). The model must be extremely flexible so that it is easy to determine how changes in preferences (such as the discount rate or rate of return) or other variables affect the group of R&D projects selected. Easily-performed, parametric analysis is particularly important when the analyst is not certain exactly what weighting scheme should be employed.

Finally, the model should make it easy to determine how the benefits and costs are affected by the inclusion of a project which would not otherwise be selected by the model. This is a particularly important tool for the decision maker, for it allows him to see in quantitative terms the consequences of hypothetical project portfolios which he may wish to consider, and how they compare with other portfolios on an attribute-by-attribute or overall worth basis. Thus, even if the model is not the final selector of the R&D project portfolio, it can still provide valuable information on how projects compare.

In previous sections, a number of commonly used and potentially useful economic measures have been described. Ideally, it is desirable to have a single non-controversial measure which could be used for making the investment portfolio decision. This measure would:

1. Be simple to calculate
2. Account for different sizes of investment and payoffs both absolute and relative
3. Account for difference in timing of costs and benefits as well as their magnitude versus time
4. Have a single unique value
5. Take into account uncertainty and risk in cost and benefits (including the uncertainty associated with the level of technology development being implemented.

It is unfortunate that no single measure has been developed which satisfies all of the above "ideal" criteria. Even though no one measure exists which satisfies the above, the previously discussed measures to various degrees have been used to assist with the project selection process. They have been used primarily in two ways, namely:

1. To see that the projects under consideration meet or exceed specified goals (that is, threshold values of the economic measures)

2. To perform project selection based upon the value of the economic measures.

Two alternative methods of project selection need to be considered since the differences between and the usefulness of the economic measures depends to a large extent upon which project selection method is utilized. The first of these methods is referred to as the "serial" selection method. Within this method, appropriate economic measures (e.g., return on investment, benefit-cost ratio, etc.) are developed for each project, the projects ranked according to the established value of the economic measures, and projects thence selected according to the ranking, selecting those projects first with the largest values (of the economic measures). The selection process continues until one or more constraints (for example, monetary, manpower or facilities) are encountered. This approach, though most frequently used, normally leads to less than optimum portfolio selection in the sense that maximum possible value is not achieved within the specified constraints. Besides not providing an optimized portfolio selection, the serial approach becomes extremely difficult when it is desired to consider multiple constraints.

The second method of project selection is referred to as the "simultaneous" selection method. The objective of this method is to select that mix of projects which maximizes the value of the portfolio within a specified set of constraints. This method does not require the specific ranking of projects according to economic measures but requires, as in the serial selection approach, a determination of project related benefits and costs. Using integer and/or linear programming techniques, the mix of projects which maximizes the net present value of the total portfolio within specified constraints is established.* This method of project

*Taha, H.A., Operations Research: An Introduction, Macmillan, 1976; Hillier F.S., and G.J. Lieberman, Introduction to Operations Research, Holden-Day, 1967.

selection, because of its sophistication, is not used as frequently as the serial method, even though it can sometimes lead to significant improvements in portfolio selections. The basic difference between the serial and simultaneous methods is one of level of optimization. The serial approach is analogous to an exercise in subsystem optimization whereas the simultaneous method is analogous to overall system optimization.

The difference of the serial versus the simultaneous methods can be seen by referring to Tables 2.7 and 2.8. Table 2.7 represents an assumed menu of projects in terms of present value of benefits and costs. Table 2.8 represents the project selection results using different crtieria at different budget levels. The net gain of an integer programming (IP) approach over a B/C ratio approach, the former representing the simultaneous selection method and the latter representing the serial selection method, is evident.

The previous discussion was centered on monetary costs and benefits and their relationship to project selection. Many other factors must be considered when formulating an R&D program. Therefore, mathematical techniques, to be of maximum assistance in R&D program formulation, must allow for the consideration of multiple project attributes (for example, costs such as dollar costs, manpower and facilities and benefits such as dollar savings, fuel savings, noise reduction, increased planning flexibility and others). The "method of best compromise", illustrated in Figures C.1 and C.2 of Appendix C, is such a technique. It seeks to select that subset of available opportunities that measures well against a family of performance indices subject to a set of resource constraints. The performance indices might be quite diverse, for example, noise reduction, pollution reduction, increased safety and monetary benefits, and relatable to each other only through human preferences. Thus, the method of best compromise accepts, in addition to

TABLE 2.7 ASSUMED PROJECT MENU (K$)

PROJECT NO.	(1) PVB	(2) PVC	(3)=(1)-(2) NPV	(4) C_1	(3)/(2) B/C RATIO
1	1426	310	1116	60	3.6
2	855	190	665	65	3.5
3	1025	250	775	30	3.1
4	984	240	744	30	3.1
5	1120	280	840	30	3.0
6	874	230	644	30	2.8
				245	

NOTE: C_1 = FIRST YEAR COST PVC = PRESENT VALUE OF COST

PVB = PRESENT VALUE OF BENEFITS B/C RATIO = NPV/PVC

TABLE 2.8 PROJECT SELECTION RESULTS USING DIFFERENT CRITERIA

BUDGET LEVEL (K$)	B/C RATIO CHOICE	NPV USING B/C CRITERIA	IP CHOICE	NPV USING IP	NET GAIN (IP OVER B/C) (K$)	(%)
30	3	775	5	840	+65	+8
60	1	1116	5,3	1615	+499	+45
90	1,3	1891	5,3,4	2359	+468	+25
120	1,3,4	2635	5,3,4,6	3003	+368	+14
150	1,2	1781	1,5,3,4	3475	+1694	+95
180	1,2,3	2556	1,5,3,4,6	4119	+1563	+61
210	1,2,3,4	3300	1,5,3,4,6	4119	+819	+25
250	1,2,3,4,5,6	4784	1,5,3,4,6,2	4784	EVEN	0

inputs that describe the various opportunities in terms of their benefits and costs, preference measures of the decision maker. The algorithm (described in Appendix C) then indicates the "optimal" portfolio obtainable within the decision maker's preferences.

The previous discussion has discussed the role of mathematical modeling in R&D program planning. Benefit-cost analysis, together with various project selection techniques, can be used to assist in the planning process by bringing important factors to management's attention, by placing the intuitive approach in perspective, by adding consistency to the analysis of many diverse projects, and can and has been used to provide a crutch or defense mechanism. The purpose of benefit-cost analysis and project selection techniques is not to usurp management perogatives but to help management exert its perogatives in a more consistent and rational fashion.

In order to formulate an efficient R&D program, it is necessary that the organization establish a formal and well-defined set of goals. The goals should be mutually independent and they should form a complete set so that all project evaluation criteria are explicitly defined. In the absence of clearly defined organization goals, R&D program planners are forced to establish a set of "perceived" goals which may or may not coincide with the organization's goals. This leads invariably to a mismatch between the proposed R&D program and organization goals.

The statement of goals should be thorough in that the ambiguities are removed to the maximum possible extent and, hence, can lead to well-defined utility or preference measures associated with the goals. When techniques such as the method of best compromise are used to assist in the R&D formulation process, it is necessary to explicitly and quantitatively express these preferences.

2.2 Business Planning in the Public Sector

NASA, through OSTA, is conducting an applications-oriented RD&D program. A substantial part of this program is aimed at developing and demonstrating the technology and creating the environment which could lead to operational systems capable of providing goods and/or services on a continuing basis (by other federal agencies or the private sector) that are in the public interest. NASA, like other government agencies, is often required to help develop and to provide goods and/or services when, because of undue perceived risk, magnitude of investment, and long time delays from initial investment to significant cash inflows, the private sector deems it undesirable to make investments that will lead to providing goods and/or services which would, if offered, confer benefits to members of society. Government participation is also often required when the production or consumption of goods and/or services provides to individuals benefits other than those normally provided to the parties of a market transaction. The benefits thus provided to members of society in total are larger than the benefits received by the individual parties to the market transaction. Finally, government participation is also generally required when the beneficial goods and/or services are in the public domain where it is not possible to establish a consumption-related pricing mechanism. This is summarized in Figure 2.8. In addition, government participation may also be required to see that goods and/or services are provided in the most efficient and economical fashion.

Given that a proposed program is consistent with agency objectives, a necessary condition for public sector funding of RD&D (including incentive progrms*) is that the benefits which are the direct result of the RD&D exceed the

*Incentive programs are aimed at effecting investment decisions by providing some form of financial assistance to the business venture. For example, NASA might defray early space processing development costs and might postpone repayment of early space processing shuttle flights in order to make the resulting business venture more attractive for private sector investment.

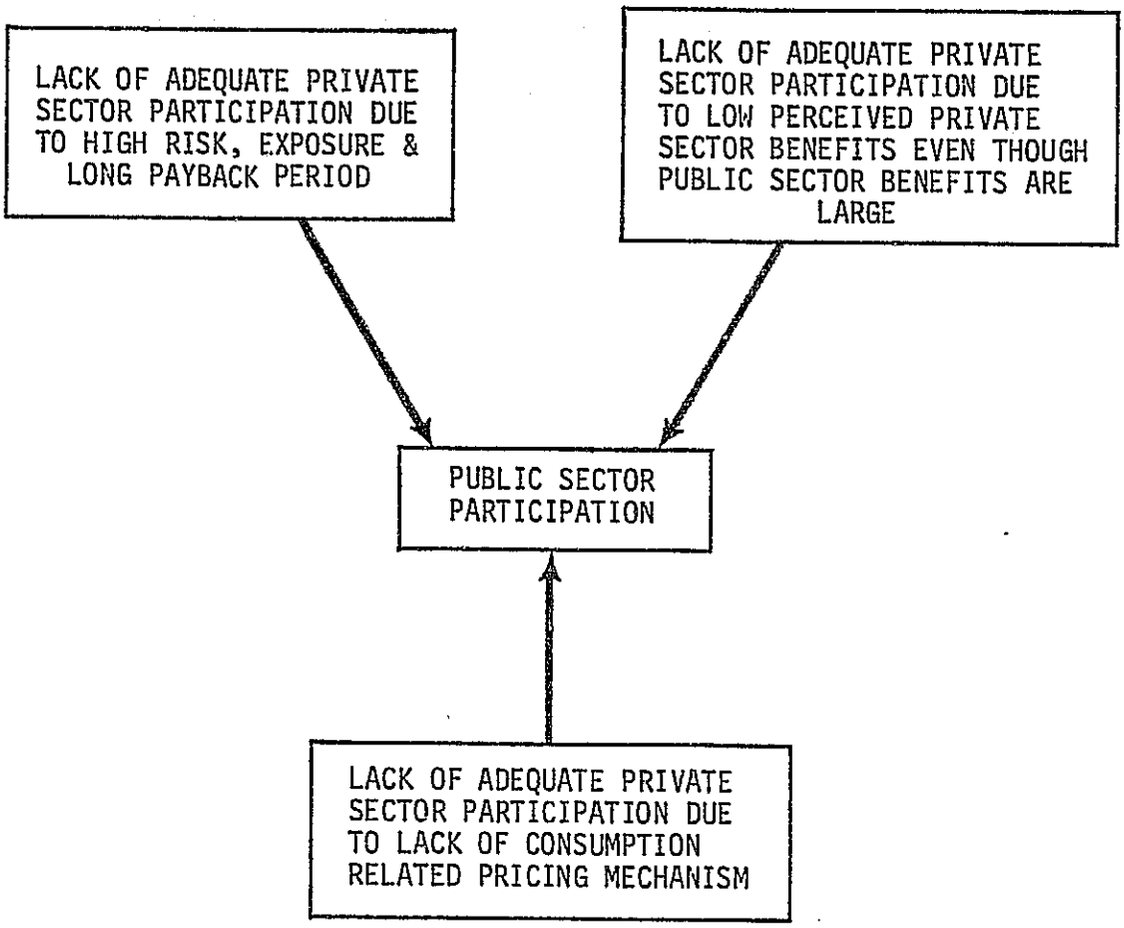

FIGURE 2.8 IMPORTANT REASONS FOR PUBLIC SECTOR PARTICIPATION

cost of the program. Thus, the overall objective of the planning process is to ensure that an RD&D program consistent with agency objectives is formulated and adopted where the anticipated benefits exceed the costs. Since, for an applications-oriented program, benefits will not be achieved unless the results of the RD&D lead to operational systems which provide goods and/or services on a continuing basis, the planning process must also be concerned with the technology transfer process (the process of converting the results of the RD&D into operational systems in the public sector or business ventures in the private sector). Thus, the planning process must place major emphasis on understanding (a) operational decision processes that may be impacted by the new or improved goods and services, and (b) the private sector investment decisions with and without the public sector RD&D.* The specific initiatives to be undertaken, the detailed set of tasks to be undertaken within the initiative, and the capabilities or attributes of the resulting operational system will, to a large degree, be a function of the reasons for public sector participation (as indicated in Figure 2.8) and the institutional arrangements and reactions of the private sector.

Public sector planning should be concerned with setting goals and objectives and establishing the RD&D program that maximizes net societal benefits (net benefits obtained by the public and includes those that are directly measured in monetary units as well as those which are not directly measurable in monetary units such as lives saved, noise reduction, pollution reduction, etc.) within the established goals and objectives and budgetary constraints. When the RD&D

*See, for example, "The Plan for the Economic Evaluation of Research for Improved Agricultural Management Decisions", ECON Report No. 78-175-1, Contract No. NAS5-20940, 15 April 1978.

program is applications oriented,* the public sector business planning should be concerned with establishing (a) the benefits that may result from the operational systems, (b) the costs that will be incurred in order to achieve the benefits, and (c) the costs of the RD&D program. The benefits and costs can then be compared and the RD&D program developed that maximizes net benefits. This approach is predicated upon the assumption that an applications oriented incentive RD&D program is undertaken with the expressed intent of improving the general welfare by altering the supply/demand structure as indicated in Figure 2.9.** (Only the supply/demand impact of a single good is shown.) The impact of these shifts on other goods should also be considered. For example, improvements in teleconferencing services may have significant impacts on the transportation sector. The important point is that the value of the RD&D in support of a new initiative must be measured in terms of the impact that the RD&D has upon public and/or private sector operational systems and the goods and services which are provided on a continuing basis. The benefits from an RD&D program are the result of providing goods and/or services that would otherwise be foregone, or speeding up the technology transfer process which will result in the goods and/or services being provided at an earlier date than if the RD&D program were not undertaken.

Business planning in the public sector should thus be concerned, in the broad sense, with estabishing the RD&D program that maximizes the net benefits that

*That is, the ultimate goals and objectives (for example, "to aid the responsible storm forecasting agencies in improving the accuracy and timeliness of severe storm forecasts and warnings...") can only be achieved if operational systems are established by the public or private sectors to provide the desired goods and/or services on a continuing basis.

**Shifting the supply curve from S to S' or shifting the demand curve from D to D'. The benefits from the program are indicated as the cross-hatched area that indicates the resulting change in consumers and producers surplus. This is discussed in more detail in Appendix B.

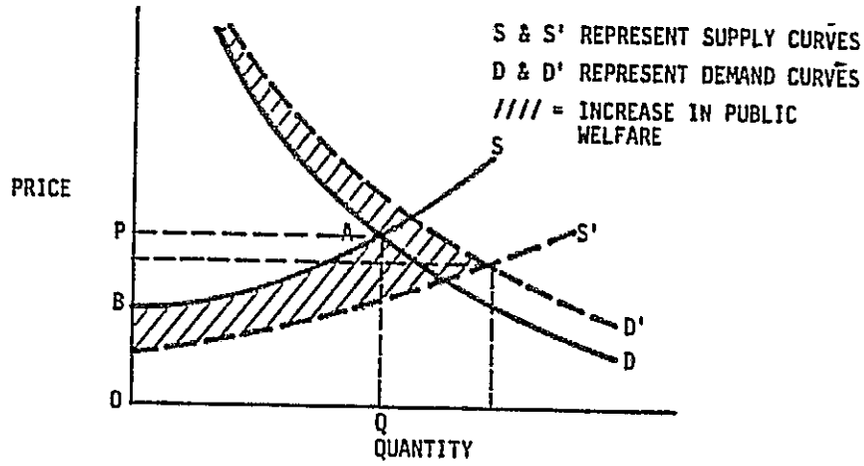

FIGURE 2.9 INCREASE IN PUBLIC WELFARE RESULTING FROM CHANGE IN SUPPLY/DEMAND STRUCTURE

may be achieved within specified resource constraints. As part of the planning process, business planning should also indicate the impact of altering resource constraints on the achievable net benefits and the specifics of the RD&D program. In the narrower sense, business planning in the public sector should lead to the specific set of RD&D programs that maximize net benefits within established resource constraints. Business planning in the public sector should, as in the private sector, be concerned with the evaluation, comparison, selection and justification of new initiatives and their supporting RD&D programs. It should be noted that when the benefits of public sector initiatives are the result of private sector operational decisions,* the analysis of private sector decision processes should be an integral part of public sector business planning. When public sector initiatives are undertaken with the objective of influencing private sector

*For example, the benefits of improved farm irrigation decisions resulting from improved soil moisture information.

investment decisions,* the analysis of private sector investment decisions (termed venture analysis) should be an integral part of public sector business planning. The venture analysis, as will be discussed in following pages, requires the analysis of a typical business venture that might develop with and without the undertaking of a new initiative by NASA. The objective of the venture analysis is to understand (in both qualitative and quantitative terms) the impact of the new initiative on private sector investment decisions and the benefits that may be derived as the result of influencing the decisions.

Before discussing a procedure for public sector new initiative evaluation, comparison, selection and justification, it is instructive to compare the key questions that are of concern to business planning in the private and public sectors. Referring to Table 2.9, a list of pertinent questions is illustrated. The private sector questions are those posed in the DuPont Guide to Venture Analysis. Their answers give a complete overview, or appraisal, required as a basis for major decisions about the venture's future. It should be noted that at some point in the development of every new venture a complete overview, or appraisal, is required as a basis for major decisions about the venture's future. Such appraisals are most frequently at the request of, or for, a decision maker who has not been intimately associated with the development. For example, an appraisal may be desirable to support a request for funds to establish a new product line. In these cases, effective communication requires a sharper focus on the business elements of the venture than on the technical elements. In addition, a more standardized reporting format and vocabulary are necessary to permit comparisons with other ventures.

*For example, communications R&D aimed at providing improved mobile communication services.

TABLE 2.9 COMPARISON OF PRIVATE SECTOR AND PUBLIC SECTOR KEY QUESTIONS CONCERNING NEW VENTURES (INITIATIVES)

PRIVATE SECTOR*	PUBLIC SECTOR
• WHAT IS THE VENTURE?	• WHAT IS THE NEW INITIATIVE?
• WHY ARE WE RISKING DEVELOPMENT MONEY IN THE VENTURE?	• WHY SHOULD THE PUBLIC SECTOR DO IT? • WHY WONT THE PRIVATE SECTOR DO IT?
• WHAT IS THE SIZE OF THE EFFORT AND THE DEVELOPMENT COST, PAST AND FUTURE?	• WHAT IS THE SIZE OF THE EFFORT AND THE DEVELOPMENT COST, PAST AND FUTURE? • WHAT ARE THE LIFE CYCLE COSTS OF AN OPERATIONAL SYSTEM?
• IF SUCCESSFUL, WHAT IS THE VENTURE 'PAYOFF'?	• IF INITIATIVE IS SUCCESSFUL, WHAT ARE THE PUBLIC SECTOR BENEFITS? • WHAT IS THE FORM OF THE BENEFITS?
• WHAT ARE THE MARKETS AND WHY CAN WE SELL THE PRODUCT IN THESE MARKETS?	• WHAT IS THE USER NEED? • WHAT IS THE MARKET POTENTIAL?
• WHAT ARE THE SALES EXPECTATIONS, CHARACTERISTICS OF THE MARKETS, AND HOW ARE WE GOING TO SELL INTO THESE MARKETS?	• WHAT IS THE MECHANISM FOR DISTRIBUTING THE GOODS AND/OR SERVICES? • HOW WILL THE PRIVATE SECTOR PARTICIPATE? • WHAT IS THE PRICING POLICY?
• WHAT ARE THE UNCERTAINTIES IN THE VENTURE TO BE CLARIFIED IN THE FUTURE DEVELOPMENT PROGRAM?	• WHAT ARE THE MARKET, COST AND PERFORMANCE UNCERTAINTIES IN THE VENTURE TO BE CLARIFIED IN THE FUTURE R&D PROGRAM? • WHAT ARE THE SPECIFIC IMPACTS OF RISK AND EXPOSURE REDUCTION ON THE LIKELIHOOD OF PRIVATE SECTOR INVESTMENT?
• WHAT ARE THE FINANCIAL IMPLICATIONS OF THESE UNCERTAINTIES?	• WHAT ARE THE IMPLICATIONS OF UNCERTAINTY IN MARKET, COST AND PERFORMANCE ON PUBLIC SECTOR PROGRAM? • WHAT IS THE IMPACT OF PRIVATE SECTOR REACTION UNCERTAINTY ON PUBLIC SECTOR PROGRAM?

*THESE QUESTIONS ARE POSED IN THE DuPONT GUIDE TO VENTURE ANALYSIS. THEIR ANSWERS GIVE A COMPLETE OVERVIEW, OR APPRAISAL REQUIRED AS A BASIS FOR MAJOR DECISIONS ABOUT THE VENTURE'S FUTURE.

The second column in Table 2.9 lists public sector questions that are comparable to correpsonding private sector questions. For example, the private sector asks the question: Why are we risking development money in the venture? The public sector must ask the following questions: Why should the public sector do it? Why won't the private sector do it? The first question is concerned with whether or not benefits exceed costs and the second question is concerned with understanding if and why the private sector will not undertake the venture.

With the questions indicated in Table 2.9 in mind, Figure 2.10 indicates a procedure for public sector new initiative evaluation, comparison, selection and justification. Public sector business planning in support of new initiatives should follow this procedure. The procedure is indicated in the framework of answering a specific set of questions. It should be noted that, in general, the level of detail of supporting analyses increases as one progresses through the procedure. In certain instances, the responses determine subsequent questions to be answered. The starting point is to establish whether or not the new initiative is worth doing (Q1); in other words, do anticipated benefits* exceed anticipated costs?* The costs include those of the R&D and incentive programs. They also include the negative cash flow stream associated with the resulting operational system that is required to provide the goods and/or services. The benefits represent the change in consumer surplus** and producers' surplus** resulting from the introduction and

*Present values.

**Referring to Figure 2.9, consumer surplus is indicated by the area under the demand curve to the price, P, and quantity, Q, established by the intersection of the supply and demand curve, less the area PAQO which is the product of P and Q. Consumer surplus, therefore, represents the difference between what consumers are willing to pay and what they actually pay. Producers surplus is given by the area PAB and represents the payments to producers in excess of the cost required to produce the quantity Q.

Q1. IS THE PROJECT WORTH DOING?

Q2. IS THE PRIVATE SECTOR DOING IT NOW?

Q3. IS IT LIKELY THAT THE PRIVATE SECTOR WILL DO IT IN THE FUTURE WITHOUT PUBLIC SECTOR SUPPORT?

Q4. IS THE LACK OF PRIVATE SECTOR PARTICIPATION DUE TO LACK OF CONSUMPTION-RELATED PRICING MECHANISM?

Q5. IS THE LACK OF PRIVATE SECTOR PARTICIPATION DUE TO THE LACK OF PERCEIVED PRIVATE SECTOR BENEFITS EVEN THOUGH PUBLIC SECTOR BENEFITS ARE LARGE?

Q6. IS IT LIKELY THAT THE PRIVATE SECTOR WILL DO IT IN THE FUTURE WITH PUBLIC SECTOR SUPPORT?

Q7. DOES THE PROJECT COMPARE FAVORABLY WITH OTHER PROJECTS COMPETING FOR LIMITED RESOURCES?

Q8. DO THE BENEFITS FROM AN OPERATIONAL SYSTEM EXCEED THE COSTS?

Q9. WILL SUBSIDIES OR OTHER INCENTIVE PROGRAMS CHANGE PRIVATE SECTOR DECISIONS AND STILL PROVIDE NET PUBLIC SECTOR BENEFITS?

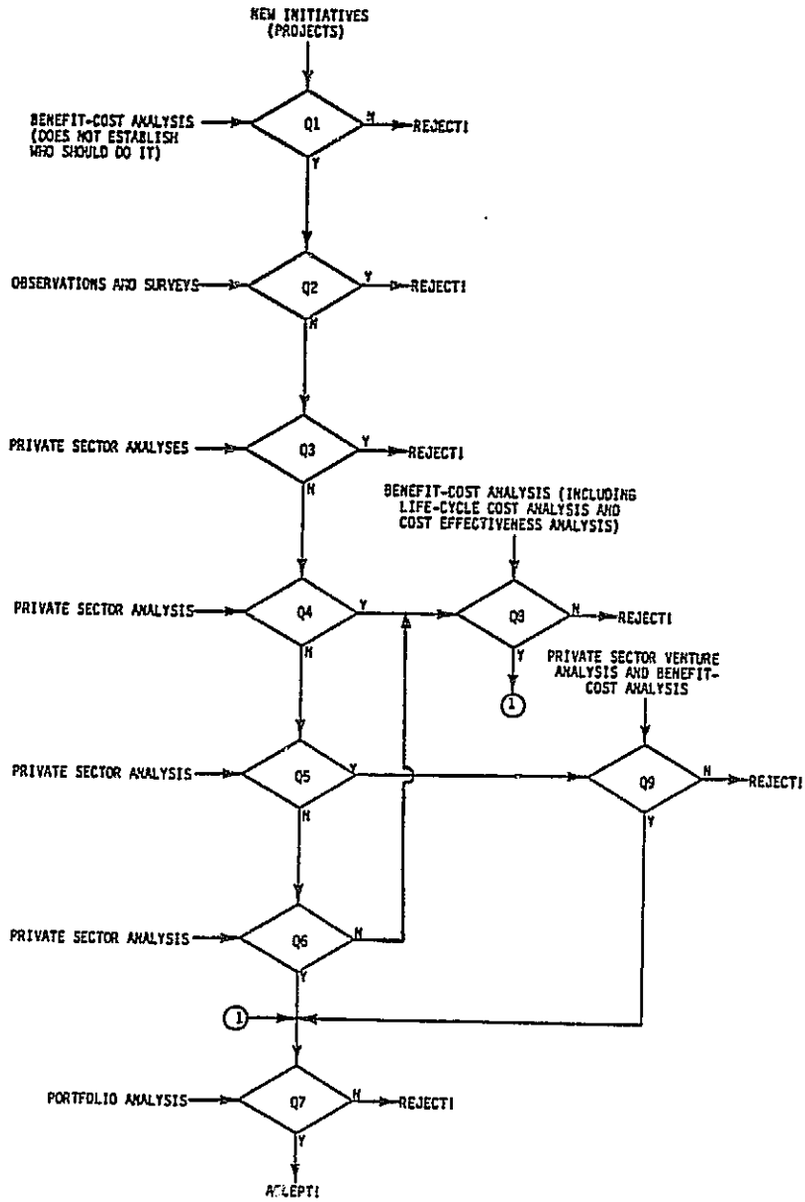

FIGURE 2.10 PUBLIC SECTOR NEW INITIATIVE EVALUATION, COMPARISON, SELECTION AND JUSTIFICATION PROCEDURE

provision of the goods and/or services. For example, for an earth resources system, the costs include the development costs and life cycle costs of the operational system (both the space and terrestrial system components) and the benefits comprise the consumers and producers surplus benefits resulting from improved forecasts plus the consumer and producer surplus benefits resulting from improved production decisions resulting from improved knowledge of pertinent decision variables (for example, improved irrigation decisions resulting from improved knowledge of soil moisture content). It should be noted that benefit-cost analysis does not provide insights as to whether the public sector or the private sector should undertake the new initiative. Benefit-cost analysis only establishes the fact that the initiative is (or is not) worth doing! Only an examination of the venture from the perspective of the private sector can provide the needed insight into the attractiveness of the venture to the private sector.

If the initiative is worth doing, it is then necessary to establish whether or not the private sector has current plans for providing the indicated beneficial goods and/or services (Q2). This can only be ascertained through observations and surveys and other contacts with private sector establishments that would be the likely providers of the goods and/or services.

When it has been established that the private sector does not currently plan to provide the beneficial goods and/or services, it is necessary to determine if the private sector is likely to provide these goods and/or services in the future in the absence of public sector support (Q3). In order to make this determination, it is necessary to perform private sector venture (i.e., new business) analyses. The result of these analyses will provide an indication of whether or not it is likely that an attractive business venture may be established in the future without public

sector support. The analyses will also provide an initial indication of what form the public sector support should take.

If it is not likely that the private sector will undertake ventures to provide the beneficial goods and/or services (or if it appears that their timing will be significantly altered), it is necessary to determine the specific reasons for this lack of participation. This can also be achieved by performing private sector venture analyses. This will establish if the lack of private sector participation is due to (a) the lack of a consumption-related pricing mechanism,* (b) the lack of adequate private sector benefits even though public sector benefits are large, or (c) the combination of unduly high risk and exposure and long payback period. If it is determined that the reason for the lack of a consumption-related pricing mechanism (Q4), it is then necessary to perform benefit-cost analyses (including life-cycle cost analyses and cost-effectiveness analyses) so as to determine (Q8) the "best" alternative or scenario for the public sector initiative and operational system. It is under this circumstance (i.e., lack of pricing mechanism) that the public sector provision of goods and/or services is justified.

If it is determined that the reason for the lack of private sector participation is due to the lack of private sector benefits even though public sector benefits are large (Q5), then it is necessary to perform both private sector venture analysis and the public sector benefit-cost analysis. The objective (Q9) is to ascertain the mix of subsidies and other incentive programs that will lead to attractive private sector business ventures that still produce (taking into account the costs of the subsidy and incentive programs) public sector net benefits.

*There is no plausible way to directly charge the consumer for the service rendered--for example, weather forecasting by NOAA.

If it is determined that the reason for the lack of adequate private sector participation is due to the combination of unduly high risk and exposure and long payback period, it is necessary to determine (Q6) the public sector RD&D program which will reduce risk, exposure and payback period to tolerable levels. This means that the venture analysis must explicitly and quantitatively consider the uncertainties associated with the venture and the resulting risk. Thus, risk analysis is the mainstay of this analysis. This follows from the fact that the likelihood of private sector participation depends upon many factors, foremost among which are perceived uncertainty, resulting risk and exposure. The public sector benefits from an RD&D program, in such a case, are thus inextricably tied to the impact of the RD&D program upon the likelihood of private sector participation through its effect on perceived uncertainty, risk and exposure. The objective of this venture and risk analysis is to establish the risk profiles (complementary cumulative probability distributions) of performance measures such as ROI (return-on-investment). The probability of private sector investment may be described in terms of the expected value, m, and standard deviation, σ , of ROI as indicated in Figure 2.11. The objective of public sector RD&D is to alter, through its impact on perceived uncertainty, the private sector perceived return on investment (ROI) from m_A and σ_A to m_B and σ_B thus changing the probability from α_A to α_B. The benefits from the public sector program are thus given by

$$\overline{B} = \alpha_B * \overline{PV}_B - \alpha_A * \overline{PV}_A - \overline{PVC}$$

where $\overline{PV}_B$ and $\overline{PV}_A$ are the expected public sector benefits with and without the R&D or incentive program, respectively. $\overline{PVC}$ is the expected value of the cost of the R&D or incentive program. α_B and α_A are the probabilities of private sector investment with and without the public sector R&D or incentive program,

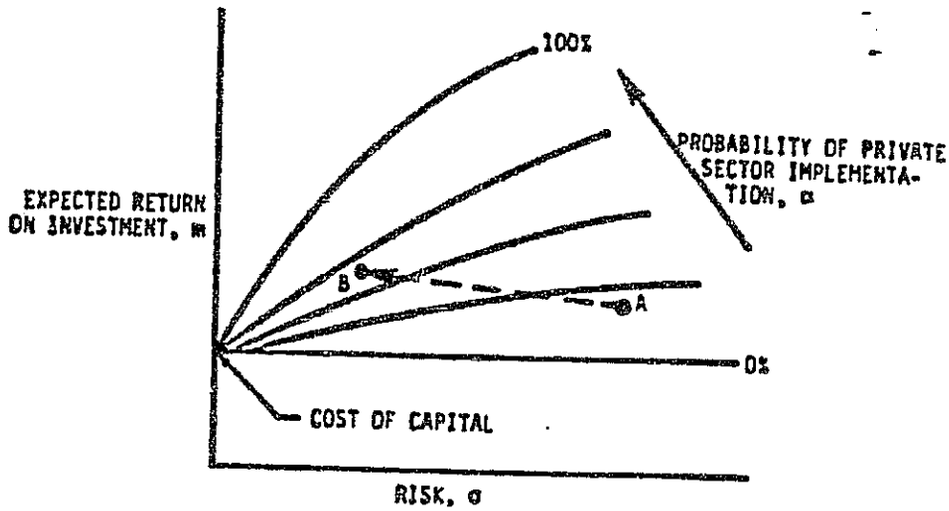

FIGURE 2.11 PROBABILITY OF PRIVATE SECTOR IMPLEMENTATION (INVESTMENT) IN TERMS OF EXPECTED VALUE AND STANDARD DEVIATION OF RETURN ON INVESTMENT (UNREGULATED INDUSTRY)

respectively. $\overline{PV}_B$ and $\overline{PV}_A$ reflect the timing of the benefits with and without the R&D or incentive program. This methodolody is developed in more detail in Appendix B, where a communications RD&D program is considered. Specifically, the methodology is developed for public sector business planning with private sector venture analysis being an integral part.

If it is found (Q6) that the RD&D program will not achieve the desired private sector response (for example, the cost of the RD&D to obtain the desired private sector response exceeds the benefits), then it is necessary to consider public sector provision of goods and/or services (Q8).

Finally, after all of the evaluation analyses have been accomplished, all new initiatives and supporting projects must be compared so that a set may be selected which maximizes overall program "value" in the light of limited resources. This project selection may take many forms ranging from an intuitive approach, to project ranking and selection according to rank until resources are fully consumed,

to multi-attribute project or portfolio selection as described in previous paragraphs. It is recommended that this latter approach be followed since it allows multiple benefit attributes to be considered and OSTA is often concerned with programs which cannot always be described in terms of a single monetary benefit attribute.

Previous paragraphs discussed the need for life cycle cost and benefit-cost analyses. Because of the importance of these techniques to NASA new initiative evaluation, they are described in more detail in the following paragraphs.

Life cycle cost analysis is concerned with establishing the annual costs (and present value thereof) that might result from undertaking a new applications initiative. The annual costs include the RD&D costs as well as the nonrecurring and recurring costs associated with initiating and maintaining an operational system and providing goods and services on a continuing basis. When providing goods and services on an operational basis, continuity of service is important. This implies that costs will be incurred that are specifically related to the continuity of service. Since continuity of service is related to reliability, life cycle cost analysis should explicitly consider less-than-perfect reliability and, because of the new technology aspects, imperfect a priori knowledge of costs should also be considered. This allows the probability distribution of the present value of the space portion of life cycle costs to be determined. There can be significant differences between the life cycle costs and present values when developed with and without the explicit consideration of less-than-perfect reliability and cost uncertainties.* In general, optimistic costs are obtained when reliability and cost uncertainties are not explicitly considered.

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*Greenberg, J. S., Risk Analysis, Astronautics & Aeronautics, November 1974.

The first cause regards the method for making cost estimates. Costs for complex systems are generally developed by breaking a total system into many parts. Cost estimates for each part are normally expressed as those values which are most likely to be achieved. However, upon investigation of the random structure of each estimate, it is common to find that the probability distribution of projected cost is skewed so that the mean or expected cost is higher than the most likely cost. When many random variables (of similar magnitude but various distributions) are summed, the probability distribution of the sum tends toward a Gaussian or normal distribution for which the mean and the most likely values are the same. Thus, the most likely cost of the total system is the sum of the expected values of the costs of the parts. It is in general mathematically incorrect to say that the total system cost is the sum of the most likely cost estimates for the parts that comprise the system. Hence, to neglect cost uncertainties is to commit a mathematical error. Many program directors have learned to cope with this error by adding a contingency fund. However, the size of this fund is all too often obtained by gut feeling and does not provide a true picture of financial risk.

The second cause for higher than anticipated costs lies in the fact that the system reliability is generally not explicitly considered when cost estimates are made. The most commonly used argument for not explicitly accounting for system unreliability is that accurate reliability data are not available. But a decision to not explicitly include the effects of system reliability upon costs is precisely equivalent to performing a thorough analysis of these effects under the assumption that all components of the system are perfectly reliable. Certainly, it should be possible to do better than this, even with crude reliability estimates.

In order to establish realistic estimates of life cycle costs of operational space systems, it is usually necessary to utilize a space mission (Monte Carlo) simulation model as indicated in Figure 2.12. This model mathematically describes

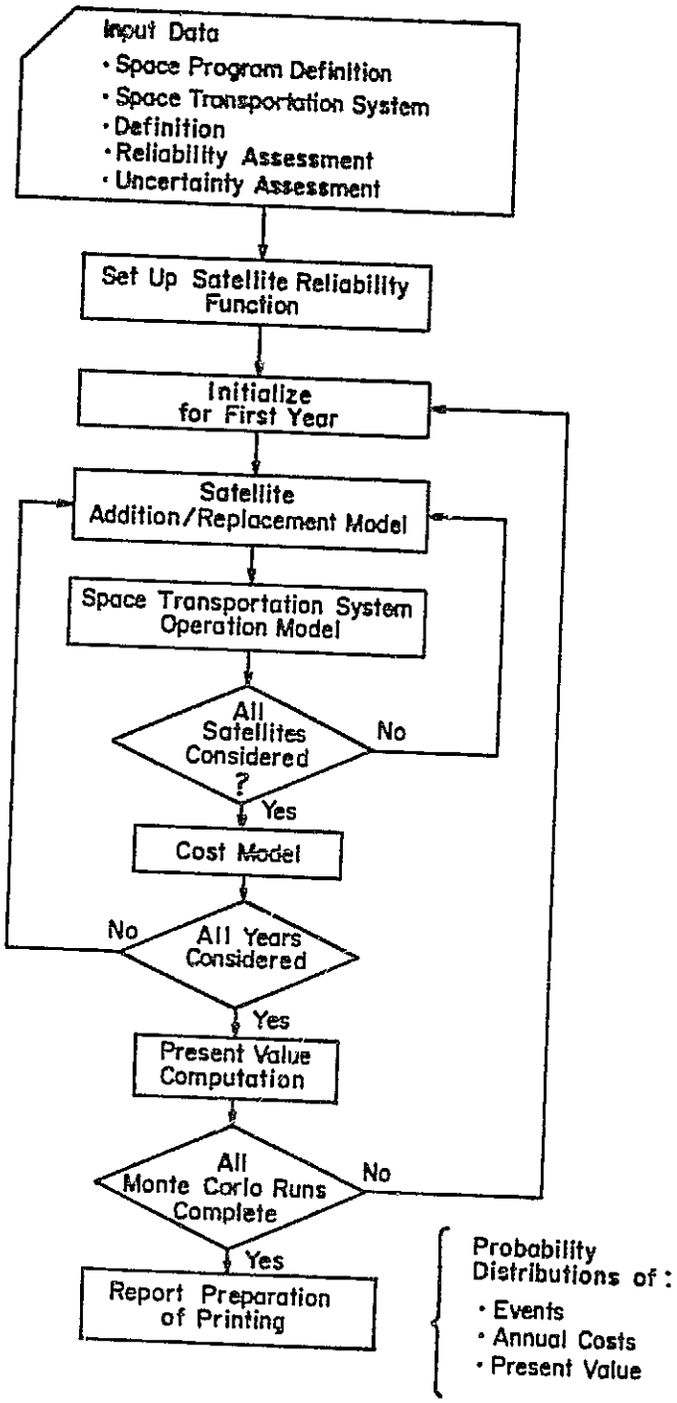

FIGURE 2.12 SPACE MISSION SIMULATION MODEL

the operational, cost and economic factors associated with the mission. The analysis actually subsumes three mathematical models:

1. A satellite addition/replacement model that establishes the number of satellites that must be added or replaced as a function of time based on the satellite reliability function. This model keeps track of each satellite to establish if and when a failure occurs and, based upon the operational requirements, determines the number of satellites which must be added and/or retrieved and refurbished.

2. A model of space transportation system operations that simulates events while placing and retrieving satellites from orbit. This model takes into account the reliability aspects of pertinent launch, placement and retrieval operations and the resulting failure and recovery possibilities, and it establishes the probability distributions of success or failure events (for example, the probability distribution for successful launch). The analyst may vary the nominal parameters so that he can evaluate effects of such parameters as satellite reliability. Space Tug retrieval, and the like on the events, cost per event, and present value of cost.

3. A cost model that, in terms of cost learning curves, establishes the recurring costs of the various events, including replacement and refurbishment costs for the Space Shuttle, Space Tug and satellites. The cost model combines the results of the operational analyses (paragraphs 1 and 2) with the appropriate cost per event (treated as uncertainty variable). The mathematical model then uses the cost data to establish the present value of costs for the entire program.

Figure 2.13 shows a typical probability distribution for launch attempts. Based upon mission needs,if failures did not occur, only two launch attempts would be required. However, due to mission and transportation system reliability factors, there is actually only a 50 percent chance of requiring two launch attempts with a 50 percent chance that more than two will be required. There is about a 30 percent chance that three launch attempts will be required, a 17 percent chance that four will be required, etc. This distribution and other event probabilities of course strongly shape costs.

The annual cost uncertainties lead to risk in terms of exceeding budget constraints. The cost uncertainties can be summarized in the form of the risk

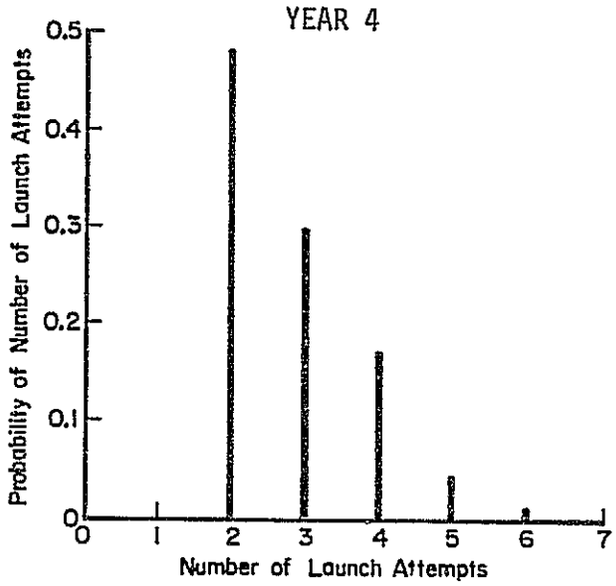

FIGURE 2.13 TYPICAL PROBABILITY DISTRIBUTION OF LAUNCH ATTEMPTS

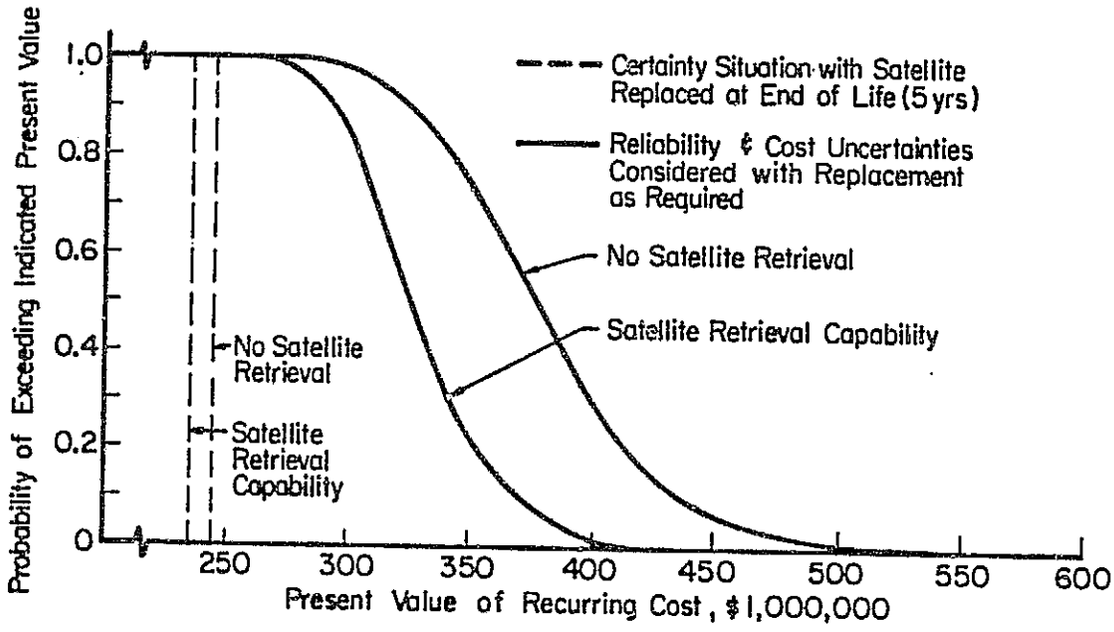

FIGURE 2.14 PROBABILITY DISTRIBUTION OF LIFE CYCLE COSTS AS DETERMINED FROM MISSION SIMULATIONS CONSIDERING RELIABILITY AND COST UNCERTAINTIES

profile of the present value of recurring costs (exceeding various levels), as illustrated in Figure 2.14.

Figure 2.14 indicates (the dashed lines) the present values associated with the certainty situations. The certainty situation assumes satellites fail at the anticipated wearout time and are thus retrieved and/or replaced. The solid curves represent the uncertainty situations and indicte the chance that present value will exceed the amount indicated on the abscissa. Note that there is a 50 percent chance that present values can exceed those of the certainty cases by more than 40-50 percent. It should also be noted that the expected present value and risk may increase when satellite retrieval and refurbishment are not possible.

The details of the life cycle costing methodology required for evaluation of operational space systems is described in detail in the footnoted references.*

Benefit-cost analysis is concerned with evaluating the benefits and the costs which may result from the public sector investment in an RD&D program. The benefits and costs are those that would result, for example, from an operational system, providing information products on a continuing and on-going basis, that is an outgrowth of the RD&D program. A standard method of analysis in benefit-cost studies involves a principle that may be called "with and without" analysis. This approach, illustrated in Figure 2.15, compares the economic gains to for example, agriculture managers using current information products in an optimum fashion with the economic gains to agriculture managers who have new and/or improved

*Greenberg, J. S., Reliability, Uncertainty and Risk Analysis of Space Systems--A Methodology for Decision Making, Princeton University, AMS Report No. 1085, December 1972; Greenberg, J. S., Methodology for Reliability-Cost-Risk Analysis of Satellite Networks, Journal of Spacecraft, September 1974; Greenberg, J. S., The Economic Implications of Unreliability, Proceedings of the Annual Reliability and Maintainability Symposium, January 1976; Greenberg, J. S., A Benefit-Cost Analysis of Nuclear Power Applied to the GPS Mission, Journal of Energy, September 1977.

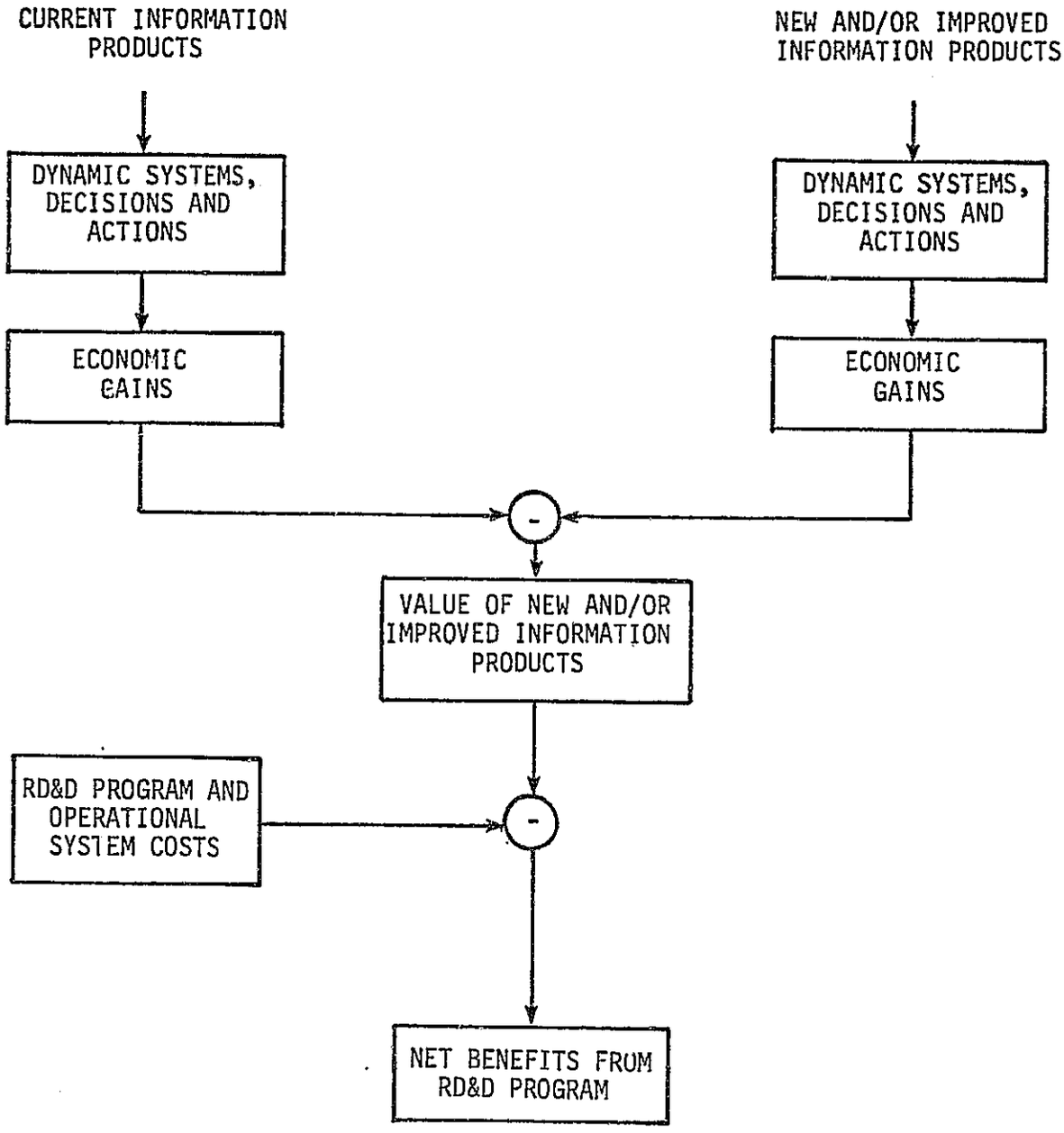

FIGURE 2.15 PROCEDURE FOR EVALUATING NET BENEFITS

information products available to them on a continuing basis. The net result is the value of new and/or improved information products in the decision process.

In order to arrive at the net benefit from the investment in RD&D, it is necessary to subtract the cost of the RD&D program from the derived value. It is also necessary to subtract the costs of the operational system which are incurred in collecting data, processing data and distributing derived information products.

The specifics of the benefit-cost analyses vary significantly depending upon the problem at hand.* A specific technique involving the determination of benefits in terms of the change in consumers and producers surplus is illustrated in Appendix C and is predicated upon determination of the price at which the new capability (in Appendix B, improved communication service is considered) will be provided. The benefits of improved communications in emergency medical applications have been obtained in terms of cost savings benefits (i.e., satellite communiations being more cost effective than terrestrial communication systems) and reduced mortality rate benefits. Reduced mortality rate is converted to economic benefits through "the human capital" approach to the value of a life. This approach relates future earning capacity to the value of life.** Specific

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*Agriculture Management Decisions--A Preliminary Benefit Assessment, ECON, Inc., Report No. 78-175-2, Contract No. NAS5-20940, May 1, 1978; The Benefits of Improved Technologies in Agricultural Aviation, ECON, Inc., Contract No. NASW-2781, February 1978; Economic Benefits of Improved Information on Worldwide Crop Production, ECON, Inc., Contract No. NASW-2558, April 15, 1977; Greenberg, J. S., A Benefit-Cost Analysis of Nuclear Power Applied to the GPS Mission, Journal of Energy, September 1977; Bradford, D. F. and H. H. Kelejian, The Value of Information for Crop Forecasting with Bayesian Speculators: Theory and Empirical Results, The Bell Journal of Economics, Spring 1978, Volume 9, No. 1; Economic Analysis of Standard Interface Modules for Use With the Multi-Mission Spacecraft, ECON, Inc., Report No. 76-103-1, Contract No. NASW-2558, August 31, 1976.

**Coger, Barbaras and Rice, Dorothy P., The Economic Cost of Illness Revisited, Social Security Administration, Office of Research and Statistics, 1975, Benefit Education of Space Processing of Biological Materials, Contract NAS-9-15338, ECON, Inc., December 1977.

techniques have been developed for evaluating the benefits of improved information (for example, meteorological forecasts) provided to decision makers who must choose between taking or not taking some specific protective action against a future forecasted unfavorable weather event:* Taking the protective action involves some cost with certainty; not taking the protective action involves escaping that cost, but incurring a certain loss if unfavorable weather condition does, in fact, occur. The details of these techniques can be found in the footnoted references.**

2.3 The Elements of a Business Plan for OSTA Projects

The objectives of a business plan for OSTA projects are to (a) provide an overall and common structure for planning and evaluation, (b) provide a common framework for management comparison and selection of desired alternatives, (c) bring into focus the broader issues of transforming the results of an R&D program to operational systems in either the public or private sectors, and (d) provide thorough and credible data and a defensible position for program justification. To accomplish these objectives, a business plan for OSTA initiatives should encompass to following sections:

1. Summary (key questions and answers)
2. Background
3. Goals and Objectives of Initiatives

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*Applications in this category involve construction scheduling, agriculture spraying, citrus crop freeze protection, snow removal crew scheduling, power and telephone emergency crew scheduling, and many others.

**Greenberg, J. S., Economic Benefits of Improved Meteorological Forecasts, Weather Forecasting and Weather Forecasts: Models, Systems and Users, National Center for Atmospheric Research Colloquium Report No. NCAR/CQ-5+1976-ASP; Thompson, J. C., Economic and Social Impact of Weather Forecasts, Weather Forecasting and Weather Forecasts: Models, Systems and Users, National Center for Atmospheric Research Colloquium Report No. NCAR/CQ-5-1976-ASP; Conklin, F. S., A. E. Baquet and A. N. Halter, An Assessment of the Economic Contribution of Frost Forecasting to Jackson County Pear Production, Technical Bulletin, Oregon Agricultural Experiment Station.

4. Description of the Initiative

   a. General
   b. Specific Projects

5. Description of Resulting Capability, Goods and Services (i.e., the operational system that will develop as a result of the R&D and incentive program)

6. The Need (The Marketplace)

   a. The End Users
   b. The Providers of Goods and Services

7. Benefit-Cost Analysis Results

8. Reason for Lack of Adequate Private Sector Participation

   a. Lack of Consumption-Related Pricing Mechanism
   b. Lack of Adequate Private Sector Benefits
   c. High Risk, High Exposure, Long Payback Period

9. Specific Impact of Proposed Program (Private Sector/Public Sector Analysis)

   a. Public Sector Provision of Goods and Services

      - Benefit Analysis
      - Cost Analysis (Life-Cycle Costs)

   b. Private Sector Provision of Goods and Services

      - Cost Reduction
      - Cost Uncertainty Reduction
      - Performance Improvements
      - Performance Uncertainty Reduction
      - Market Uncertainty Reduction
      - Private Sector Venture Analysis (Probability of Private Sector Implementation With/Without NASA Initiative)
      - Public Sector Benefit-Cost Analyses

   c. Environmental Considerations

10. Technology Transfer Considerations and Plan

   a. Institutional Constraints
   b. Regulatory Constraints
   c. Patent Ownership
   d. Demonstrations
   e. User Working Groups
   f. Implementation of Operational System

11. R&D and Incentive Program Plan

    a. Manpower
    b. Skills
    c. Facilities

12. Schedule

    a. Funding Requirements
    b. Anticipated Results

The following paragraphs describe the content of each of the above sections of the business plan for OSTA projects. It should be noted that detailed studies and supporting documents are required for a number of the sections. It should also be noted that the Business Planning document is in support of each initiative. Further planning, comparison and selection is necessary to choose between the various initiatives and associated R&D programs so as to establish an overall OSTA plan. This is discussed further in Section 2.4.

Some of the elements of the Business Plan described above are now prepared by OSTA as a part of the planning or budgeting process for new initiatives; however, many are not. The establishment of a business planning format results in a self-imposed discipline in terms of the identification of the knowns and unknowns concerning a proposed venture. Through the iterative process of planning and analysis, the unknowns are gradually reduced to knowns and the information available for management decision making is improved. Since NASA currently engages in both budgeting and planning, it is important to consider the relationship between business planning as described in this report and NASA budgeting and planning as currently practiced. This is discussed in Section 3, The Current Planning Process in OSTA.

1. Summary

The purpose of the Summary is to provide an overview of the proposed initiative and answers to a number of key questions that are of major importance

to decision makers. The specific wording of these questions needs further development, but they may be summarized as follows:

- What is the new initiative?
- What are the specific objectives? What is the likelihood of achieving or exceeding objectives?
- What are the resulting operational goods and services?
- How will the goods and services be provided?
- Is the project worth doing (what are the benefits, to whom, how much, what type)?
- Why should the public sector do it?
- What is the role of the public sector?
- What is the role of the private sector?
- What is the user need and market potential?
- What is the magnitude of the effort and the development cost, past and future?
- If the public sector is to provide operational system, what are life-cycle costs?
- What are major areas of uncertainty and risk?

2. Background

The background section indicates what has transpired that has led up to the proposed initiative. Has the impetus come from the need (the users and/or the private sector) or from the technology? What has been the historical funding and the results obtained to date? Why is it important to pursue the new initiative? What needs will be satisfied as a result of the initiative and the resultant goods and services?

3. Goals and Objectives of Initiative

The goals and objectives of the proposed initiative should be clearly stated, for example, to increase capability, reduce costs, reduce market, cost or performance uncertainty and/or shift the burden of funding (i.e., reduce exposure) from the

private to the public sector. The goals and objectives should be stated quantitatively; for example, if the objective is to improve the accuracy of 24-hour precipitation forecasts, it should be stated as increasing the probability that precipitation (in excess of δ inches) actually occurs given a forecast for precipitation from X percent to $X + \Delta X$ percent and decreasing the probability that precipitation actually occurs given a forecast for no precipitation from Y percent to $Y - \Delta Y$ percent. In other words, the goals and objectives should be stated relative to the capability that would exist if the new initiative were not undertaken.

4. Description of the Initiative

The general role of the initiative should be described from the point of view as to how the proposed initiative will accomplish the goals and objectives as well as the impact that it will have on the operational system or goods and services that will result and be provided on a continuing basis. The specific proposed R&D and incentive projects which are required in support of the initiative should also be delineated. This should be broken down into two groups: (a) those new projects requiring funding as part of the initiative and (b) those projects being funded or proposed for funding under other initiatives and whose undertaking is required in order to achieve the objectives of the new initiative.

5. Description of Resulting Capability, Goods and Services

The capability that will result from the RD&D program should be described. This description should include an assessment of the likelihood of achieving different levels of capability as indicated in Figure 2.16. It should be noted that if the probability of achieving objectives is too high, then there may be little or no reason to undertake the RD&D (other than shifting the burden of funding from the

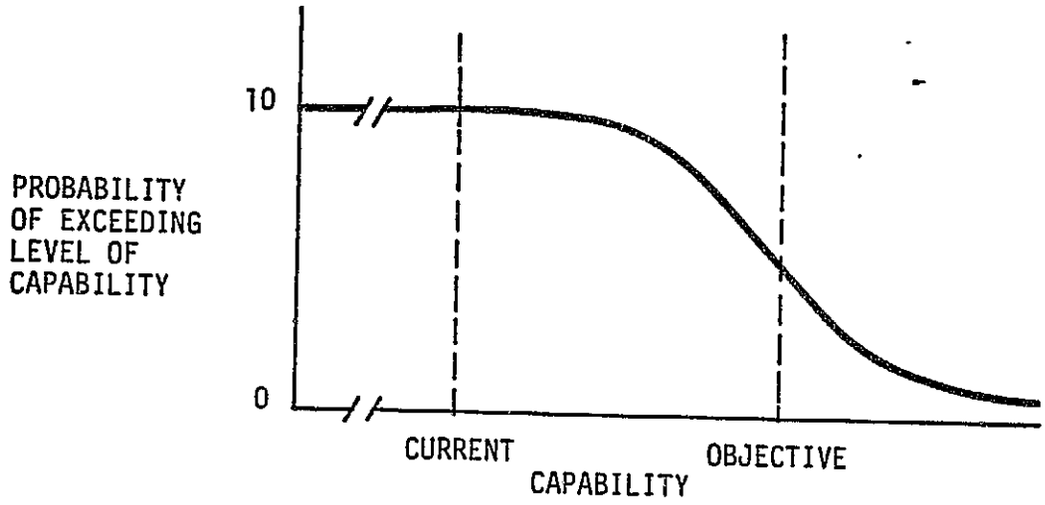


FIGURE 2.16 DESCRIPTION OF LIKELIHOOD OF ACHIEVING CAPABILITY OBJECTIVE

private to the public sector). On the other hand, if the probability of achieving objectives is too low, then there may also be little desire to undertake the RD&D because the expected benefits may be too low. It is also necessary to provide a detailed description of the operational system or business venture that might evolve from the RD&D program. The goods and services which will be provided by the operational system or business venture must also be described. They must be described in sufficient detail so that the specific user needs which may be satisfied and their effect on end user decision processes may be clearly stated.

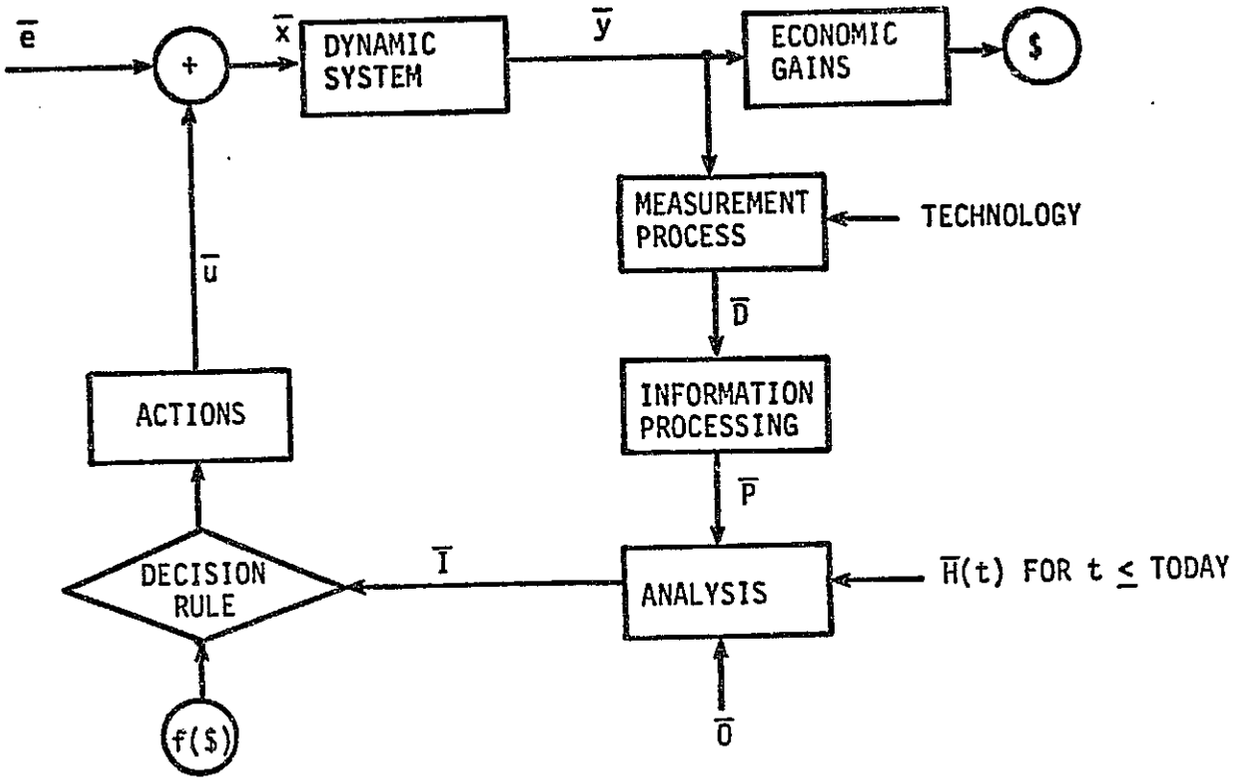
6. The Need (The Marketplace)

The need for the goods and services should be estabished as a function of price. The need should be summarized in the form of a demand function and should include quantitative uncertainty assessments (for example, see Figure C-16 in Appendix C). The establishment of the demand function must consider market segmentation in terms of geography, crop type, income level or other appropriate factors. In order to establish the need and hence the demand for goods and services, it is necessary to understand end user applications (for example, see

Appendix A) and decision processes. It is through an understanding of user applications and decision processes that the value of the new and/or improved goods and services can be established. An example of agriculture management decision processes is illustrated in Figure 2.17. The need and value of new information can only be established in terms of its effect on decisions and the value derived from the improved decisions.

Figure 2.17 depicts the general agricultural decision process. The objective of the decision maker is to achieve a goal such as profit maximization. To accomplish this, the decision make must observe (either directly or indirectly) and/or deduce current status and forecast future status of a dynamic system (for example, crop growth). The forecast of future status must be made in terms of the actions (for example, irrigation and amount) which may be taken, the variability of exogenous inputs (for example, past and future precipitation) and the uncertainty of the dynamic system response to the set of exogenous inputs and actions to be taken. Thus, the value of the RD&D program, and the demand for information products, has to be established by evaluating the change in economic gains which results from improved decisions made possible by incorporating new and/or improved information products into the decision process.

The marketplace should be characterized in terms of the current providers of goods and services. This should include a description of the current industry and projections of the industry characteristics into the future. Of interest is the existing goods and services mix that are used by the end users, who provide these goods and services, how many firms or agencies are involved, the magnitude of current and future sales, capital structure, ability and willingness to make major innovative investments, etc. The dominant firms, agencies, unions, etc. should be identified and their likely reaction to the public sector initiative should be indicated.



$\bar{e}$ SET OF EXOGENOUS INPUTS SUCH AS TEMPERATURE, PRECIPITATION, SOIL CHARACTERISTICS, AND OTHER FACTORS.

$\bar{u}$ SET OF INPUTS WHICH ARE THE RESULT OF MANAGEMENT DECISIONS SUCH AS QUANTITY OF FERTILIZATION, FUNGICIDE, PESTICIDE, WATER.

$\bar{x}$ THE SET OF TOTAL INPUTS (EXOGENOUS AND ENDOGENOUS) TO THE DYNAMIC SYSTEM.

$\bar{y}$ SET OF RESPONSES OF THE DYNAMIC SYSTEM TO THE INPUT SET $\bar{x}$. THE RESPONSES ARE IN THE FORM OF LEAF AREA, YIELD, ETC.

$\bar{D}$ SET OF DATA OR OBSERVABLES WHICH ARE OBTAINED FROM OBSERVATIONS OF THE SET OF RESPONSES OF THE DYNAMIC SYSTEM.

$\bar{P}$ SET OF INFORMATION PRODUCTS WHICH ARE DERIVED FROM THE SET OF DATA OR OBSERVABLES.

$\bar{H}(t)$ SET OF HISTORICAL DATA AVAILABLE TO THE DECISION MAKER SUCH AS METEOROLOGICAL CONDITIONS.

$\bar{O}$ SET OF OTHER DATA, SUCH AS CURRENT PRICES, AVAILABLE TO THE MANAGEMENT DECISION MAKER.

$\bar{I}$ SET OF PERTINENT INFORMATION WHICH IS DETERMINED TO BE OF IMPORTANCE IN THE DECISION MAKING PROCESS.

f($) DECISION MAKER OBJECTIVE FUNCTION SUCH AS PROFIT MAXIMIZATION AND EXPECTED UTILITY MAXIMIZATION.

FIGURE 2.17 AGRICULTURAL MANAGEMENT DECISIONS - THE DECISION PROCESS

7. Benefit-Cost Analysis Results

The benefit-cost analysis results should be described so as to indicate the general desirability of a new initiative in the proposed area. The benefit-cost analysis is concerned with establishing whether or not the benefits that may result from the proposed initiative exceed the costs. The benefit-cost analysis is concerned with whether or not the initiative is worth doing and not with who should do it or who should ultimately initiate and maintain an operational system and provide goods and services. The benefit-cost analysis should not be concerned with technology transfer issues, institutional constraints, etc., other than from the standpoint of identifying their issues and their potential impacts on benefits and costs. It should be concerned with the net benefits that might be achieved as a direct result of the new initiative. It is generally necessary to evaluate the benefits and costs in terms of capability so that the desired level of capability (i.e., the attributes of the goods and services that may be offered on a continuing basis) can be obtained. The desired level of capability is that which maximizes net benefits (present value of benefits less the present value of recurring and nonrecurring costs). It should be noted that "in a land of scarcity, economics is king; in a land of plenty, economics is just another member of the court."*

8. Reason for Lack of Adequate Private Sector Participation

The reasons for the lack of adequate private sector participation should be described. These should be described at both the conceptual level and at the practical level. With respect to the former, it is necessary to describe whether the lack of adequate private sector participation is due to the lack of a consumption-related pricing mechanism, the lack of adequate private sector benefits, or a

*Votow, D., Genius Becomes Rare: A Comment on the Doctrine of Social Responsibility, California Management Review, Winter 1972, Volume 15, No. 2.

combination of high risk, high exposure and long payback period. This is important since it will determine the form of venture analysis that is necessary to evaluate the benefits of the new initiative (see, for example, Appendix B for a description of the methodology required to evaluate the new initiative when the reason for the lack of adequate private sector participation is due to private sector perceived high risk, high exposure and long payback period). At the practical level, important constraints, such as industry domination by a small number of firms, capital structure of the industry and investment attitudes, regulation, etc., should be described. This should provide NASA and other decision makers with insight into the problems and likelihood of achieving the benefits indicated in the preceeding paragraph, Benefit-Cost Analysis Results.

9. Specific Impact of Proposed Program (Private Sector/Public Sector Analysis)

The specific impact of the proposed program upon the public and private sectors should be described. The level and form of participation should also be described. The form of the analysis required to substantiate the anticipated form and level of participation depends to a large extent upon the reasons for anticipated lack of private sector participation without the NASA proposed new initiative.

When it is determined that the inadequate private sector participation is related to the lack of consumption-related pricing mechanisms or inadequate private sector benefits, then there is good justification for public sector provision of the goods and services. When this is the case, benefit-cost analyses should be performed. The cost analysis should consider the life-cycle costs that will be incurred in order to achieve and provide the desired goods and services on a continuing basis. The benefit-cost analyses should be dynamic in nature--that is,

the time element should be taken into account through the benefits and costs which are to be considered as functions of time. Realistic projections must be made with respect to the rate at which users will acquire the goods and services. These projections can be made in terms of the value of the goods and services particularly when these goods and services will be used to improve user decision processes, or when the goods and services will result in benefits (for example, cost savings) directly to the user (for example, emergency medical services use of improved communications services).*

When it is determined that the inadequate private sector participation is related to private sector perceived high risk, high exposure and long payback period, then there is good justification for public sector participation in a program that reduces these impediments to providing the desired goods and services. It is necessary to assess the uncertainties as perceived by the private sector with and without the NASA initiative. Cost reduction, performance improvement, and cost, performance and market uncertainty reduction must be considered explicitly and the impact of the RD&D and incentive program assessed. As described in Appendix B, the public sector benefits are derived from the change in the probability of private sector participation as affected by the reduction in perceived risk resulting from the reduction in cost, performance and market uncertainties resulting from the RD&D program. To accomplish this, it is necessary to perform private sector venture analyses that develop risk profiles (see Appendix B) of venture performance measures. These risk profiles may then be related to the probability of private sector participation (investment). Changing the RD&D

*Actually in this case, the hospitals will make decisions that affect the recipients of the medical services and can thus provide public sector benefits (for example, reduced fatalities) which may be well in excess of cost-saving benefits.

program will impact these risk profiles which, in turn, will affect the probability of private sector participation. Since the change in this probability has a direct effect on public sector benefits, the specifics of the RD&D program can be related to benefits. As indicated in Appendix B, the public sector benefits may be established from supply-demand-price considerations where price is determined from the private sector venture analysis.

10. Technology Transfer Considerations and Plan

Technology transfer issues must be considered, constraints determined and plans presented for overcoming the constraints. Institutional, regulatory, capital, etc. constraints should be considered in order to find those that are limiting or impeding factors. Plans should be developed which indicate that mechanisms or approaches exist that will achieve the desired technology transfer. The role of demonstrations, experiments (technical and economic) and user working groups should be developed. Various approaches to operational system implementation should be considered such as limited (geographic) coverage phasing in over a period of time to total coverage.

11. RD&D Program Plan

The RD&D program should be described in terms of the individual projects that comprise the program. The manpower, skill, facilities and funding requirements should be delineated and contrasted with available manpower, skills, facilities and funds.

12. Schedule

The proposed new initiative should be summarized from the point of view of schedule. The schedule should indicate each of the RD&D projects and their funding requirements and their major milestones should be indicated. The schedule

should also indicate the major milestones associated with the technology transfer program and the operational system and the provision of goods and services.

2.4 Criteria for Program Selection

In order for OSTA to consider investing resources in a new initiative it is necessary that the thrust of the initiative be consistent with the NASA legislative mandate, that it be consistent with the responsibility, goals and objectives of OSTA and that the expected net benefits be positive; that is, the present value of the benefits from goods and services provided on a continuing basis which are the direct result of the new initiative should exceed the present value of the costs incurred in providing the goods and services on a continuing basis and the cost incurred in pursuing the new initiative. The actual selection of a new initiative for the investment of resources must be made after due consideration and review of all proposed new initiatives and on-going programs. That set of initiatives should be selected for investment of resources which maximize the net benefits which may be achieved within actual or anticipated resource constraints. Other basic criteria must focus upon the level of current private sector efforts and the likelihood of future private sector efforts in the absence of the OSTA initiative.

These basic criteria are indicated in Table 2.14 along with other areas of consideration which, though of lesser importance, must nevertheless be considered when evaluating and selecting new initiatives for resource investment. Attention should be given to the type of benefits that may result from the initiative. It may be desired to emphasize one benefit area (i.e., pollution reduction, cost-savings, etc.) over another. Specific benefit types, such as cost savings, are more likely to have direct influence on budgets and acquisition decisions, making projections based upon these more meaningful. The specific roles of the public and private

TABLE 2.10 BASIC CRITERIA AND OTHER CONSIDERATIONS FOR OSTA PROGRAM SELECTION
BASIC CRITERIA • CONSISTENCY WITH NASA LEGISLATIVE MANDATE • CONSISTENCY WITH OSTA GOALS AND OBJECTIVES • MAGNITUDE OF NET BENEFITS • LEVEL OF CURRENT PRIVATE SECTOR EFFORTS • LIKELIHOOD OF PRIVATE SECTOR EFFORTS IN FUTURE
OTHER CONSIDERATIONS • TYPE OF BENEFITS • ROLE OF PUBLIC/PRIVATE SECTORS • END USER ACCEPTANCE OF RESULTING GOODS AND SERVICES • PUBLIC SECTOR AND FINANCIAL AND BUSINESS COMMUNITY ACCEPTANCE • SPECIFIC ROLE OF NEW INITIATIVE (I.E., REDUCE COST, PERFORMANCE OR MARKET UNCERTAINTY; SHIFT BURDEN OF FUNDING, ETC.) • PRIVATE SECTOR PATENT POSITION • LIKELIHOOD OF ADEQUATE PRIVATE SECTOR PARTICIPATION • OBSERVABILITY OF BENEFITS (IMPACT ON NASA IMAGE)

sectors must be considered since certain public sector roles may be more realistic. Such roles as

- Public sector RD&D programs; public sector operational system; public sector provision of goods and services to end users
- Public sector RD&D programs; public sector operational system; private sector provision of goods and services to end users
- Public sector RD&D programs; private sector operational system; private sector provision of goods and services to end users.

Public sector and financial and business community acceptance of the initiatives must be considered. Actually this can be quantitatively taken into account when performing the benefit analyses and reflected in the benefit estimates. The specific role of the new initiative such as cost reduction, performance or market uncertainty, shifting of funding from private sector to

public sector, should also be considered since specific roles may be more important than others from OSTA's point of view. The resulting private sector patent position should not be overlooked since patent position may be a major factor in private sector business decisions. Actually the impact of patent uncertainties can be related to market share uncertainties and quantitatively accounted for in venture analyses.

The likelihood of adequate private sector participation in terms of the specific RD&D program is an important indicator of the effectiveness of the new initiative. This should be contrasted to the likelihood in the absence of the new initiative. Finally, the observability of benefits that might result from the new initiative should be considered from the points of view of performing experiments that demonstrate the benefits, and their impact on NASA image.

3. THE CURRENT PLANNING PROCESS IN OSTA

3. THE CURRENT PLANNING PROCESS IN OSTA

3.1 The Current Planning Process

The objective of this study was to examine the feasibility of applying accepted techniques of strategic business planning to certain RD&D initiatives proposed by OSTA. In the course of this effort, the study team was exposed to the current planning process in OSTA. The methodology employed involved a review of current planning products produced within OSTA, and extensive interviews with the personnel responsible for the preparation of the planning products. This resulted in an understanding of the current OSTA planning process and the determination that the OSTA planning process could be improved.

In this study, an initiative is defined as a proposed research, development or demonstration, technique or program that, if successful, could subsequently lead to an operational system. The important element here is that the initiative will have an impact on either (a) the decision to institute an operational system, (b) the timing and rate of implementation and use of an operational system, or (c) the design or operational characteristics of the system.

With this objective in mind, the study logically divided into two tasks. The first was to identify what is meant by business planning, and how the concept of business planning can be applied to the public sector of the economy. The second was to identify those initiatives under consideration by OSTA for the three fiscal years of interest and then to study the feasibility of preparing business plans for the identified initiatives. In order to perform this second task, it was necessary to obtain information on those programs under consideration as initiatives by OSTA for fiscal years 1980, 1981 and 1982, and for the operational systems that could

result from these initiatives. Since the preparation of a business plan implies the consideration of factors such as technology, schedule, costs, markets and benefits, it was then necessary to examine the availability of information on these and other factors for each candidate initiative.

The initial step in this direction was to obtain OSTA planning information for the three fiscal years, 1980, 1981 and 1982. The material furnished by OSTA for the assessment of initiatives consisted of the NASA five year plan for fiscal years 1979 through 1983, and planning documents prepared by the Divisions of OSTA for review by various advisory committees and the NASA Planning Council. Since no formal organization structure with responsibility for planning existed within OSTA at the time of this study, supplemental information was obtained through the process of interviews with Division Directors and cognizant program personnel. Thus, within this study, it was not possible to go to a single centralized source, either person or document, to obtain information on either the planning process or the products produced. The documents obtained for analysis were not all at the same state of preparation as some of the Divisions had completed the process of review by OSTA management and had presented their plans to the NASA Planning Council while others were still in the process of review by OSTA management. In this manner, the difficulty of the job of identifying initiatives was compounded by the absence of a formal planning organizational structure with which to interface and the variations in the status of the plans.

The current OSTA planning process appears to be related in a primary way to the federal government annual budget cycle, and only in a secondary way to the NASA requirement for the preparation of a five year plan. Although the outputs of the process are defined in terms of supporting data for the forthcoming fiscal year budget and general planning data to update the NASA five year plan, neither the

process nor the products are defined in a formal sense. For example, none of the planners interviewed in this study were aware of the existence of a flow chart that defined the planning process that they were engaged in, or an operating instruction or handbook that defined the products that the process is intended to produce.* Thus, the planning data appears to be arrived at by a process of ad hoc iteration with successive layers of NASA management and external advisory committees. This process continues until the Associate Administrator for OSTA is satisfied with the planning product produced by each Division, at which time the product is taken forward for review by the NASA Planning Council. This ad hoc process appears to place primary emphasis on the preparation of information to support the budget cycle with the planning information produced as a by-product of the budget exercise. It is felt that this process should be reversed with budget data being developed as a result of the planning process as described in Section 2 in a manner that generally conforms with current practice in the private sector. At the present time, policy decisions are made during the budget cycle and the planning documents are revised to reflect budget decisions. This flow of information from budget to plan is the reverse of the generally accepted business planning process. It is felt that the reversal of this process will result in more informed decision making by OSTA and NASA management. In most business planning processes, alternatives and options are explored in order to obtain insight into the impact of

*Guidelines for Project Planning, NHB 7121.4, July 1972, National Aeronautics and Space Administration, provides the broad guidelines for the planning of major research and development projects in NASA. NHB 7121.4 emphasizes the technical, scheduling and procurement aspects of research and development management, but does not discuss the need for a methodology of business planning for research and development projects which are intended for eventual transfer to another federal agency or the private sector.

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business decisions on the organization. Options are presented to management and a decision made to defer action, rework the options or to proceed with a selected initiative. In this manner, the necessary budget information is produced as a by-product of the planning.

The lack of formalism in the current planning process also leads to a wide degree of variability in the form, content and organization of the planning products produced by the program managers and the divisions. It is felt that a more formalized planning process will provide NASA management more consistent information upon which to make decisions.

In some programs, technology building blocks, schedules and costs were clearly identified, and an effort was made to identify the potential users and uses of the NASA-developed technology. Few of the programs consider issues of technology transfer; i.e., how does an operational program evolve if the NASA initiative is successful? Fewer yet give even qualitative consideration to economic issues such as the market for the NASA-developed technology, benefits and the return to federal government investment. In some instances, major program initiatives that will require coordinated action with other agencies, such as the Department of Commerce, OMB and OSTP, are simply listed along with proposed research programs, without any indication of technical, cost or schedule data or the plan to obtain such data. In the main, the emphasis is on the NASA-sponsored technology and the schedule for the development of the technology. In general, benefits, when considered, are described qualitatively and not quantitatively. In most instances, only research and development costs are considered with resulting life-cycle costs receiving little consideration. Issues such as private sector participation, or the economic, institutional or legal factors that might accelerate or impede the transfer of NASA-developed technology to operational status are

given only brief, passing consideration (in comparison to technical issues). Moreover, the use of a five year planning window does not encourage consideration of issues that could arise at times past the window. Experience has shown that the time from the start of an initiative by NASA in the applications field to the beginnings of an operational system will almost always exceed five years. For example, the LANDSAT initiative began in 1968 and the issues of an operational system still have not been resolved in 1978. The SEASAT initiative began in 1973 and current planning describes a limited demonstration operational system (NOSS) that will fly in 1985. Clearly, in these cases, a five year planning window is inadequate, and the use of a five year window leads to avoidance of serious consideration of questions relating to the eventual operation and ownership of NASA-developed technology, as well as the costs of the operational systems and resulting benefits.

In summary, it is felt that the current OSTA planning process and the products produced by this process can be improved. The major areas which will be impacted by the introduction of a more formal planning process, including the previously described (Section 2) business planning techniques, are:

1. Planning Versus Budgeting

   The present emphasis appears to be heavily oriented toward supporting the annual budget cycle. Currently, planning appears to be a sequential process of program proposal and review in response to anticipated or real budget constraints. The process does not begin with the fundamental question of goals and objectives and the consideration of alternative paths to achieve these goals. The emphasis on planning in support of budgeting also leads to the annual production of a planning document that is "cast in concrete" once a year, and then set aside and not considered again until the start of the next budget cycle.

2. Formalism

   Neither the process nor the products required of the process are formally defined. This leads to a great deal of variability in the content of the plans as well as to frustration on the part of the people involved in the planning. The business planning approach outlined in

Section 2 will impose a high level of formalism to the planning and budgetary process.

3. Planning Organizational Structure

Planning is an essential part of management, and within OSTA planning at the program level should begin with the Program Manager. In research and development, planning cannot be relegated to a completely separate planning department. In NASA, the planning function for applications oriented programs should be performed by OSTA. There are two elements to planning, strategic and tactical. The strategic planning is involved in the setting of goals and objectives, and is best done by management. Tactical planning, involving the selection of programs to achieve the goals and objectives of the organization, often involves the selection of an optimum set of programs once the management objective function has been specified. Tactical planning of this sort is best performed by a specific organization with the skills to analyze and select an optimum set of programs. However, in any organization it is necessary that a specific office be responsible for the development and implementation of the planning process. This function does not now exist in OSTA.

4. The Planning Window

The use of a five year planning window encourages the planner to avoid the really difficult but very necessary planning questions and to concentrate on descriptions of research, development, technology and costs at the point of starting a new initiative. Questions of quantifiable benefits, return on federal investment and transfer from RD&D to operations involve events that occur outside of the five year window at the startup of a new program. This puts NASA in the awkward position of committing to programs without appraising the long term strategic impacts of the program on NASA and the federal government, and without understanding the nature of the decisions that must be made to terminate a program or move it to operational status.

3.2 Systematizing Planning in OSTA

The preceding section discussed some of the attributes of the current OSTA planning process which may be improved through the use of business planning techniques. The following paragraphs describe some general steps that could be taken by OSTA to systematize the planning process through the incorporation of business planning techniques.

3.2.1 Responsibility for Planning

In the management of research and development, planning cannot be done by a separate "planning department". "Planning departments" work most successfully when they are planning and schedule routine or repetitive tasks. In a research and development organization, planning is an essential part of management and requires the attention of the people directly involved in the management of the research and development. However, the individuals concerned with the management of RD&D normally are not, by training nor inclination, the best persons to do the planning. This does not imply that there is no need to define the planning process and to assign specific responsibility for the management of planning within OSTA. For example, within OSTA there is a need to develop and specify the planning process, and then to implement the agreed-upon process to produce the desired planning products. Thus, it is felt that OSTA should consider the possibility of centralizing the management of the planning process within OSTA. This should entail the identification of a specific office with the responsibility to develop the planning requirements and the authority to implement those requirements within OSTA.

3.2.2 Formalization of the Planning Process

It is difficult to plan in an environment where planning is treated as an "ad hoc" responsibility, and where the planning process is viewed by management as secondary to the budget cycle. Within OSTA, this problem appears to be further compounded by the fact that while the budget process is specified, neither the planning process nor the products are specified. As an initial step, the desired planning outputs and the annual time frame for these outputs should be specified. The process should then be defined so that planning information, including options and alternatives, are presented to management prior to or as an integral part of

the budget process. The process should be designed so that budget alternatives and their impacts are clearly identified. If properly done, the budget information should then be obtained as a normal output of the planning process. Therefore, it is recommended that OSTA study their planning needs, with particular emphasis on the planning and budgeting cycles. One result of this study should be the specification of the required planning outputs and the process to obtain these outputs in a manner that satisfies both planning and budgeting requirements.

3.2.3 Planning Objectives

Planning represents the establishment of a hierarchical flow of requirements for management decisions concerning the commitment of resources in the process of striving for agreed-upon goals and objectives. The first step in this process is the identification of the goals and objectives. The goal setting step is an iterative process between OSTA management, NASA management and other federal agencies such as OMB, OSTP and the Congress. Once the goals and objectives have been set, the second phase of the planning process involves the selection of the initiatives to be taken to achieve these goals. Within OSTA, these can be defined as applications capabilities that are important to achieve at a future date. As shown in Figure 3.1, this can then lead to a hierarchy of capabilities, missions, systems, technology and research. This hierarchy can then provide an organized framework for proposed initiatives to be taken by OSTA to achieve agreed-upon planning objectives. In recognition of the fact that not all RD&D performed by OSTA can be identified with specific applications or missions, a requirement for a category of basic research is also shown. Specifically, it is recommended that OSTA describe planning objectives in terms of future applications capabilities. These objectives can then be used to structure the proposed research and development initiatives so that the initiatives are directed toward the agreed-upon

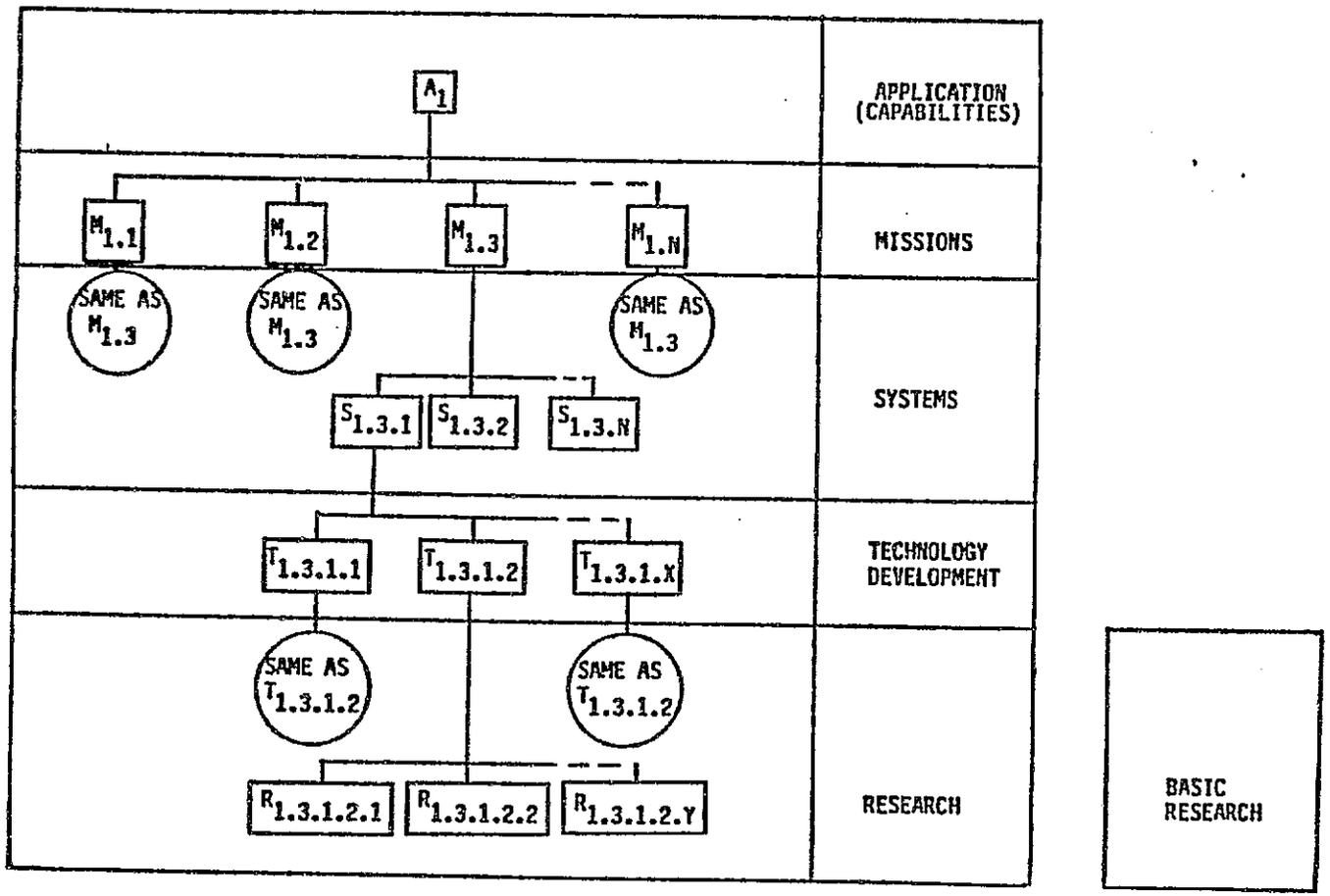

FIGURE 3.1 A SUGGESTED PLANNING HIERARCHY

objectives. In order to select or rank initiatives, it is then necessary to assess the value of each initiative. This process is discussed further in Section 3.2.5, The Ability to Forecast Costs and Benefits.

3.2.4 Choice of an Appropriate Planning Time Frame

To a great extent, the choice of the planning time frame determines what is to be considered by the planner. If an event falls outside of the specified time frame, it is unlikely that the planner will consider that event in his plans. For example, if the potential transfer of a NASA-sponsored initiative from the public sector to the private sector may take place 10 to 15 years after the initiative is taken by NASA, currently it is unlikely that the implications of this possibility will be considered in a five-year plan. On the other hand, the nature, timing (and even probable outcomes) of events that occur in the near future are probably better understood than events that could occur in the distant future, and it is appropriate to deal with the near term in more detail than the distant future. For this reason, it is probably not appropriate to talk in terms of a specific planning window such as five or ten years, but to strive to keep the planning window consistent with the time scale and nature of the initiative. If an initiative can be described in terms of a future applications capability, it may be appropriate to consider questions of life cycle costs, benefits, technology transfer and institutional issues that could occur in a 10 to 20 year period of time. When an initiative is mature, a shorter planning time frame may be appropriate. For this reason, it is suggested that longer planning horizons be used with those initiatives that could eventually lead to operational systems so that the downstream implications of early program decisions can be considered by management.

3.2.5 The Ability to Forecast Costs and Benefits

The need to forecast costs and benefits results from a recognition of the fact that it is the intent of an OSTA applictions initiative to impact (a) the decision to proceed with an operational system at some future date, (b) the schedule of implementation of an operational system, or (c) the design or operational characteristics of the system. This implies that it is necessary for OSTA planning to go beyond the consideration of RD&D initiatives into the performance, costs, benefits and technology transfer issues of the operational systems that could derive from the OSTA initiative. The ability to forecast costs and benefits are both dependent upon the capability to describe the technical attributes and performance of the derivative operational systems. The derivative operational systems may come into being five to ten years after the NASA initiatives and it may be necessary to consider both costs and benefits over a 10 to 20 year life cycle for the operational system. This uncertainty is inherent in this kind of long-range forecasting; however, the uncertainty can be considered in the quantitative evaluation of costs and benefits. Various NASA offices have extensive experience with the use of "top down" cost estimating models for the estimation of space and ground segment costs for advanced systems. It is suggested that OSTA either acquire the use of these models or delegate the responsibility for life cycle cost estimating to a group in NASA experienced in the use of these models for this purpose. The estimation of benefits requires an understanding of the economic and operational impacts of the derivative operational systems on the user of the NASA-developed technology. This implies an understanding of the users, their operations and their potential uses of the new technical capabilities (in the form of goods and services provided). This requires specific studies directed toward understanding the operations and economics of the potential user community. These marketing studies are a necessary

part of business planning and should be performed by OSTA in support of initiatives that could lead to operational systems. Where user agencies or institutions have been identified these studies should be performed in full partnership with these organizations. Once the costs and benefits have been evaluated, it is possible to estimate the value of the proposed initiative toward fulfilling the goals and objectives of OSTA.

3.3 The Relationship Between Business Planning and Current Practices

It is clear that business planning as described in this report imposes both a discipline of planning and a requirement for information that exceeds current practice in OSTA. As has been stressed earlier in this report, business planning is an iterative process, and in the process of planning, both the knowns and unknowns concerning a proposed initiative are identified. Analysis in support of the business planning aims at reducing unknowns to knowns. Thus, the discipline imposed by a formalized business planning process should assist NASA management by highlighting the unknowns and uncertainties associated with a proposed venture.

Table 3.1 describes the current budgeting and planning process and annual cycle as practiced in NASA. Superimposed upon the present planning cycle shown in this table is the preparation of a longer range agency-wide plan at infrequent (five to ten year) intervals. The process described in Table 3.1 is, to a great extent, the result of reaction by NASA to demands for information imposed by OMB and the Congress, and is tied to the fiscal year cycle. As such, business planning as described in this report can both supplement and feed information into the existing budgeting and planning cycles. However, business planning is not a substitute for the existing budgeting and planning practices, nor are the existing practices a substitute for business planning. As opposed to the external motivation behind the current budgeting and planning proesses, the motivation for improved

TABLE 3.1 CURRENT BUDGETING AND PLANNING PROCESS

MONTH	BUDGET	PRESENT PLANNING
JANUARY	PRESIDENT SUBMITS (N+1) BUDGET TO CONGRESS.	USE (N+1) SUBMISSION TO UPDATE (N+1) PLAN.
FEBRUARY (BUDGET HEARINGS)	LETTER FROM OMB GIVING TARGET NUMBERS FOR (N+2) TO (N+4) REQUESTING INFORMAL SUBMISSION OF BUDGETS FOR THESE YEARS BY APRIL.	ISSUE (N+1) PLAN. KICK OFF PLANNING FOR (N+2), (N+3), (N+4). USE (N+1) SUBMISSION AS BASELINE FOR FUTURE PLANS.
MARCH	ESTIMATE COSTS OF EXISTING PROGRAM RUN OUT AND NEW STARTS.	
APRIL	INFORMAL SUBMISSION OF BUDGETS FOR (N+2), (N+3) AND (N+4) TO OMB.	PROGRAM OFFICES DEVELOP PLANS.
MAY	REWORK INFORMAL SUBMISSION BY PROGRAM. COMPLETE INTERNAL NASA REVIEW CYCLE. PREPARE PRIORITIZED LIST OF PROGRAMS FOR AGENCY ZBB EXERCISE.	REVIEW PLANS AT PLANNING WORKSHOP.
JUNE		PROGRAM OFFICES REQUEST NEW INITIATIVES FROM CENTERS.
JULY		
AUGUST		
SEPTEMBER	SUBMIT PRIORITIZED BUDGET TO OMB.	
OCTOBER	MEET WITH OMB TO DEFEND SUBMISSION.	
NOVEMBER	GET BUDGET MARK FROM OMB. GO THROUGH RECLAMA PROCESS.	
DECEMBER	PREPARE FINAL (N+2) BUDGET AND DATA FOR (N+3) AND (N+4) FOR SUBMISSION TO CONGRESS.	PREPARE (N+2) PLAN BASED UPON (N+2) SUBMISSION.

CURRENT FISCAL YEAR (FY) = N.

business planning must come from within NASA and be derived from a desire to improve the management of applications-oriented R&D. While business planning could also be tied to the budget cycle, it can also proceed independently of the budget cycle, and yet provide important inputs to both the budget and planning processes. Examples of specific inputs shown in the budget process that could be derived from business planning are:

1. program cost
2. program prioritization (within OSTA).

In addition, the Business Plan could be a convenient vehicle for use in program justification with OMB and the Congress, and will be useful in the preparation of congressional testimony. Since nearly all of the elements of the Business Plan receive consideration to a lesser or a greater extent in the development of the support for a new initiative in OSTA, it is important to realize that the major new imposition of the Business Plan is a formalized, disciplined planning process that brings together in a single document all of the information available to support a management decision or a new initiative. In those cases where approval of an initiative is requested and there are major unknowns in the Business Plan, NASA management has the discretionary authority to perform studies aimed at converting the unknowns to knowns, or to proceed with the initiative. The Business Plan simply facilitates the decision process.

4. AN ASSESSMENT OF INITIATIVES IN OSTA THAT COULD BE CANDIDATES FOR BUSINESS PLANNING

4. AN ASSESSMENT OF INITIATIVES IN OSTA THAT COULD BE CANDIDATES FOR BUSINESS PLANNING

4.1 Candidate Programs

A set of proposed RD&D programs (initiatives) that could be candidates for business planning is described in the following pages. The information concerning these initiatives is drawn primarily from planning data furnished to the study team by OSTA, supplemented by data obtained in interviews with the Division Directors and cognizant program managers. The planning data made available to the study team was in the process of preparation and review during the study. Thus, the data received by the study team consisted largely of individual presentations by programs, application areas and divisions to OSTA management and external advisory committees. The data furnished to the study team was often fragmented or incomplete. In nearly all of the initiatives considered it was necessary for the study team to look beyond the time frame of the NASA planning in order to identify the operational systems that could be derived from the NASA initiative. Since the operational systems were outside of the time frame of the NASA planning, neither the costs, technology transfer issues, nor questions of private sector participation were considered in the NASA planning. In the opinion of the study team this state of the planning data cannot be wholly attributed to the fact that this study took place in parallel with the planning, but must also be attributed to the absence of an organized or formal planning process within OSTA. The current planning process in OSTA, along with some suggestions to systematize the planning process, was discussed in Section 3.

In addition to the planning material furnished to the study team by OSTA, during the course of the study the President announced the results of a National

Security Council Review of space policy.* This announcement called for NASA and the Department of Commerce to develop a plan to encourage private sector investment and direct participation in remote sensing programs, and directed NASA to study the options for an integrated national remote sensing system. Although the planning material provided to the study team by OSTA did not identify an integrated national remote sensing system as a NASA initiative, it is clear that as a result of the President's announcement that the technical, programmatic, private sector and institutional features of an integrated system will be studied by NASA and other federal agencies during the forthcoming year. It is the recommendation of the study team that a Business Plan for an integrated system be one of the elements of response to the President's announcement. For this reason we have included an integrated national remote sensing system as an initiative, even though it cannot be identified as such in the planning data furnished to the study team by OSTA.

For ease in organization and identification, the initiatives have been grouped by divisions within OSTA. Each initiative has been identified by the division code for the area within which it falls, an identifying number, and the title of the initiative. These initiatives have been selected as having sufficient definition of objectives and technical capabilities of the systems involved so that at least a preliminary determination could be made of the feasibility of business planning. Using the planning data provided by OSTA and other sources available to the study team, the best available information as of the date of the study is summarized for the technical, programmatic, economic and technology transfer attributes of each initiative.

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*Press Release, Office of White House Press Secretary, The White House Fact Sheet, U.S. Civil Space Policy, October 11, 1978.

4.2 Environmental Observations Initiatives

Described below are six applications initiatives which might be candidates for business planning and which fall within the subject area of the Division of Environmental Observations of OSTA. These initiatives are divided between the two departments within this division: Oceanic Processes and Atmospheric Processes. It should be noted that these initiatives must be considered in the context of the President's space policy announcement which requires NASA and other federal agencies to review defense and civilian meteorological and ocean satellite programs to determine the degree to which these programs can be integrated in the 1980s.

4.2.1 Oceanic Processes Initiatives

EB-1: The National Oceanic Satellite System (NOSS)

The objective of the current Interagency NOSS mission is to provide a limited operational demonstration of a global sea surface observation capability based on remote sensing from space. The characteristics which have been defined for a limited operational demonstration are:

- Produce the geophysical measurements required of an operational system even though some of the accuracies and resolutions need further development
- Provide the data system that the user agencies should expect in an operational system
- Provide a frequency of measurements such that the demonstration data are useful to the user agencies
- Provide a mission lifetime of sufficient length that user agencies will invest in taking advantage of the data.

A derivative operational system based upon this initiative would have the same capabilities with, perhaps, improved accuracies or resolutions on some of the measurements provided. The NOSS initiative could be the first step toward an operational system in the 1985-90 time period.

The description of the baseline system resulting from the Phase I option/trade study includes five sensors which are improved versions of the SEASAT-A sensors: an altimeter providing improved sea state estimation; a scatterometer with added antennae and processing to improve wind direction measurement; a scanning multifrequency multibeam microwave radiometer, advanced high resolution coastal zone color scanner; and possibly a synthetic aperture radar with a higher duty cycle than the SEASAT-A system (25 percent versus 6 percent).* The technical goals for this system, in terms of the expected accuracy of the observations is provided in Table 4.1. A conceptual design for a satellite incorporating the aforementioned sensors is shown in Figure 4.1, and the relationship of the satellite to the other system components necessary for the transmission, analysis and distribution of the information products to marine users is shown in Figure 4.2. It should be noted that this system relies on a number of complementary technologies, including the global positioning system (GPS), surface truth data systems such as buoys, platforms and ships, and data relay systems like TDRSS and Domsat. Figure 4.3 shows the projected timeline for the initiative system.

Figure 4.2 also indicates that a variety of potential users exist for a NOSS operational system, including the primary agency users, DOD and NOAA, and a number of private users--both domestic and international--involved in both research and commercial activities. Many of these users and their needs have been examined in earlier and ongoing studies of the costs and benefits of an operational

*The specific NOSS configuration had not been settled at the time of this report. Discussions with program personnel at NASA and DOD indicate some uncertainty concerning the inclusion of the synthetic aperture radar.

TABLE 4.1 MEASUREMENTS AND EXPECTED ACCURACY FOR THE NOSS BASELINE SYSTEM

Parameter	Precision	Absolute Accuracy	Range	Frequency	Delay	Model Grid Size	Horizontal Resolution
Wind							
Speed	0.5 m/s	2 m/s	0 to 50 m/s	6 hrs	3 hrs	200 km	25 km
Direction	5°	10°	0° to 360°	6 hrs	3 hrs	200 km	50 km
Sea Surf. Temp.							
Global	0.25°C	1.0°C	-2°C to 35°C	3 days	12 hrs	200 km	25 km
Local	0.10°C	0.5°C	-2°C to 35°C	1 day	12 hrs	10 km	10 km
Waves (Sea State)							
Sign. Wave Ht. Amplitude	0.3 m	0.3 m	0 to 25 m	3 hrs	3 hrs	100 km	25 km
Components	0.7 m	0.7 m	1 to 8 m	3 hrs	3 hrs	100 km	25 km
Wave Length Components	10%	10%	6 to 1000 m	3 hrs	3 hrs	100 km	25 km
Direction	10°	10°	0° to 360°	3 hrs	3 hrs	100 km	25 km
Ice							
Cover	15%	15%	0 to 100%	3 days	12 hrs	20 km	20 km
Thickness	2 m	2 m	0.25 to 50 m	3 days	12 hrs	50 km	50 km
Age	New, 1st yr multi-yr	New, 1st yr multi-yr	0 to 3 yrs	3 days	12 hrs	20 km	20 km
Sheet Height	0.1 m change	0.5 m change	-5 to +5 m/yr	1 yr	30 days	TBD	10 km
Bergs	N/A	±2 km of true location	N/A	2 days	12 hrs	N/A	0.1 km
Water Mass Definition							
Chlorophyll	10% (mg/m³)	Within factor of 2	0.1 to 100 mg/m³	2 days	8 hrs	TBD	0.4 km
Turbidity	0.1 PPM	Lo, Med, Hi	0 to TBD	1 day	10 hrs	TBD	0.4 km
Horizontal Surface Currents							
Speed	5 cm/s	5 cm/s	0 to 250 cm/s	1 day	1 day	100 km	20 km
Direction	10°	10°	0° to 360°	1 day	1 day	100 km	20 km

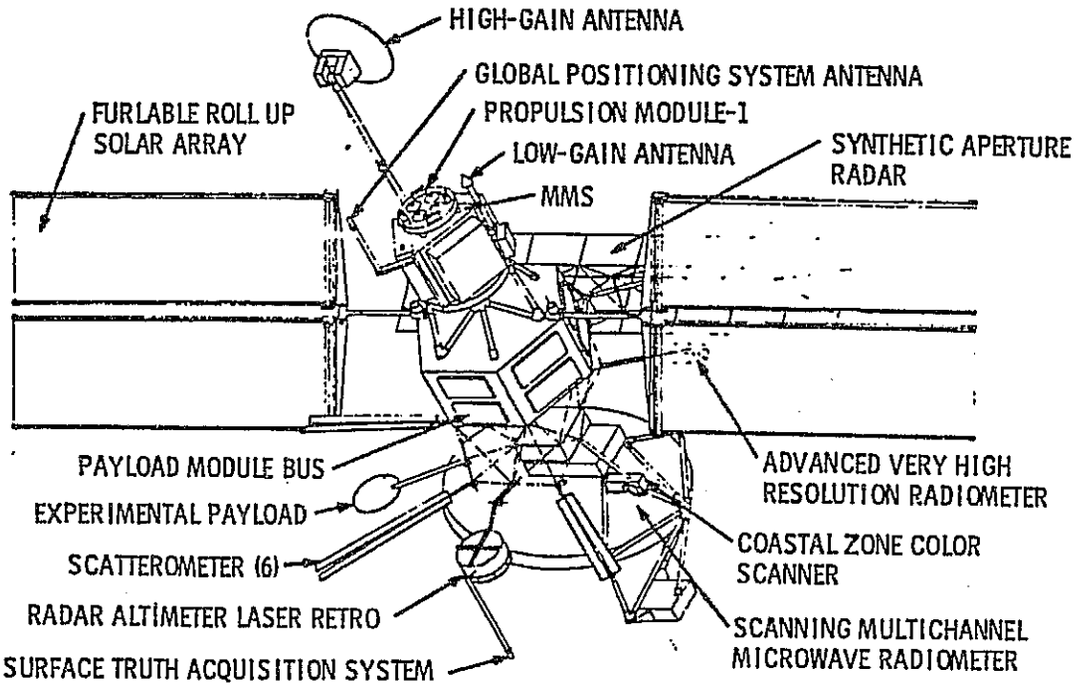

FIGURE 4.1 CONCEPTUAL DESIGN FOR NOSS SATELLITE (SOURCE: JPL NOSS DEFINITION PHASE FINAL REPORT, JUNE 16, 1978)

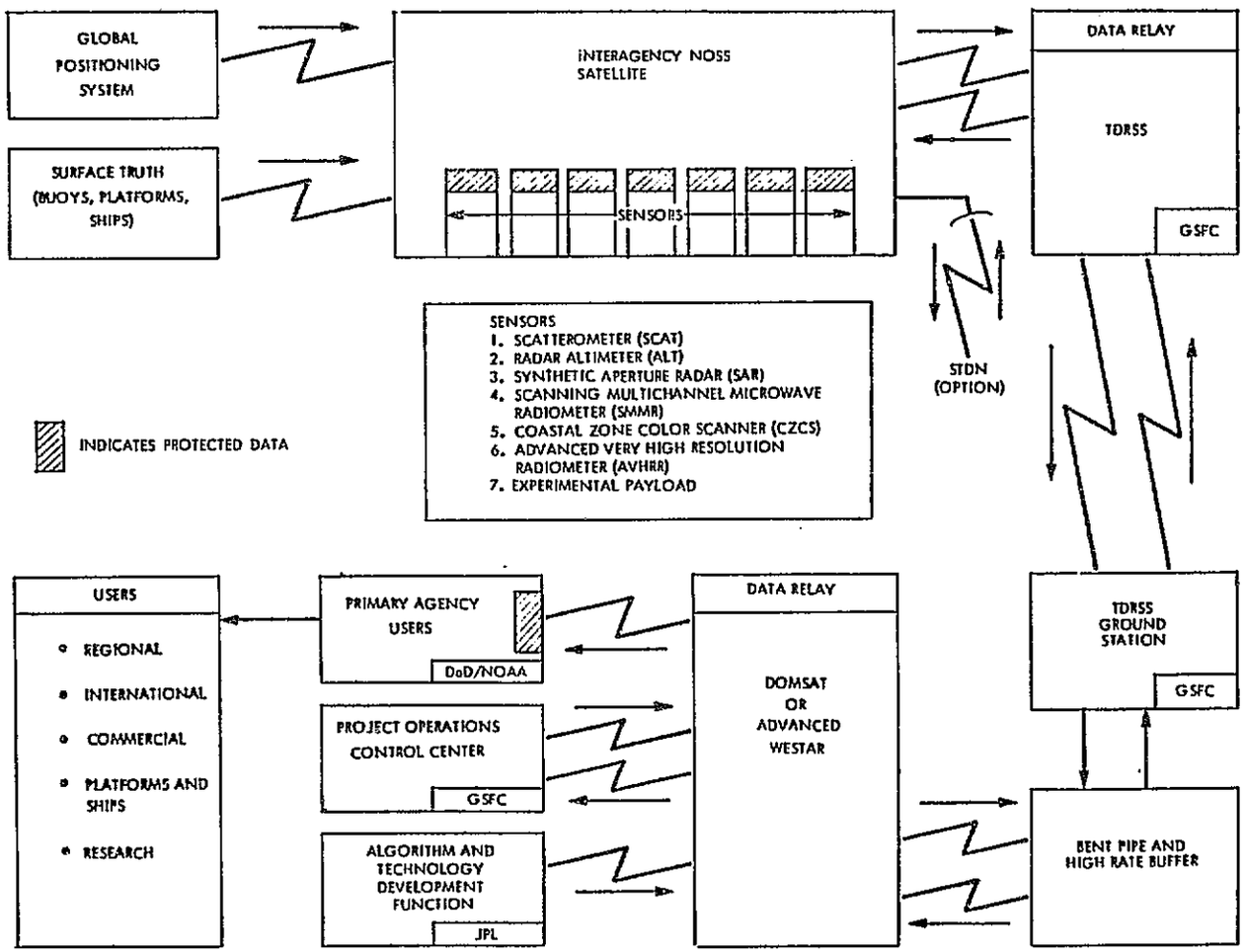

FIGURE 4.2 OVERVIEW OF NOSS DATA SYSTEM (SOURCE: JPL NOSS DEFINITION PHASE FINAL REPORT, JUNE 16, 1978)

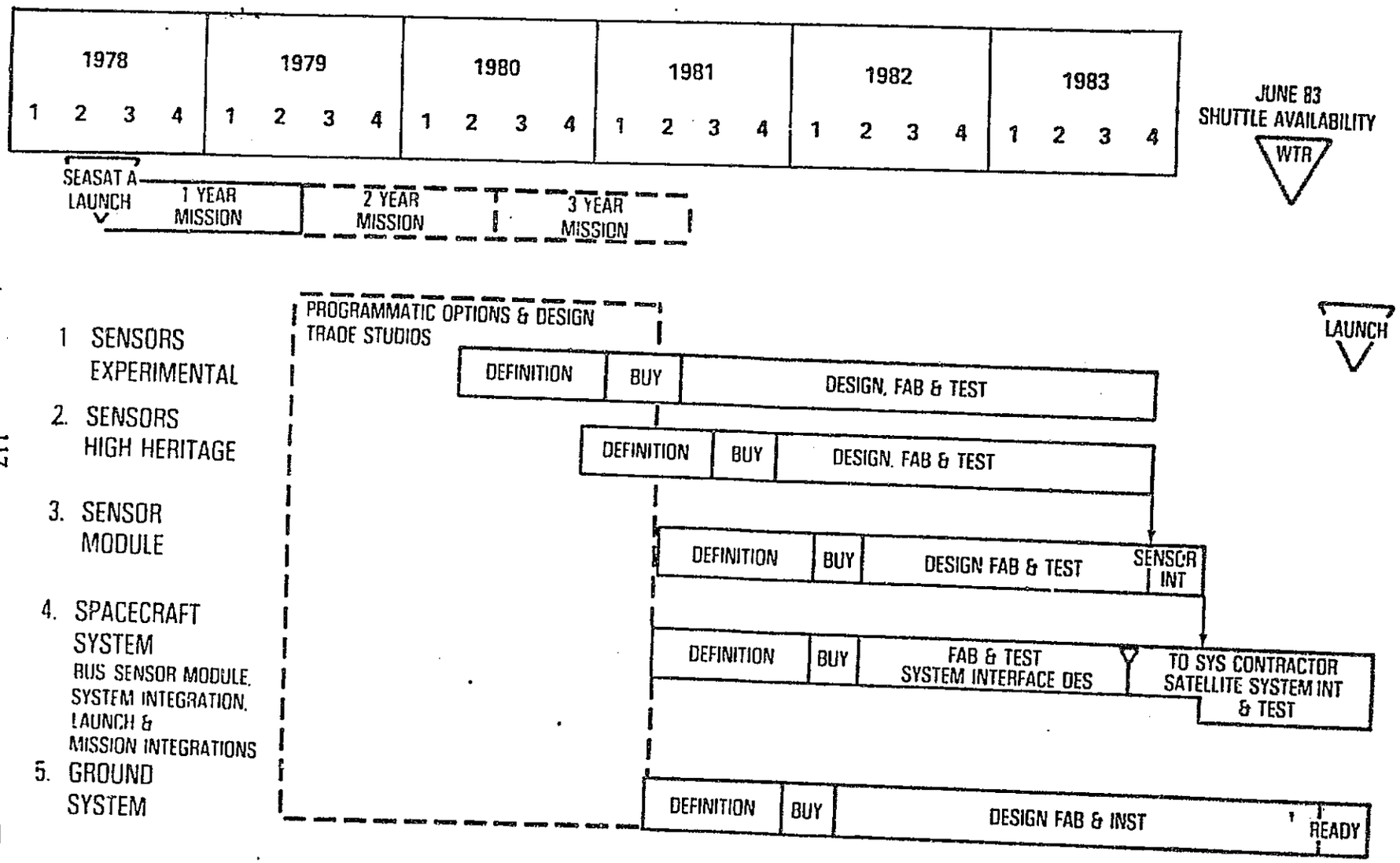

FIGURE 4.3 NOSS TIMELINE

oceanic satellite system.* These studies could be used as the basis for business planning in this area. However, in order to perform business planning for NOSS it will be necessary for NASA to select the technical characteristics of the NOSS systems and the operational systems that could be derived from NOSS. This additional step is necessary in order to provide a finer basis for the estimation of the costs and benefits of the NOSS derivative operational systems.

4.2.2 Atmospheric Processes Initiatives

EB-2: System 85

"System 85" is the designation given to the next generation operational global weather system to be developed by NASA. This initiative is, as yet, in the evolutionary stage and neither the characteristics nor capabilities of either the initiative itself or the operational system which would derive from it were specified at the time of this study. This specification of concepts for System 85 is listed as one of the long-range strategies in data acquisition for the NASA Global Weather Research Program.

It will not be possible to develop business plans for operational systems in this area until the capabilities of the current global weather system are defined quantitatively and the quantitative capability objectives of System 85 are established. It will further be necessary to identify the major system components anticipated to achieve System 85's capability goals in order to identify and examine potential competing and complementary technologies, as well as to examine potential technology transfers or cooperation on the part of the private sector.

The most recent available projected costs for the System 85 initiative are: $20M for FY81, $45M for FY82, $30M for FY83 and $13M for FY84. It is assumed

*SEASAT Economic Assessment, Volumes I through X, August 31, 1975, ECON, Inc.

that these costs pertain to NASA research and development and do not include NOAA expenditures for the follow-on operational system.

Although the likely recipient of the NASA developed technology in this instance will be NOAA, further business planning for this initiative will not be possible until technical, cost and benefit studies have been performed. It must be noted that the incremental contribution of present meteorological satellite systems to the accuracy of weather forecasting does not appear to be well quantified, although many examples exist of the contribution of satellites to improved weather forecasting.* For this reason, it will be necessary to quantitatively specify the capabilities of present systems and the incremental expected improvement from System 85 before business planning can be performed on this initiative.

EB-3: Severe Storm Forecasting and Warning System

The goal of the NASA Severe Storm Research Program is to improve the accuracy and timeliness of severe storm forecasts and warnings through improvements in basic understanding and technological developments. Three possible initiatives for which at least some definition exists derive from this area of research. The first of these, described here, is a severe storm forecasting and warning system. (The other two--lightning occurrence monitoring and nowcasting systems--are described below.) The initiative for a forecasting and warning system could constitute the development of an end-to-end system based upon the Stormsat concept. Such a system would include the measuring of three-dimensional temperature and water vapor profiles, the modeling of storm development, with updating of the predictions using satellite-observed gradients.

*For example, see World Meteorlogical Organization Technical Note No. 132, Applications of Meteorology to Economic and Social Development, or Weather Forecasting and Weather Forecasts: Models, Systems and Users, Vol. 2, Notes from a Colloquium: Summer 1976, National Center for Atmospheric Research.

However, the capabilities of such a system have not yet been defined; consequently, it is not possible at this time to conduct business planning for this initiative.

The benefit mechanisms for this type of forecasting and warning system are reasonably well understood. However, the magnitude of the benefits is directly dependent upon the increase in timeliness and accuracy of severe storm forecasts over the current operational systems (SMS/GOES). It is necessary to quantify the operational capabilities of the new derivative system both to assess the potential benefits from the increase in capability and to estimate the costs for applied research and development involved in the initiative and the cost of the operational system itself. Furthermore, it is necessary to know the capabilities of the system in order to determine the extent to which related technologies may either compete or be encompassed complementarily in the derivative operational system.

Depending upon the capabilities of the new system, there may be opportunities for transfer of technology to private weather forecasters; however, the most likely option is an intragovernment transfer to NOAA, as has been done with the development of operational weather satellite systems in the past. A business plan for this initiative area is not possible until the capabilities or technology goals for the new system are defined, as the costs, benefits, opportunities for private activity and technology transfer all depend upon such a definition of operational capability.

EB-4: Lightning Occurrence Monitoring System

Another possible initiative to be derived from the NASA Severe Storm Research Program is a lightning occurrence monitoring system. Such a system would map the rate of lightning occurrence for established users such as power companies, airlines, telephone companies and railroads. Information on lightning

occurrence is potentially useful to such customers in the planning of new power distribution or communication lines, the location of power plants and transmission antennae, as well as in the analysis of such phenomena as forest fires. Information on lightning occurrence might also be useful as a severity indicator for thunderstorms. At the moment neither the definition of a sensor capable of monitoring lightning occurrence nor the specification of its operational capabilities exists. However, the definition of a sensor capable of the detection of lightning is listed as one of the short-term instrument development goals of the Severe Storm Research Program, although no cost estimate has been made for such development. The benefits which would derive from such a capability, when defined, require examination. This initiative offers potential for transfer either to public or private weather monitoring organizations. When the capabilities of the system have been defined, the costs concomitant with both the application initiative and the derivative operational system have been estimated, and the benefits attendant to such a capability have been analyzed, it should be possible to develop an overall business plan. At the present time this initiative appears to be in the early stage of development and is not a likely candidate for business planning until further studies have been completed.

EB-5: Nowcasting Systems

A third potential initiative deriving from the Severe Storm Research Program is the development of nowcasting systems. Such systems would place more emphasis on the storm severity indicator approach for use in the prediction of imminent (0-1 hours) severe storm activity. This approach contrasts with the standard forecast model approach for short-term forecasting (1-12 hours) of severe storms. However, before the feasibility of analyzing this initiative from a business plan standpoint can be determined, current and potential new capabilities must be

specified. Some of the mechanisms by which benefits could be derived in this area are understood, while others are not. Consequently, further analysis of possible benefits would have to be conducted, and these benefits would of course be dependent upon the definition of operational system capability. Likewise the costs of both the application initiative and the resultant operational system are dependent upon a definition of system capability. As with the other weather forecasting and warning initiatives, nowcasting offers some potential for technology transfer to, or cooperation with the private sector; however, the most likely candidates for transfer are governmental agencies responsible for weather monitoring and prediction.

EB-6: Monitoring of Regional Air Pollution

The basic goal of the NASA Environmental Quality Program is to develop and apply advanced technology from space platforms for contributing to the solution of critical national environmental quality problems. This R&D effort may lead to an operational system for monitoring regional scale air pollution. A cooperative program exists between NASA and the Environmental Protection Agency (EPA) for the development and application of space technology for synoptic air pollution monitoring. The NASA and EPA cooperative program in tropospheric pollution program has two objectives:

1. Evaluate the capabilities of existing satellite systems to detect and monitor visible evidence of polluted air masses, (i.e., "hazy blobs"), and determine the possible future role of space systems in monitoring large-scale air pollution phenomena

2. Demonstrate, through a cooperative ground and aircraft measurement program, the application of space-oriented remote sensing technology to near-term scientific investigations of regional air pollution problems.

The time-phasing of the tasks involved in this NASA/EPA cooperative effort to evaluate the capabilities of a regional air pollution monitoring satellite system are

shown in Figure 4.4, and the resource requirements of this program are listed in Table 4.2. The results from these planned studies are intended to provide the basis for a conceptual design for a long-term monitoring system that would meet long-term objectives of both NASA and EPA.

The primary candidate for transfer of a regional air pollution monitoring capability is EPA, both for the purposes of air pollution control enforcement and for the purposes of scientific investigation into the physical phenomena involved in atmospheric pollution development and transfer. Benefits estimates of the development of regional air pollution monitoring appear to be possible if the operational system capabilities are defined. Consequently, business plan formulation is possible in this area and could be performed as a logical outgrowth of the planned studies.

4.3 Communications Initiatives

EC-1: Development of Technology in the 20/30 GHz Band for Satellite Fixed Service

The objective of this initiative is to develop and demonstrate the operation of the technology needed to open the 20/30 GHz fixed-satellite band for commercial utilization. The proposed intiative is intended to perform the leading edge research and development in areas currently viewed as constraining technologies to the use of the 20/30 GHz band. A NASA initiative in the area is believed to be required as the governmental and industrial organizations that would be the recipients and the users of this technology perceive this research and development as high risk activities which industry is economically unable to justify supporting at the present time. This initiative is further supported by studies which indicate that based upon traffic projections the currently used 4/6 GHz and 12/14 GHz bands will be saturated by the early 1990s, and that the higher assigned frequencies must be opened to commercial use if satellite systems are to continue to be used to meet

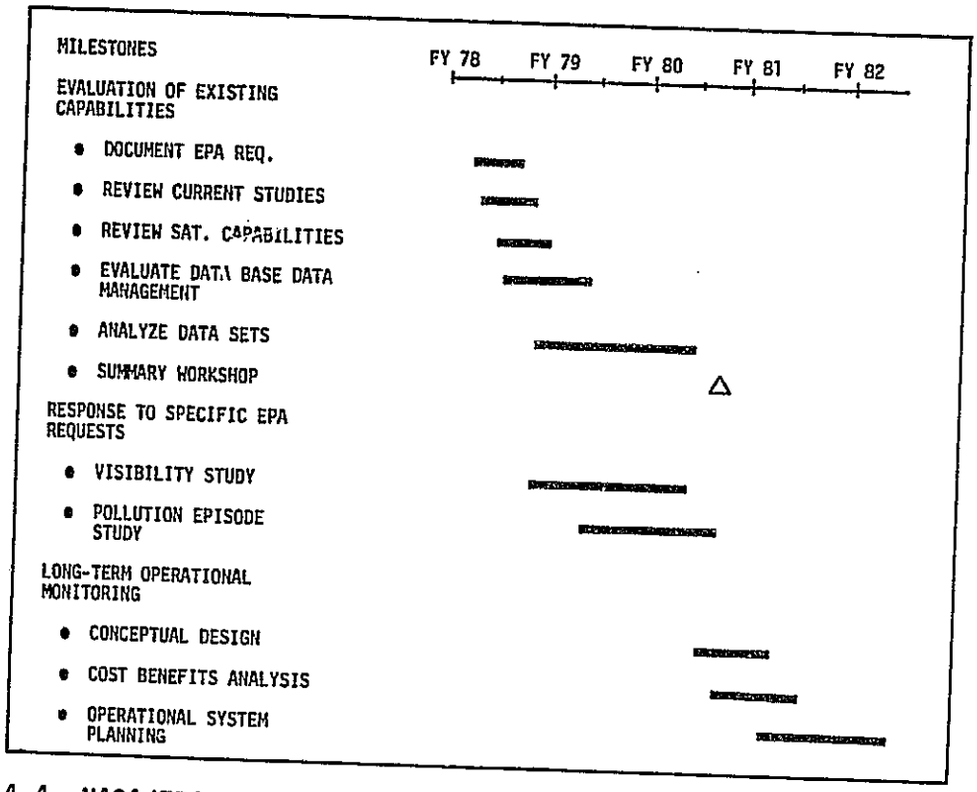

FIGURE 4.4 NASA/EPA COOPERATIVE PROGRAM TO EVALUATE SATELLITE CAPABILITIES FOR MONITORING REGIONAL AIR POLLUTION

TABLE 4.2 NASA RESOURCE REQUIREMENTS FOR NASA/EPA COOPERATIVE PROGRAM TO EVALUATE CAPABILITIES TO MONITOR REGIONAL AIR POLLUTION SATELLITE

ACTIVITY	NASA RESOURCE REQUIREMENTS			TOTAL
	FY 79 MY/$K	FY 80 MY/$K	FY 81 MY/$K	
JOINT STEERING COMMITTEE	3/25	4/35	4/35	11/95
EXISTING CAPABILITIES STUDIES	2/75	2/75		4/150
SCIENCE WORKSHOP		1/40		1/40
VISIBILITY STUDY	2/90	3/100		5/190
POLLUTION EPISODE PREDICTION STUDY	1/10	3/100	1/10	5/120
CONCEPTUAL DESIGN OF REGIONAL SATELLITE MONITORING SYSTEM		2/125	4/520	6/645
COST BENEFITS			2/120	2/120
TOTAL	8/200	15/475	11/685	34/1360

the increasing demand for high density trunking services.* The NASA initiative in this area is viewed as an effort to reduce the uncertainty in the private sector in the use of the 20/30 GHz as opposed to a flight demonstration of a complete 20/30 GHz network. This implies that the NASA developed technology may not require a dedicated satellite system for demonstration, but that it could be demonstrated in flight tests on an operational commercial communications satellite.

In this initiative the technology transfer would be from NASA to the private sector. The recipients of the technology would be the carriers and the providers of the space and terrestrial segments of satellite communications systems. The derivative operational systems would consist of geosynchronous communications satellites operating in the 20/30 GHz band as well as at the currently used lower frequencies.

The preparation of a business plan for this initiative appears to be feasible, but would require information not provided as a part of this study. Technical and programmatic information concerning the initiative would be required. In order to prepare a business plan it would be necessary to estimate the potential demand (market) for domestic and international communications as well as the costs of the systems to provide these services (space and terrestrial). It is highly likely that extensive use could be made of existing models to estimate both the demand and supply aspects of the data needed for this plan.

EC-2: Land Mobile Satellite Applications

Land mobile communications differ significantly in both traffic and technology requirements from the high density fixed trunking services provided by

*Technological Priorities for Future Satellite Communications, NASA Goddard Space Flight Center, July 1978.

commercial carriers. Land mobile applications are generally thin route services with low (and often intermittent) traffic demands. As opposed to fixed services that can utilize a large high gain antenna for wide band communications, mobile services require either narrow band (voice and data) communications with a moving vehicle or with an easily transportable earth station. Although a frequency has not been allocated for land mobile satellite communications it is likely that L-band or the lower end of S-band will be used for this application. The technical feasibility of land mobile (or transportable) communications has been demonstrated in experiments conducted with the ATS and CTS satellites.* However, the scale of these experiments has been limited by the available technology, and the most likely applications require improved technology to become economically feasible. Marketing and economic studies now in process appear to indicate the possibility of substantial economic and social beneits for certain land mobile communications applications such as emergency medical services, fighting forest fires and public safety applications.** Because of the disaggregate nature of the market and substantial research and development needed to develop the systems needed to provide these services, as well as the uncertainty concerning frequency allocation, the carriers have not moved to develop this market. The purpose of this initiative is to develop the high risk technology and to reduce the market uncertainty needed to accelerate the development of the land mobile satellite aided communications market. In the main, this technology consists of multibeam satellite antennas, satellite beam switching equipment, on-board communications processing

*Communications Satellite Systems: An Overview of the Technology, edited by R. G. Gould and Y. F. Lum, IEEE Press.

**The Economic Benefits and Cost Effectiveness of Improved Communications for Emergency Medical Services, Fighting Forest Fires and Pickup and Delivery Trucking, ECON, Inc., Contract NASW-3047, report in preparation.

equipment and low cost mobile and transportable earth terminals. This technology could then be demonstrated in a large-scale experiment, either with a dedicated experimental satellite or as a part of an operational commercial communications satellite. The derivative operational system for this initiative could consist of operational geosynchronous communications satellites working with both mobile and transportable earth terminals. At this time, it is not clear that it is either technically feasible or economically desirable to combine both the fixed and mobile services in a single satellite.

Additionally, issues of technology transfer remain to be resolved in this initiative. For example, in the emergency medical services applications the benefits accrue primarily to individuals in the form of reduced mortality and morbidity, while the costs must be borne by political entities such as counties, states or the federal government. In this case, the end user of the NASA developed technology could be in either the public or private sector; however, in either case pricing of the service is an important unresolved issue.

The preparation of a business plan for this initiative appears to be feasible but would require significant additional effort. Studies now nearing completion by ECON, Mitre and others have partially addressed the market or demand side of this initiative. Preparation of a business plan would require further technical study to define the characteristics and costs of the derivative operational system, as well as studies to investigate institutional and technology transfer questions.

4.4 Materials Processing in Space Initiatives

EM-1: Space Materials Processing Venture

This program comprises the development of a process to produce monodisperse latex spheres in larger sizes than can be currently produced on the ground. Monodisperse latex particles have found a remarkable number of uses ranging from

calibration standards for electron microscopy, light-scattering devices and filters, to medical uses such as measuring pore sizes in membranes and sereological tests for a multitude of diseases. Monodisperse particles in the range from 2 to 20 microns are not available because they are too large to be grown in production quantities by emulsion polymerization and they are too small to be separated by microsieving. Particles in this range are in demand by the scientific community for calibration of devices, particularly those used for counting blood cells and for various membrane sizing applications.

The difficulty in preparing particles larger than 2 microns on the ground lies in the fact that the density of the particles changes during the process as the polymerization progresses. Since such particles are too large to be held in suspension by Brownian motion, they tend to "cream" during the early stages of growth and sediment during the later stages. This can be prevented by vigorous stirring or agitation, but this tends to coagulate the mixture. These problems should be eliminated in a low-gravity environment since the buoyant forces are absent and the larger particles should stay in suspension more or less indefinitely.

The experimental system will use a pressurized Spacelab Module for the production of experimental quantities. The first available hardware will be a four-chamber (500 ml) system which is expected to yield about 4 grams of the monodispersed latex product. Later versions of the experimental system include a two-liter system which will also be used in the early commercial stages. It is expected that production runs of one-pound quantities of four different sizes will be available from the derivative operational system planned for Spacelab III.

The test flights of the Space Shuttle will be used to establish the reaction rates and will provide the necessary design parameters for the production runs to be carried out on Spacelab III. A monomer is mixed with water and a seed latex in

a reactor vessel, and heat is used to initiate the reaction. Careful control of the reaction must be maintained to prevent coagulation or initiation of new crops of particles. Larger particles must be produced by successive steps in which the product of the previous reaction serves as the seed for the next reaction.

The next experiment will be performed on the first scheduled Shuttle mission scheduled in August 1981. Additional tests are anticipated in orbital flight tests of the Shuttle and Spacelab III during fiscal years 1982 and 1983 with commercialization beginning by about fiscal year 1984.

It is believed that the technology of the process and hardware involved in this initiative will be directly transferable to commercial ventures. Currently work with precise calibrating equipment, particularly those used for counting blood cells and membrane sizing etc., that would have use for the larger spheres is going on at universities, in government labs and in private industry. Currently there is a private market for the smaller latex spheres that are available and it is expected that there would be a private market for the larger sizes. Current selling prices for monodisperse latex spheres are $30,000/pound, and a premium price could be expected for the larger sizes. In addition to the use of the larger size particles as calibration standards, they are also in demand for studying the diffusion of carcinogenic particles such as asbestos through the stomach and intestinal walls. Other such uses will become apparent when the particles become available to researchers.

A preliminary estimate of the costs per pound for monodisperse latexes produced in space are presented in Figure 4.5.

Figure 4.6 is a decision tree for the monodisperse latex initiative and illustrates the wide range of possibilities implied by the NASA initiative. Each of the branches implies different costs and benefits, as well as different risks to

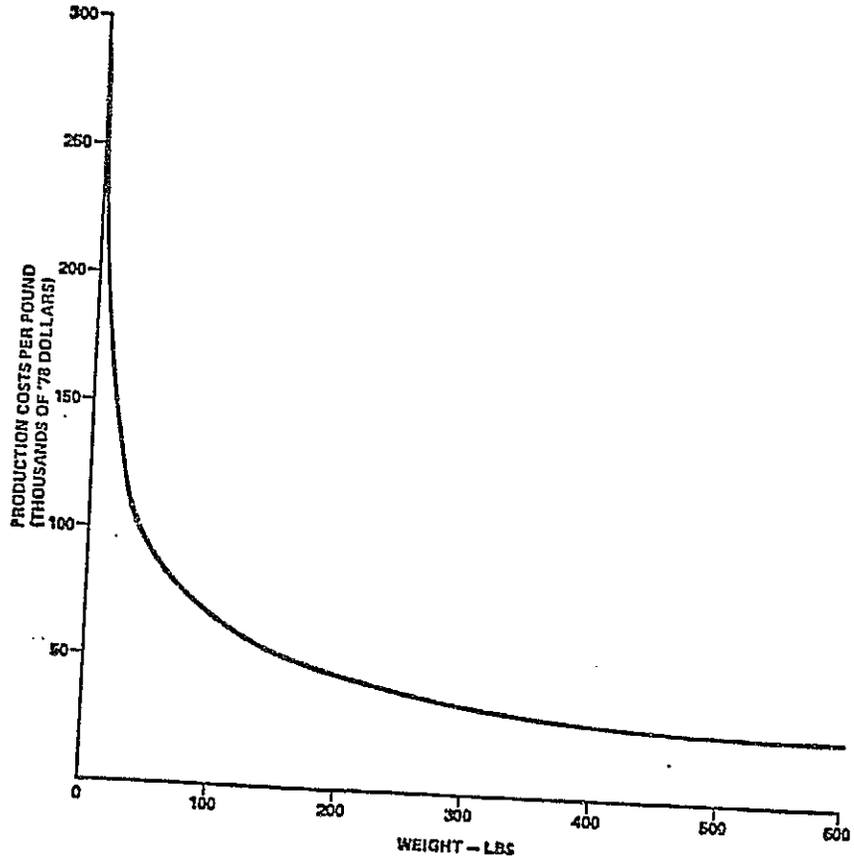

FIGURE 4.5 MONODISPERSE LATEX SPACE-BASED PRODUCTION COST (ROM ESTIMATE)(SOURCE: NASA)

NASA and the private sector participant in the initiative. Although the decision tree indicates that the initiative may be transferred from the public to the private sector with the eventual production of commercial quantities of monodisperse latex spheres, the economic and institutional questions regarding this transfer have not yet been studied. Since this initiative could result in near-term commercial interest it is suggested that the required studies be undertaken and that a business plan be prepared for this initiative.

EM-2: National Space Laboratory for Materials Pocessing Experiments

The object of this initiative is to develop the hardware and support facilities necessary to provide for a national space laboratory for materials processing

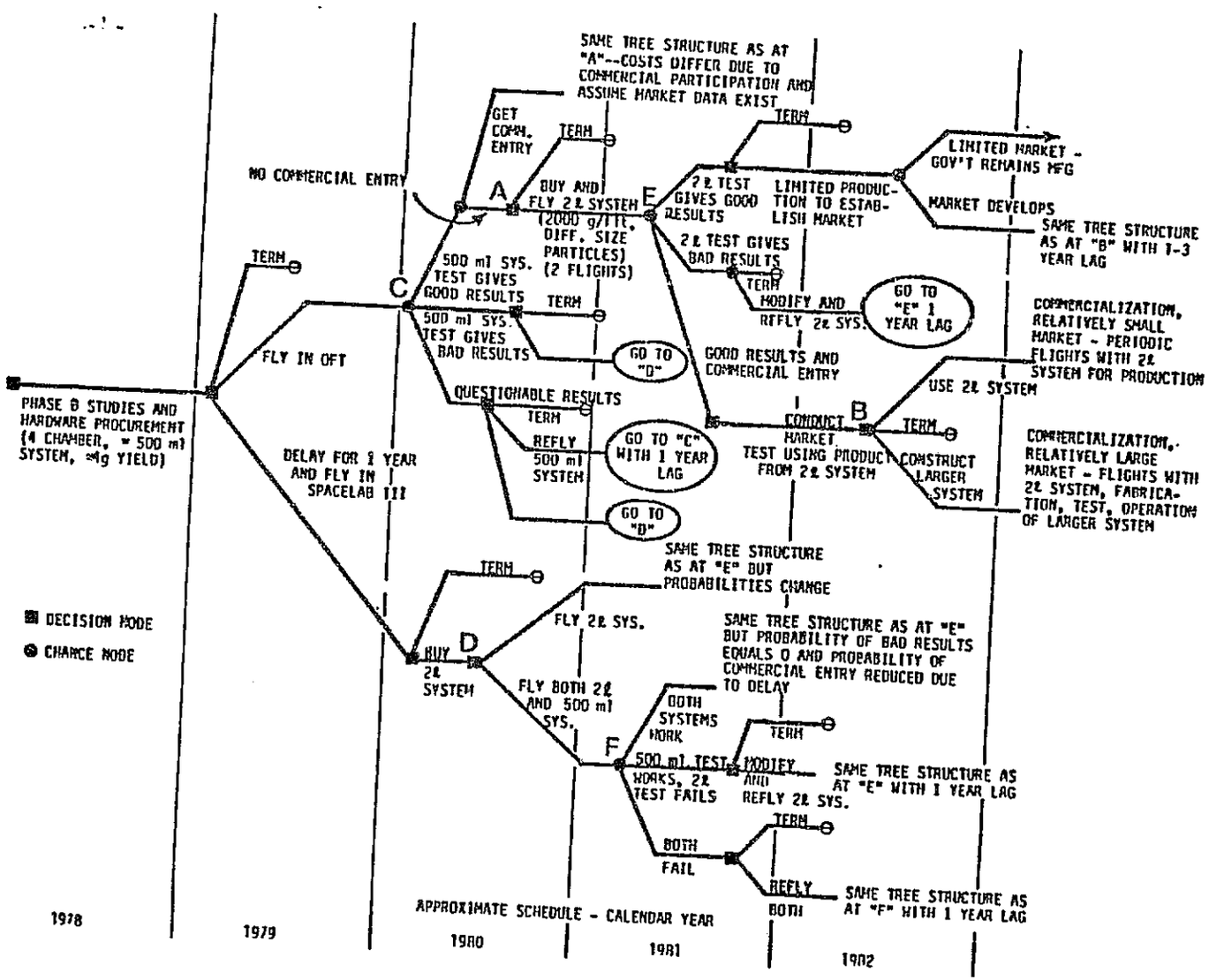

FIGURE 4.6 DECISION TREE--MONODISPERSE LATEX INITIATIVE

experimentation. The concept of this national laboratory facility is an outgrowth of the two phase program proposed by the Committee on Scientific and Technological Aspects of Materials Processing in Space of the National Academy of Sciences.* Phase One, Development and Demonstration, would involve the use of the Space Shuttle and Spacelab to perform experiments that clearly delineate the potentials and limitations of materials experiments in space and that provide NASA with the experience necessary to develop facilities of maximum value to the scientific and engineering communities. It was estimated that this first phase may span the first five years of Shuttle use (i.e., the period of approximately 1981-1985). Phase Two would involve the development of a space-based national facility for materials research. Although the referenced report implies the use of the Shuttle and Spacelab for an operational national facility, current NASA thinking indicates that it may be desirable to develop a 25 kW power module and a materials experiment module (MEM) for this purpose. Figure 4.7 indicates the time phasing of a long-range program leading to the development of an advanced MEM. The National Academy of Sciences report stresses the fact that the development of a national facility should be undertaken only if Phase One convincingly demonstrates the usefulness of materials processing experiments in space, and if experimenters are willing to pay for time on the facility. Although this phased sequence is logical, the planning for a national facility must begin during FY1980 or 1981 if the facility is to capitalize on the early Shuttle experience. This planning should include a business analysis of the proposed national facility. Important questions to be answered are:

- What are the expected technical capabilities and costs of the facility?
- What is the anticipated user demand for the facility as a function of the user cost schedule?

*Materials Processing in Space, National Academy of Sciences, 1978.

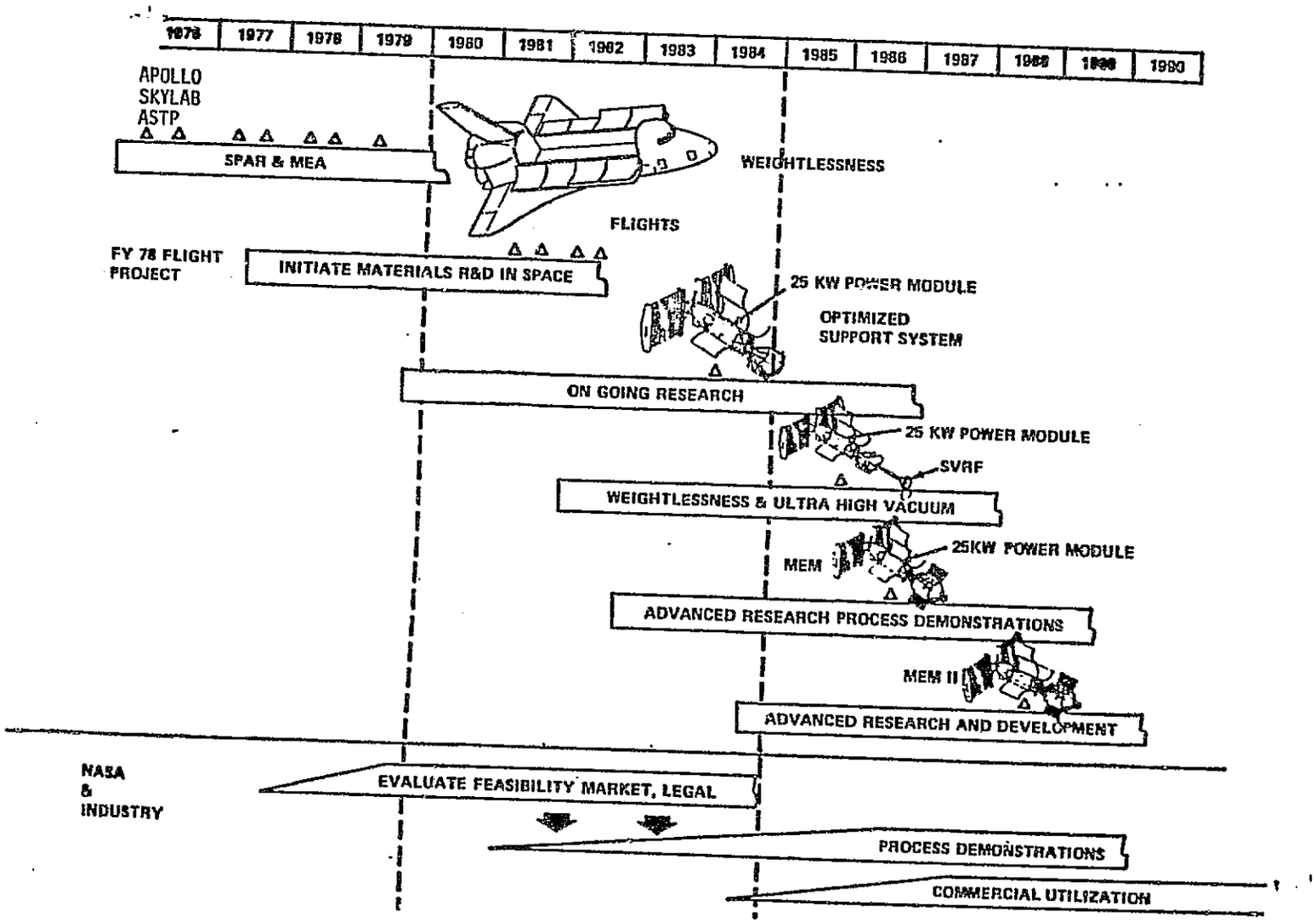

FIGURE 4.7 MATERIALS PROCESSING IN SPACE (SOURCE: NASA)

- What is an appropriate schedule of user costs?
- How will the facility be operated and managed?
- Could the facility be a private sector venture?

It is probably premature to begin business planning for the facility until further studies have been performed to explore these and related issues.

4.5 Resource Observation Initiatives

ER-1: Soil Moisture Monitoring

Soil moisture is an important parameter used in modeling of hydrology and water management, weather forecasting and climatology. A proposed soil moisture monitoring system to be available in the 1990 time frame is depicted in Figure 4.8. Such a system would employ a variety of sensors on different remote sensing spacecraft in addition to a synchronous communications relay satellite and regional data centers. The desired capability for such a system is reviewed in Table 4.3.

At present a capability exists only to address water demand using irrigated agriculture as an indicator and to mensurate and classify major irrigated crops. However, with the capability specified above for the 1990 time period, it would be possible to do the following:

- River basin analysis
- Use passive microwave to measure soil moisture levels for hydrologic modeling to predict water yield, potential ground water recharge and actual evapotranspiration
- Using TM/MLA to mensurate and classify specific crop types to infer potential water demand by field
- Measure soil water availability with passive and active microwave techniques
- Compare with potential demand to get actual water demand at a given time
- Use above data for irrigation scheduling, reservoir releases and flood protection.

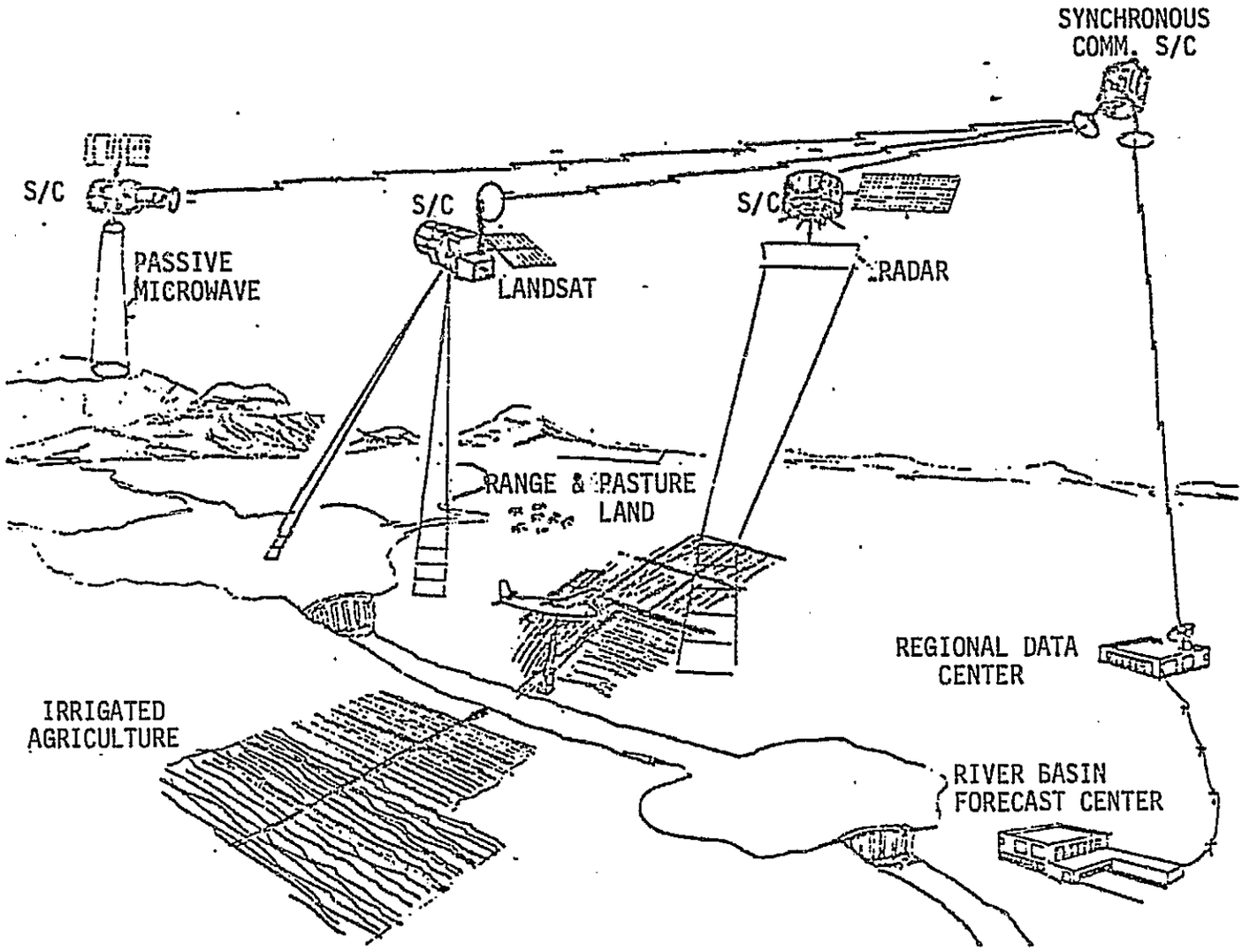

FIGURE 4.8 SOIL MOSITURE MONITORING SYSTEM (SOURCE: NASA)

TABLE 4.3 DATA REQUIREMENTS FOR SOIL MOISTURE REMOTE SENSING

RESOLUTION (m)			ACCURACY	FREQUENCY	RESEARCH FEASIBILITY (COMPLETED BY)	SPACE DEMONSTRATION (COMPLETED BY)
A*	B*	C*				
100	300	1000	±10%	1-3 DAYS	1984	1988

*DRAINAGE BASINS--A: < 100 KM^2, B: 100-1000 KM^2, C: > 1000 KM^2.

SOURCE: WMO, 1976.

The potential user groups include governmental agencies involved in water management, weather forecasting and climate monitoring, as well as universities conducting research and private engineering consulting firms. The question of the operating agency for a derivative operational system has not yet been addressed, although it is likely that operational responsibility would remain within the federal government. Given the specification of system capabilities it appears possible to conduct benefit analyses for a derivative operational system. When, in addition, cost estimates are available for the initiative phase and the derivative operational system, it should be possible to conduct business planning in this area.

ER-2: Integrated Remote Sensing System

The purpose of this initiative is to provide support to the planning activity requested by the President's Space Policy Announcement on October 11, 1978. As such, the impetus for this initiative does not come from internal NASA planning documents furnished to the study team, but arises from the requirement to provide a comprehensive plan concerning the technical, programmatic, private sector and institutional arrangements for an integrated remote sensing system prior to the FY1981 budget cycle. Since NASA is to chair an interagency task force to examine the options for integrating current and future systems into an integrated national system, the study team suggests that NASA examine the business aspects of the alternatives as a part of the option analysis. Performance of business planning to support the activity will require the examination of the technical capabilities, costs and benefits of options, as well as questions of public and private sector involvement and institutional arrangements to support and operate an integrated system. Because of the studies performed in support of the LANDSAT follow-on operational system decision an extensive background of analysis and models is

available to support business planning in this area.* In view of the focus on this area as a result of the President's announcement and the interagency activity, the study team recommends this as a high priority area for business planning.

*A Cost-Benefit Evaluation of the LANDSAT Follow-On Operational System, NASA Goddard Space Flight Center, March 1977.

5. OPERATIONAL EARTH RESOURCES SYSTEM (ERS)--AN EXAMPLE OF BUSINESS PLANNING

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5. AN EXAMPLE OF BUSINESS PLANNING--THE OPERATIONAL EARTH RESOURCES SATELLITE (ERS) PROGRAM

5.1 Introduction

Earlier sections of this report discuss business planning in the private sector, and the possible adaptation of planning techniques found to be useful in the private sector to certain proposed major new initiatives in OSTA. In these earlier sections, the requirements of a business plan are developed along with the methodologies and analytical tools commonly used in private sector business planning. To some extent, these earlier sections are a tutorial on the theory and practice of business planning. The tutorial is adequately supplemented with several practical examples of the application of planning tools to private sector ventures.

The authors of this report fully realize that public sector ventures often differ in magnitude of investment, scale, complexity and risk from private sector ventures. However, in recent years even the largest of the NASA initiatives, the Space Shuttle, is matched or exceeded in cost, complexity and risk by private sector undertakings such as the development of the North Slope and North Sea oil and gas fields. The initiatives contemplated by OSTA are not on the scale of the Space Shuttle and are perhaps more comparable in size of investment, complexity and risk to private sector ventures such as the development and introduction of a new engine technology in the passenger automobile business, the design and development of a new model passenger jet aircraft, or the design and construction of a fleet of new cargo ships by a commercial marine transport company. In each of the cited private sector examples, it is a certainty that extensive business planning would be performed to analyze the viability of the investment before

significant funds are committed. While there are many reasons for business planning in the private sector, perhaps the most important are to provide a rigorous framework for the analysis and comparison of alternative investment opportunities, to explore the impacts of alternative actions and developments that could occur during the life cycle from research through production on the investment, and to establish a well-thought-out and quantitative advocacy position. All of the differences between private and public sector ventures notwithstanding, it is clear that these reasons are as important to the measure of ventures in the public sector as they are in the private sector.

The concept of accountability for the use of venture funds leads to major differences between the private and public sectors. If a private sector venture of this magnitude fails it could as a minimum detrimentally affect the market share, profits, cash position and stock value of the company, and result in the wholesale replacement of the management team that sponsored the venture.* In a worst case it could lead to the outright failure of the company. The management of federal agencies are not measured by these criteria, nor is the penalty function for failure as severe in the public sector. While it is possible for the public or the Congress to lose faith in an agency or a program and cut back on funding, in our present concept of government organization, federal agencies do not go bankrupt. In public sector ventures the risk is ultimately borne by the taxpayers. This element of risk sharing generally does not exist in the private sector, and for this reason many economists suggest that the public sector should be less risk averse than the private sector in the evaluation of prospective new ventures. It is possible that the combination of these factors leads to a less rigorous and disciplined attitude toward business planning in the public sector.

*For example, see "Programmed for Disaster--The Story of RCA's $490 Million Computer Debacle," The Atlantic Monthly, May 1972; or "Lockheed: Can It Make a Commercial Comeback?" Forbes, October 1, 1967 and "Anatomy of a Disaster," Forbes, March 15, 1967.

When viewed as investment opportunities, ventures that might be undertaken by OSTA provide an opportunity for return on investment by impacting decisions in the public sector and/or the private sector. An example of the former is the development of a communications system that is more cost effective than alternative systems for the delivery of public services, or the development of improved communications for emergency medical services that reduces the incidence of mortality and morbidity resulting from automobile accidents and other forms of trauma. An example of the latter is an operational ERS that could provide benefits to farmers and consumers through improved price stability resulting from knowledge concerning major crops. Thus, an important reason for business planning for major OSTA initiatives is to quantify the economic impacts of these initiatives on both the public and private sectors. Most federal agencies involved in applied research, development and the delivery of services attempt to evaluate the economic impacts of their investments. This evaluation most often takes the form of either a cost-efffectiveness or benefit/cost analysis that aims to provide estimates of the expected value of the investment.* Major OSTA initiatives fall into this category. However, the concept of business planning as practiced in the private sector is rarely found in the public sector.** In the public sector, there is

*Civil Agencies Make Limited Use of Cost-Benefit Analysis in Support of Budget Requests, Report to the Congress, Controller General of the United States, January 14, 1975.

**The Department of Energy (DOE) appears to be an exception to this statement. Because of the fact that virtually all of the research and development conducted by DOE is aimed at impacting decisions in the private sector, DOE planning appears to be sensitive to questions of commercialization, consumer motivation and technology transfer. Examples of DOE concern with the marketability of their research and development can be found in internal DOE documents such as the Office of Conservation and Solar Applications, Division of Building and Community Systems and Building and Federal Programs, Management Review and Control Document (Operating Draft for FY 1978), November 21, 1977 and Solar, Geothermal, Electric and Storage Systems Program Summary Document, FY 1979. Many DOE contractor studies deal with questions of technology transfer, market penetration and institutional problems concerning the private sector adoption of DOE-sponsored technology.

a tendency to concentrate on the technical and financial aspects of planning, and to treat economic (market) and strategy issues as separate matters rather than to bring together all of these factors into an integrated business plan.

The purpose of this section is to provide a specific example of the formulation of a business plan for a potential OSTA initiative. In the case of this example, the initiative, LANDSAT-D, has been approved, while the derivative operational system, the operational ERS, has been hypothesized for the purpose of this example. While every effort has been made to hypothesize a realistic operational ERS, it should be understood that studies that could affect both the technical characteristics and the operational strategy of this system are now in process. For this reason, the reader is invited to overlook the technical and programmatic specifics, and to concentrate on the generic types of information provided by and required for this example. It should also be noted that business planing is an iterative process and that an important function of early planning work is to identify where more information is needed in order to provide a sound basis for an evaluation of the investment opportunity and formulation of strategy. Since this is the first attempt at the preparation of a business plan for the operational ERS, virtually all areas of the plan could benefit from additional work. Thus, the paragraphs that follow consist of a combination of what is known at present, and a definition of what is required in order to complete business planning for an operational ERS.

5.2 Background

In the mid-1960s, NASA initiated an Earth Resources Survey Program in response to the interest shown in the high resolution imagery of the surface of the earth taken by astronauts in the Mercury and Gemini Programs. The initial objective of this program was to conduct experiments with various sensors carried

in aircraft to evaluate film and filter combinations that could yield information on vegetation and surface phenomena by identifying the spectral signatures of these phenomena in the visible and near infra-red parts of the spectrum. In the beginning of the program, film systems were emphasized as it appeared that the successful Apollo Program would be followed by an earth-orbiting manned space program, called the Apollo Applications Program, that would provide opportunities on a continuing basis to carry film cameras into space and return the film to earth for development and analysis. As the Apollo Program achieved its goals in the late 1960s, it became increasingly apparent that it would not be followed by a manned earth-orbiting program and the Apollo Applications Program was dropped because of funding constraints. The emphasis of the Earth Resource Survey Program then shifted away from film cameras to the use of unmanned satellites and electronic imaging devices.

In 1970, NASA began the development of two advanced electronic imaging devices and an unmanned spacecraft intended specifically to carry these imaging devices on the earth resources survey mission. Called the Earth Resources Technology Satellite (ERTS), these satellites and imaging devices were designed to provide nearly complete coverage of the surface of the earth in four spectral bands in the visible and near infra-red parts of the spectrum at a surface resolution of about 100 meters. Funds for two such satellites were appropriated in FY 1969. The first of these satellites, ERTS-1, was launched in 1972, and the second, ERTS-2, was launched in 1975. Following several years of successful operation, the name of these satellites was changed from ERTS to LANDSAT. The initial period of operation of these satellites from 1972 through 1975 focused on the development of the technologies for data acquisition, processing and distribution, and on the identification of the applications of the data produced by the satellites.

Research with the satellite imagery during this time period identified two major applications, agricultural mapping and mineral exploration. By the time of launch of LANDSAT-2 in 1975, the LANDSAT program had become international in scope, and had grown to involve users from many federal government agencies and the private sector. In the period following 1973, NASA placed increased emphasis on applications and programs with an operational flavor, including multi-year experiments with the Departments of Agriculture and Interior, the U.S. Army Corps of Engineers, NOAA, state governments, regional authorities and the private sector.

A third LANDSAT, LANDSAT-3, was launched in 1978. LANDSAT-3 incorporates features shown to be desirable by the nine years of experience with the two earlier LANDSATs. These include imaging devices capable of producing higher resolution and improved thermal infra-red data, as well improved data handling that will provide the capability to get data to the users about a week after it was acquired by the satellite.

5.3 Goals and Objectives of the LANDSAT-D Initiative

The goals of the LANDSAT-D initiative are to provide a continued capability for experimentation with improved remotely-sensed data, as well as the continued capability for operational-type demonstrations using this data.

Specific objectives of the LANDSAT-D are:

1. To assess the capability of a new imaging device, the Thematic Mapper, to provide improved information for earth resources management. In comparison to imaging devices now in use, the Thematic Mapper is capable of providing greater spectral and spatial resolution

2. To provide continuity of Multi-Spectral Sensor data to existing users, and to provide a transition for domestic and foreign users to the higher resolution and data rate of the Thematic Mapper

3. To demonstrate the operation of new technology in the areas of:

   a. A highly automated end-to-end data system

   b. Improved high resolution and high data rate sensor technology

c. The use of advanced sensor and data collection capabilities in conjunction with a Tracking and Data Relay Satellite

d. A new Multi-Mission Modular Spacecraft that is compatible with the Space Shuttle transportation system

4. To provide system level feasibility demonstrations in conjunction with user agencies to define the need for and the characteristics of an operational earth resources satellite system.

Since these objectives can only be defined in a qualitative manner at present, future effort on this plan should aim to provide quantitative objectives that are necessary to provide a basis for future benefit estimation, and to provide a measure of accountability as system performance is demonstrated.

5.4 Description

The following sections describe the LANDSAT-D initiative, and the presently identifiable characteristics of the derivative operational system, and operational Earth Resources Satellite System. These system characteristics, particularly the characteristics of the operational Earth Resources Satellite System, provide the basis for the estimation of the market for the goods and services of the operational system, and the costs and benefits of the system.

The reader of this plan will note that although a general description of the LANDSAT-D space segment can be provided at the present time, a comparable description of the ground segment is lacking. More importantly, information is not available at the present time on the experiments and demonstrations planned using the data to be provided by the LANDSAT-D system. As work is continued on this plan, an effort should be made to complete the description of theground segment in terms of the data products and the characteristics of these products. In the case of the pre-operational and operational uses of the spacecraft data, effort should be expended to quantitatively

define both the data requirements and the performance objectives of these applications.

5.4.1 The LANDSAT-D Initiative

5.4.1.1 General

The LANDSAT-D system is an experimental earth resources monitoring system that builds on the nine years of experience with the predecessor LANDSATs-1, 2 and 3. The LANDSAT-D system consists of an advanced observatory satellite, using the Multi-Mission Modular Spacecraft equipped with a new thematic mapping imaging instrument and a multi-spectral scanner similar to that used in the earlier LANDSATs. The spacecraft is designed to be compatible with the Space Shuttle launch, retrieval and replacement capabilities. The data collected aboard the spacecraft can be transmitted to earth stations via the Tracking and Data Relay Satellite System, or directly from LANDSAT-D to earth stations. The processing of the data collected by the satellite will be performed by a highly automated end-to-end data processing system. The first LANDSAT-D configuration spacecraft is scheduled for launch in the third quarter of 1981 (CY). The backup spacecraft in this series will be available for launch in the following year.

5.4.1.2 The Space Segment

The space segment of the LANDSAT-D system consists of a Multi-Mission Modular Spacecraft equipped with two electronic imaging devices. The imaging devices used are the Multi-Spectral Scanner (similar to those used in the earlier LANDSATs) and the new, higher resolution thematic mapper instrument. The LANDSAT-D spacecraft will be 7 feet in diameter and 18 feet long. It will carry a 140 square foot solar array with a 1,400 watt output capability. The spacecraft will carry an antenna that is 6 feet in diameter for communication with the

Tracking and Data Relay Satellite. Both the Thematic Mapper and Multi-Spectral Scanner Data can be transmitted to the ground either directly from LANDSAT-D to appropriately equipped earth stations or via the Tracking and Data Relay Satellite. LANDSAT-D will also carry equipment to enable the satellite to work with the DOD Global Positioning Satellite system for satellite position and orbit determination.

LANDSAT-D will be launched in 1981 (CY) on a Delta launch vehicle. The spacecraft will have a design life of three years in orbit and will be built so that it can be retrieved by the Space Shuttle for refurbishment.

5.4.1.3 The Ground Segment

The LANDSAT-D ground segment will consist of a user-oriented end-to-end highly-automated data system. The ground system will have the capability to utilize the data analysis techniques required by specific applications, thus providing the user with a data product that is tailored to the needs of the specific application.

5.4.1.4 Experiments and Operational Demonstrations

Although the specific experiments to be performed using the data collected by the imaging sensors aboard LANDSAT-D have not been defined, it is likely that the mix of experiments will be similar to those planned for LANDSAT-3 with increased emphasis on the demonstration of the capabilities of an operational system. As in the case of previous LANDSATs, both international and domestic experiments will be performed; however, in the case of LANDSAT-D, increased emphasis will be placed on the performance of cooperative experiments with user agencies in the public sector and on experiments to be performed in the private sector. Specific experiments or demonstrations of operational capability may include:

1. Extension of the completed Large Area Crop Inventory Experiment to estimate wheat production into a joint effort with USDA to use LANDSAT-D data to aid in the production estimation of other agricultural commodities

2. Multi-agency demonstration projects to use LANDSAT-D data to aid in snow and water runoff projections, and to estimate water usage for irrigation

3. A joint project with the Bureau of Census to evaluate the use of remotely-sensed data on urban land usage to support the five-year census requirement

4. A cooperative effort with the Geosat Committee, Inc., representing the mineral and petroleum exploration industry to provide data that can be used for rock-type discrimination for mineralogical exploration.

5.4.2 The Operational Earth Resources Satellite System

5.4.2.1 General

In the sections that follow, a scenario is described for the evolution of an operational Earth Resources Satellite system. The scenario is based upon the development of an operational system that has considerable inheritance from LANDSAT-D, but with improved imaging sensors and data processing capabilities. Although the concept of an operational Earth Resources Satellite system has been studied,* this system is not an approved program at the present time. For this reason, the system described, although based upon the best available current understanding of user needs, technical capabilities, and institutional and budgetary considerations, is hypothetical. The completion of studies now in process and experience with LANDSATs-3 and D will no doubt modify the system described. For example, in response to the President's Space Policy Announcement, NASA is presently conducting two studies that bear on the issues of an operational system.** These two studies, to be completed prior to the FY 1981 budget cycle, are concerned with the options for an integrated national remote-sensing system,

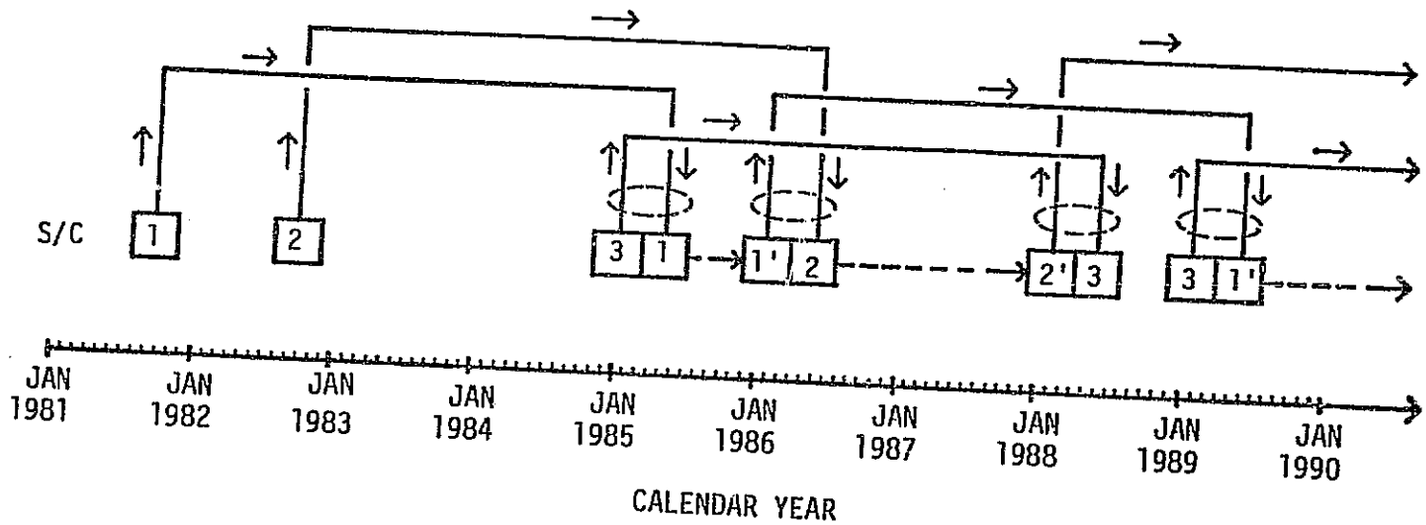
*Total Earth Resources System for the Shuttle Era, General Electric Space Division, Contract No. NAS9-12301, March 1975.

**The White House Fact Sheet--U.S. Civil Space Policy, October 11, 1978.

and with the questions of private sector investment and participation in civil remote-sensing programs. The reader of this section should also note that bills introduced in the 95th Congress and scheduled for reintroduction in the 96th Congress could have considerable bearing on the impetus for and institutional arrangements of an operational system.* Although each of the referenced bills differ in detail, they each promote the implementation of an operational Earth Resources Satellite System. Even if these bills do not result in the enactment of legislation, it is apparent that there is interest in Congress in an operational system; and if these bills proceed to hearings, some additional clarification of the interests and positions of the organizations that could be participants in an operational system will be obtained.

Figure 5.1 illustrates a possible scenario for the transition from LANDSAT-D to an operational Earth Resources Satellite System used in this business plan. The operational demonstration phase of the system will commence in September 1981 with the launch of LANDSAT-D1, while the second spacecraft in this configuration, LANDSAT-D2 will be available for launch about one year later. Each of these LANDSAT-D spacecraft will be equipped with a Multi-Spectral Scanner (MSS) and a Thematic Mapper (TM), and will have a nominal life of three to four years. When the two LANDSAT-D spacecraft are in orbit, they will provide a repeat average pattern of nine days. At the end of its nominal life early in 1985, LANDSAT-D1 will be recovered in a Space Shuttle mission and returned to earth for refurbishment. During this same mission ERS-1 will be launched. During the refurbishment cycle, the MSS will be replaced by a new pointable sensor, the Multi-Spectral Resource Scanner (MRS), and the spacecraft will be upgraded to the

*S.3625, Earth Resource and Information Satellite Act of 1979; S.3530, Space Policy Act of 1978; S.3589, Earth Data and Information Service Act of 1979.



NOTES:

- 1 = LANDSAT-D1
- 2 = LANDSAT-D2
- 3 = ERS-1
- 1' = ERS-2 = 1 MODIFIED TO BE EQUIVALENT TO 3
- 2' = ERS-3 = 2 MODIFIED TO BE EQUIVALENT TO 3

↑ = LAUNCH ↓ = RETRIEVAL → OPERATIONAL ON-ORBIT

--→ = REFURBISHMENT

= PLACEMENT AND RETRIEVAL FLIGHT

FIGURE 5.1 EARTH RESOURCES OPERATIONAL SYSTEM--A POSSIBLE SCENARIO

operational ERS configuration (ERS-2). In early 1986, this refurbished spacecraft will be launched again as ERS-2. During this mission LANDSAT-D2 will be retrieved so that it can be refurbished and available as ERS-3. The first in the fully-operational series of spacecraft, ERS-1, will be launched in March 1985, and will be fitted with a TM and MRS. When equipped with the pointable MRS sensor, the repeat pattern capability of the operational ERS system will be approximately four days. Thus, the operational ERS system will consist of two MMS spacecraft in orbit, each equipped with TM and MRS imaging devices. A third such spacecraft will serve as backup to the two in orbit. Each of these spacecraft will be recovered, refurbished and reflown upon completion of its nominal mission.

It should be noted that this nominal mission scenario does not allow for the consideration of random failures associated with the sensors, MMS or launch systems. Since an operational service is to be provided to users it is necessary to consider the reliability aspects of the system and the implications upon sparing concepts, costs and continuity of service. This requires further analysis.

5.4.2.2 The Space Segment

The space segment of the operational ERS will use an MMS equipped with a TM similar to that flown in in the earlier LANDSAT-D missions and a new pointable imaging device, the MRS. The MRS will provide for coverage of up to 20 spectral bands in the range of 0.4μ to 1.0 μ. The spectral bands to be used will be selectable in order to best match the use of the MRS to the spectral characteristics of the target to be observed. The MRS will also be pointable ± 45 degrees fore and aft and to ± 36 degrees either side of the satellite track. The space segment of the ERS system will consist of two such spacecraft in orbit, and a third backup spacecraft on the ground. The pointable MRS capability will enable the ERS system to achieve a four-day repeat pattern when both ERS spacecraft are in orbit.

The operational ERS will be launched by the Space Shuttle, and will be recovered (and refurbished) at the conclusion of its nominal mission.

5.4.2.3 The Ground Segment

The ground segment of the ERS system will build upon the demonstrated capability of the pre-operational LANDSAT-D system. The operational system will be capable of processing 2,000 MRS and 200 TM scenes per day. The system throughput time (from data acquisition to availability for the user) will be about 72 hours. Both of these characteristics represent significant improvements over the LANDSAT-D ground system.

5.4.2.4 Operational Use

The operational uses of the ERS have not been specified; however, it is likely that many of the experiments and operational demonstrations identified for the LANDSAT-D mission will be transitioned to a fully-operational status by the time of the ERS.

5.5 Market and Economic Analysis

5.5.1 Need for Goods and Services

With increasing worldwide population and intensity of organized activity in areas such as agriculture, commerce, resource development and transportation, the need for an improved capability to understand and predict the behavior of the environment is apparent. An ability to measure accurately the state of the environment, and the impact of man on the environment, is an important step in the development of models which will predict such behavior. These models might also be used to predict levels at which man can hope to extract food and fiber products as well as other resources from the earth.

It is important to realize that the concepts of a resource management system are not new. What is new is that within the past three decades, the technology of

data collection and processing and management decision sciences have developed to the point where it is now feasible to begin to implement large-scale resource management systems at the national and international levels. LANDSAT-D and the operational ERS are intended to provide improved systems for the collection of data for use in decision models in the areas of natural and cultural resources. Experience with the earlier LANDSATs has shown that there is a need for this data, as well as improved decision models to use the data, in numerous areas of application.

Earlier studies and experience with LANDSATs-1, 2 and 3 have suggested the demand for, and utility of LANDSAT data in applications such as:*

- Agricultural Crop Information
- Petroleum and Mineral Exploration
- Hydrologic Land Use
- Water Resources Management
- Forestry
- Land Use Planning and Monitoring
- Soil Management
- Rangeland Management
- Crop Pest Management
- Construction Siting.

The above applications are both national and international in scope. Some of the resource management functions involved in these applications reside in the private sector, while others are performed by federal, state and local agencies. All of these applications have been demonstrated with varying degrees of success in the LANDSAT program. In general, however, the need and the demand for services

*A Cost-Benefit Evaluation of the LANDSAT Follow-On System, NASA, GSFC, X-903-77-49, March 1977.

provided by an operational system will depend upon the quality of the service provided and how well the services and information products match the needs of the users. This requires that user decision processes be analyzed in order to determine the impact of information attributes (accuracy, timeliness, etc.) upon user decisions and the importance of the decisions. The user needs so established must then be matched with the information products that may be available from the operational ERS system.

Various studies have attempted to quantify the information needs of users in these applications in terms of spectral and spatial information content and frequency of coverage.* In order to define the need for the goods and services that could be produced by an operational ERS, it is now necessary to move beyond these preliminary studies into a market study. The objective of the market study should be to estimate the quantity of the data products that could be produced by an ERS that will be demanded by users of the system as a function of the price of the product.

5.5.2 Value of Goods and Services

Many studies have been performed to estimate the costs and benefits of earth observation systems and their applications. These studies generally approach the issue of costs and benefits from the perspective of the public sector as a provider and the private sector as a consumer of information. Although benefit estimates are provided in an aggregate manner by sector of the economy, the studies do provide useful insight into the location of the benefits in the economy and hence the location of potential venture opportunities.

Since the specific information products (and associated attributes) that will be available from an operational ERS system have not as yet been defined it is not

*Total Earth Resources System for the Shuttle Era, Contract NAS9-13401; LANDSAT Follow-On: A Report by the Applications Study Groups, JPL TM 33-803, December 15, 1976.

possible to establish the value of the ERS system and its information products. The following paragraphs summarize the results of prior benefit studies. It should be noted that in only several of these have user decision processes been modeled and the benefits developed in terms of the impact of information products on decisions. In no cases have user costs associated with the acquisition of information products (i.e., purchasing of information) been considered.

Further, it should be noted that these studies of costs and benefits were performed for a LANDSAT Follow-On Operational System (LSFO). The technical characteristics of the LSFO are not the same as the operational ERS described in Section 5.4.2. The significant differences between these two systems are shown in Table 5.1.

From the information presented in Table 5.1 it is apparent that the capabilities of the operational ERS exceed those posited for the LSFO. It is also likely that the costs of an operational ERS system will exceed those estimated for the LSFO system. However, while very preliminary estimates have been made for

TABLE 5.1 SIGNIFICANT DIFFERENCES BETWEEN LANDSAT FOLLOW-ON AND THE OPERATIONAL ERS SYSTEMS

CHARACTERISTIC	LSFO	ERS
NUMBER OF SATELLITES IN ORBIT	1	2
REPEAT COVERAGE	16 DAYS	4 DAYS
SENSORS	MSS	MRS
	TM	TM
GROUND SYSTEM CAPABILITY IN SCENES PROCESSED PER DAY		
MSS	200	--
MRS	--	2000
TM	100	200

the cost of an operational ERS, the benefits of the operational ERS have not been estimated. Since the costs and benefits form an important part of this business plan, it is necessary that studies be performed to estimate the costs and benefits of the operational ERS. As these studies have not yet been performed, a summary of the LSFO costs and benefits is provided as an indication of the potential value of the operational ERS.

The demonstation that the present value of benefits exceed the present value of costs is a necessary condition for public sector support of the LANDSAT-D initiative. However, the fact that the benefits exceed the costs does not imply that the operational ERS would be a desirable private sector investment. The desirability of private sector investment is determined by analysis of performance measures of the proposed venture. Performance measures of interest to the private sector include profit, cash flow, indebtedness, return on investment and present worth of the venture. The understanding of these parameters require a thorough marketing study and financial analysis of the venture. In order to perform the financial analysis, it is necessary to establish a model of the venture from the point of view of flow of information products and services and resulting costs and revenues. This has yet to be accomplished.

5.5.2.1 LSFO Costs and Benefits*

This section presents the results of benefit and cost studies for a LANDSAT Follow-On System. The study was directed by Goddard Space Flight Center with ECON, Inc. and General Electric Corp. providing significant support in the areas of economic benefit analyses and data system trade-off studies respectively. The major conclusion is that the system benefit cost ratio is in the range of 4 to 9 with

*A Cost-Benefit Evaluation of the LANDSAT Follow-On Operational System, NASA, GSFC, X-903-77-49, March 1977.

the benefits and costs discounted at 10 percent (OMB Circular A-94).* Table 5.2 presents an overview of the discounted benefits by application and the corresponding system and user costs. The costs are separated into the space and data management system common to all users and the unique user data subsystems. The basis for the benefits and costs in Table 5.2 are further detailed below.

It should be noted that the quantitative estimates of benefits in the various economic and public sectors are limited to currently developed or developing uses of the satellite imagery. Since the LANDSAT technology is continuing to grow in its applications the quantitative benefit estimates and the corresponding benefit cost ratios are believed to be conservative.

The annual economic benefits of each application are listed in Table 5.3. It is seen that agriculture dominates with petroleum and mineral exploration being the second most important. Benefits on the order of or larger than some of those

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*An important issue in connection with the discounting of future benefits and costs is the selection of the discount rate; that is, what specific discount rate should be used in translating future benefits and benefits into present values? In the case of NASA projects the selection of the discount rate is specified by OMB; however, it should be understood that the magnitude of the discount rate can be a critical factor in determining the desirability of a program. Higher discount rates rapidly diminish the present value of both benefits and costs that occur in the relatively distant future. For most programs this means that higher discount rates will yield lower benefit-to-cost ratios or lower net present values. Because of research and development costs, most NASA projects incur most of their costs relatively early while the benefits are received over longer periods of time. With this pattern for benefit and cost flows higher discount rates produce lower net present values. Since the present value of an investment can be considered to be the maximum amount that an organization could pay for the opportunity of making the investment at the current cost of capital without being financially worse off, it can be argued that the discount rate should bear a relationship to the long-term cost of capital. When the nominal interest rate paid for long-term capital is deflated by the current inflation rate, the real rate of interest for long-term capital in the United States is in the range of 1 to 2 percent per year. At a discount rate of 10 percent, a benefit of $1000 in the tenth year of a program has a present value of $386, while at a discount rate of 2 percent a benefit of $1000 in the tenth year has a present value of $820.

TABLE 5.2 PRESENT VALUE OF THE BENEFITS AND COSTS OF THE LANDSAT FOLLOW-ON SYSTEM (FY 76 DOLLARS DISCOUNTED AT 10 PERCENT)

SYSTEMS AND USERS	BENEFIT ($ MILLION)	COST ($ MILLION)
SPACE AND DATA MANAGEMENT SYSTEMS	--	342
AGRICULTURAL CROP INFORMATION	1,705 - 3,370	55
HYDROLOGIC LAND USE	128	10
PETROLEUM-MINERAL EXPLORATION	202 - 819	
WATER RESOURCES MANAGEMENT	75 - 237	
FORESTRY	41	122
LAND USE PLANNING-MONITORING	87 - 278	
SOIL MANAGEMENT	29 - 52	
TOTAL (ROUNDED)	2,260 - 4,920	530
BENEFIT COST RATIO = 4.3 - 9.3		

SOURCE: NASA, GSFC, X-903-77-49.

TABLE 5.3 ANNUAL BENEFITS OF LANDSAT FOLLOW-ON (MILLIONS OF FY 76 DOLLARS)

	BENEFITS
AGRICULTURAL CROP INFORMATION	294 - 581
PETROLEUM-MINERAL EXPLORATION	64 - 260
HYDROLOGIC LAND USE	22
WATER RESOURCES MANAGEMENT	13 - 41
FORESTRY	7
LAND USE PLANNING AND MONITORING	15 - 48
SOIL MANAGEMENT	5 - 9
TOTAL	420 - 968

SOURCE: NASA, GSFC, X-903-77-49.

Econ

listed in Table 5.3 have not been included due to the relatively strict criteria followed in this study. Benefits have been included only where (i) a definite need for the information has been identified, (ii) a mechanism for disseminating the information has been defined, (iii) a technical capability can be quantified, and (iv) a defendable method of evaluating the economic worth has been developed. For example, benefits of range management are not included in Table 5.2 or 5.3 because a satisfactory data system was not established.

The rate of adoption of LANDSAT technology, and hence the rate of achieving the potential annual benefits, cannot be precisely estimated. The study assumes that 50 percent of the estimated potential benefits will be achieved within the first year that the LANDSAT system becomes available; 80 percent of the potential benefits will be achieved three years after the system becomes available and 95 percent of the potential benefits obtained three years after that. For petroleum and mineral it is assumed that the benefits last only ten years. This is shown schematically in Figure 5.2. The reductions in yearly benefits beyond 1991 reflect the decline in Petroleum-Mineral Exploration benefits. The benefits of Table 5.2 are based on the phase-in assumption displayed in Figure 5.2. It should be noted that there is little actual experience to support the adoption rates used in this study. Although there is no comparable experience to point to in the introduction of a new information-based technology in the major LANDSAT benefit areas, it could be argued that the assumed adoption schedule that 50 percent of the estimated potential benefits will be achieved in the first year, 80 percent by the third year and 95 percent by the sixth year is very optimistic. If the adoption rate is less than that assumed, the benefits achieved in the early years of system operation will be less than those shown in Figure 5.2, and the benefits shown in Table 5.2 will also be reduced. The rate of adoption will effect not only the

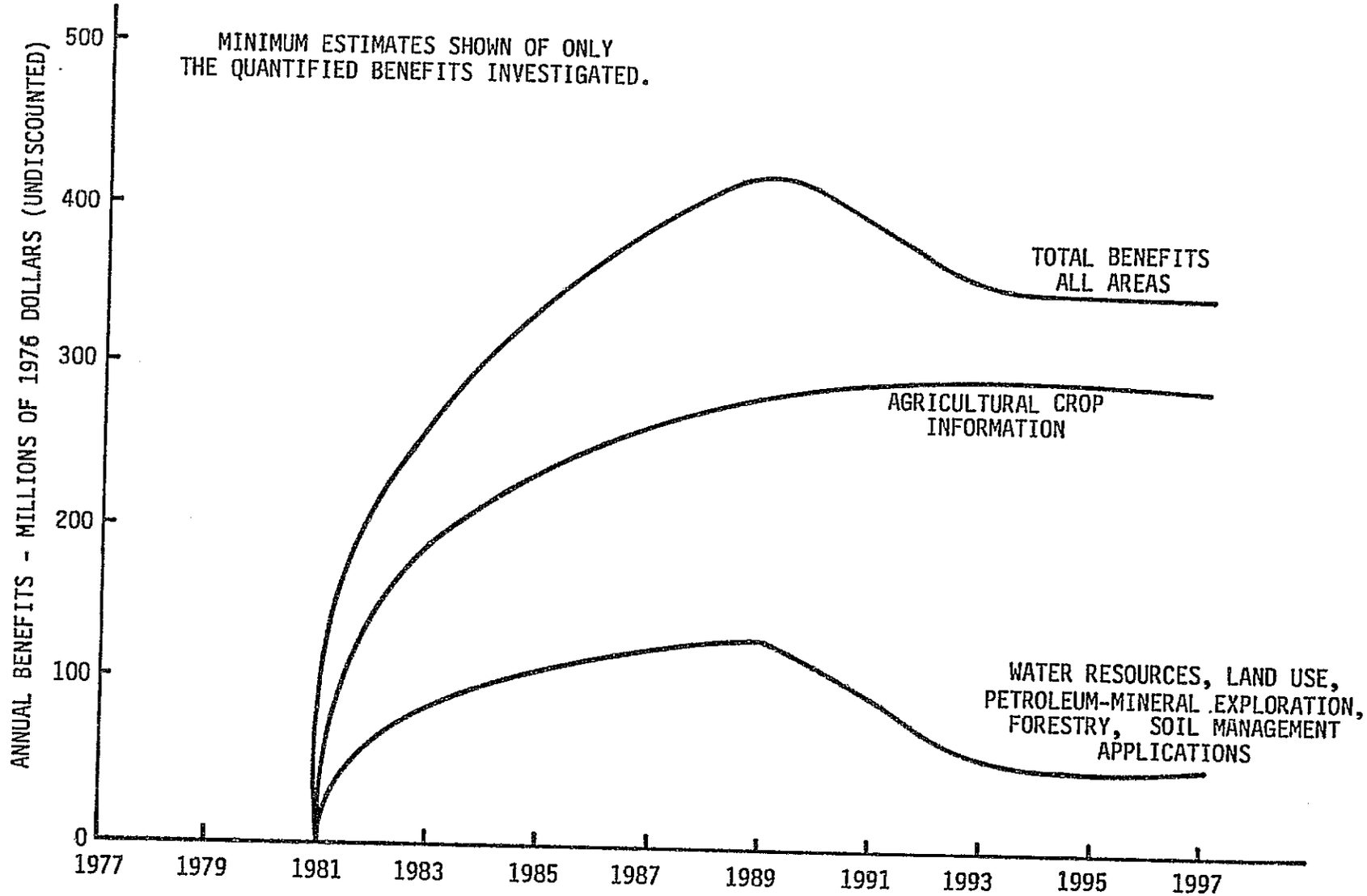

FIGURE 5.2 BENEFIT STREAM OF LANDSAT FOLLOW-ON SYSTEM WITH THE THEMATIC MAPPER (SOURCE: NASA, GSFC, X-903-77-49)

present value of the benefits, but also the cash flow of an ERS venture. The sensitivity of these financial parameters of the venture to rate of adoption of the technology reinforces the earlier argument that it is necessary to obtain better information concerning the potential markets for the goods and services that could be produced by an operational ERS and to establish a financial model of the venture.

The costs of an operational LANDSAT Follow-On System were developed by Goddard Space Flight Center supported by data system trade-off studies by General Electric Corporation. The components of the system for cost purposes may be subdivided as:

- Space Segment
- Basic Processing System
- Agriculture User System
- Hydrologic Land Use System
- EROS Data Center.

Table 5.4 shows the first ten years of costs of each subsystem and the projected present worth at the 10 percent discount rate for an infinite horizon.

The space segment includes all the costs of spacecraft acquisition, launching and maintenance of an operational system launched in 1981 and utilizing shuttle launch and retrieval beyond 1984. The maintenance and operation costs include acquisition of additional spacecraft, shuttle servicing and refurbishment of shuttle retrievals. The basic processing system includes the NASA tracking and data acquisition system and data management system to produce a generally available archival tape. Every ten years costs for replacing worn out equipment are included resulting in a ten-year cycle.

TABLE 5.4 LANDSAT FOLLOW-ON SYSTEM COSTS (MILLIONS OF FY 76 DOLLARS)

SPACE SYSTEM	UNDISCOUNTED COSTS											PRESENT WORTH TOTAL
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	. . .	
	4	32.8	74.1	56.5	33.4	25.5	29.1	9.1	4.5	12.5		220
								3 year cycle				
GROUND SYSTEM						CONSTANT RECURRING COSTS*						
1. BASIC PROCESSING SYSTEM	0.0	9.9	13.8	14.0	17.1	11.8	11.8	11.8	11.8	11.8	. . .	122
2. AGRICULTURE USE SYSTEM	0.0	1.6	3.7	3.7	8.1	6.5	6.5	6.5	6.5	6.5	. . .	55
3. HYDROLOGIC LAND USE SYSTEM	0.0	0.5	1.3	1.2	1.5	1.0	1.0	1.0	1.0	1.0	. . .	10
4. EROS DATA CENTER	0.0	1.0	6.0	6.0	16.0	16.0	16.0	16.0	16.0	16.0	. . .	122
SUBTOTAL	0.0	13.0	24.8	24.9	42.7	35.3	35.3	35.3	35.3	35.3		310
TOTAL	4.0	45.8	98.9	81.4	76.1	60.8	64.4	44.4	39.8	47.8	. . .	530

*EVERY TEN YEARS A NONRECURRING COST OF EQUIPMENT REPLACEMENT OCCURS. THE REPLACEMENT PERIOD IS TWO YEARS. THE FIRST REPLACEMENT IS SCHEDULED IN 1990 - 1991. THE BASIC PROCESSING SYSTEM REPLACEMENT COSTS $25 MILLION, THE AGRICULTURE SYSTEM COSTS $7.5 MILLION, THE HYDROLOGIC SYSTEM $2.5 MILLION AND THE EROS DATA CENTER $9.2 MILLION.

SOURCE: NASA, GSFC, X-903-77-49.

The user costs include facilities for special processing of the archival tape to other management information.

The marginal agriculture costs of $55 million are to build and maintain a data processing facility for the United States Department of Agriculture (USDA). The costs were derived using GSFC/General Electric Study data. This facility would produce foreign crop production estimates. Public announcements of the improved estimates automatically produce the production and distribution benefits through the marketplace.

The Hydrologic Land Use cost of $10 million includes the initial construction of facilities by the Corps of Engineers and the subsequent operation and maintenance costs with equipment replacement every ten years. Again, these are GSFC/General Electric study results.

The EROS Data Center costs include augmentation of equipment and software at the physical facility at Sioux Falls and the costs of operation and maintenance of the facility as obtained from the GSFC/General Electric Studies. The Center is expected to fill the needs of all the other applications except the USDA and the Hydrologic Land Use data.

The LANDSAT Follow-On System costs estimates should be realistic since they are based on past experience of very similar systems. A small contingency has been included to provide for some growth. The $530 million present value of the total cost compared to the corresponding benefit of $2.3 to $4.9 billion indicates a dominant economic advantage in favor of the LANDSAT Follow-On system. It should again be noted that these costs are for a LANDSAT Follow-On system. The significant differences between the LANDSAT Follow-On System and the Operational ERS System are described in Table 5.1. Since the capability of the Operational ERS exceeds that of the LANDSAT Follow-On System, it is likely that

the cost of the Operational ERS System will also exceed that of the LANDSAT Follow-On.

5.5.3 Feasibility of Private Sector Business Ventures

The feasibility of establishing a private sector business venture concerned with the initiation and continued operation of an ERS system that provides a multitude of information products and services depends upon many factors. Of primary concern are the attributes of the information products and services, the decision processes that will utilize these products and services, the value (to the user) of the products and services in the user decision processes, and a pricing mechanism that allows for the receipt of adequate revenues. The revenues must be adequate in the sense that desired return on investment and other financial objectives, such as maximum exposure, annual profit, annual cash flow, etc., are met.

The feasibility and the form of a private sector business venture will be determined by financial considerations. It is necessary to consider all aspects of the venture, such as institutional constraints, regulatory constraints, pricing mechanisms, etc., in terms of financial impacts. Thus, the existence of an information dissemination network such as the USDA's county extension service, may significantly affect the attributes of the information products and services that will be offered, the marketing channels and the pricing mechanism.

In order to evaluate the feasibility of a business venture it is necessary to develop a detailed diagram of the flow of goods and services and dollars.* This includes the end users, the intermediaries or distributors, government agencies, competitive sources of goods and services, etc. This must be developed in sufficient detail so that all important sources and uses of funds can be identified.

*See, for example, J. S. Greenberg, A Corporate Planning Model for a New Business Venture, 1971 Winter Simulation Conference Record, December 1971, New York.

Since this has not as yet been accomplished it is not, at this time, possible to evaluate the feasibility of private sector business ventures associated with the ERS system.

5.5.4 The Need for a Public Sector Initiative

The need for a public sector initiative has been established qualitatively and to some degree quantitatively. The benefit studies of the LANDSAT Follow-On System indicate the public sector benefits from an operational ERS system are likely to exceed the costs. At the present time in the LANDSAT program there is currently a lack of, or at least inadequate, private sector initiatives resulting in public sector net benefits that are being foregone. The lack of private sector participation is undoubtedly due to a combination of (a) high risk, exposure and long payback period, (b) low perceived private sector benefits even though public sector benefits may be large, and (c) lack of adequate consumption related pricing mechanisms. Of these, it is felt that the first (high risk, exposure and long payback period) is dominant.

The high risk is due to the combination of performance, cost and market uncertainties. One expected result of the LANDSAT-D initiative is to reduce these uncertainties and the resultant risk. The magnitude and sufficiency of the impact is not known since the effect of the uncertainties on financial risk have not been established nor has the LANDSAT-D initiative been defined adequately so as to understand its possible impacts upon the specific existing uncertainties. Much needs to be accomplished in this area in order to achieve maximum value from the LANDSAT-D initiative.

High exposure and long payback period are the result of the capital intensive nature of the business. Public sector initiatives which shift some of the burden of funding from the private to the public sector can impact the likelihood of private sector investment. The LANDSAT-D initiative will obviously affect the private

sector cash flow by shifting high cost development programs from the private to the public sector.

Since the details of a private sector business venture have not been developed adequately to understand institutional constraints and the effect of performance, cost and market uncertainties upon perceived risk and, in turn, the effect of risk on investment decisions, the effect of reducing these uncertainties is not known. The effects of uncertainty and risk must be understood before an initiative can be effectively planned and implemented that will affect private sector investment decisions.

5.6 Business Strategy

The purpose of this section is to define the elements of the strategy that could be followed by NASA in the implementation of the LANDSAT-D initative and the follow-on operational Earth Resources Satellite (ERS) system. In subsequent paragraphs, the role of the public sector, with emphasis on the role of NASA as the provider of the system technology, along with possible roles that could be played by the private sector in the implementation of the operational system is discussed. The need to estimate life cycle costs and benefits is discussed along with possible strategies for the transfer of the technology developed by NASA to the ultimate operators of the ERS system.

At this point, the reader should again be reminded that this plan is intended to be an example of the use of the planning techniques discussed in this report. As of the date of this study only the LANDSAT-D system has been approved. While studies of an operational ERS have been performed and others are currently in process, a national commitment to an operational ERS has not yet been made. For this reason, the strategies described in the following paragraphs are at least as hypothetical as the operational ERS system described in Section 4.4 of this report.

The discussion of a strategy in this plan is not meant to imply that it is preferred over other strategies that could be used. Many different strategies are possible for the transition from the LANDSAT-D to the operational ERS. In the paragraphs that follow, some alternative strategies will be discussed, along with the issues related to these strategies. The selection of a preferred business strategy must necessarily await both a commitment to the program and the selection by the public sector of the desired role of the private sector in the operational system.

5.6.1 The Roles of the Public and Private Sectors

5.6.1.1 The LANDSAT-D Initiative

The space and ground segments of the LANDSAT-D pre-operational demonstration system will be funded and operated by NASA. Extensive participation of the public and private sector users of the data produced by the LANDSAT-D system will be sought in the experiments and operational demonstrations to be performed using the LANDSAT-D data. Funding support to the operational demonstrations by these user agencies will be sought, with the objective of transitioning to full user funding support of the operational demonstrations by the planned date of launch of the first operational ERS (1985).

5.6.1.2 The Operational ERS

The selection of the business strategy to be used to implement the operational ERS must be made in the context of the desired degree of participation of the private sector in the funding and operation of the system. Alternative boundary (or limiting case) scenarios that could be considered for private sector investment and participation are:

1. Ownership and Operation by the Public Sector

   In this scenario, the space and ground segments of the system are funded and operated by the public sector. Processing of the data collected by the satellites is accomplished entirely within the public sector, and the processed data, the information or data products, are

made available for sale to interested users in both the public and private sectors. In this scenario, the system would be operated by NASA or by a user federal agency such as NOAA or the Departments of Agriculture or Interior. This scenario implies a limited role for the private sector, either as a contractor to the public sector in the provision and operation of the system, or as a consumer of the data produced by the system.

2. Ownership and Operation by the Private Sector

In this scenario, the private sector perceives the opportunity for a satisfactory return on investment for an operational ERS. Legislation is enacted to enable the private sector to raise the capital necessary to buy and operate the ERS. A positive cash flow is generated by the sale of data products by the private sector operator to public and private sector users of the data products. The data products may cover a very broad range from basic digital data which a user may require for performing a specific research task, to processed data in the form of specific recommendations concerning operational decisions (for example, harvesting, irrigation and other decisions).

It is obvious that many other alternative scenarios for public/private sector investment and operation exist between these two boundary conditions. These intermediate scenarios involve varying degrees of private sector investment in the system, with possible private sector ownership of the space segment and/or all or part of the ground segment.

The specific business strategy to be employed by NASA is a function of the scenario to be implemented. On the other hand, the choice of the scenario to be implemented cannot be made by the public sector without consideration of the expected behavior of the private sector. For example, it may be considered desirable by the federal government to transfer the funding responsibility and ownership of the operational ERS to the private sector. The interest of the private sector in assuming this responsibility will be determined by the uncertainty and risk perceived by the private sector in achieving a satisfactory return on the investment in the system. If the uncertainty and risk are too great, the private sector will be unwilling to invest or will demand other incentives as a condition for investment.

For sake of argument in this sample plan, it will be assumed that ownership and operation of the ERS is to be transferred to a corporation that "...will not be an agency or establishment of the United States Government"; i.e., the private sector.* Under this scenario, the strategy to be used by NASA is to minimize the uncertainty and risk associated with the technical and economic characteristics of the operational system. This implies that the LANDSAT-D program will be used by NASA to identify the characteristics of the space and ground segments that are important to the anticipated operational users of the system. Moreover, an appropriate strategy for NASA under this scenario is to use LANDSAT-D data in a series of pre-operational demonstrations to help ascertain the costs of the operational system and the prices to be charged for the products to be provided. As will be discussed in Section 5.6.4, an important element of the NASA strategy for the transition from LANDSAT-D to the ERS is to create the environment for the successful transfer of the technology and its use from the public to the private sectors.

5.6.2 Private Sector Analysis

Since the scenario selected for consideration is one of private sector ownership and operation of the ERS system, it is necessary to understand the likelihood of this occurring and the impact that a NASA initiative (and the desired form of the initiative) may have on the timing and likelihood of the private sector undertaking. In order to provide this understanding it is necessary to plan and evaluate the private sector business venture from the point of view of the private sector. This includes the definition of specific products and services to be offered, including selling prices and sales volume, and all expenses and expenditures required to achieve the indicated sales. It also includes the financial evaluation of

*The quotation is taken from S.3625, Earth Resources Information Satellite Act of 1979. This bill provides a convenient vehicle for the discussion of strategy.

the business entity in terms of financial performance measures such as annual profit and cash flow, net present value and return on investment. Uncertainty and risk must be explicitly considered since perceived market, performance and cost uncertainties and resulting risk will play a major role in the private sector decisions. Since little has been accomplished in this area it is not possible to include results in a business plan at this time. The following paragraphs are concerned with delineating the analyses that are necessary in order to understand the likelihood and form of private sector ERS business ventures and the impact of NASA R&D and incentive initiatives.

The starting point for the analysis is the specification of the product line in terms of the information products and services and their attributes. Once this is accomplished market analyses may be undertaken with the end result being the determination of information product demand functions (i.e., price versus quantity). This will serve as a major input to the private sector business venture revenue computation. The determination of the demand function should consider potential user decision processes, the information products currently used in these processes and the value of new or improved information products in these decision processes. The impact of new or improved information products in changing current decision processes that have developed as a result of currently available information should also be considered. Because of the many areas of uncertainty associated with potential user decisions, the market and sales forecasts should include quantitative subjective assessments of uncertainty, as described in Section 2.1.3, which culminate in the product demand functions having an uncertainty dimension (see Appendix B). The uncertainty dimension is extremely important because (a) it is a major contributor to risk and hence the likelihood of private sector investment decisions, and (b) new initiative programs may be designed that aim specifically to reduce this uncertainty.

The other side of the coin is the determination of the costs that will be incurred and the capital expenditures that will be necessary to produce and provide the information products and scenarios on a continuing basis. The costs and expenditures are a function of the information products to be provided, the required number and location of operating sensors in orbit, sensor and spacecraft supporting subsystem reliability characteristics, launch operations including mission modes (i.e., placement, placement and retrieval, on-orbit repair), launch system reliability and failure and recovery modes, and both nonrecurring and unit recurring costs. The annual costs associated with providing the information products are probabilistic because of the random failure characteristics of all of the portions of the system, the uncertainties associated with the unit costs of the components of the system, and the uncertainties associated with the performance characteristics of many portions of the system. Thus, annual costs are probabilistic because the timing of events (failures) is probabilistic and the cost associated with each of the events is uncertain. This is described in more detail in Section 2.2 under life-cycle costing.

The private sector business evaluation from a financial point of view is summarized in Figure 5.3 which indicates, in a simplified form, the financial analysis required to develop performance measures such as payback period, return on investment and net present value. It implies that a pricing structure is established and its consequences evaluated. Since, for the reasons discussed above, the revenue and annual cost (expenses) are probabilistic quantities, annual profit, cash flow, cumulative cash flow, payback, return on investment and net present value are also probabilistic quantities. These quantities can be described in terms of risk profiles (see Section 2.1.3) and private sector investment decisions evaluated in terms of the risk perceived to be associated with the business venture.

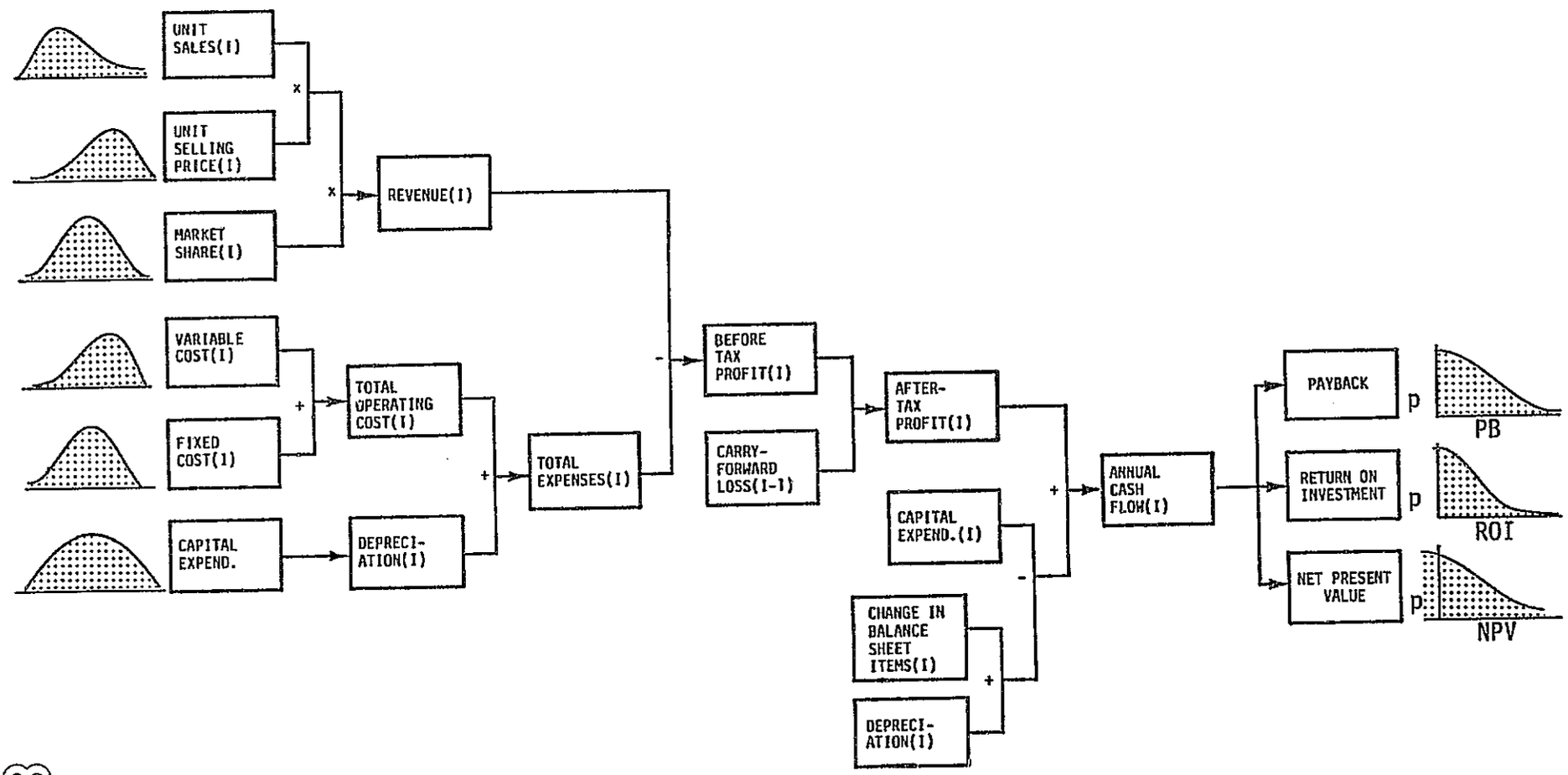

FIGURE 5.3 SIMPLIFIED FINANCIAL ANALYSIS OF AN ERS PRIVATE SECTOR BUSINESS VENTURE

In order to perform the above analyses it is necessary to develop a mathematical model* as outlined in Appendix B. The mathematical model should be based upon Monte Carlo techniques and should allow for the explicit consideration of unreliability and system and cost uncertainties. The necessary characteristics of a life cycle costing model for space operations is summarized in Appendix D.

5.6.3 Public Sector Net Benefits

The scenario selected for consideration is one of private sector ownership and operation of the ERS system. The benefits from the public sector initiative are the result of improving the likelihood of the private sector making the necessary investments to establish the ERS system and/or speeding up the implementation process which in turn reduces the time from initial public sector investment to the receipt of benefits. As described in Appendix B, the public sector benefits, $\overline{B}$, may be expressed as

$$\overline{B} = \alpha_B * \overline{PV}_B - \alpha_A * \overline{PV}_A - \overline{PVC}$$

where $\overline{PV}_B$ and $\overline{PV}_A$ are the expected public sector benefits** with and without the public sector intiative. $\overline{PVC}$ is the expected cost** of the public sector initiative. α_B and α_A are the probabilities of private sector investment with and without the public sector initiative, respectively.

Before discussing the public sector benefits, consider the impact of the NASA initiative on the private sector. The private sector business venture risk profiles of net present value with and without the NASA initiatives are shown in Figure 5.4. The illustrated impact of the new initiative is to increase the expected NPV and

*Greenberg, J. S., Evaluating the Economic Impact of Design Alternatives on Domestic Communication Satellite Ventures, International Astronautical Federation Paper IAF-78-A-38, October 1978.

**Present values.

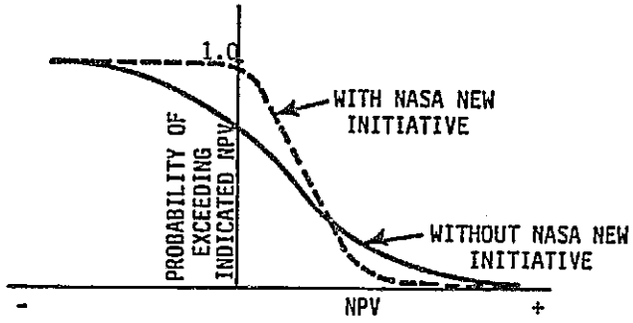

FIGURE 5.4 RISK PROFILE OF NPV WITH AND WITHOUT NASA NEW INITIATIVE

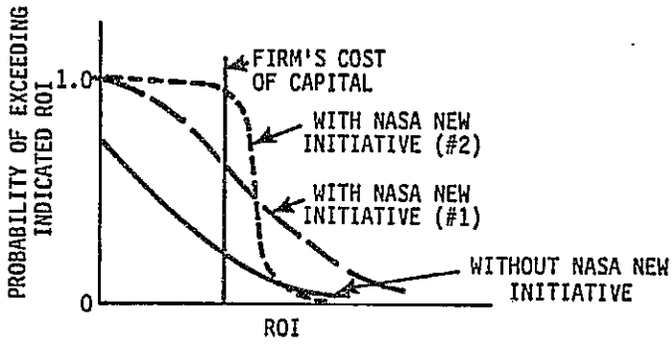

FIGURE 5.5 RISK PROFILES OF ROI WITH DIFFERENT LEVELS OF NASA NEW INITIATIVES

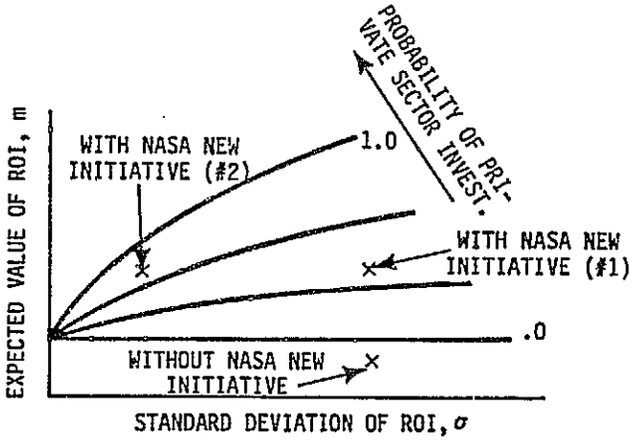

FIGURE 5.6 IMPACT OF NEW INITIATIVES UPON THE LIKELIHOOD OF PRIVATE SECTOR INVESTMENT

reduce its variability (risk). Figure 5.5 further illustrates the impact of the new initiative on the risk profile of return on investment, ROI. The risk profile of ROI is shown without the NASA new initiative and with two different new initiatives. Note that the expected values and standard deviations differ. Note also the relationship of these risk profiles to the firm's cost of capital. All of the risk profiles are developed using the methodology described in Section 5.6.2 and Appendix B. It is evident that the likelihood of investment when there is no NASA new initiative is probably negligible, with the NASA new initiative (#1) the likelihood is low, and with the NASA new initiative (#2) the likelihood is relatively high. This is further illustrated in Figure 5.6.

The ROI risk profiles (and therefore the likelihood of private sector investment) are developed in terms of specific information product pricing policies. Once the pricing policies have been established* public sector benefits may be evaluated in terms of cost savings in public sector operations and the change in consumers and producers surplus that results from the introduction of the new or improved information products into the decision processes of the users.

Since the specific scenario for private sector ownership and operation of an ERS system and the details of the information products have not as yet been developed, the specifics of the public sector benefits cannot be developed. However, it should be pointed out that the specific benefit estimation methodology may differ depending upon the specifics of the information products. For example, the benefits from improved yield forecast information products may be measured in terms of their impact on price fluctuations due to more efficient planting, harvesting and inventorying decisions;** the benefits from improved soil moisture

*This may be an iterative process where different policies are postulated and the resulting risk profiles developed.

**Bradford, D. F. and H. H. Kelejian, The Value of Information for Crop Forecasting with Bayesian Speculators: Theory and Empirical Results, The Bell Journal of Economics, Spring 1978, Vol. 9, No. 1.

measurements and timely information products may be estimated in terms of irrigation cost savings resulting from improved irrigation scheduling decisions*; improved warning of floods due to improved information products describing snow melt run-off may produce benefits in the form of reduced flood damage as well as a reduction in lives lost. Note that from the point of view of a private sector business venture, it may be difficult to place a price on the improved yield forecast information products other than to establish the price based upon cost savings (in data collection) that might result to the USDA. A price may be established for improved soil moisture information products based upon the cost savings resulting from the improved irrigation decisions. It probably is not possible to establish a price for snowmelt run-off information products that bears any direct relationship to the potential benefits in terms of lives saved. Thus there may be little or no correspondence between private sector benefits and decisions based upon these benefits and public sector benefits and decisions based upon these benefits.

5.6.4 Technology Transfer

Under the scenarios described in Section 5.6.1, the primary objectives of the NASA LANDSAT-D technology transfer program are to reduce the uncertainty and risk associated with the operational systems and to identify the characteristics of the operational system of importance to the users of ERS system data. During the past 25 years, the federal government has assumed an increasingly important role in stimulating technological change and innovation in the private sector. In many instances, the federal government has moved far beyond the traditional role of funding of research and development activities into the support of demonstrations of initiatives such as nuclear power reactors, personal rapid transit vehicles and solid-waste-to-fuel conversion plants in order to accelerate the commercialization

*Agriculture Management Decisions--A Preliminary Benefit Assessment, ECON, Inc., Report No. 78-175-2, May 1, 1978.

of these innovations. In these cases, major purposes of these demonstrations have been to crease the institutional infrastructure in the private sector to deal with these innovations, and to reduce the uncertainty and risk as perceived by prospective private sector investors. Other such demonstrations have been used to provide information for regulatory decisions or to promote U.S. foreign policy objectives. This process of demonstration, with the objective of facilitating the transition from R&D to operations is often called technology transfer, in that it is intended to help to move the technology from R&D to full operational status.

In this part of the business plan, the public policy issues and constraints are identified, and the specific plans for technology demonstration are described.

5.6.4.1 Criteria for Technology Transfer for Demonstrations

A study of a large number of federally-funded demonstration projects by the Rand Corporation has succeeded in identifying factors related to success or failure in the technology transfer process.* The Rand study correctly points out that the technologies that are adopted for commercial use are those that show economic advantage, and that there are several factors in a demonstration that can help or hinder to show whether such economic advantage exists. The Rand study shows that instances of successful technology transfer have the following attributes:

1. The principal technology problems have been solved before the demonstration
2. Cost and risk are not actively borne by the sponsor of the technology, but are shared with intended recipients
3. The initiative for the demonstration comes from outside of the federal agency that has developed the technology
4. A strong industrial system exists for the production and consumption of the technology

*Analysis of Federally-Funded Demonstation Projects, R-1926-DOC, The Rand Corporation, April 1976.

5. All of the actors in the commercialization process are included in the demonstration

6. Artificially tight time constraints are not imposed for the completion of the demonstration.

Further important findings of the Rand study are that large demonstration projects with heavy federal funding are particularly prone to difficulty, and that demonstration projects are probably not the correct tool for tackling institutional and organizational barriers to commercialization.

With the results of this experience as a background, it is then possible to formulate a proposed technology transfer program for the LANDSAT-D initiative.

5.6.4.2 Public Policy Issues

The central public policy issue in the transition from LANDSAT-D to an operational ERS is the institutional arrangement for the operational system. The use of S.3625 as the basis for the institutional scenario resolves these issues. The system is to be operated by a "for profit" corporation in the private sector. The corporation will be responsible for planning, initiating, constructing, owning and managing a commercial earth resources information service. This responsibility includes the ownership and operation of the space and ground segments, and the marketing of the earth resources data produced. In this arrangement, NASA is to provide reimbursible services to the corporation and the corporation in the definition of the system and RD&D needs. The activities of the corporation are to be regulated by the Federal Communications Commission, and NASA is to provide technical support to the FCC. It is important to realize that although this scenario resolves the major public policy issues of ownership, operation and regulations, other federal agencies such as the Department of Agriculture are relegated to the position of data consumers, and it is not clear that this will be an acceptable role for these agencies. Assuming the realization of this scenario and the interest of

NASA in the successful completion of the transfer process, it is suggested that it would be appropriate for NASA to take the initiative in the organization of a transfer committee (with the participation of other agencies and the private sector) to explore the ramification of this and other scenarios, and to identify the public policy issues raised by these scenarios for action by appropriate parts of the federal government.

5.6.4.3 Technology Transfer Plan

In this part of the plan, the specifics of the demonstration projects are to be described along with the programmatic detail for these projects. As discussed in Section 5.4.1.4, the specific experiments and operational demonstrations to be performed using LANDSAT-D have not been defined. Given the fact that LANDSAT-D is scheduled for launch in CY 1981, and that under the scenario described in this plan an operational system is to be implemented in CY 1985, it is important that the design of these demonstration experiments commence immediately and that emphasis be placed on the development of technology transfer demonstrations.

6. CONCLUSIONS AND RECOMMENDATIONS

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6. CONCLUSIONS AND RECOMMENDATIONS

The objective of this study is to examine the feasibility of applying business planning techniques developed and used in the private sector to planning the work of OSTA. The focus of this study is on the possible use of strategic or long-range business planning tools, rather than operational or tactical planning of the type that is used to support near-term and day-to-day operations. In the private sector, strategic planning is used in the implementation of long-range business goals and objectives, and as a part of major programs that span a number of years.

In order to fulfill this objective it was first necessary to examine the methods of business planning currently in use in the private sector. While this study was not intended to be a tutorial on this design of a business plan, or a substitute for the many excellent textbooks on strategic business planning, it is apparent that strategic business planning is widely used in the private sector. Strategic business planning is used to anticipate the decisions that must be made by management as a corporate program proceeds through the stages of RD&D, production and sales. Used in this manner, strategic business planning represents an effort to identify and integrate the requirements for capital, labor, facilities, training, marketing advertising, and the other many diverse factors that are an important part of a program, and to provide the information needed by corporate decision makers at each stage of the program. Failures in strategic business planning, particularly as it applies to major corporate programs such as the introduction of a new model automobile or commercial jet aircraft, or the entry of a corporation into a new area of business that is dominated by a competitor, are both highly visible and

dramatic. On the other hand, the result of successful planning is measured by the bottom line of the income statement and is less likely to be a newsworthy event. Upon establishing the extensive use of strategic business planning for major programs in the private sector, the study next examined the question of how these strategic business planning techniques might be used to advantage by OSTA. This entailed an evaluation of the current long-range or strategic planning practices in OSTA, as well as the study of program initiatives under consideration by OSTA that might be candidates for the application of strategic planning methods that are used in the private sector. Finally, a program that has occupied a position of prominence in OSTA for more than a decade, in which there is a national committment to continue RD&D in support of an eventual decision regarding an operational system, and a program in which there is extensive interest in both the legislative and executive branches of the federal government as well as the private sector--the LANDSAT Program--was selected as a test case for the preparation of a sample business plan.

The conclusions drawn from this work are:

1. Strategic business planning techniques are widely used in the private sector to support major programs.

Although the contents of a strategic business plan may vary from one company to the next, or may be varied to suit the requirements of a specific project, strategic business planning has found wide acceptance in the corporate world. The plan itself is a combination of both qualitative and quantitative information. Various forms of analysis and mathematical modeling are used to evaluate measures of venture worth that are widely used in the private sector to compare the desirability of alternative business investments. Although it is difficult to generalize, private sector business planning usually begins when a

program progresses from basic to applied research, or from research to development. At this stage in the life of a program the issues of the market and transfer from development to production are analyzed in a business planning effort to provide the basis for management decisions.

2. The institutional arrangement of OSTA within NASA, NASA within the federal government, and the nature and content of the RD&D performed by OSTA is similar in many respects to that of large research and development organizations in the private sector.

A large part of the RD&D performed by OSTA is intended to impact decision making in the public and private sectors relative to the implementation of operational capabilities and systems. The significant institutional feature that differentiates OSTA from its private sector counterparts is that NASA does not operate the systems that are supported or derived from the RD&D performed by OSTA. This means that other federal agencies or the private sector are often the end user for the RD&D performed by OSTA, and it is necessary for OSTA to transfer the results of its RD&D to another federal agency or to the private sector if an operational system is to be implemented. The significant difference in work content between the RD&D performed by OSTA and that performed in the private sector lies in the area of technical uncertainty, with the work performed by OSTA generally involving a greater degree of technical uncertainty than in the private sector. These two factors increase the need for strategic planning for those RD&D programs undertaken by OSTA as part of an effort to influence decisions concerning the implementation of an operational system.

3. The planning now performed by OSTA does not fulfill the requirements of strategic or long-range business planning.

The principal outputs of the planning now performed by OSTA are aimed at

satisfying the requirements of the annual federal budget cycle and the NASA Five Year Plan. While the requirements of these two processes could be satisfied by more comprehensive strategic business planning, the requirements of strategic business planning are not fulfilled by the information produced in support of the annual NASA budget and Five Year Plan. Most of the major programs undertaken by OSTA span a time period of about ten years to implementation of an operational system from the onset of RD&D. For example, RD&D on LANDSAT began in the late 1960s and the technical and institutional characteristics of an operational system are still evolving in 1979. The use of a five-year planning window encourages the planner to concentrate on research, development, technology and costs at the time of initiation of a program. The really difficult questions of benefits, return on federal investment and transfer from RD&D to operations fall outside of the five-year window and in the past were often not considered until NASA was well into the development and demonstration phases of the program. Furthermore, the OSTA palnning process observed in this study lacks formalism. While OSTA has sponsored many benefit/cost and technology transfer studies, these studies have not been integrated into an overall planning process. Neither the process nor the products required of the process are formally defined. This leads to a great deal of variability in the content of the plans that are produced.

4. Several OSTA initiatives could be candidates for the preparation of strategic business plans. None of the candidates have been studied to a sufficient extent that the information needed to prepare a strategic business plan is available at the present time.

The OSTA RD&D program contains many initiatives that are intended to produce information to support or influence decisions concerning the implementation of operational systems in the public or private sectors. Each of

the operating divisions within OSTA have programs with this often unstated but implicit objective. However, in no case does sufficient information exist as a result of previous work to allow for the preparation of a strategic business plan for the operational system that could be derived from these OSTA initiatives. The fact that it was not possible at this time to produce a reasonably complete strategic business plan (as defined in this study) for sample initiative--an Operational Earth Resource Satellite (ERS) Program—after more than ten years of federal investment in the RD&D for this program should be of great concern to NASA.*

5. When OSTA performs RD&D that is intended for eventual transfer to the private sector, it is necessary that OSTA view the business aspects of the intended operational technology or system from the perspective of the private sector.

Some of the RD&D performed by OSTA is intended for possible transfer to the private sector. Space materials processing and communications are two current examples of this type of RD&D. Since it is intended that these operational technologies or systems be implemented in the private sector it is necessary that OSTA also consider the attractiveness of the technology or system as an investment by the private sector. In this case it is necessary that the benefits of the OSTA RD&D program be developed in terms of the impact of the program upon private sector investment decisions. It is anticipated that the impact will be primarily through private sector perceived risk reduction and shifting of funding requirements from the private to the public sector.

*It should be noted that interagency studies and planning activities concerning the future of the LANDSAT program were in process during this study. The results of these studies were not available at the time of this report. It is hoped that the planning basis for an ERS will be improved by this continuing effort.

6. It is feasible to apply many of the methodologies used for strategic business planning in the private sector to certain initiatives in the OSTA RD&D program.

While some of the RD&D performed by OSTA is basic or general in nature, much of it is intended to demonstrate the technical and economic feasibility of using technology or systems developed by OSTA in support of the operational needs of other federal agencies or the private sector. It is this latter category of initiative (which involves interagency or intersector transfer of results) where there is need for improved strategic business planning and where it should be possible to apply techniques developed in the private sector.

As a result of this study, it is recommended that OSTA undertake to improve the planning capability and process within OSTA and to improve the capability of OSTA to support a strategic planning effort for those initiatives that could benefit from the use of strategic planning methods. In support of this general recommendation, it is urged that OSTA take the following specific steps:

1. Clearly identify those major initiatives within the OSTA RD&D program that are intended to influence decisions concerning operational use of the systems or technologies developed by OSTA. At least at the outset, the objective should be to identify those initiatives that could require large scale federal investment, or action by the private sector in order to achieve a successful transfer of the technology developed by OSTA.

2. In those cases where the technologies or system are to be transferred to another federal agency, the recipient agency and OSTA should jointly prepare a strategic business plan. The time horizon of the plan should extend from the present state of RD&D through the implementation of the operational technology or system in order to anticipate the information needed to support critical

downstream decisions.

3. When the results of the RD&D initiative are intended for transfer to the private sector OSTA should prepare a strategic business plan in consultation with the intended private sector recipients of the technology or system. In order to anticipate information needs associated with the transfer of the technology, the plan should extend through the implementation of an operational capability. In this case, the strategic business plan must include an analysis of its potential venture from the perspective of the priavte sector.

4. Improve the capability to perform strategic business planning within OSTA by:

(1). Formalizing and documenting planning requirements.

(2). Assigning the responsibility for preparing strategic business plans for those initiatives selected by OSTA (and NASA) management to a specific organization function within each of the operating divisions within OSTA. Within OSTA an organizational function should be designated as responsible for integrating the results of planning, and ensuring consistency of approach and compatibility between Divisions.

(3). Developing an improved set of tools to support strategic business planning within OSTA. These should include a capability for life cycle costing and a data base of benefit estimtes related to technical capability drawn from OSTA work and other sources. In order to support those initiatives requiring transfer to the private sector, a financial venture simulation model is also necessary. General models of this type exist and could be obtained for in-house use by OSTA.

5. Recognize that strategic planning is a continuing function of management, and that the strategic business plans should be updated and reviewed at least annually by OSTA management. Used in this manner the strategic business plans

could support and improve both the annual budget and five-year planning processes.

6. For those initiatives where it is applicable, make the results of strategic planning an integral part of the criteria used by OSTA management to recommend an RD&D program to NASA management. Specifically, for those initiatives institute a concept of accountability for the expenditure of public RD&D funds that requires that the estimated life cycle economic and social benefits of the initiative exceed the life cycle costs. In the case of initiatives intended for eventual transfer to the private sector, it should also be required that the attractiveness of the investment opportunity be demonstrated from the perspective of the private sector.

APPENDIX A

AN EXAMPLE OF SALES FORECASTING (COLOR SCANNER MARKET ANALYSIS)

APPENDIX A

AN EXAMPLE OF SALES FORECASTING (COLOR SCANNER MARKET ANALYSIS*)

The following material is presented to illustrate a typical sales forecasting technique that has been employed by the private sector. Many different forecasting techniques are employed by the private sector ranging from econometric techniques to intuitive techniques. The material presented in this appendix illustrates the level of detail that has been found to be reasonable when evaluating sizeable new business ventures.

A.1 Introduction

The use of color in printing material has been growing steadily for the last two decades. It has spread from magazines into such areas as corporate annual reports and newspapers. Bureau of Census surveys indicate that over 50 percent of the dollar volume of lithographic printing is now in color. While present-day methods can yield highly attractive color printing, there is, however, room for improvement in the color fidelity for certain advertising purposes.

The preparation of color separations, a necessary step in the conversion from original art into printing plates, requires a high degree of skill involving artistic abilities as well as a highly sophisticated knowledge of photography and printing. The supply of skilled labor for the preparation of color separations is short and is growing shorter. The average age of skilled workers in this field is estimated to be over 50 years, an indication that younger men are not interested in entering this very difficult field. Thus, the use of automation is indicated, both to lessen the demands for skill and training required and to increase the productivity of labor and the quality level of the final product.

*The analysis described was undertaken in 1970.

Color separation today is done principally by photographic techniques. The proposed system of equipment to meet the industry need centers around the use of a color scanner with a more versatile and powerful computer than has heretofore been possible. This is a small general purpose digital computer that permits closed loop operation for automatic calibration and compensation of all the parameters of the reproduction system including (1) the printing process (letterpress, planograhpic and gravure), (2) plate-making and etching procedures, (3) paper, (4) ink, (5) screening, (6) the process of separation into the three colors and an optimum block printer, and (7) various photographic steps.

A.2 Approach

It is desired to estimate in a rational manner the number of color scanners and related products which may be sold as a function of time. While there are some 31,000 printers in the United States, not all of these do color work or make color separations. Of those that make color separations, some are too small to be prospective purchasers for a color scanner system. In a small plant the savings generated by the work volume may not be sufficient to pay for the equipment, the earnings may be insufficient to pay the rental charges, or the net worth may be too low to warrant the purchase of expensive equipment.

The basic methodology employed in the market estimation is illustrated in Figure A.1 and is applicable when the desire to purchase an industrial product depends primarily upon the estimation of the savings that might result from the utilization of the product. In order to estimate the market potential of the scanner product line, the characteristics of the marketplace have been determined. This information (number of firms which make up the market and their profit, sales volume, net worth, etc.) is based upon Bureau of the Census data, industry reports and firsthand knowledge of the printing industry. In order to obtain detailed

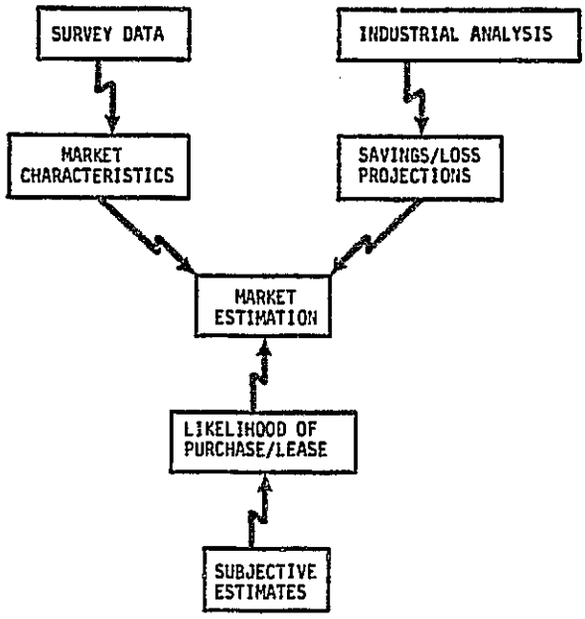

FIGURE A.1 MARKET ESTIMATION METHODOLOGY

information not available from the literature, a telephone survey of the printing industry was conducted. Over 1,000 respondents were queried. The survey was aimed at establishing industry characteristics and not specific purchase decisions regarding the color scanner equipments.

Estimates have been made as to the savings or loss that might result from the utilization of the color scanner equipments. These estimates are the result of an industrial analysis (i.e., in-depth analysis of the procedures and actual and projected costs of operations) performed at a number of establishments. These analyses were performed with management's assistance. Based upon detailed knowledge of the printing industry, subjective estimates were made relating to the likelihood of purchase or lease of new equipment under various conditions.

The following paragraphs describe the procedure for combining the market characteristic data, the savings and loss projections, and the subjective estimates.

The end result is an estimate of the number of color scanner equipments which may be sold as a function of time.

The market survey data establishes the number of establishments in the survey sample which do color separations. The number of establishments doing color separations was also determined in terms of the number of color separations per day and by market segment and number of employees. The "number of employees" is a very convenient parameter to use since Bureau of the Census data is available by number of employees. The survey data was used to scale (Figure A.2) or extrapolate to the total marketplace. (Newspapers were not

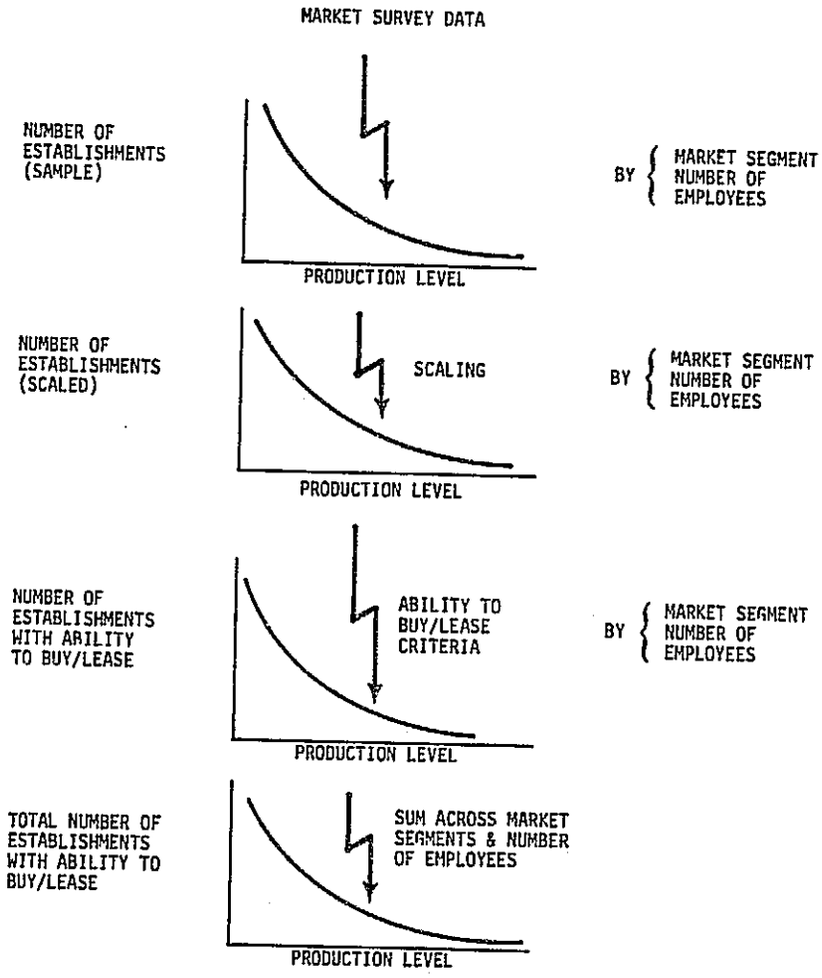

FIGURE A.2 METHODOLOGY FOR ESTABLISHING POTENTIAL NUMBER OF ESTABLISHMENTS WHICH COMPRISE THE MARKET

considered to be part of the potential market since at present they do little color work.) As a result, a projection was obtained of the number of establishments doing color separations in terms of production level (separations per day) by market segment and number of employees. The number of establishments having various production levels was thence screened to eliminate those firms which did not appear to have the ability to buy or lease. After the screening, the total number of establishments with the ability to buy or lease, in terms of production level, was established by summing across all of the market segments and the number of employees.

The results of in-depth industrial analyses conducted at a number of printing establishments are summarized in Figure A.3 where estimated payback period is plotted in terms of production level (separations per day). The payback period is a

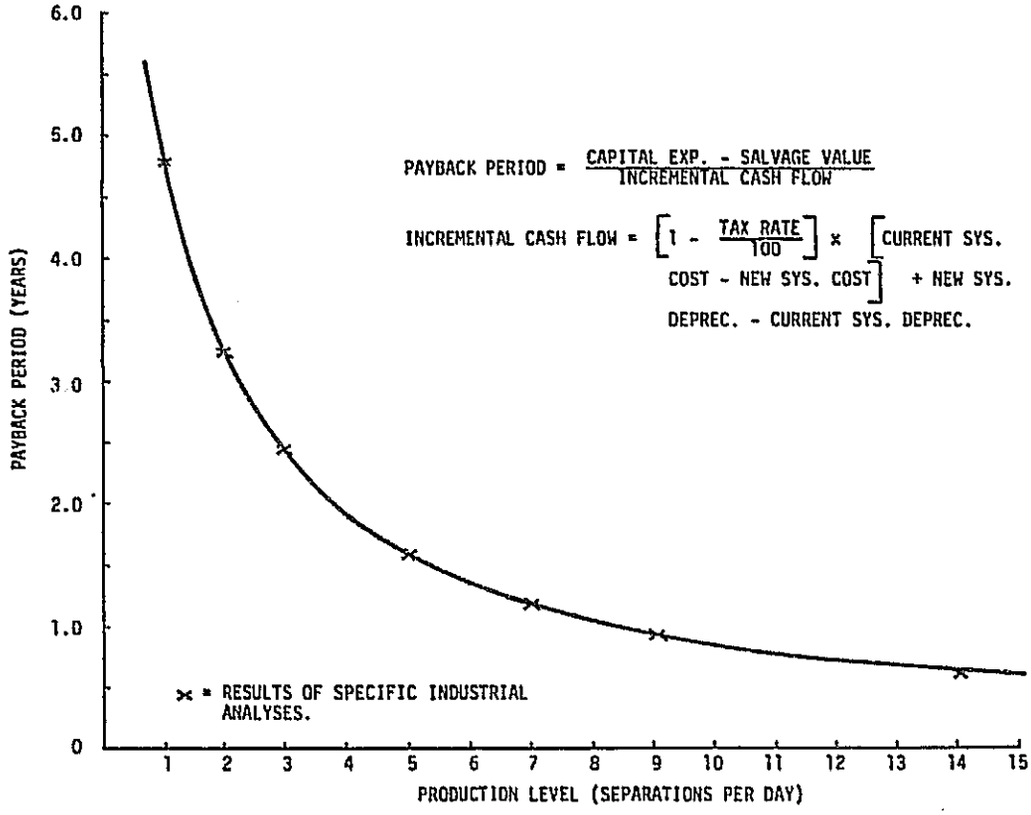

FIGURE A.3 PAYBACK PERIOD IN TERMS OF PRODUCTION LEVEL

function of current system costs, new system costs and equipment purchase price. The current system costs include the labor, materials, depreciation, facilities, etc., expenses associated with color separation operations as performed today. The new system costs are similar but are based upon the utilization of the color scanner equipments in the separation operations. Figure A.3 indicates that a payback period of four or less years is to be expected when the production level is greater than two separations per day.

The final input data required for the market analysis are the subjective estimates. The subjective estimates (Figures A.4 and A.5) have been broken down into two areas, the saturation level and the probability or chance of making a purchase. The saturation level is defined as the percentage of the firms which will purchase the scanner equipment over a long period of time. The saturation level is a function of payback period. If payback period were extremely short then it might be expected that nearly all of the firms would ultimately purchase the product. On the other hand, if the payback period were extremely long, it might be estimated that an extremely small percentage of the firms would ultimately purchase. Figure A.4 illustrates the assessment of saturation level in terms of payback period.

Having made estimates as to the fraction of the firms which will ultimately acquire the scanner equipments, the next question to be answered is at what rate will they be acquired? To answer this, the chance of purchasing the scanner equipments was estimated in terms of payback period. It was assumed that if payback period were very short, acquisition rate would be high; if payback period were long then acquisition rate would be low. Figure A.5 indicates the cumulative chance of purchase as a function of time. For example, there is a 60 percent chance that by the fourth year firms which have a one-year payback (and will

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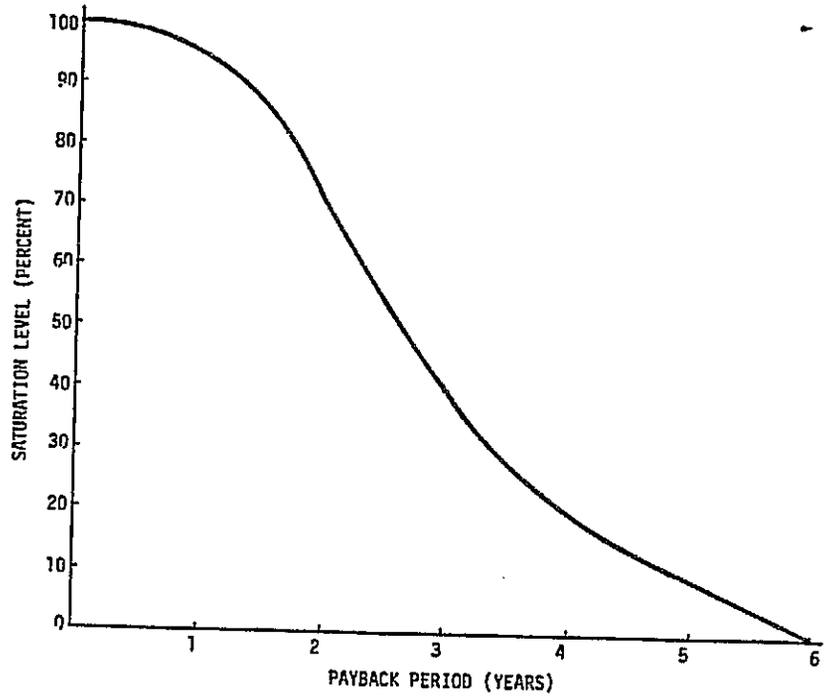

FIGURE A.4 ESTIMATED SATURATION LEVEL IN TERMS OF PAYBACK PERIOD

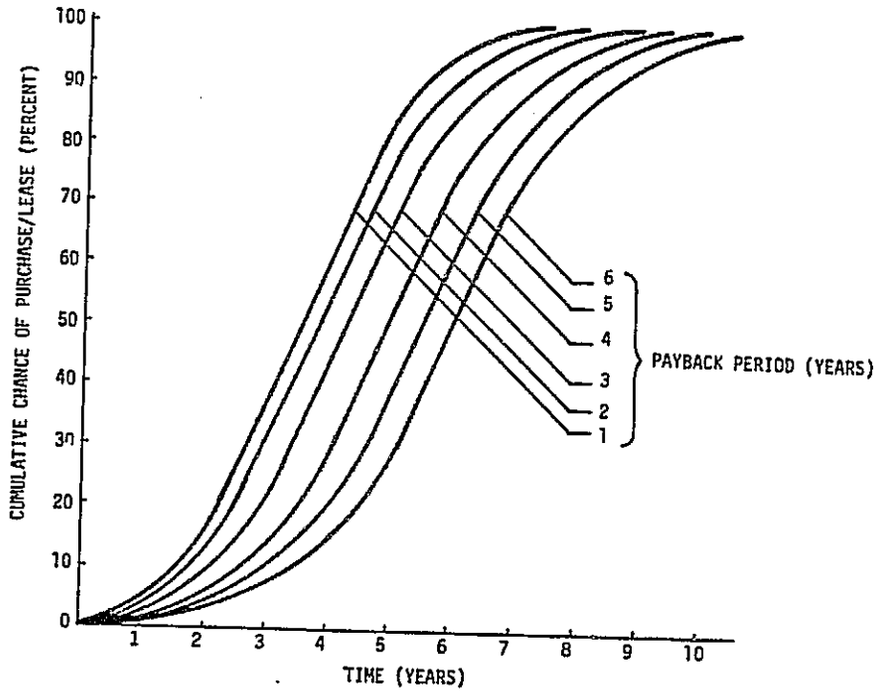

FIGURE A.5 ESTIMATED CUMULATIVE CHANCE OF PURCHASE AS A FUNCTION OF TIME

ultimately purchase) will have purchased the scanner equipment. The subjective estimates were based upon detailed knowledge of the printing industry and the rate of acceptance of other high priced equipment by the industry.

Figures A.6 and A.7 illustrate the manner in which the various projections can be put together to obtain the end result--the number of establishments that will purchase as a function of time. For each production (or output) level, the number of establishments and the associated payback period is obtained. The payback period, at a particular production level, is used to enter the saturation level and chance of purchase curves (Figure A.6). The results are the number of establishments, saturation level and chance of purchase which, when multiplied together yield the total market to date at a particular production level (separations per day). The market to date is obtained at various production levels. Summing across the production levels yields the total cumulative market. The annual market is the difference between the cumulative market of any two consecutive years.

The increasing use of color printing in recent years has resulted in an increase in the number of color separations. Thus, changes in the production level have been forecast and taken into account (Figure A.7). It is anticipated, for example, that a plant averaging five separations per day in 1969 will average approximately 8 to 9 separations per day in 1974 (15 percent growth rate).

A.3 Market Estimation Computations

The computations described in the following paragraphs make use of the data presented in Figures A.3, A.4 and A.5. Table A.1 summarizes (for establishments with 20 to 49 employees) the potential scanner market as extrapolated from the survey data. Similar market data was developed for establishments of different sizes. Establishments with less than 20 employees and newspapers were not

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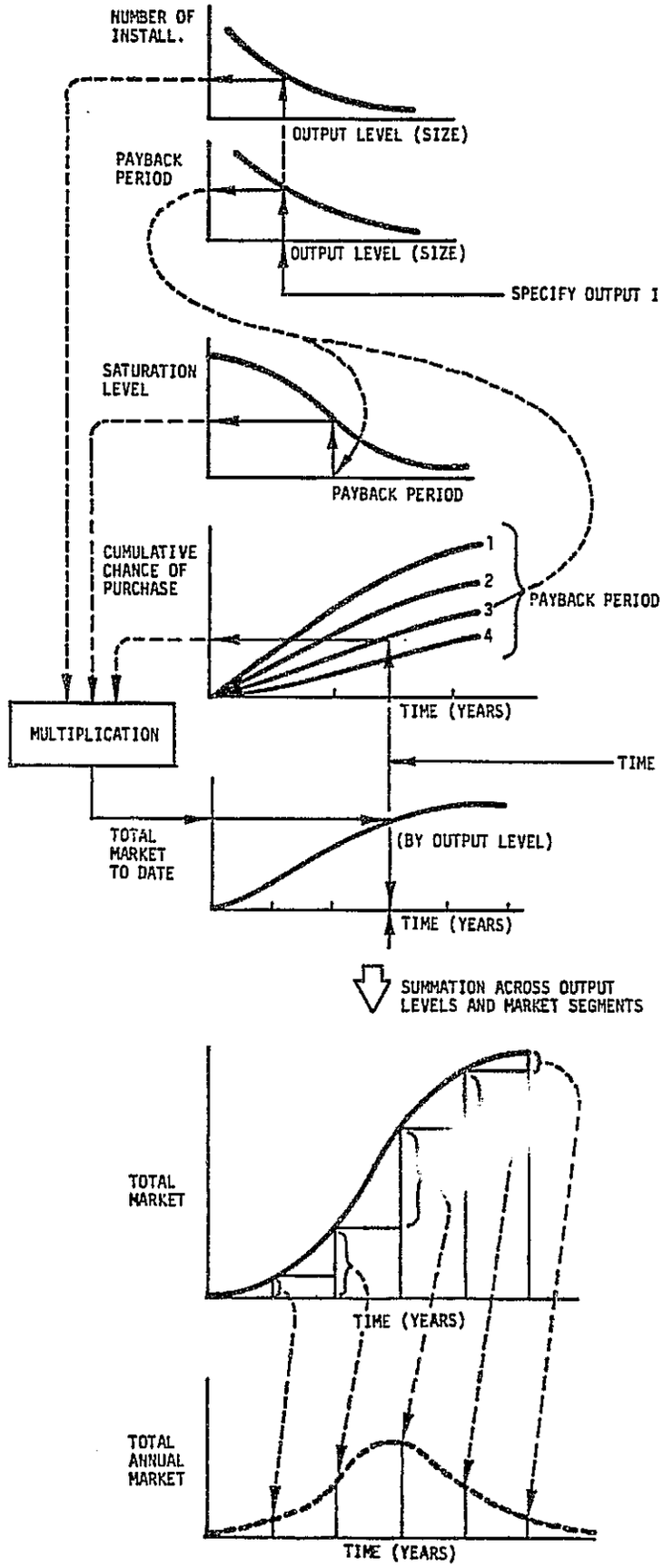

FIGURE A.6 MARKET ESTIMATION PROCEDURE

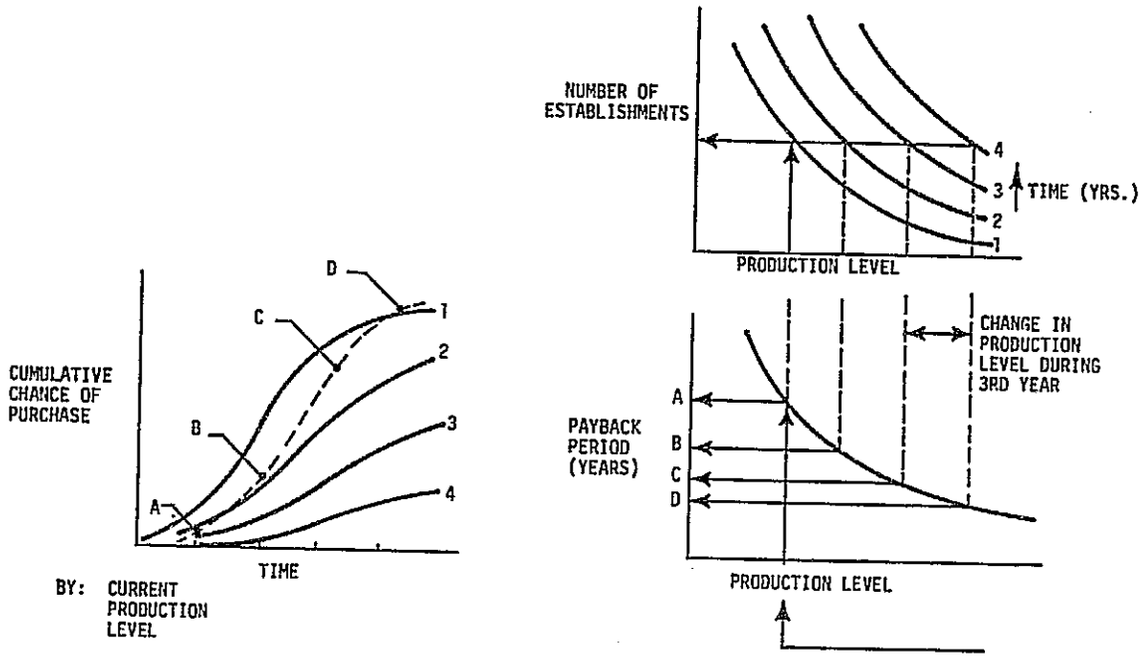

FIGURE A.7 PRODUCTION LEVEL WITH TIME AND THE IMPACT ON MARKET ESTIMATION

TABLE A.1 POTENTIAL SCANNER MARKET (ESTABLISHMENTS WITH 20-49 EMPLOYEES)

SIC CATEGORIES	MARKET SURVEY RESPONSES		ESTIMATED PERCENT DOING COLOR	TOTAL NUMBER ESTABLISHMENTS*	ESTIMATED NUMBER DOING COLOR	MULTIPLE EQUIPMENT FACTOR	POTENTIAL SCANNER MARKET**
	NUMBER OF YES RESPONSES	NUMBER OF NO RESPONSES					
2721		32	10%	212	21	1	21
2731			10%	117	12	13/12	13
2732			10%	161	16	1	16
2741	2	9	14%	97	13	1	13
2751	8	42	18%	876	157	25/21	187
2752	13	37	25%	854	215	25/21	256
2771	1	2	35%	36	13	5/3	22
2793	35	30	53%	258	84	34/25	114
TOTALS	59	152		2511	531		642

*BUREAU OF CENSUS DATA.
**NOT INCLUDING REPLACEMENTS.

considered. Where survey data was sparse, that is, where there were relatively few yes-no responses, extrapolations were made based upon detailed knowledge of the industry and data in similar SIC categories. The "multiple equipment factor" accounts for the fraction of establishments which, it is anticipated, will purchase more than one scanner equipment. It is assumed that those establishments which have high volume (on the order of more than 8 to 10 separations per day) or have high peak to average ratios will, in the long term, acquire more than one scanner. The detailed data on separations per day and peak to average ratios is available from the survey. The total potential scanner market* is thus 1276 equipments (642, 313 and 321 equipments to establishments with 20-49, 50-99, and more than 99 employees, respectively). Of the total equipments, 988 are "initial equipment" and 288 are "additional equipment" to handle high volume and/or high peak loads.

Figure A.8 illustrates the number of establishments in several SIC categories in terms of the average number of separations per day. This information was obtained from the survey data. Table A.2 summaries the total number of establishments in terms of separations per day. The sales forecast computations are performed for each production level (i.e., separations per day). For example, 1.5 separations per day is used for the establishments with 1 to 2 separations per day. This is estimated to increase at about 15 percent per year (linear growth) so that by the ninth year of the forecast period slightly under 3 separations per day will be performed by those establishments currently performing 1.5 separations per day. No allowance was made for the distinct possibility that lower costs, lower skill level requirements, and higher quality (through the use of the scanner) will further stimulate the growth of color.

*Not including the replacement market.

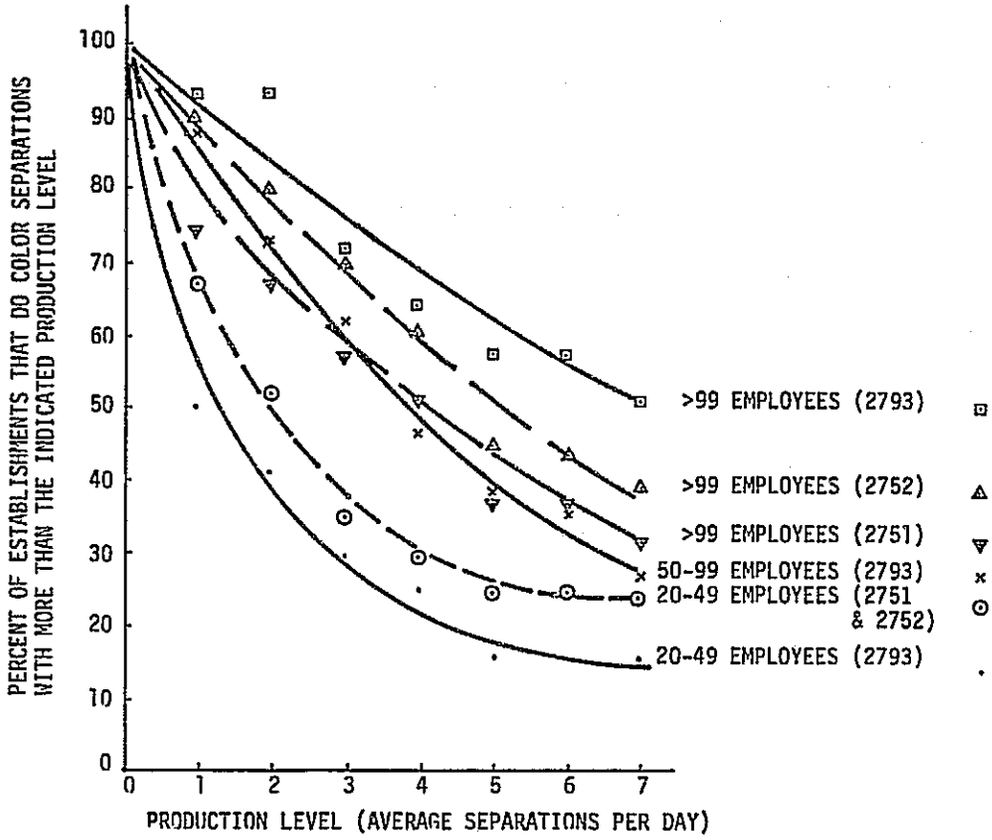

FIGURE A.8 SURVEY RESULTS--NUMBER OF ESTABLISHMENTS IN TERMS OF PRODUCTION LEVEL AND NUMBER OF EMPLOYEES

TABLE A.2 NUMBER OF ESTABLISHMENTS VERSUS PRODUCTION LEVEL (SEPARATIONS PER DAY)

SIC CATEGORY	NUMBER OF SEPARATIONS PER DAY	NUMBER OF ESTABLISHMENTS 20-49 EMPLOYEES	NUMBER OF ESTABLISHMENTS 50-99 EMPLOYEES	NUMBER OF ESTABLISHMENTS >99 EMPLOYEES	NUMBER OF ESTABLISHMENTS WITH INDICATED SEPARATIONS PER DAY
2793	0-1	37	5	1	43
	1-2	14	5	1	20
	2-3	8	5	1	14
	3-4	7	4	1	12
	4-5	3	3	1	7
	5-6	2	3	1	6
	6-7	1	2	1	4
	>7	13	9	7	29
2751, 2752, 2721, 2731, 2732, 2741, 2771 *	0-1	148	36	27	211
	1-2	67	30	27	114
	2-3	67	26	21	114
	3-4	31	22	19	72
	4-5	18	14	15	47
	5-6	9	6	17	32
	6-7	9	8	11	28
	>7	98	57	74	229

*2751 AND 2752 DATA USED TO EXTRAPOLATE ACROSS ALL THESE CATEGORIES.

Following the procedure described in Figure A.6, for each level of separations per day, payback period is obtained from Figure A.3. The payback period is thence used to determine saturation level and cumulative probability of purchase from Figures A.4 and A.5, respectively. Multiplication of saturation level, cumulative probability of purchase and number of establishments (at the initial separations per day) yields the cumulative sales. Cumulative and annual industry sales are summarized in Table A.3.

Figure A.9 illustrates the computation of the additional equipment sales (i.e., to handle high volume and high peak loads). The sales are based upon the subjective estimate of chance of purchase as a function of time shown in Figure A.10.

The remaining part of the market computation is the assessment of the replacement market. Figure A.11 illustrates the estimated fraction of scanners remaining in use (that is not replaced) as a function of number of years that equipment is in use. The total market is thus the sum of the initial, additional and replacement equipment markets. Table A.4 summarizes both the total industry

TABLE A.3 FORECASTED ANNUAL AND CUMULATIVE SALES (NOT INCLUDING BACK-UP OR 2ND OR 3RD EQUIPMENTS)

YEAR	ANNUAL SALES (UNITS)	TOTAL CUMULATIVE SALES (UNITS)
1	--	--
2	--	--
3	26	26
4	57	83
5	127	210
6	146	356
7	161	517
8	90	607
9	51	658

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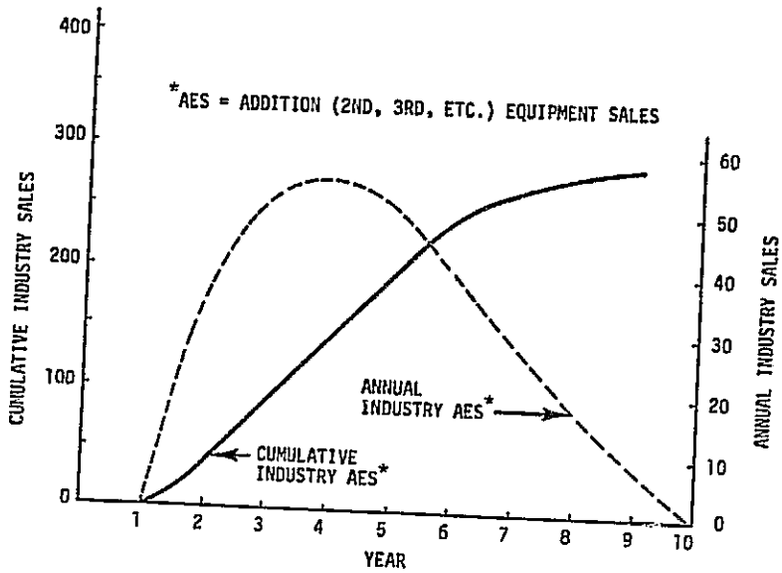

FIGURE A.9 INDUSTRY ADDITIONAL EQUIPMENT SALES (AES)

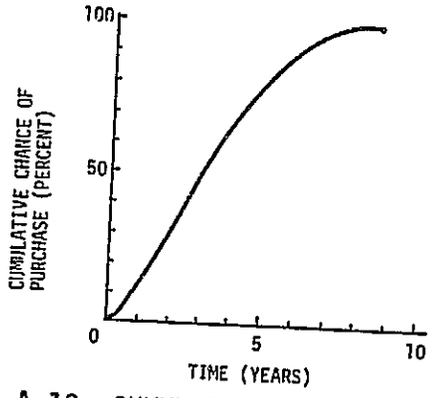

FIGURE A.10 CUMULATIVE CHANCE OF PURCHASE OF ADDITIONAL EQUIPMENT

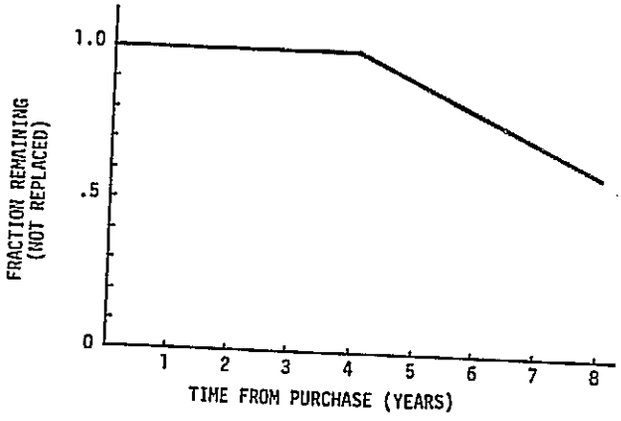

FIGURE A.11 ESTIMATED FRACTION OF SCANNERS REMAINING IN USE (NOT REPLACED) AS A FUNCTION OF TIME

TABLE A.4 SUMMARY OF SCANNER SALES FORECAST								
	YEAR OF SALES							
	3	4	5	6	7	8	9	TOTAL
INDUSTRY SALES								
ORIGINAL EQUIPMENT	26	57	127	146	161	90	51	658
ADDITIONAL EQUIPMENT	--	37	51	55	50	41	29	263
REPLACEMENT EQUIPMENT	--	--	--	--	4	20	46	70
TOTAL	26	94	178	201	215	151	126	991
COMPANY X SALES								
% ORIGINAL EQUIPMENT	90%	75%	60%	50%	50%	50%	50%	--
% ADDITIONAL EQUIPMENT	--	90%	75%	60%	50%	50%	50%	--
% REPLACEMENT EQUIPMENT	--	--	--	--	50%	50%	50%	--
TOTAL UNITS SOLD	23	76	114	106	107	76	63	565

sales forecast and Company X's sales forecast. The indicated market shares are based upon the high technology aspects of the equipment with the commensurate time lag for competition to develop comparable equipment and the anticipated strong patent position of the company.

It should be noted that industry sales have been forecast as approximately 1000 equipments over a seven-year period (two years required to develop the products and produce first production units). Over this seven-year period it is forecast that Company X will achieve approximately 57 percent share of the market (565 equipments).

APPENDIX B

A METHODOLOGY FOR EVALUATING PUBLIC SECTOR R&D OR INCENTIVE PROGRAMS PERFORMED IN SUPPORT OF THE PRIVATE SECTOR

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APPENDIX B

A METHODOLOGY FOR EVALUATING PUBLIC SECTOR R&D OR INCENTIVE PROGRAMS PERFORMED IN SUPPORT OF THE PRIVATE SECTOR

B.1 Introduction

Public sector funded research and development (R&D) and incentive programs should yield social benefits which exceed program costs. The social benefits, in many cases, can only be achieved if the R&D or incentive program results are transformed into business ventures that provide goods and/or services which are adopted and find widespread utilization in the public and/or private sectors. This transformation process is usually referred to as "technology transfer."

When technology transfer requires private sector participation, it follows that the achievement of the anticipated social benefits also depends upon private sector participation. Thus, from the public sector's point of view, the estimation of the benefits which may result from a public sector funded R&D or incentive program must take into account the likelihood of private sector participation. The likelihood of private sector participation depends upon many factors, foremost among which are perceived uncertainty, resulting risk and exposure (i.e., magnitude of investment). The public sector benefits from an R&D or incentive program are thus inextricably tied to the impact of the R&D or incentive program upon the likelihood of private sector participation through its effect on perceived uncertainty, risk and exposure.

A part of government-sponsored R&D is undertaken with the specific objective of developing technology and/or creating the environment which will lead to the formation of commercial ventures which are in the public interest. For

example, much of the Department of Energy (DoE) effort is in this direction. The early NASA communication satellite R&D efforts were also in this direction. Should the public sector invest in an R&D or incentive program aimed at developing the technology and creating the environment which will lead to commercial ventures capable of providing goods and/or services on a continuing basis? This paper outlines a methodology for answering this question. The methodology explicitly takes into account the role of public sector R&D and incentive programs in reducing private sector perceived uncertainty, risk and exposure.

The public sector (DoE, NASA, etc.) is currently considering funding R&D and incentive activities, the goal of which is the development of products and/or services which will be provided by private sector ventures. It is assumed that the government will provide the bulk of funds required for the R&D and that the private sector, within the constraints imposed by government, will capitalize at the appropriate time by commercializing the developments which have resulted from the government funding. It is obvious that both government and private industry must have incentives to bring to fruition the desired products and/or services. The public sector incentive is the perceived, estimated or anticipated benefits which may be provided to members of society as a result of the development of advanced technology and/or the reduction in private sector risk and exposure, but which would be foregone in the absence of government investment. The added benefits can only be achieved, however, if the private sector ultimately commercializes the results of the public sector R&D. It is assumed that this commercialization will not take place unless it is perceived, estimated or anticipated that minimum profit, return on investment and other objectives can be exceeded at a tolerable level of risk.

Government is often required to help develop and to provide goods and/or services when, because of undue perceived risk, magnitude of investment and long payback period, the private sector deems it undesirable to provide goods and/or services which would, if offered, confer benefits to members of society. Government particpation is also often required when the production or consumption of goods and/or services provides to individuals benefits other than those normally provided to the parties of a market transaction. The benefits thus provided to members of a society in total are larger than the benefits received by the individual parties to the market transaction [1]. Under this situation, decisions which are optimal from the private sector's point of view may be far from optimal from the public sector's point of view. This mismatch in optimal decisions is the very reason for public sector R&D and incentive programs.

A number of questions which must be answered by the public sector project selection process are listed in Figure B.1. A necessary condition for public sector funding of an R&D or incentive program is that the benefits which are the direct result of the program exceed the cost of the program. Thus, the initial step is to determine if the benefits which may result from providing goods and/or services on a continuing basis will exceed the present value of the cost of providing the goods and/or services plus the present value of the cost of the R&D or incentive program which is required in order to make the goods and/or services a reality.

Given that the benefits exceed the costs, then a sufficient condition for public sector funding of an R&D or incentive program is the anticipated lack of timely and/or adequate private sector participation required to achieve the indicated benefits. Thus, the next step is to answer the second, third and forth questions indicated in Figure B.1, and as a result establish the likelihood and level of private sector participation in the absence of public sector participation, and

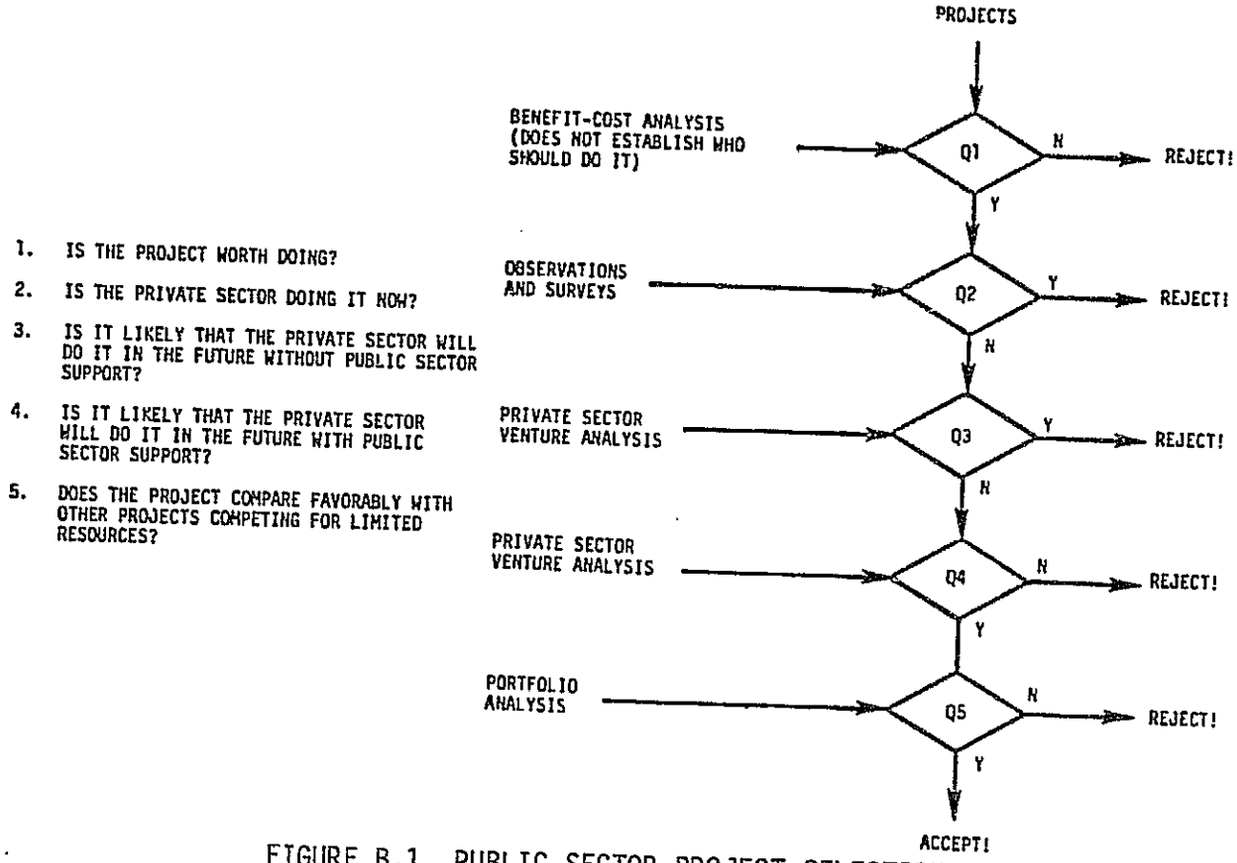

FIGURE B.1 PUBLIC SECTOR PROJECT SELECTION

the desired form and level of public and private sector participation from the R&D stage through and including continuing operations.

When the benefits and cost streams which may result from the R&D or incentive program have been estimated and the likelihood of private sector participation has been evaluated, the R&D or incentive program can be compared with other programs vying for limited resources. This is normally referred to as portfolio selection and is discussed in References 2 through 5.

B.2 Evaluation of Public Sector Investments

The public sector should generally invest in an R&D or incentive program if it can be shown that the present value of the benefits which may be derived as a result of the R&D or incentive program exceed the present value of the cost of the

R&D or incentive program. Benefit-cost analysis is concerned with evaluating these benefits and costs. The benefits and costs are those that would be realized by society and include the benefits received and costs incurred by members of society who are direct parties to the resulting market transactions (for example, the provider and user of a communications service) as well as those who are not direct parties to the market transaction but who are indirectly affected.* Benefit-cost analysis is concerned with all of the costs and benefits which are the direct or indirect result of the R&D or incentive program.

As discussed previously, the benefits of the government investment in R&D result from commercialization by the private sector. The goods and/or services, if they are offered, will be provided at prices which are below those possible through other means. In order to compare alternatives, it is necessary to quantify the net public sector benefits (benefits less costs incurred by the public sector). The analysis of the benefits of a research and development project, from the public sector's point of view, can be assessed by considering Figures B.2 and B.3. Figure B.2 illustrates supply and demand curves in terms of price and quantity [6-8]. With the indicated supply/demand curves, a quantity Q of a good (or service) will be sold at a price P. Three cross-hatched areas are shown, namely consumers' surplus, producers' surplus and factor costs. Consumer surplus [6] represents the maximum sum of money a consumer would be willing to pay for a given amount of a good, less the amount he actually pays (P). The consumer

*For example, improved communications services may increase both the effective skills and productivity of teachers. The increased productivity leads to cost savings benefits and the increased skill leads to increased capability benefits to the students or recipients of improved education. The teachers (i.e., the school system) are the direct parties to the market transaction through their purchase of the communications service, whereas the students are not direct parties to the market transaction.

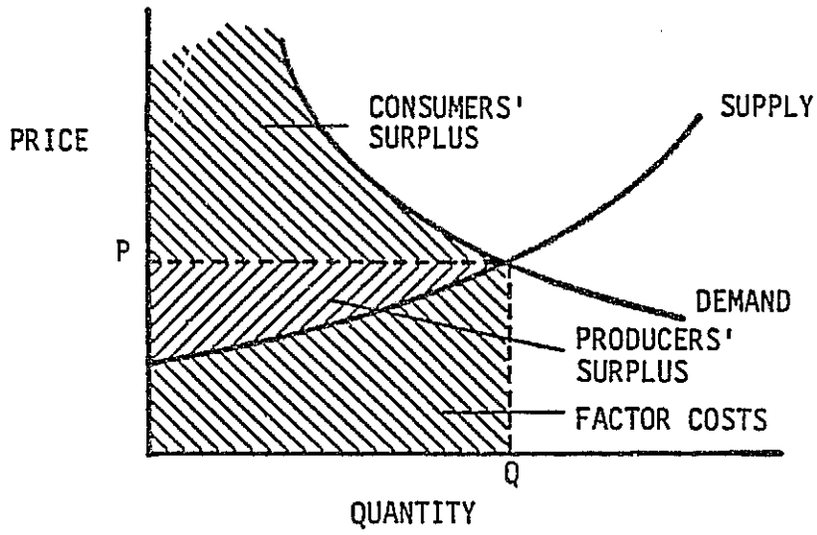

FIGURE B.2 SUPPLY/DEMAND/BENEFIT RELATIONSHIP

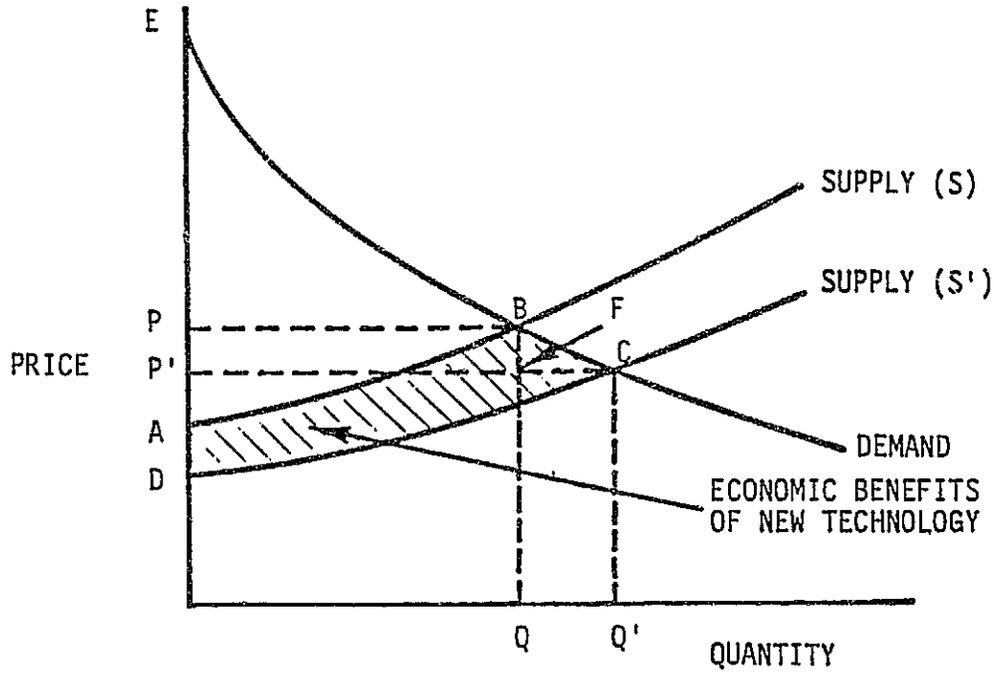

FIGURE B.3 IMPACT OF NEW TECHNOLOGY--ECONOMIC BENEFITS

surplus is the net benefit to the consumer from consumption of a particular good or service at a given price. The producers' surplus represents the net benefit or profit obtained by the suppliers. The factor costs represent payments made by the producers for materials and services and other expenses of production. The area under the demand curve out to the quantity Q (as determined from the supply-demand functions), consisting of consumers' surplus and producers' surplus, is a measure of the total public welfare or net social benefit associated with the good or service under consideration. Let the demand curve represent the demand for a particular good or service and the supply curve, S, referring to Figure B.3, represent the marginal cost of supply based upon current technology. The price of the good or service is thus P. If, because of government funding, a commercial venture is developed that results in supply curve S', assuming "ceteris paribus" conditions [6], then there is an associated decrease in unit price to P'. It should be noted that the reduction of the price of the good or service is deemed to confer a benefit on society. The added public welfare or the net public sector benefits of the new technology can thus be measured by the cross-hatched area ABCD. This area depends upon the shape of the supply and demand curves and represents the change in consumers' and producers' surplus. Note that the benefits are obtained as a result of factor cost reductions. It is assumed that in the long term all displaced factors will seek and find their next best use.

Referring to Figure B.3, it can be seen that the area ABCD, representing the increase in benefits, consists of the change in consumers' surplus (PBCP' = ECP' - EBP) plus the change in producers' surplus (P'CD - PBA). The change in consumers' surplus consists, in turn, of two parts: that referred to as the equal capability benefits given by (P - P') x Q and the added capability benefits as per the area BCF. Simply multiplying the quantity consumed by the price differential (P - P')

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yields a measure of the equal capability consumers' surplus benefits; it does not include the added capability benefits and does not necessarily properly (because of the producers' surplus) provide an accurate measure of the added public welfare or net public sector benefits resulting from the development of the new technology. When demand is inelastic,* i.e., $|\epsilon| = 0$, there are no added capability benefits resulting from a price decrease. On the other extreme, when demand is perfectly elastic, i.e., $|\epsilon| \rightarrow \infty$, the added capability benefits resulting from a price reduction may become very large, depending on the specific shape of supply and demand curves and the price before and after the price reduction. Depending upon the value of ϵ and the shape of the supply curves, it is clear that the added public welfare may differ from the increase in equal capability consumers' surplus by a nonnegligible amount. The point is that a reduction in price of a good or service confers a benefit on the community and the magnitude of the reduction can be used to ordinally rank the order of desirability of alternative courses of action; the price reduction in itself may not be a reliable quantitative measure of the added public welfare and thus may provide little insight into the magnitude of the R&D project that is allowable in order to produce the price reductions.

Since the public sector benefits depend upon private sector decisions, public sector benefits must be considered as the present value of the change in consumers' and producers' surplus multiplied by the change in the probability of private sector implementation which is the direct result of the public sector R&D project. The remainder of this paper is concerned with the effect of public sector R&D and

*Elasticity, ϵ, is defined [7] as the percentage change in quantity divided by the percentage change in price; $\epsilon = \frac{P}{Q} \frac{dQ}{dP}$.

incentive programs on private sector decisions, in particular, the effect on the probability of private sector implementation.

B.3 Impact of Public Sector R&D on Private Sector Decisions

Since the benefits which result from the public sector investment in R&D are the result of technology implementation by the private sector, it is necessary to understand the impact of public sector funded R&D on private sector decisions and the type of information required by the private sector in making investment decisions. The evaluation of new business ventures by the private sector is concerned with determining sales potential, profit potential, required investment (exposure), when investment will be returned, cash flow, present value of cash flow, expected rate of return, risk and many other factors [9,10]. Their determination is based on delineating R&D, operating, engineering, manufacturing and other costs and expenditures. Profit is the difference between revenue and expenses.

$$\text{Profit} = (1 - \text{Tax Rate}) * (\text{Revenue} - \text{Depreciation Expense} - \Sigma\ \text{Expenses}).$$

Capital expenditures are not explicitly included in the profit computation but occur only indirectly (and in any one year only partially) through depreciation expense. Cash flow, on the other hand, reflects the flow of funds through the business entity. The cash flow computation includes the magnitude and timing of the in-flow and out-flow of funds.

$$\text{Cash Flow} = \text{Profit} + \text{Depreciation} + \text{Change in Payables} - \text{Change in Inventory} - \text{Change in Receivables} - \text{Capital Expenditures}.$$

This includes after-tax profit, depreciation, increase in payables, decrease in inventories, decrease in receivables, etc., as cash in-flows (sources of funds); and losses, capital expenditures, decrease in payables, increase in inventories, increase in receivables, etc., as cash out-flow (uses of funds). It should be noted that cash flow (which includes profit and loss as a component), and not profit, is the important determinant of the value of a venture. Profit is an accounting artifact--cash flow is a basic measure; a profitable business venture may fail because of cash flow problems. The significance of profit, however, cannot be overlooked, since it is a key consideration when evaluating the availability of funds from the financial community. (Stock prices are normally measured in terms of price-earnings ratio.)

Typical profit, cash flow and indebtedness patterns are illustrated in Figure B.4. The cash flow and profit streams normally start off as net cash out-flows and losses, respectively, due to R&D expenditures, engineering efforts, initial operating or start-up costs, etc., which precede revenue from sales. Maximum annual net cash out-flow decreases, eventually becoming a net cash in-flow. The maximum funding requirement is indicated by the peak of the indebtedness (the negative of the cumulative cash flow to time t) curve. When the indebtedness is positive, the total investment has not been recovered and the cumulative cash out-flow exceeds the cash in-flow. When the indebtedness is negative, the cumulative cash in-flow exceeds the cash out-flow. The indebtedness decreases to zero when sufficient cash has been generated to "pay off" the total investment. The time for this to occur is referred to as the "payback" period. The viability of a venture depends on many factors and is influenced significantly by the potential sources of capital and what the investors consider as significant. The federal government and many large corporations rely heavily on present value concepts and quantitiative

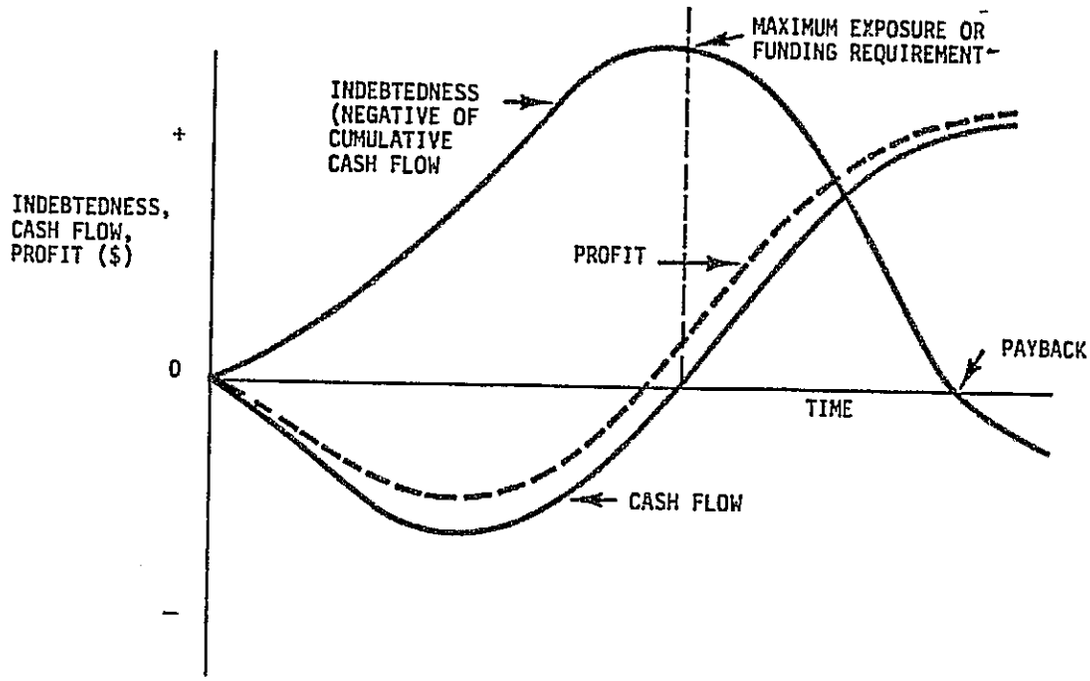

FIGURE B.4 TYPICAL PATTERN OF PROFIT, CASH FLOW AND INDEBTEDNESS

measures of risk. Venture capitalists, in many cases, are concerned with their maximum exposure, the first profitable year and payback period. Others establish a value (used in their investment decision) of K times the profit in the fourth year. Thus, part of the private sector venture analysis is an assessment of the various likely sources of funds and an evaluation of the likelihood of obtaining the necessary funds in terms of the investor's criteria and other investment alternatives.

It is important, particularly in a business venture based upon new technology and new services, to explicitly consider uncertainty and resulting risk. Uncertainty refers to the subjective assessment of the variability (i.e., expressed in the form of a probability density function) of basic parameters, such as the number of customers for a specific good or service as a function of time; and risk refers to

the chance that various performance indicators (for example, profit, cash flow, present value) exceed different levels. Thus, risk is expressed in the form of the complement of a cumulative probability distribution, referred to as a risk profile, which is developed as a result of the uncertainty associated with the basic input parameters and their functional relationship [11,12]. Thus, private sector decisions must be made in light of the type of information shown in Figure B.4, to which appropriate probability distributions (either on a subjective level or quantitatively determined level) are added. It is the risk profiles (inplicit or explicit) which are major determinants of the acceptability of a new business venture. In other words, if a venture is not acceptable from the point of view of the tradeoffs of the data from Figure B.4, then the impact of risk is immaterial. If, on the other hand, a venture is acceptable from the point of view of the data from Figure B.4, then risk assessments will determine the acceptability of the venture.

It is important to understand the possible impact that a public sector R&D project may have on the private sector [5]. In general, an R&D program consists of basic research projects, applied research projects and development projects. From an economic point of view, basic research projects extend knowledge into new areas which offer the opportunity for making choices that would not otherwise be possible. They provide benefits through the demand for the new opportunities which are created. It is normally difficult or impossible to perform a benefit analysis of basic research projects since the opportunities which will be created in the future are not known in the present.

Applied research consists of projects that will result in knowledge that has an immediate, known application. The primary purpose of applied research activities, from an economic point of view, is not to provide an opportunity for new choices (new research), but rather to reduce uncertainty associated with choices that might

presently be made. The reduction in uncertainty can be with respect to level of achievable technology and/or cost (recurring and/or nonrecurring). By reducing the uncertainty associated with the implementation of known technologies, applied research brings the use of these technologies one step closer. The benefit of applied research lies in the added value obtained as a result of implementation decisions affected by the perceived reduction of uncertainty and risk reduction. In other words, benefits of an applied research activity are the result of the increased probability and rate of implementation of technology.

Development is viewed as the demonstration and testing of components or systems in the actual or near actual form or design in which they will ultimately be implemented. Benefits result from producer decisions which are impacted by reduced uncertainties, similar to the applied research project, and/or shifting development funding from the private sector to the public sector. Shifting development funding to the public sector reduces the investment required by private industry and, hence, their exposure to risk associated with new opportunities. Benefits also result from increased market penetration rates due to reduced uncertainty on the part of consumers.

As stated above, the benefits of an applied research project are the result of a reduction in the uncertainty and, hence, risk associated with private sector implementation. The uncertainties are related to market, cost, schedule, performance, etc. To illustrate the benefits of an applied research project, a simplified example is shown in Figure B.5. A priori, three alternatives facing the private sector may be considered as the consequence of a government decision to undertake or not to undertake an applied research project. These alternatives are (A) continue the status quo, (B) implement the technology which results from a successful applied research project funded by the private sector in the absence of a

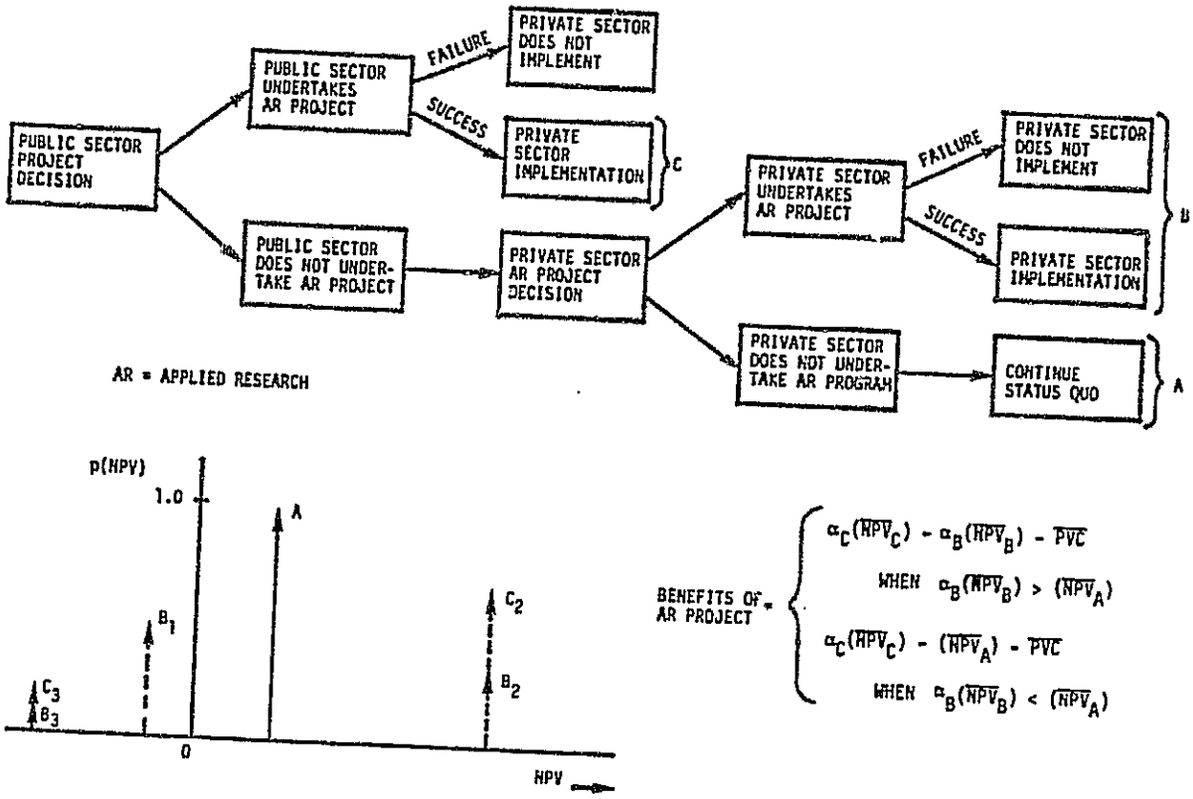

FIGURE B.5 BENEFITS OF AN APPLIED RESEARCH PROJECT

public sector funded applied research project, and (C) implement the technology which results from a successful applied research project funded by the public sector. Actually, a fourth alternative is possible: Implement the technology without the benefit of an applied research project. This requires the assumption of higher risks by the private sector and, although a viable alternative, will not be discussed further. Note that Alternatives B and C require private sector decisions to be made relative to the commitment of funds. Alternative C requires a decision regarding the implementation of technology developed by a public sector applied research project. Alternative B requires a decision regarding the undertaking (by the private sector) of the applied research and, if the research is successful, a decision regarding the undertaking of technology implementation. It is assumed

that Alternative A, the continuation of the status quo, is based upon known technology and therefore there is little uncertainty in the net present value,* NPV. NPV is the a priori net present value as viewed by the private sector, but estimated by the organization evaluating benefits of the public sector applied research project.

Alternative B, which represents the implementation of new technology without the public sector applied research project, has, for illustrative purposes, three possible outcomes, as denoted by B_1, B_2 and B_3. B_1 represents the NPV associated with the applied research project if the technology goal is not achieved, B_2 represents the NPV given successful applied research and implementation and B_3 represents the NPV given unsuccessful implementation. Alternative C, which represents implementation given a successful public sector applied research project, is characterized by C_2 and C_3, which are similar to B_2 and B_3, respectively. Note that C_1 is zero since the applied research project is funded by the government and the probability of C_2 and C_3 are greater than that of B_2 and B_3, respectively, since implementation will only take place if the government-funded applied research project is successful. Note that the indicated NPVs do not consider the public sector investment in the applied research project since only the private sector is considered.

The estimated private sector expected values and standard deviations differ for the three alternatives. Let α_B and α_C be the a priori estimates of the probability of private sector implementation associated with Alternatives B and C, respectively. The values of α_B and α_C are based upon estimates of the private sector response when faced with the indicated probability distributions of NPV.

*Discussion of the Present Value Concept can be found in many standard economics or business text books; for example, see Reference 13.

Alternative B has a somewhat greater expected net present value, $\overline{NPV}_B$, than Alternative A, that is $\overline{NPV}_B > \overline{NPV}_A$. However, conservative management would normally forego Alternative B because they are risk averse. On the other hand, if the public sector applied research project is undertaken at a present value of cost $\overline{PVC}$, it is anticipated that the uncertainty associated with Alternative C will be diminished as indicated by its probability distribution. The decision to implement the new technology is now based upon a low probability of a negative NPV and a high probability of a positive NPV. The probability of implementation in light of this reduced uncertainty and risk is estimated as α_C. From the government's point of view, when

$$\alpha_C * \overline{NPV}_C > \begin{cases} \alpha_B * \overline{NPV}_B + \overline{PVC} \\ \quad \text{and} \\ \overline{NPV}_A + \overline{PVC} \end{cases}$$

then the applied research project should be undertaken and the benefits are as indicated in Figure B.5. It should be noted that a number of subjective probability estimates are necessary and have to be made relative to the uncertainty reduction and the actions of the private sector which are affected by the uncertainty and risk reduction.

Figure B.6 illustrates a possible effect of public sector investment in development projects.* As a result of public sector investment in development, private sector projected indebtedness is reduced and is better defined. This is illustrated as the probability distribution associated with indebtedness with and without the public sector projects. Similar probability distributions for payback

*The effect of public sector incentive projects is similar.

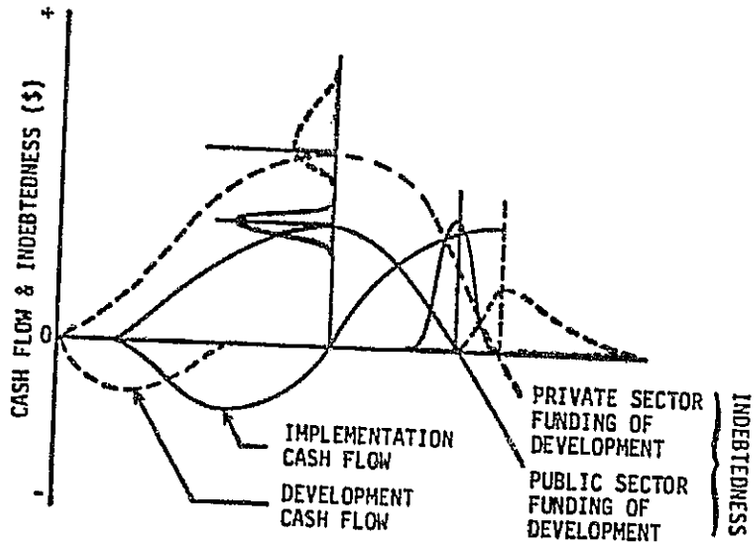

FIGURE B.6 EFFECT ON THE PRIVATE SECTOR OF GOVERNMENT INVESTMENT IN DEVELOPMENT PROJECTS

period are also indicated. It is the combined effect of both lower expected indebtedness and lower risk (standard deviation of indebtedness) coupled with similar insights into other performance measures (for example, NPV of cash flow) that lead to increased likelihood of private sector implementation when the public sector undertakes a development project.

B.4 Public Sector Evaluation Methodology

As previously described, public sector R&D and incentive programs are undertaken to (1) reduce performance uncertainty, (2) reduce cost uncertainty, (3) reduce market uncertainty and (4) reduce private sector exposure. The impact on the private sector is through a reduction in private sector perceived risk and/or exposure with the increased likelihood of developing and marketing beneficial goods and/or services. Public sector benefits can only be achieved if the R&D and incentive programs affect private sector investment decisions. Investment decisions may be affected both in the polarity (yes or no) of the decision and the timing

of the decision. The expected benefit of a public sector R&D or incentive program performed in support of the private sector, $\bar{B}$, is obtained as

$$\bar{B} = \alpha_B * \overline{PV}_B - \alpha_A * \overline{PV}_A - \overline{PVC} \tag{1}$$

where $\overline{PV}_B$ and $\overline{PV}_A$ are the expected public sector benefits with and without the R&D or incentive program, respectively. $\overline{PVC}$ is the expected value of the cost of the R&D or incentive program. α_B and α_A are the probabilities of private sector investment with and without the public sector R&D or incentive program, respectively. $\overline{PV}_B$ and $\overline{PV}_A$ reflect the timing of the benefits with and without the R&D or incentive program. α_B and α_A reflect the polarity of the private sector investment decision in terms of the probability of private sector investment with and without the public sector R&D or incentive program.

Note that the benefits are established as the result of a "with and without" analysis. This can be accomplished by postulating various possible private sector business venture scenarios and developing appropriate business plans, including pro forma income and cash flow projections, establishing payback period, present value, etc. Since private sector decisions are normally based upon profit, cash flow, payback period, magnitude of investment, present value and risk (the chance that performance measures exceed specified levels) considerations, it is necessary to assess these performance measures resulting from the postulated scenarios in terms of the decisions which might be made by a "prudent businessman." In other words, would a prudent businessman invest in a business venture having the established performance measures?

An important element of this analysis is the explicit consideration of the uncertainty (i.e., probability density function) associated with various input variables to the analysis such as demand, unit costs, time of initiation of service, etc.

The explicit consideration of uncertainty in combination with Monte Carlo business venture simulation or risk analysis models results in the establishment of risk profiles, the cumulative probability distributions associated with the pertinent performance measures [11,12]. Risk analysis, Figure B.7, is a formal procedure [9, 11, 12, 14) whereby quantitative estimates of uncertainty associated with basic input quantities are converted to risk profiles of performance data. The basic input data consists of deterministic data and probabilistic data. Examples of deterministic data are the number of time periods to be considered, the discount rates, tax rates, etc. The probabilistic data consist of the probability density functions, the "uncertainty profiles," associated with the variables whose values cannot be predicted or known exactly in advance. The uncertainty profiles are thus subjective estimates which describe the range of uncertainty and the form of the uncertainty. Typical uncertainty variables are unit sales, selling price, market share, expense items, capital expenditures and others.

These data are input to a financial simulation model which is of the complexity necessary to adequately represent the real world situation being evaluated. The model, indicated in Figure B.7 and elaborated upon in Figure B.8, states that revenue in the Ith time period is equal to the product of unit sales (US), selling price (SP) and market share (MS); before-tax profit (BTP) is equal to revenue less the sum of all expense items (E) less the depreciation expense (D); after-tax profit is one minus the tax rate (TR) multiplied by the before-tax profit.

Risk analysis is performed by random sampling of the input data (according to the weighting of the uncertainty profiles), performing the computations contained within the simulation model, saving the results and then repeating the process. This process is repeated a large number of times (Monte Carlo) until a reasonable set of histograms can be developed from the saved output data. These histograms

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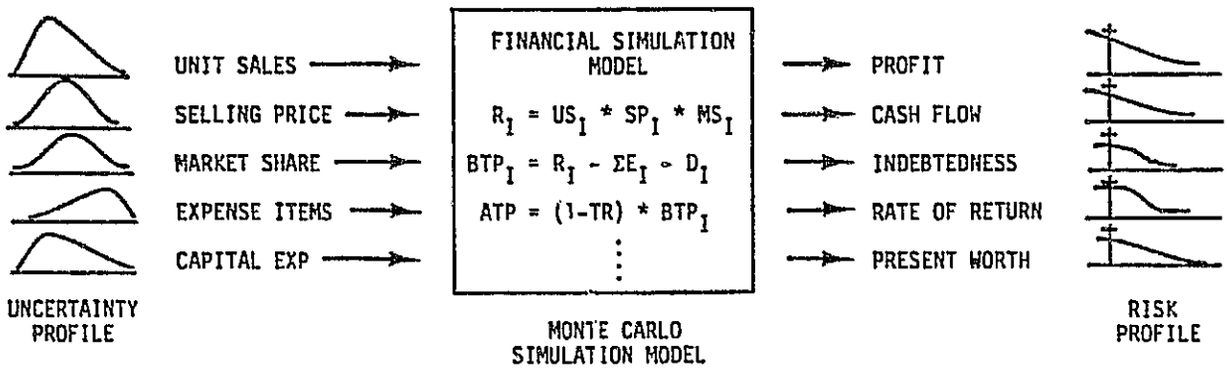


FIGURE B.7 THE CONCEPT OF RISK ANALYSIS

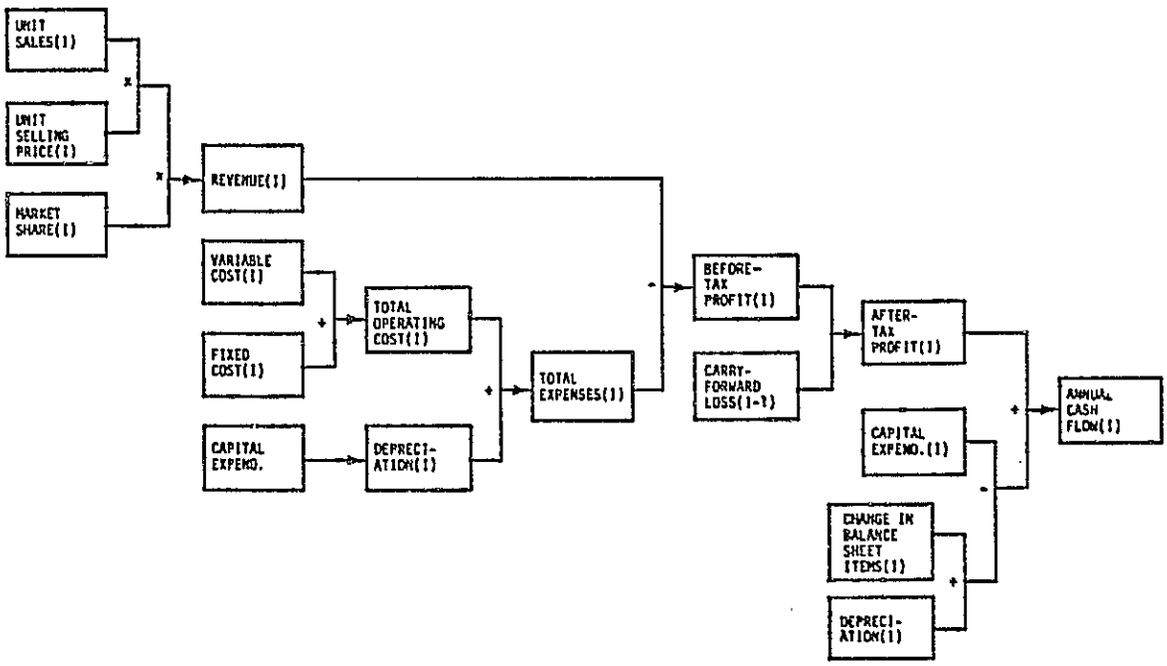


FIGURE B.8 TYPICAL RISK ANALYSIS STRUCTURE

are then manipulated into the desired form so as to indicate the variability of pertinent measures such as profit, cash flow, indebtedness (negative of the cumulative cash flow to date), rate of return and present worth. A convenient form of displaying the performance measures is that of "risk profiles" which indicate the chance of the performance measure exceeding specific levels (i.e., the complementary cumulative probability distribution).

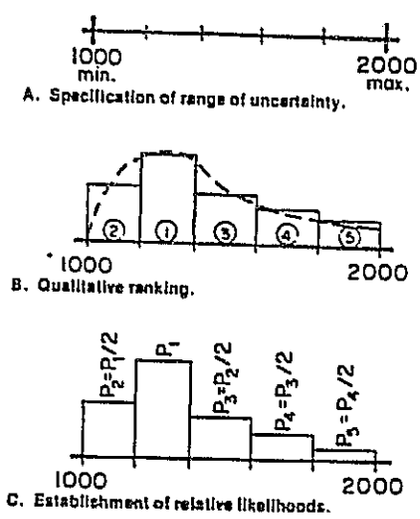
All uncertainty variables (for example, unit sales, selling price, market share) are specified as the range of uncertainty (i.e., minimum and maximum values) and the name or I.D. number of the applicable stored probability density function. Normally, a large number are stored and can be easily accessed by specifying the I.D. number. The uncertainty profiles consist of piecewise continuous approximations to continuous functions. The reason for this particular form is the necessity to have an easy way of developing and inputting other uncertainty profiles and having an understanding and appreciation of the meaning of the profiles.

A useful and frequently-used procedure for establishing the shape of new uncertainty profiles is as follows:

A. Estimate the range of uncertainty--minimum and maximum bounds (little or no chance of falling outside these bounds). Divide this range into a number of equal intervals--five has been found, through experimentation, to be useful and is therefore used in the RISK Program.

B. Make a relative ranking of the likelihood of the variable falling into each of the intervals; this establishes the general shape of the uncertainty profile (i.e., skewed left, central, etc.).

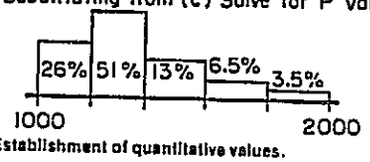
C. Set relative values for the chance of falling into each interval. (For example, the chance of falling into Interval 1 is half that of falling into Interval 2.)



D. Having assumed the probability of falling within the range of uncertainty as 1.0, the chance of falling in each of the five intervals can be summed and set equal to unity. This equation can be solved (by substituting the relative values as obtained in Step C) for the probabilities associated with each interval.

$P_1 + P_2 + P_3 + P_4 + P_5 = 1$

By Substituting from (c) Solve for P Values



D. Establishment of quantitative values.

As a result of the input data uncertainty profiles and the specifics of the business venture, risk profiles may be developed as illustrated in Figure B.9. Three typical risk profiles for return-on-investment are shown resulting from the following situations: (1) there is no public sector program, (2) there is a public sector R&D program that reduces the private sector perceived uncertainty pertaining to unit manufacturing cost, and (3) there is a public sector R&D program that reduces the private sector perceived uncertainty plus an incentive program

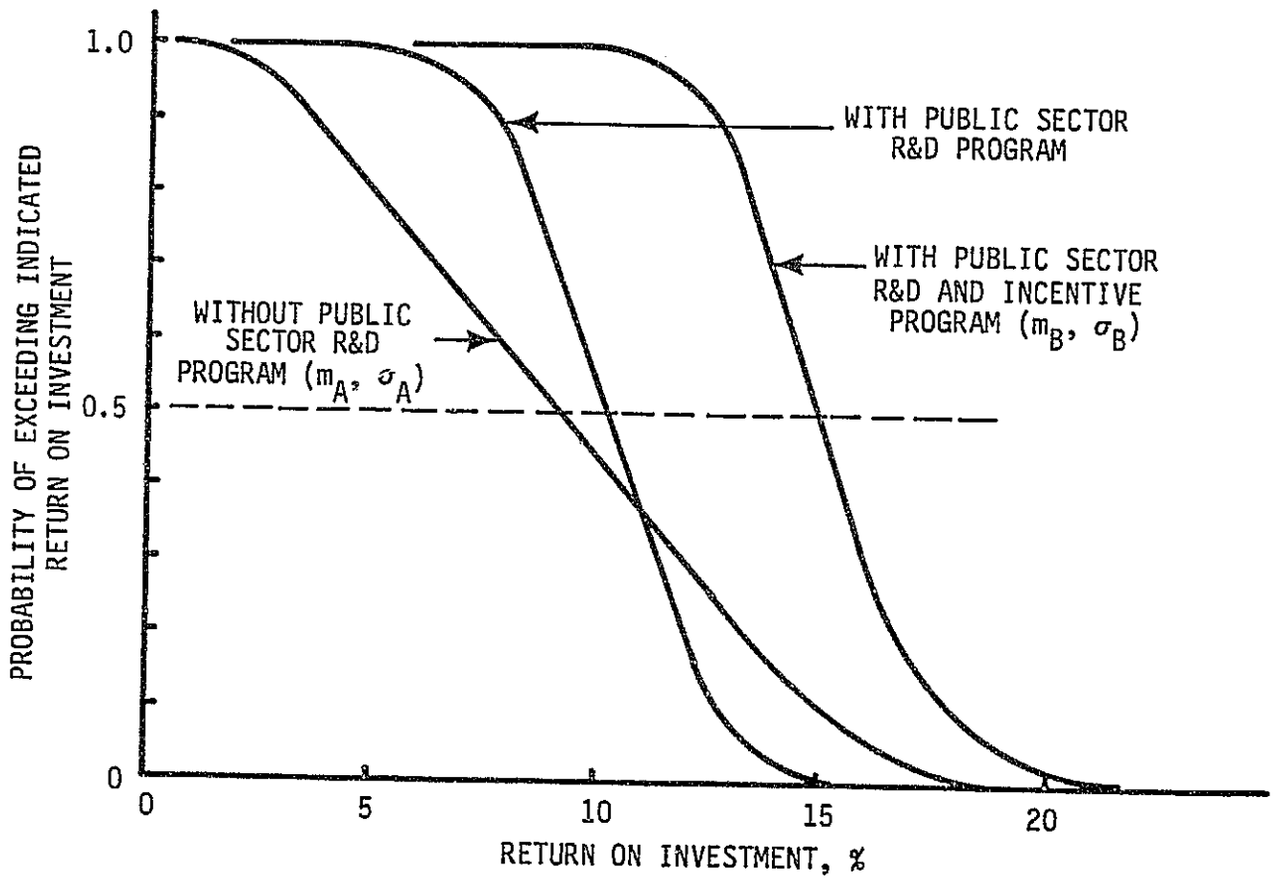


FIGURE B.9 RISK PROFILES OF RETURN ON INVESTMENT

that shifts a portion of the capital expenditures burden from the private to the public sector. These risk profiles, along with other information, can provide insights into the likelihood of private sector investments.

Once the risk profile data are established, decisions can be made explicitly taking into account risk levels. The specific estimates required pertain to the probability that the prudent businessman would invest, in terms of expected value and risk measures, as illustrated in Figure B.10. The risk profiles tend to be near normal and can thus be categorized in terms of standard deviation, σ, and expected value, m. Since σ describes the variability, it is a measure of risk. The probability of private sector (unregulated industry) investment may be described in terms of the expected value and standard deviation of return on investment as indicated in Figure B.10. The objective of public sector R&D and incentive projects is to affect, through their impact on perceived uncertainty, the private sector perceived return on investment (ROI) from m_A and σ_A to m_B and σ_B thus changing the probability of private sector implementation from α_A to α_B. The values of m_A, σ_A and m_B, σ_B are as obtained from Figure B.9. The benefits from the R&D or incentive project can thus be obtained from Equation 1.

In order to determine the feasibility of establishing the probability of private sector implementation in terms of expected and standard deviation of ROI, a questionnaire was developed and used by a small group of private sector decision makers. The preliminary results are illustrated in Figure B.11. It was found to be necessary to add the dimensions of expected investment (exposure) and expected payback period to the characterization of the probability of implementation.

The general procedure for evaluating the benefits of a public sector R&D or incentive project in support of the private sector is illustrated in Figure B.12. This procedure results in the determination of the expected benefits and requires that

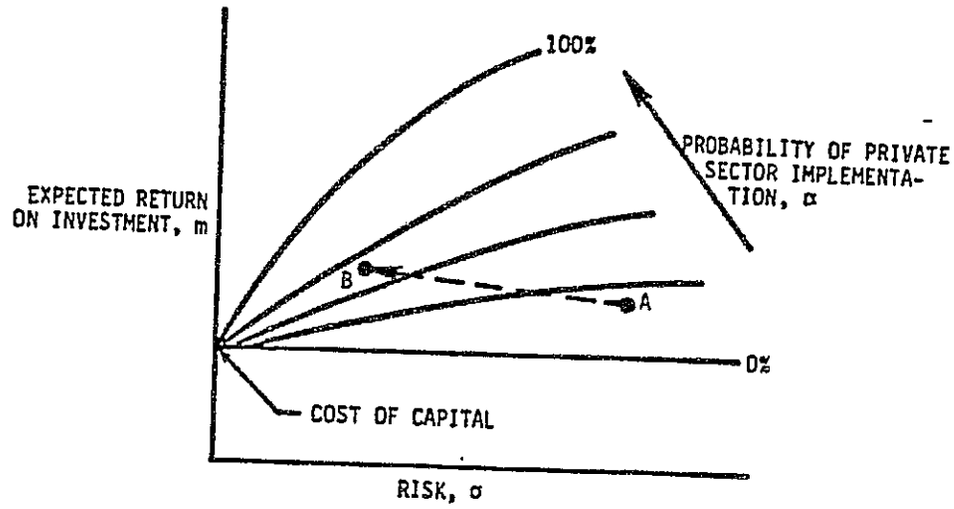


FIGURE B.10 PROBABILITY OF PRIVATE SECTOR IMPLEMENTATION (INVESTMENT) IN TERMS OF EXPECTED VALUE AND STANDARD DEVIATION OF RETURN ON INVESTMENT (UNREGULATED INDUSTRY)

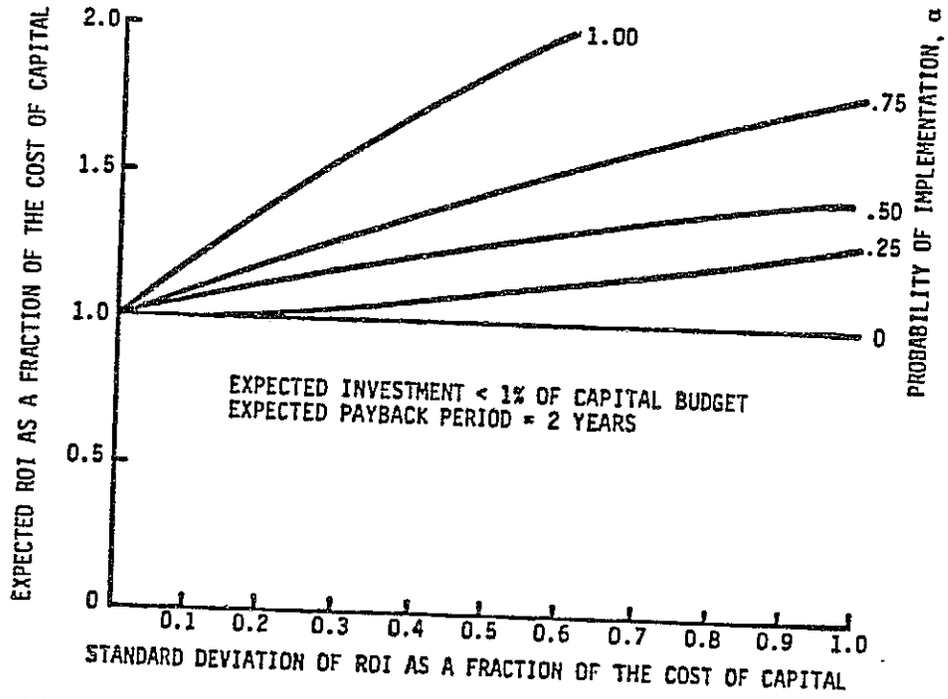


FIGURE B.11 PROBABILITY OF PRIVATE SECTOR (UNREGULATED INDUSTRY) INVESTMENT IN TERMS OF EXPECTED VALUE AND STANDARD DEVIATION OF RETURN ON INVESTMENT (PRELIMINARY DATA)

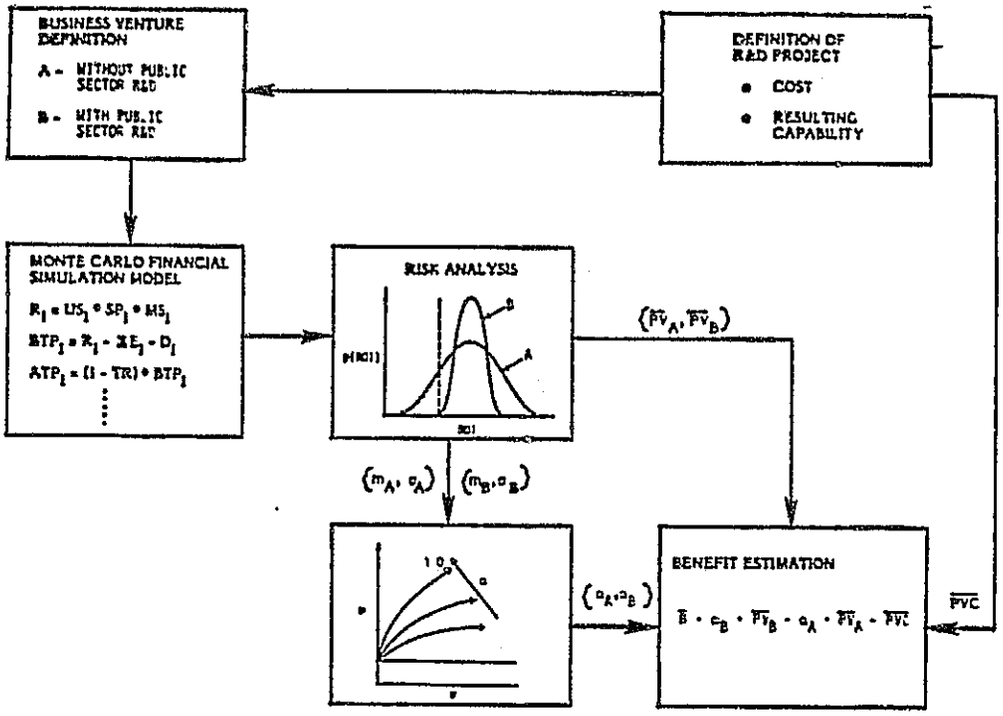


FIGURE B.12 GENERAL PROCEDURE FOR EVALUATING THE BENEFITS OF A PUBLIC SECTOR R&D OR INCENTIVE PROJECT IN SUPPORT OF THE PRIVATE SECTOR

the probability of private sector implementation be established in terms of expected and standard deviation of ROI where for each combination of m and σ there is a specific value of α, the probability of private sector implementation. A more general procedure for establishing the probability distribution of the benefits is illustrated in Figure B.13. In this case, PV_A, PV_B and PVC are described by probability distributions and for each combination of m and σ there is an associated probability distribution of private sector implementation, $p(\alpha)$.

In summary, if it is determined that the likelihood of private sector participation without public sector participation is inadequate, it is necessary to consider the form and scope of public sector participation which will promote the desired benefits. It should be noted that, since private sector unwillingness to participate is likely to be traced to a combination of large investment, long

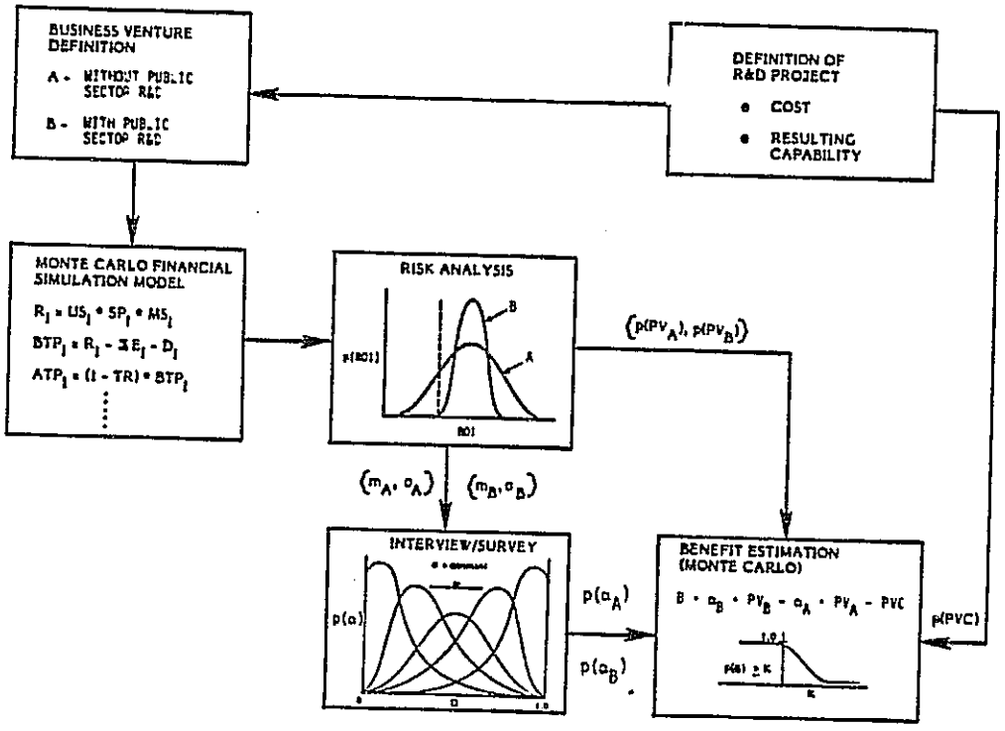


FIGURE B.13 ALTERNATIVE PROCEDURE FOR EVALUATING THE BENEFITS OF A PUBLIC SECTOR R&D OR INCENTIVE PROJECT IN SUPPORT OF THE PRIVATE SECTOR

payback period and high risk together with low expected rate of return, public sector participation should be aimed, as appropriate, at risk, investment and payback period reduction and at increasing the expected rate of return. The benefits of a public sector R&D or incentive program in support of the private sector are a function of how the program results affect private sector perceived risk and the probability of private sector investment in terms of risk.

B.5 An Example of Public Sector Benefit Estimation

The paragraphs that follow describe a methodology which relates benefits to the form of public sector participation (i.e., R&D and incentive programs) and the likelihood of private sector participation. Thus, by considering alternative forms of public sector participation, the R&D and incentive program can be established

that "maximizes" benefits which are the direct result of the R&D and incentive expenditures. Only the framework of the methodology is presented--the details remain to be filled in. To illustrate the concepts and methodology, the NASA goal of supporting research and development and incentive activities to develop the technology and create the environment leading to commercial systems that will provide public and other communications services on a continuing basis is considered.

The previous discussion concerned the evaluation of benefits associated with unregulated business ventures where the probability of investment was related to the probability distribution of ROI. The example discussed in the following paragraphs considers a regulated business venture. The basic concepts for the analysis are the same as those described previously with the exception that the probability of investment is related to the probability that the price of the good or service resulting from the investment will be less than the price of alternative goods or services.

As discussed previously, the benefits of a government R&D or incentive program aimed at the development of commercial services can be measured in terms of consumers' surplus and producers' surplus. When producers' surplus is based upon after-tax considerations (as it is herein), it is also necessary to establish the tax revenues generated by the private sector since these tax revenues mean (to a first order approximation) taxes which may be foregone by the consumer for the same level of public services. Thus, the benefits from a government R&D or incentive program may be measured as

R&D or Incentive Program Benefits = Present Value of Change in Consumers' Surplus + Present Value of Change in Producers' Surplus + Present Value of Tax Revenues Generated by New Commercial Ventures - Present Value of Cost of Government - R&D or Incentive Program. (2)

Since consumers' surplus depends upon price, it is necessary to establish the market price of the pertinent commercial communication services and the impact of the government R&D or incentive program upon these prices. To accomplish this, it is necessary to plan a commercial venture which may be the result of the government R&D or incentive program and establish the pro forma financial plans for the hypothetical communications supplier. It is assumed that there will be government regulation of private sector ventures that are the direct result of the government's R&D or incentive program specifically aimed at developing new and/or improved commercial services.

The specifics of today's regulations probably will influence future regulations but will probably not dictate them because of the changes that may occur within the communications sector during the next ten to fifteen or more years. It is assumed that there will continue to be government regulation and that the particular form of regulation will be related to imposing constraints on private sector return on investment. More specifically, it is assumed that a constraint will be imposed such that the present value of the positive cash flow stream will be equal to the present value of the negative cash flow stream at a specified after-tax discount rate. This is equivalent to specifying the allowable rate of return [13] and determining the pricing policy that will make possible the allowed rate.

The consumers' surplus benefits may be determined as follows. Figure B.14 illustrates the price/quantity relationship under conditions of equilibrium. The cross-hatched area represents the change in consumers' surplus due to a price reduction resulting from the new technology. The demand function is f(P), that is, the quantity of a service which will be consumed under equilibrium conditions at price P. Since equilibrium conditions are not expected to be achieved instantaneously, it is necessary to consider the quantity of service consumed as a

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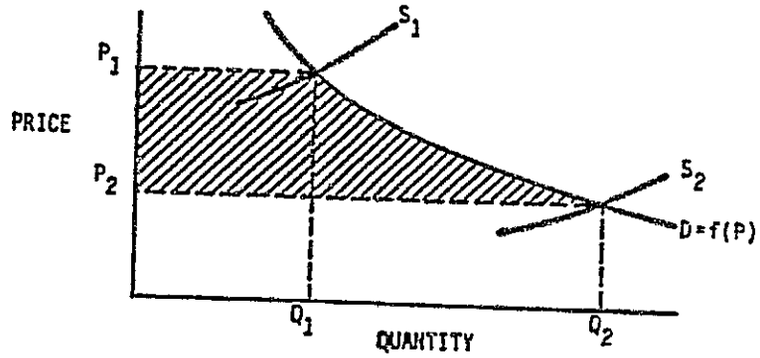

FIGURE B.14 PRICE/QUANTITY RELATIONSHIP (EQUILIBRIUM)

function of time, Q(t), given an instantaneous price change from P_1 to P_2. This is illustrated in Figure B.15. Figure B.16 illustrates the assumed functional relationship of the acceptance rate of the new service (i.e., the growth from Q_1 to Q_2). The quantity of service consumed as a function of time is given by

$$Q(t) = f(P_1) + \frac{[f(P_2) - f(P_1)]}{\sqrt{2\pi}\ \delta} \int_{-\infty}^{t} e^{-\frac{(T-x)^2}{2\delta^2}} dx. \qquad (3)$$

It is assumed that the demand function, D = f(P), can be established from in-depth analyses of specific application areas or through econometric techniques [15]. It is also assumed that the price of the service, (based upon current technology) P_1, is known or can be determined. Therefore, if P_2 can be established, then Q(t), the quantity which will be consumed as a function of time, can be established. The rate of acceptance of the service is controlled by the variables T and δ assuming a typical "S" shaped product or service type of market growth where

T = time required to achieve 50 percent of the change from Q_1 to Q_2 given a sudden price change from P_1 to P_2, and

δ = standard deviation of the normal curve which describes the growth of demand as a function of time from Q_1 to Q_2.

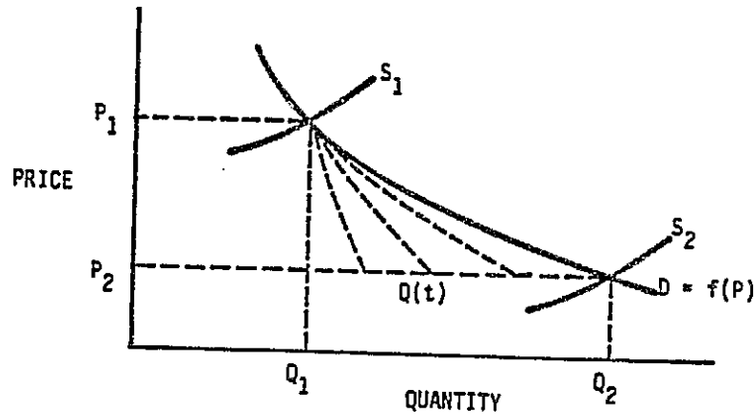

FIGURE B.15 PRICE/QUANTITY RELATIONSHIP (NON-EQUILIBRIUM)

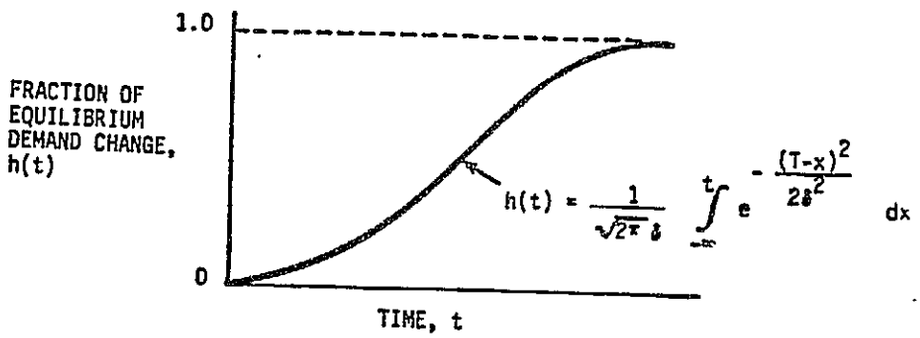

FIGURE B.16 FRACTION OF CHANGE IN EQUILIBRIUM DEMAND ACHIEVED AS A FUNCTION OF TIME

P_2 can be established from profit, cash flow and present value considerations as follows. After tax profit, ATP'_t, is established by subtracting expenses from revenues:

$$ATP_t' = [1-TR/100] * [REV_t - OE_t - ENG_t - GA_t - DEP_t - INT_t] \qquad (4)$$

where

TR = tax rate (percent)

REV_t = revenue in year t

OE_t = operating expenses in year t

ENG_t = engineering and R&D expenses in year t

GA_t = general and administrative expenses in year t

DEP_t = depreciation expenses in year t

INT_t = interest and debt service expense in year t.

ATP_t' represents the "bottom line" values which normally appear in pro forma income statements.

When decision making relies upon present value determinations, interest or debt service expense should not be included when determining cash flows. Its inclusion would lead to double counting. It should be noted that the internal rate of return (return on investment) is the discount rate which makes the net present value of an investment equal to zero. It represents the highest rate of interest an investor could afford to pay, without losing money, if <u>all</u> the funds to finance the investment were borrowed and the loan (principal and accrued interest) was repaid by application of the cash proceeds from the investment as they are earned.

Therefore, the applicable after-tax profit, ATP_t, contribution to cash flow is given by:

$$ATP_t = [1-TR/100] * [REV_t - OE_t - ENG_t - GA_t - DEP_t] \quad (5)$$

and the annual cash flow, CF_t, is given by

$$CF_t = ATP_t + DEP_t - CE_t + \Delta BAL_t \quad (6)$$

where

CE_t = capital expenditures in year t (it is these expenditures which determine DEP_t), and

ΔBAL_t = the net change, from the year t-1 to year t, in the balance sheet items such as receivables, payables and others.

The indebtedness, IND_t, is determined as:

$$IND_t = - \sum_{i=1}^{t} CF_i. \quad (7)$$

The interest expense can thence be established (to a first order approximation) based upon the previous year's indebtedness* as:

$$INT_t = IR * IND_{t-1}/100. \tag{8}$$

where

IR = interest rate on indebtedness (percent).

As stated previously, the objective is to establish a price, P_2, such that

$$PV = \sum_t \frac{CF_t}{[1+DR/100]^{t-1}} = 0 \tag{9}$$

when the discount rate, DR, is specified. It is thus necessary to determine the value of P_2 which satisfies the above. This may be accomplished by an iterative procedure as follows, noting that REV_t is a component of CF_t, $REV_t = P_2 * Q(t)$, Q(t) is a function of P_2, and various expense items and expenditures may also be functions of Q_2 and Q(t):

1. Select an initial or starting value of P_2
2. Compute REV_t
3. Compute values of all expense items, capital expenditures and balance sheet items
4. Compute ATP_t and CF_t for all t in the time horizon
5. Compute PV at specified discount rate (DR)
6. If $|PV| \leq k$,** then terminate iteration procedure and go to step (8)
7. If $|PV| > k$,** then select new value of P_2 and continue from step (2)
8. Compute consumer surplus benefits.

*Relating interest expense to current year's indebtedness implies an iteration process.

**k is a small number and reflects the desired accuracy of the iteration process.

The annual consumers' surplus benefits, CS_t, are therefore obtained from:

$$CS_t = \int_{P_1}^{P_2} f(P) * h(t) * dP. \tag{10}$$

Some comments are necessary about the discount rate. The discount rate is the cost of capital of the private sector. Because social costs of public expenditures should reflect true opportunity costs of utilizing otherwise employable or potentially employable resources of the private sector, it is necessary to charge to public projects the opportunity cost of capital diverted from the private sector to the public sector. That is, it is required that public sector investments yield at least the social return over time that would otherwise be earned by these funds in the private sector from which they must be withdrawn. This requirement is met in the benefit-cost analysis by selecting an opportunity cost rate-of-return for the purpose of discounting social costs and benefits associated with the public project [1].

In the previous paragraphs a general methodology was described for establishing the net public sector benefits and the private sector benefits due to private sector commercialization resulting from a public sector R&D or incentive program. A major question still remains to be answered: Will the private sector make the decision to invest in the desired business ventures as a result of the public sector R&D or incentive program? To answer this question requires the consideration of how the private sector will react to uncertainty and risk and exposure and how the government R&D or incentive program can affect private sector decisions through uncertainty and risk reduction and reduction of private sector exposure.

When dealing with the introduction of new products or services, there exist many areas of uncertainty which contribute to private sector perceived risk. A

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major area of uncertainty is the marketplace, that is, the demand function. In the previous paragraphs, D as well as all of the other variables have been considered as deterministic quantities. In actuality, many are and should be treated as probabilistic quantities (i.e., random variables). It is necessary to describe D (i.e., f(P)) as a probability distribution as well as all other important variables (i.e., T, δ, all unit costs, etc.). A typical probabilistic demand function is illustrated in Figure B.17 and may be established by making subjective estimates of the variability of demand at a number of prices. D_1, D_2, ..., D_6 represent different levels of demand, with D_1 representing the minimum demand estimates and D_6 the maximum demand estimates. The intermediate curves are drawn such that at any price level P there is a constant probability, P_i, that the demand will be between D_i and D_{i+1}. A typical resulting probability density function at price P is also illustrated in Figure B.17. It should be noted that one of the major objectives of an R&D program should be to narrow down or better define this probability density function. A general procedure for making subjective probability assessments is described in Reference 12.

The computed variables such as OE_t, DEP_t and others also need to be described as probability distributions since their values are determined to a large extent by launch system reliability, spacecraft performance and reliability, subsystem cost uncertainties, ground terminal cost uncertainties, etc. References 12, 16 and 17 describe techniques for establishing the probability distributions of the computed variables. In particular, Reference 17 describes a probabilistic model of a domestic communication satellite business venture. Since this model is probably typical in character and complexity to those required for evaluating other space-related business ventures, it is briefly described in the following paragraphs.

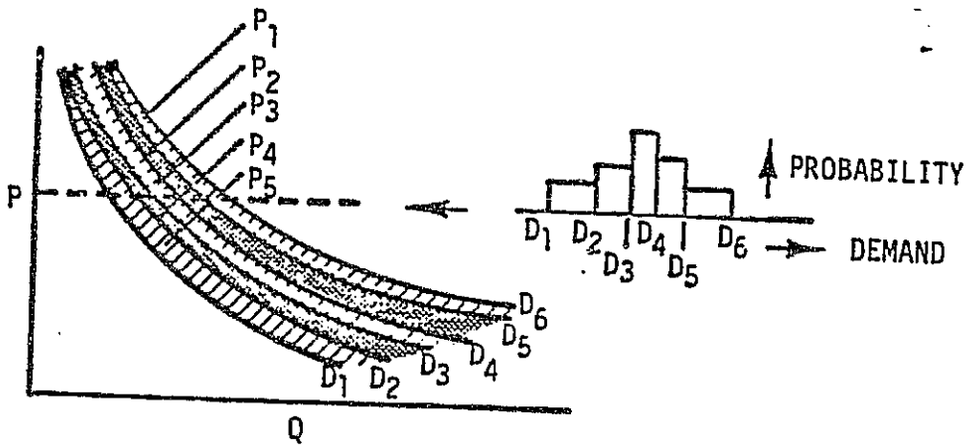

FIGURE B.17 PORTRAYAL OF DEMAND UNCERTAINTY

The mathematical model represents a generalized domestic satellite communications mission under conditions of uncertainty and provides output information as probability distributions, expected values and standard deviations which reflect the uncertainty in the input data and the impact of unreliability. Uncertainty data are specified as bounded probability distributions which represent subjective estimates [11,12] of the possible values of pertinent parameters. The model consists of:

- An operational section which simulates and records the performance and operational events such as system failures, launch attempts, satellites employed and communications system performance. The impact of using alternative systems and technologies, for example the satellite power subsystem, is registered through its effect on the simulated operation of the communication service.
- A financial section which establishes the annual revenues, expenses, profit, cash flow, etc., resulting from communication services.
- A market section which simulates the market environments surrounding the communication services and contains the decision processes which dictate the response of the communication service operation to the market model. The communications marketplace is considered to be a known though probabilistic function of time consisting of a mix of guaranteed* and nonguaranteed channels.

*Guaranteed in the sense that a contract exists which guarantees the availability of the channels.

The output financial information is presented in the form of probability distributions describing quantities such as annual revenue, after-tax profit, cash flow, indebtedness and present value of cash flow. Additional information such as certain expense items are presented as expected annual values. Quantities of interest relating to the operational aspect, such as the number of launch attempts, number of satellites required, number of propulsion systems and satellites refurbished, are also available in the form of probability distributions.

The model provides a mechanism for establishing the value of new or improved technology and operational alternatives. It also provides a mechanism for evaluating the impact of uncertainty (and hence risk) reductions resulting from the undertaking of R&D programs. The impact of uncertainty reductions and launch system and technology changes can be observed and evaluated in terms of financial measures such as annual profit, cash flow, net present value, etc. The following provisions are included in the model:

- Specification of the launch system to be used including the price of the service as a function of time and the technologies employed (type of orbit injection system used and ability to refurbish)
- Consideration of reliability of the launch system at the major subsystem level
- Spacecraft failure model which allows for initial random and wearout failures
- Communications repeater failure model which allows for random and wearout failures
- Repeater redundancy between satellites based upon frequency-wise corresponding repeaters on separate satellites to provide a mutual backup facility
- Consideration of demand for communications over the time period of concern in a form of an annual demand input
- Consideration of a mix of guaranteed and nonguaranteed communications demand

- The incorporation of decision rules and threshold criteria which dictate the response of the communication system to the demand function. Of particular importance is the decision to initiate launching additional satellites to maintain the service.

The model determines the probability distributions of:

- Annual revenue
- Annual profit (loss)
- Annual cash flow
- Quantities pertinent to the service operations such as number of launch attempts, number of satellites purchased, number of propulsion modules refurbished and others
- Present value at several different discount rates.

Thus, it is necessary to establish the pro forma financial plans in a probabilistic sense so that risk can be established explicitly and quantitatively. This can be accomplished by simulating the business venture and the benefit computations (as described above) in a Monte Carlo fashion with P_2 being a derived random variable. Recalling that P_2 is the price that must be charged for the communications service which yields a net present value of zero at an allowed discount rate (equivalent to the internal rate of return), it can be seen that the probability of $P_2 \geq P_1$, as obtained by the Monte Carlo simulation, is a measure of the risk associated with the regulated private sector venture since presumably, if a lower price (than P_1) is not possible, there cannot be an attractive commercial venture. The probability that $P_2 \geq P_1$ is related to the likelihood that the venture will not be entered into by the private sector. This, in turn, is the probability that the consumer surplus benefits are zero. The probability distribution of consumer surplus benefits can also be determined from the Monte Carlo simulations.

When performing the Monte Carlo simulation, it should be noted that when $P_2 < P_1$, <u>then</u>

$$PVCS = \sum_t \frac{CS_t}{(1+GDR/100)^{t-1}}$$

$$PVPS = \sum_t \frac{PS_t}{(1+GDR/100)^{t-1}} \qquad (11)$$

$$PVTR = \sum_t \frac{TRB_t}{(1+GDR/100)^{t-1}}$$

<u>when</u> $P_2 \geq P_1$, <u>then</u>

$$PVCS = 0$$

$$PVPS = 0$$

$$PVTR = 0. \qquad (12)$$

In the above,

CS_t = annual consumer surplus benefits

PS_t = annual producers' surplus benefits

TRB_t = annual tax benefits

PVCS = present value of consumers' surplus benefits

PVPS = present value of producers' surplus benefits

PVTR = present value of tax benefits

GDR = government discount rate (percent).

The above methodology will result in an assessment, from the private sector's point of view, of the probability that $P_2 \geq P_1$. This can be accomplished in terms of specific alternative public sector R&D and incentive programs, the objectives of which must be clearly identified as the anticipated change in the uncertainty profiles of the input data to the venture analysis.

The impact of an R&D or incentive program can be evaluated in terms of its impact on the subjective assessments of the various uncertainty variables and on the overall system configuration and performance. The effect of the changes in

the subjective assessments can thence be measured in terms of the probability $P_2 \geq P_1$ and the direct impact on the consumers' surplus benefits.

As discussed previously, it is necessary to estimate the a priori probability of achieving different specific outcomes or capability levels which may result from the R&D and incentive programs. This is not an easy task since it requires prejudging the results of the R&D and incentive programs. It should be noted that not providing these assessments is tantamount to stating that the outcomes of the R&D and incentive programs are known with certainty. It is also necessary to translate the impact of the R&D and incentive program outcomes to the probability distributions of related input paramaters of the private sector venture analysis (for example, the demand function uncertainty assessments). The specific impact of the R&D and incentive programs may be expressed in terms of the estimated percent reduction, f, in the standard deviation, δ, of the uncertainty estimate which was made in the absence of the R&D or incentive program [18]. The resulting probability distribution may then be considered as being normal with the same expected value (as the original subjective uncertainty estimate) but with a standard deviation equal to $\delta/(1+f)$.

From the assessment of the probability that $P_2 \geq P_1$, and other related factors such as maximum required investment and payback period, a decision will be made by the private sector as to whether or not to establish a commercial venture. The decision will obviously depend upon the magnitude of this probability measure, which in turn depends upon the public sector R&D or incentive program (refer to Figure B.18). Therefore, it is also necessary to establish the probability of private sector implementation in terms of the perceived probability of $P_2 \geq P_1$ and the expected exposure and payback period. This is the regulated industry counterpart of the unregulated industry assessment indicated in Figures B.10 and

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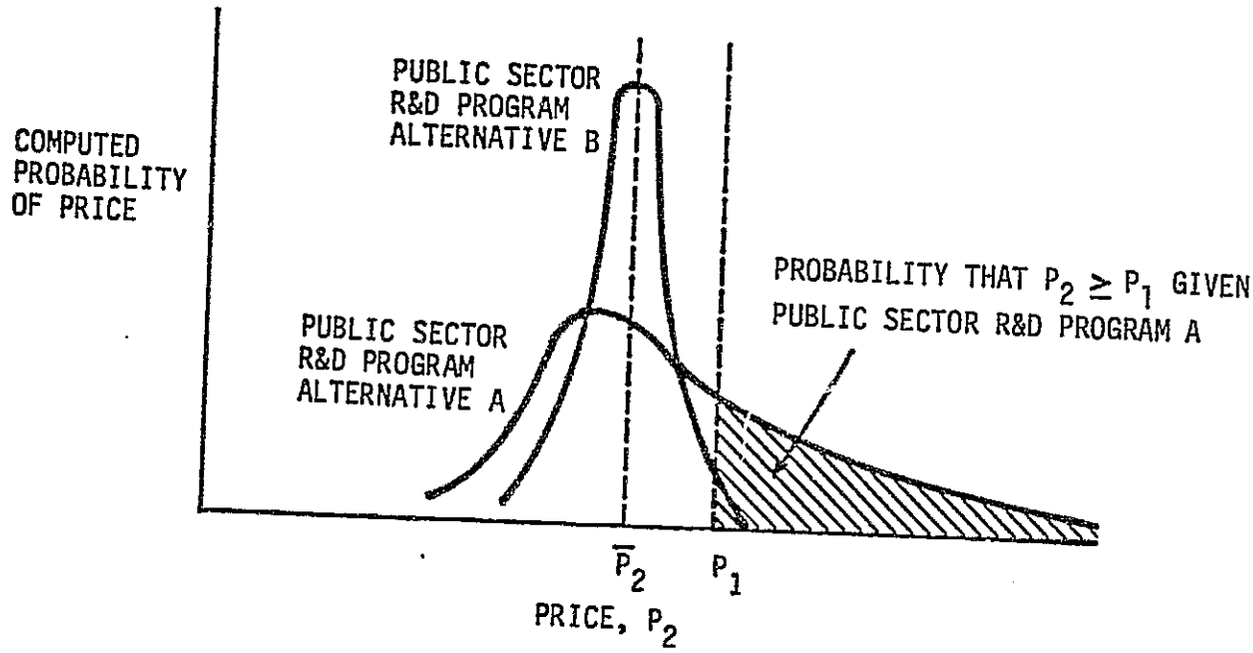

FIGURE B.18 COMPUTED PRICE (P_2) PROBABILITY DISTRIBUTIONS WITH DIFFERENT PUBLIC SECTOR R&D PROGRAMS

B.11. In other words, it is necessary to establish, through interview/survey techniques, the probability of private sector implementation in terms of the expected value and standard deviation of the probability distribution of $P_2 - P_1$.

Therefore, a probability of implementation given the probability that $P_2 \geq P_1$, $p(I|p(P_2 \geq P_1))$, can be established in terms of the probability of $P_2 \geq P_1$. The expected net public sector benefits from a government-funded R&D or incentive program are thus given by (for the regulated business ventures):

$$\text{Expected Net Public Sector Benefits} = p(I|p(P_2 \geq P_1) * [\overline{PVCS} + \overline{PVPS} + \overline{PVTR}] - \overline{PVRD}. \quad (13)$$

It should be noted that PVCS, PVPS, PVTR, are computed random variables as previously defined. PVRD, the present value of the public sector R&D or incentive program cost, is also a computed random variable. $\overline{PVCS}$, $\overline{PVPS}$, $\overline{PVTR}$ and $\overline{PVRD}$ are the expected present values of consumers' surplus benefits, producers' surplus

benefits, tax benefits and public sector R&D or incentive program costs, respectively.

The present value of the incremental tax stream generated by the private sector venture may be established as previously discussed by noting that TRB_t is given by

$$TRB_t = [REV_t - OE_t - ENG_t - GA_t - DEP_t - INT_t] - ROS_t * [REV_t + P_1 * Q_1] \quad (14)$$

where ROS_t is the computed after-tax return on sales of the private sector venture. The present value of the tax benefits, PVTR, and its expected value, $\overline{PVTR}$, can thence be established.

The final benefit area is concerned with estimating the producers' surplus benefits, PS_t. In order to establish the producers' surplus benefits as the change in producers' surplus resulting from the public sector R&D or incentive program, it is necessary to establish the shape of the supply curves (AB and DC in Figure B.3). Since this is an extremely complex task and possibly too detailed relative to the other parts of the analysis, it is reasonable to approximate the producers' surplus benefits. A reasonable approximation might be to assume that the return on sales will be comparable for similar types of ventures (for example, communications) established with and without the benefit of a public sector R&D or incentive program. Therefore

$$PS_t = ROS_t * (REV_t - P_1 * Q_1) \quad (15)$$

and the present value of producers' surplus benefits, PVPS, and its expected value, $\overline{PVPS}$, can thence be established.

B.6 Summary

An attempt has been made to develop the framework of a methodology which will lead to the quantitative evaluation of the net public sector benefits which may result from a public sector R&D or incentive program. The specific public sector R&D or incentive program of concern is that of developing the technology and creating the environment that will lead to the development of commercial businesses that will provide new and/or improved goods or services on a continuing basis. This implies that benefits from, and hence the value of, the public sector R&D or incentive program will result only if there is private sector (or public sector) implementation of the new and/or improved goods or services. In particular, the methodology develops the social benefits as the change in consumers' surplus and producers' surplus which are a direct result of the public sector sponsored R&D or incentive program. The change in consumers' and producers' surplus is the result of price reductions in the private sector brought about by private sector decisions and resulting technology implementations affected by the public sector R&D or incentive programs. It is argued that the public sector R&D or incentive program should be designed specifically to reduce private sector perceived uncertainty and risk and exposure since its value is derived from its impact on private sector decisions. This means that it is necessary to understand the private sector ventures that may result and the areas of uncertainty and resulting risk, and how private sector decision makers may react relative to level of risk.

The developed methodology is that of a strategic approach with much of the tactical details omitted. The basic concept is to design and select that R&D or incentive program which maximizes the present value of the net public sector benefits. The net public sector benefits are measured in terms of consumers'

surplus, producers' surplus and additional tax revenues* from the private sector venture.

When a regulated business venture is considered, it is necessary to determine the price of the services to be provided by the private sector venture. A pricing policy is considered such that the price per unit of service makes the net present value of the cash flow of the private sector equal to zero at a specified (regulated) rate of return (the internal rate of return).

Since there are many areas of uncertainty which affect the perceived risk (a measure of risk is the probability that the new and/or improved products or services that would result from the public sector R&D or incentive program would have to be priced higher than existing prices in order to generate the required rate of return), it is necessary to treat the analysis on a probabilistic basis, utilizing, for example, Monte Carlo simulation techniques. Thus, the life-cycle costs and revenues of the private sector venture can be ascertained on a probabilistic basis and likely private sector decisions pertaining to the venture can thence be assessed.

For the nonregulated business ventures, it is necessary to establish the probability of private sector implementation in terms of the expected and standard deviation of ROI and expected exposure and payback period. For the regulated business venture, it is necessary to establish the probability of private sector implementation in terms of the expected value and standard deviation of the probability distribution of the price change resulting from the R&D or incentive program. These implementation probabilities can be established through the use of interview/survey techniques.

*When producers' surplus is measured on an after-tax basis.

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APPENDIX C

THE METHOD OF BEST COMPROMISE

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APPENDIX C

THE METHOD OF BEST COMPROMISE

In using the method of best compromise to aid in project selection, see Figures C.1 and C.2, projects are described in terms of their resource requirements, C_{ijkt}, where C_{ijkt} is the magnitude of the kth type of resource required by the jth variant of the ith project in year t, and in terms of benefits, b_{ijmt}, where b_{ijmt} is the magnitude of the mth type of benefit obtained from the jth variant of the ith project in year t. The control variable of the optimization is x_{ij} where if $x_{ij} = 0$, the jth variant of the ith project is not chosen and if $x_{ij} = 1$, it is chosen. x_{ij} is subject to the constraint that $0 \leq x_{ij} \leq 1$ and possibly also $x_{ij} = 0$ or 1. Clearly, in using this algorithm, it is necessary to determine appropriate and consistent measures of costs and benefits. The project selection is subject to a set of resource constraints given by A_{kt} where A_{kt} is the magnitude of available resource of type k in year t. Thus, the objective is to simultaneously maximize the NPV of benefits B_m, of types m, given by

$$B_m = \sum_i \sum_j \sum_t \frac{x_{ij} b_{ijmt}}{(1+r_m/100)^t}$$

where r_m is the discount rate used, subject to the resource constraints:

$$\sum_i \sum_j x_{ij} C_{ijkt} \leq A_{kt}$$

In general, however, it is not possible to find a solution that maximizes B_m for all m. Realizing this, it is then desired to make the best compromise as follows. First, solve the optimization problem treating B_1 as the only objective

PROJECT	RESOURCE REQUIREMENTS(c_{ijkt})						BENEFITS(b_{ijmt})						VALUE
	1	2	3	4	•	•	1	2	3	4	•	•	
1,1	c_{1111} c_{1112} c_{1113}		c_{1131} c_{1132}				b_{1115} b_{1116}						V_{11}
1,2	c_{1211} c_{1212} c_{1213}		c_{1231}				b_{1215} b_{1216}						V_{12}
1,3													V_{13}
2													V_2
⋮							↓	↓	↓	↓			⋮
							B^*_1	B^*_2	B^*_3	B^*_4	•	•	$\bar{V}$

FIGURE C.1 AN APPROACH TO R&D PROGRAM FORMULATION

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- PROJECTS ARE DESCRIBED IN TERMS OF
  - RESOURCE REQUIREMENTS, c_{ijkt}
  - BENEFITS, b_{ijmt}

FIRST

- MAXIMIZE $B_m^* = \sum_i \sum_j \sum_t \frac{x_{ij} b_{ijmt}}{(1+r/100)^t}$

- SUBJECT TO THE CONSTRAINT

$$\sum_i \sum_j x_{ij} c_{ijkt} \leq A_{kt}$$

$$\sum_j x_{ij} \leq 1$$

$$0 \leq x_{ij} \leq 1$$

THENCE

- MINIMIZE TOTAL REGRET $R = \sum_m W_m R_m$

  WHERE

$$R_m = \frac{B_m^* - B_m}{B_m^*}$$

FIGURE C.2 THE METHOD OF BEST COMPROMISE

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function. Denote max (B_1) subject to resource constraints by B_1^*. Then, successfully, solve for B_2^*, B_3^*, etc. The set of values B_1^*, B_2^*, B_3^*, ... represents the maximum benefit of each type obtainable and defines a desired set of projects for each m. It is now desired to select the best compromise set of projects from amongst the total project set. To accomplish this a regret function, R_m, is defined as

$$R_m = \frac{B_m^* - B_m}{B_m^*}$$

and the total regret as the weighted sum of regrets of type m,

$$R = \sum_m w_m R_m$$

where the w_m represent weighting factors that indicate the preferences of the decision make for achieving the various m benefits. The objective of the method of best compromise is now to select that subset of projects that minimizes the total regret subject to the resource constraints.

Techniques such as the method of best compromise seek to provide a structure for the decision maker in which he can exercise his own preferences and which also aid in a rational selection of projects within the present and expected resource constraints.

APPENDIX D

SUMMARY OF A LIFE CYCLE COST MODEL (SATIL)

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APPENDIX D

SUMMARY OF A LIFE CYCLE COST MODEL (SATIL)

A simulation model has been developed to assist with the programmatic evaluation of alternative approaches to establishing and maintaining a specific desired mix of operational sensors on spacecraft in geocentric orbits. The program enables the assessment of the effects of operational requirements and reliability (spacecraft support subsystems, sensors and transportation systems) on the time-phased costs of alternative approaches to satisfying mission requirements. The program is specifically designed to allow for the explicit consideration of reliability and cost uncertainties. In order to perform this evaluation, the launch systems and spacecraft (support systems* and sensors) are considered in detail from the points of view of reliability and cost. All costs are treated as uncertainty variables where ranges of possible values are considered as well as subjective estimates pertaining to the form of the uncertainty (the probability distribution) within the range. The input to the program consists primarily of a set of numbers which describes the demand for various operational sensors in orbit as a function of time, the mix of sensors available per spacecraft type, the transportation system to be used for each spacecraft type as a function of time, spacecraft subsystem, sensor and transportation system reliability, subsystem and sensor nonrecurring costs including cost spreading and explicit quantitative uncertainty assessments, spacecraft and transportation system costs including explicit quantitative uncertainty assessments and cost learning rates. The output from the simulation program consists of a set of probability distributions associated with costs and events (i.e.,

*The group of support systems is frequently referred to as the spacecraft bus.

number of launch attempts, etc.) as functions of time and the probability distribution of the present value of total recurring plus nonrecurring cost.

The reliability, uncertainty and risk assessment capability embodied in the simulation model allows for:

- Specification of the mix of operational sensors required in geocentric orbits as a function of time.
- Consideration of multiple spacecraft which are defined in terms of the reliability of the major support subsystems, the mix of on-board sensors and their reliability and spacecraft cost.
- Consideration of spacecraft subsystem and sensor failure models which allow for both random and wearout failures.
- Specification and consideration of multiple transportation systems which may consist of current or new expendables or the Space Shuttle. The transportation systems may also include (as necessary) orbit-to-orbit shuttles or propulsion modules (for example, Agena, Centaur, Space Tug, etc.). The propulsion modules may be expendable or reusable and may be used for placing spacecraft in orbit and retrieving spacecraft which fail and require replacement. The specification of the transportation systems include cost and reliability assessments. Reliability is considered at the major subsystem level.
- Specification of transportation systems to be utilized for placing different spacecraft into orbit as a function of time. Changing the specification of transportation system-spacecraft assignment as a function of time allows performance capability (such as allowable mission modes and reliability) and cost variations to be considered.
- Explicit consideration of multiple time periods thus allowing for annual costs to be established.
- Consideration of cost learning curves.
- All costs to be treated as uncertainty variables.

The simulation model, taking into account the required number of sensors as a function of time, number of operational sensors in orbit (as determined from spacecraft subsystem and sensor reliability characteristics) and spacecraft and launch costs, determines a near optimal mix of spacecraft launches as a function of time. Since the simulation is based upon Monte Carlo techniques, it is possible to

establish the probability distributions of pertinent performance measures, which allows alternatives to be compared by considering both expected values of performance measures and the chance of variation (i.e., the risk) of the value of the measures. Specifically, the simulation model establishes the probability distributions of:

- Pertinent quantities by year (for example, number of launch attempts, number of spacecraft required, number of propulsion modules required, number of propulsion module refurbishments, etc.)
- Launch, spacecraft and total costs by spacecraft type and by year
- Bus and sensor nonrecurring costs
- Present value of recurring plus nonrecurring costs.

APPENDIX E

A GLOSSARY OF FINANCIAL AND ECONOMIC TERMS

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APPENDIX E

A GLOSSARY OF ECONOMIC AND FINANCIAL TERMS

After tax profit - Before tax profit less payments made for federal income taxes.

Before tax profit - Difference between revenue from sale of goods and services in a specified time period less the expenses associated with generating the revenue. The expenses include depreciation.

Benefit/cost ratio - (also called profitability index) present value of the stream of net cash flows (see cash flow and Figure E.1), B_t, divided by the present value of the stream of net cash outflows, C_t, as expressed by:

$$\sum_{t=1}^{n} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=1}^{n} \frac{|C_t|}{(1+r)^t}$$

where B_t = net cash inflow (benefits) in period t and is zero when there is a net cash outflow, C_t = net cash outflow (costs) in period t and is zero when there is a net cash inflow, and r = discount rate or cost of capital expressed as a decimal. B_t represents positive cash flows and C_t represents negative cash flows.

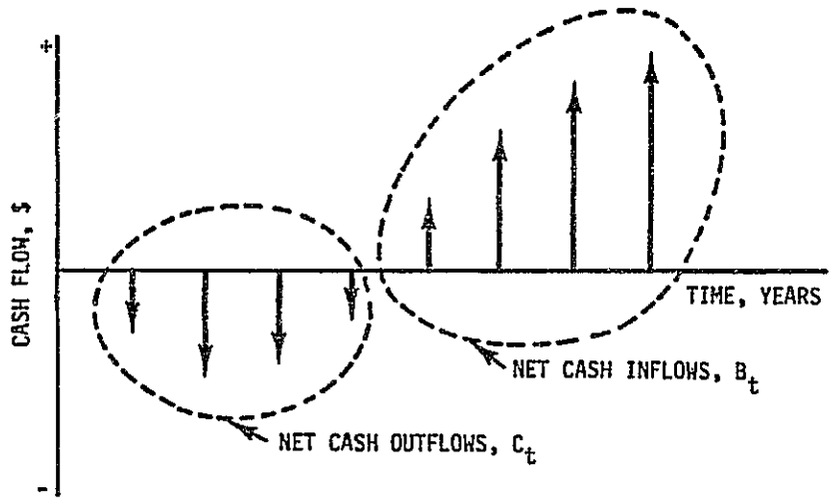

FIGURE E.1 CASH FLOW AS A FUNCTION OF TIME

Capital expenditures - Funds expended for fixed (tangible) assets such as land, buildings, equipment and intangible assets such as patents that are used in the conduct of business for an extended period of time (i.e., in excess of one year).

Cash flow - Cash flow in time period t is the difference between cash inflow and cash outflow. Cash inflow is represented by after tax profit, depreciation and

increase in payables. Cash outflow is represented by losses, capital expenditures, increases in inventories and increases in receivables. Cash flow is positive when inflow exceeds outflow and negative when outflow exceeds inflow. The time period, t, is usually one year.

Consumer surplus - Difference between amounts consumers are willing to pay and amounts consumers actually pay to acquire a specific quantity of a good or service. In Figure E.2, linear supply and demand functions are indicated. At price P_o consumers buy quantity Q_o. They pay $P_o \times Q_o$, but they would be willing to aggregately pay an additional amount of $P_m \times Q_o/2$, if it were possible to sell to each consumer at the highest price that consumers would pay. Consumer surplus is defined as $P_m \times Q_o/2$ in this example (the shaded area). The change in consumer surplus as a result of a shifting in the supply or demand curves as a result of a new technology (or policy) is a measure of the economic impact.

Consumption related pricing mechanism - Pricing that takes into account the fact that higher prices will decrease sales and lower prices will increase sales. There is a relationship between the providers and consumers of goods and/or services such that the price can be established and payments collected.

Demand - The total amount of a good or service that will be bought at a particular price. The set of all prices and their corresponding demand, as illustrated in Figure E.3, will usually show that demand rises when prices fall.

Depreciation - An expense item which aims to distribute the cost of tangible capital assets, less salvage (if any), over the estimated useful life of the unit in a systematic and rational manner. It attempts to match the annual cost (expense) of the asset with the consumption of the asset. There are several methods for calculating depreciation, including straight-line methods (where depreciation is the same each year) and accelerated methods (where depreciation is greater at the beginning).

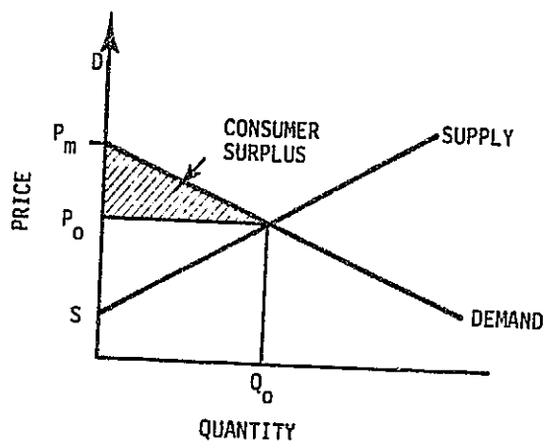

FIGURE E.2 CONSUMER SURPLUS

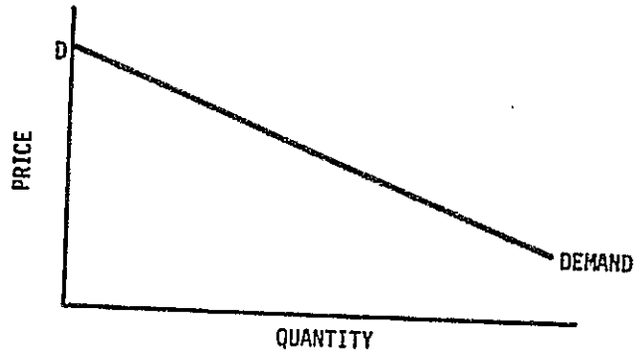

FIGURE E.3 DEMAND CURVE

Discount rate - An effective interest rate used in investment analysis to reflect the fact that a dollar spent (or earned) in the future has less value than a dollar spent (or earned) in the present. The discount rate represents the cost of capital utilized in the venture to be undertaken. See Internal Rate of Return and Net Present Value.

Earnings - After-tax profit.

Histogram - A representation of a frequency distribution by means of rectangles whose widths represent class intervals and whose heights corresponding frequencies. This is indicated in Figure E.4 which illustrates a histogram of men's heights, with midpoints of a cell every three inches.

Internal rate of return - The value of the discount rate which makes the present value equal to zero. It is the rate r, such that

$$\sum_{t=0}^{n} \left[\frac{A_t}{(1 + r)^t} \right] = 0$$

where A_t is the cash flow in period t, n is the last year of the project's life. A typical present value, discount rate relationship is shown in Figure E.5 with the internal rate of return indicated.

Inventories - Unsold stored goods.

Life cycle costs - All costs insured from the beginning until the end of a project (includes both non-recurring and recurring costs).

Monte Carlo - Implies the repetition of a modeled experiment, sequence of events, physical process, etc., whose component outcomes are probabilistic, a sufficient number of times to generate a "smooth" profile or histogram of all possible outcomes (for example, the actual or simulated rolling of two die a large number of times to obtain the histogram and probability distribution of the sum of the outcomes of each die). It is a simulation technique often used in risk analysis problems where the assumed probability distributions of the financial input

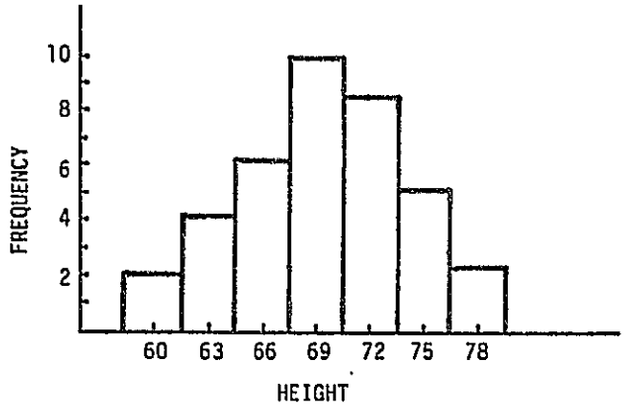

FIGURE E.4 TYPICAL HISTOGRAM

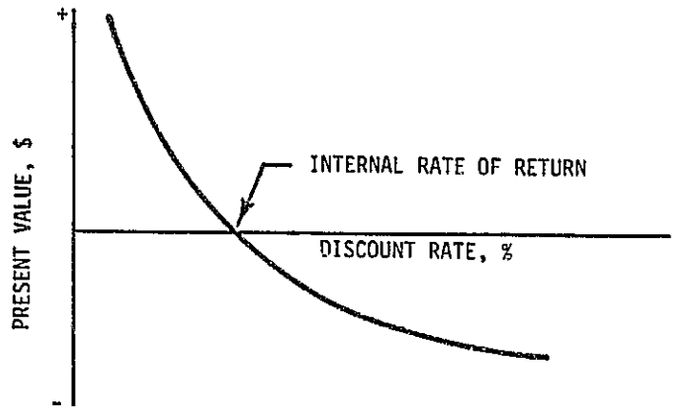

FIGURE E.5 TYPICAL PRESENT VALUE, DISCOUNT RATE RELATIONSHIP

variables are sampled using a random number table. This process is repeated many times with different sets of sampled values to analyze the behavior of the venture under a variety of conditions.

Net cash infow - The excess of cash inflow over cash outflow in time period t (refer to Figure E.1).

Net cash outflow - The excess of cash outflow over cash inflow in time period t (refer to Figure E.1).

Net present value - The stream of future cash flows discounted to the present. The discounting is accomplished using a discount rate that is equal to the cost of capital or a required rate of return. Net present value is obtained from

$$NPV = \sum_{t=0}^{n} \frac{A_t}{(1 + r)^t}$$

where A_t is the cash flow in period t, r is the discount rate, n is the number of time periods.

Payables - Expenses which have been incurred but have not been paid (for example, salaries owed for work performed).

Payback period - The number of years required to pay back an investment. It is the time required for cumulative net cash inflows to equal cumulative net cash outflows.

Present value of cash flow - The value of the cash flow stream discounted to the present (see net present value).

Producer's surplus - The difference between total revenues and total costs as shown graphically as the cross-hatched area in Figure E.6

Receivables - Revenue that is due but not yet received (for example, delayed payments for the purchase of a good or service through the use of a charge card).

Return on assets - Net after tax profits divided by total book value (purchase price less accumulated depreciation) of assets.

Return on investment - The rate of return that makes the present value of cash flow equal to zero. This is then a discounted return on investment equivalent to the internal rate of return.

Sales volume - Amount of goods sold within time period t.

Simple rate of return - (also called accounting rate of return) The expected average annual net income from an investment divided by either initial investment or average investment over the life of the venture. This rate of return does not take into account the timing of the payments.

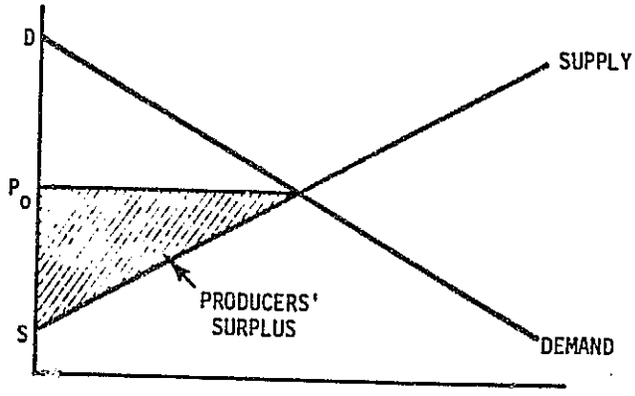

FIGURE E.6 SUPPLY/DEMAND CURVES AND PRODUCERS' SURPLUS

Social benefits - The benefits of a program or a project measured at the level of society as a whole, rather than at the level of a subset of society such as a particular governmental entity or a firm. Social benefits consist of all benefits conferred upon the private parties to a transaction plus the benefit conferred upon all other parties by the transaction.

Supply - The total amount of a good or service that is provided at a particular price to the consumer. A typical supply curve (the set of prices and corresponding supply quantities) is shown in Figure E.7 and indicates that supply rises when prices increase.

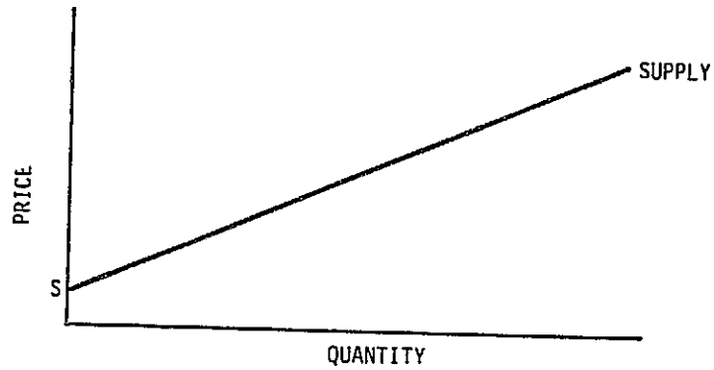

FIGURE E.7 SUPPLY CURVE