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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-176104

June 15, 1972

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Dear Mr. Miller:

As the result of a series of meetings between our staffs, the General Accounting Office undertook a study to identify those National Aeronautics and Space Administration (NASA) programs susceptible to cost-benefit analysis. Your staff expressed primary interest in one of two basic types of cost-benefit analysis - that in which benefits are measurable in terms of dollars. Your staff also expressed interest in identifying NASA programs susceptible to the other basic type of cost-benefit analysis -- that in which benefits are not measurable in terms of dollars. In accordance with general usage, the latter type will be referred to as "cost-effectiveness analysis." As an introduction we thought it might be useful to include a brief discussion of the uses of these two types of cost-benefit analysis.

Cost-benefit analysis involving dollar-measurable benefits can (1) facilitate direct comparison of costs with benefits to see whether the benefits appear worth the costs, (2) assist in selecting from alternatives having different objectives, or (3) assist in selecting from alternatives having the same objective.

Cost-effectiveness analysis -- cost-benefit analysis in which benefits are not measurable in dollar terms -- facilitates selection of the most economical way of accomplishing a particular objective by either (1) identifying the alternative providing the greatest benefit for a particular cost or (2) identifying the least costly way of providing a particular benefit. Cost-effectiveness analysis can assist in selecting from alternatives having the same objective.

We believe that, for practical purposes, only certain NASA programs are susceptible to cost-benefit analysis involving dollar-measurable benefits. On the other hand, we believe that all NASA programs are susceptible to cost-effectiveness analysis.

We believe that cost-benefit analysis involving dollar-measurable benefits should be performed only on those NASA programs producing potential inputs to non-NASA activities (Government and/or non-Government) that actually produce dollar-measurable benefits, such as agriculture, transportation, and communication activities.

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Attachment I lists NASA programs (budget line items) satisfying this condition. For reference purposes, these are called "applications programs."

We concluded that cost-benefit analyses involving dollar-measurable benefits should be performed on NASA applications programs only after careful evaluation, on a case-by-case basis, of the value of the expected analytical results. In our opinion such analyses are valuable if they meet their overall goals, that is, if they assist decisionmakers in selecting from alternatives having the same, or different, objectives.

The determination of the value of cost-benefit analysis of NASA applications programs should consider (1) the necessity for arbitrarily selecting from among many plausible sets of assumptions concerning non-NASA activities, (2) the wide differences in the analysis that could result depending on the assumptions selected, and (3) the difficulty in defending the selection of one set of assumptions instead of another. We found that the results of the analyses of NASA applications programs that we examined could vary widely depending on which of many plausible sets of assumptions concerning non-NASA activities was incorporated into the analysis. These assumptions had to be made for those non-NASA activities expected to produce dollar-measurable benefits using outputs from NASA applications programs.

A discussion of existing studies and the bases for our conclusions are briefly discussed below.

EXISTING STUDIES

The use of cost-benefit analysis in evaluating the worth of space programs is already a well established practice in the United States and in other countries. One authority estimates that over 200 separate studies were made between 1962 and 1967. NASA has been a leader in using this technique. Studies have also been made in the United States by other public organizations and by private firms. Cost-benefit analyses have also been made by France and Germany.

For the most part NASA analyses have been concerned with the Earth Resources Satellite Program. They have also considered the impact on market applications of other programs including communications and weather satellites. The following are examples of major NASA-oriented cost-benefit analyses and their dollar and manpower costs.

Made by	Analysis title and date completed	Cost	Man-hours
International Business Machines	ORL (Orbiting Research Laboratories) Experiment Program, 1966	$937,500	44,075

Made by	Analysis title and date completed	Cost	Man-hours
Planning Research Corporation	A Study of the Economic Benefits and Implications of Space Station Operations, 1968	$357,073	14,928
Planning Research Corporation	A Systems Analysis of Applications of Earth Orbital Space Technology to Selected Cases in Water Management and Agriculture, 1969	807,043	30,742
National Academy of Sciences, National Research Council	Useful Applications of Earth-Oriented Satellites, 1969	285,000	N/A
Interplan	Review and Appraisal: Cost-Benefit Analysis of Earth Resources Survey Satellite Systems, 1971	67,100	2,880

Unlike the first four analyses, the Interplan study was not a cost-benefit analysis but rather a review and appraisal of cost-benefit analyses. It represents an attempt by NASA to determine (1) the adequacy of 10 selected studies as indicators of cost-benefit ratios and (2) if the studies could be used to direct research and development activities. Interplan concluded that the studies were adequate cost-benefit indicators and were valuable in identifying areas considered important by potential users.

A list of studies and papers concerning research and development oriented cost-benefit analyses, particularly of NASA programs, is provided as Attachment II.

COST-BENEFIT ANALYSIS - DOLLAR-MEASURABLE BENEFITS

The principal value of cost-benefit analysis involving dollar-measurable benefits is the aid it provides a decisionmaker in choosing among two or more programs having different objectives. For example, the costs and benefits of a scientific program, such as a weather satellite, could be compared with the costs and benefits of a non-scientific program, such as highway construction, using dollars as a measure.

However, as previously stated, we believe the value of cost-benefit analysis, involving dollar-measurable benefits, of NASA applications programs should be assessed on a case-by-case basis only after due consideration of the problems posed by (1) the necessity of arbitrarily selecting from among many plausible sets of assumptions concerning non-NASA activities, (2) the wide differences in the analysis that could result depending upon assumptions selected, and (3) the difficulty in defending the selection of one set of assumptions instead of another.

The necessity for arbitrarily selecting from among many plausible sets of assumptions concerning non-NASA activities results from the inherent nature of research and development programs. Such programs do not directly produce dollar-measurable benefits themselves but do produce potential inputs to non-NASA activities that could produce such benefits. The fundamental problem here is that those who do an analysis of such a program have to make many assumptions concerning the non-NASA activities to estimate the costs and dollar-measurable benefits associated with the NASA program under consideration. In the studies we reviewed, a partial listing of assumptions made included (1) assumptions of mission lifetimes, operating lifetimes, and configurations for the non-NASA program, (2) assumptions of costs for the non-NASA programs, (3) assumptions of the degree to which the non-NASA activities would achieve their objectives, (4) assumptions of the extent to which information supplied by the NASA program in question would impact on the non-NASA activities, and (5) assumptions of the impact that non-NASA activities would have on the eventual beneficiaries. Because authoritative information was not usually available to influence the selection of assumptions in the analyses we reviewed, the people doing the analyses had to make many assumptions on a subjective and arbitrary basis.

We found that the value of cost-benefit analysis, involving dollar-measurable benefits, of NASA applications programs was affected by the wide differences in the analysis that could result depending upon the assumptions selected. The potential import of the differences can be appreciated by considering some examples. We found program cost estimates of $83 million in one study and $2.5 billion in a different study of the same program. We found an estimate of program benefits of $150 thousand in one report and $38 billion in another on the same NASA applications program. These differences and others we reviewed indicate that the assumptions selected in a cost-benefit analysis could be very important to the decisionmaker planning to select from among programs with different objectives.

The difficulty of defending the selection of one set of assumptions instead of another can be seen by examining the following description from a National Research Council study of a partial list of the assumptions required to perform a cost-benefit analysis of a NASA applications programs.

"Benefits from new and improved data are assessed by forming a subjective estimate of their usefulness relative to data currently being gathered.

* * *

"To obtain even crude quantitative hints it is necessary to make rather specific assumptions about the data that might be expected to emerge from the systems. Briefly, for agriculture and forestry we assume that the system will provide useful information on broad land-use classes, on acreages in major crops (perhaps 8 to 12 of the more than 60 crops now covered), on forest areas by broad types, on indicators of forest and crop conditions at selected times of the year, on incidence and extent of certain plant and tree diseases and pests, on some aspects of soil condition (perhaps moisture, erosion, salinity), on the extent of special disasters (including forest fires), on livestock types and numbers, on wildlife numbers and habitat conditions, and on recreational use.

"Regarding accuracy of the data, it is assumed that information directly comparable with information currently gathered will be of similar accuracy. For data not presently compiled we have formed rough subjective judgments of probable accuracy after talks with sensor experts.

"What will actually be possible in extent and accuracy of information will depend on the success of the R&D (research and development) program."

It is because of the subjective nature of the assumptions described (as well as many others not mentioned) that a defense of any specific set of assumptions would be difficult.

COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis is a type of cost-benefit analysis generally used to decide among alternatives once objectives have been decided upon. Either of two approaches is usually taken. The fixed-effectiveness approach entails establishing a specific level of effectiveness to be achieved and identifying the various alternatives that would provide this level of effectiveness. The fixed-cost approach requires establishing a certain level of program costs, identifying alternatives having this cost, and estimating the levels of effectiveness for each alternative.

In general, a program or project is susceptible to cost-effectiveness analysis if:

1. The program or project has one or more clearly-stated objectives that can be translated into one or more meaningful measures of effectiveness, and

2. There are alternative ways of obtaining the objectives.

We believe every NASA program or project has one or more objectives that can be clearly stated. At the most elementary level the objective is whatever the program is supposed to do. For example, in the case of research into the characteristics of the earth's upper magnetosphere, the goal might be to monitor space weather and the boundary of the geomagnetic field as it interacts with the solar wind. We believe that at a minimum these goals can be translated into meaningful measures of effectiveness, which are nothing but quantitative descriptions of the project or program goals. For the above example this might be done by using selected characteristics, such as reliability and time-on-station.

In every program, there are alternative ways of achieving the established objectives. In the above example two different approaches might be (1) to build more satellites with lower reliability or (2) to build fewer satellites with higher reliability. The higher reliability satellites would generally be more costly per unit and would require a particular number of satellites, whereas the lower reliability satellites would cost less per unit but would require a larger number of satellites.

Thus, this type of analysis assists the decisionmaker in selecting the best alternative to use to achieve the stated objective.

NASA COMMENTS

While agreeing with the major conclusions of our report, NASA did not believe that our position on the feasibility of applying cost-benefit analysis to the list of programs in Appendix I was clear. NASA stated that some of these programs might be reasonable candidates for cost-benefit analysis while others "such as life sciences, propulsion, operational systems, and power are so general that it would be difficult to define the scope and predict the potential quantifiable benefits in the areas."

We believe that since these programs meet the criteria of having potential dollar-measurable benefits, they are candidates for cost-benefit analysis. While agreeing that the problems in defining scope and benefits for these programs would be difficult, as we stated previously, these problems permeate any attempt to use this type of cost-benefit analysis in research and development areas. In our opinion the question raised by NASA is one of degree of difficulty, rather than a disagreement with our opinion that programs with potential dollar-measurable benefits are candidates for this type of cost-benefit analysis.

NASA also stated that cost-effectiveness analysis tends to be "an integral part of the decisionmaking process and frequently" does not result in a formal report or study. Since the pertinent part of our report was directed at the question of the susceptibility of NASA programs to cost-effectiveness analysis, rather than the extent to which NASA has done cost-effectiveness analysis, we are not in a position to comment on this statement.

We are including NASA's comments as Attachment III.

We plan to make no further distribution of this report unless copies are specifically requested and then we shall make distribution only after your agreement has been obtained or public announcement has been made by you concerning the contents of this report.

We would be pleased to discuss our conclusions in greater depth or answer any questions that you or your staff might have regarding this subject at your convenience.

Sincerely yours,

Comptroller General
of the United States

Enclosures - 3

The Honorable George P. Miller
Chairman, Committee on Science and Astronautics
House of Representatives

LIST OF NASA PROGRAMS (BUDGET LINE ITEMS) HAVING POTENTIAL DOLLAR-MEASURABLE BENEFITS

Aircraft Program

Earth Resources Technology Satellite

Improved Tiros Operational System

Nimbus

Synchronous Meteorological Satellite

Applications Technology Satellite

Cooperative Applications Satellite

Geodetic Explorer

Atmosphere Explorer

Meteorological Soundings

Experimental STOL Transport Research Airplane

Aerodynamics and Vehicle Systems

Life Science

Propulsion

Operating Systems

Material and Structures

Guidance Control and Information

Power

Supercritical Technology

Skylab

ATTACHMENT II

LIST OF RESEARCH AND DEVELOPMENT ORIENTED COST-BENEFIT STUDIES

1. A Study of the Economic Benefits and Implications of Space Station Operations, Planning Research Corporation, 1968

2. A Systems Analysis of Applications of Earth Orbital Space Technology to Selected Cases in Water Management and Agriculture, Planning Research Corporation, 1969

3. Cost-Benefit Study of the Earth Resources Observation Satellite System: Estuarine and Coastal Management, Mathematica, 1969

4. Cost-Benefit Study of the Earth Resources Observation Satellite System: Grazing Land Management, Mathematica, 1968

5. EROS (Earth Resources Orbital Satellite) Application Benefit Analysis, Westinghouse, 1968

6. Final Report on the Space/Oceanographic Study, General Electric Company, 1968

7. Indicators of the Effect of Jet Noise on the Value of Real Estate, The RAND Corporation, 1969

8. On the Benefit of Space Research Seen from the German Point of View: A Macro-Model for Evaluating the Order of Magnitude of Space Research Benefits for the Federal Republic of Germany, Institut Fuer Raumfahrttechnik Technische Universtaet Berlin, NASA Technical Translation, 1970

9. ORL (Orbiting Research Laboratories) Experiment Program, International Busines Machines, 1966

10. Organizing Space Activities for World Needs, International Academy of Astronautics, 1968

11. Potential Benefits to be Derived from Applications of Remote Sensing of Agriculture, Forest and Range Resources, Cornell University, 1967

12. Potential Time-Cost Benefits from Use of Orbital-Height Photographic Data in Cartographic Programs, Geological Survey, 1966

13. Priority Analysis of Manned Orbital Research Applications, Stanford Research Institute, 1965

14. Proceedings of the Princeton University Conference on Aerospace Methods for Revealing and Evaluating Earth's Resources - The Princeton University Conference, 1970

15. Review and Appraisal: Cost-Benefit Analysis of Earth Resources Survey Satellite Systems - Interplan Corporation, 1971

16. Review of Department of Defense Economic Analysis of High Technology Systems, Mathematica, 1972

17. Technology Assessment of Space Stations, Program of Policy Studies in Science and Technology, George Washington University, 1971

18. The Economic Benefits of National Meteorological Services, World Weather Watch Planning Report No. 27, World Meteorological Organization, 1968

19. The National Research Effort on Improved Weather Description and Prediction for Social and Economic Purposes, U.S. Department of Commerce Weather Bureau, 1964

20. The Possible Uses of Satellites for Air Traffic Control, Societe D'Economie Et De Mathematique Appliquees (S.E.M.A.), Paris, 1968

21. Useful Applications of Earth-Oriented Satellites, Summer Study on Space Applications, National Academy of Sciences, National Research Council, 1969

Attachment III

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: D

JUN 7 1972

Mr. Donald L. Scantlebury
Director
Financial and General Management
Studies Division
General Accounting Office
Washington, D.C. 20548

Dear Mr. Scantlebury:

We appreciate the opportunity to comment on the draft letter report of the GAO survey "Identification of NASA Research and Development Programs Subject to Benefit-Cost Analysis." We agree with the general conclusion of the analysis that

> Cost-benefit analyses involving dollar-measurable benefits should be performed on NASA "application programs" only after careful evaluation, on a case-by-case basis, of the value of the expected analytical results... The basic determinant of the value of such analyses is whether they meet their goal--that is, whether they assist decision-makers in selecting from alternatives.

The GAO staff recognizes the immense difficulties, both conceptual and practical, encountered in attempting to measure the dollar value of the benefits of many NASA projects. We endorse the GAO recommendation that such studies should only be performed if they can directly contribute to the decision-making process.

Concerning the content of the report, we have two additional comments. First, page 4 refers to a study by the Planning Research Corporation of "Space Shuttle Operations." The study in question was concerned with Space Station operations.* Secondly, we have some questions about the list of NASA programs included in Attachment 1. Although the heading indicates that the activity areas addressed are those which the GAO staff considers to have "potential dollar-measurable benefits," it is unclear whether the GAO intends to suggest that cost-benefit studies are feasible for each of the programs listed. Some projects, such as certain earth resources and communications satellites may be reasonable candidates for a cost-benefit analysis, especially those which are in the pre-operational/prototype phases. Other programs,

*Correction has been made.

such as life sciences, propulsion, operational systems, and power are so general that it would be difficult to define the scope and predict the potential quantifiable benefits in these areas.

We agree, however, that cost-effectiveness analyses (i.e., cost benefit analyses in which the benefits are not always expressed as dollar values) have a much wider range of potential applicability to NASA programs, particularly in the selection of alternative methods for accomplishing the goals or objectives of particular projects. We might note, in this connection, that such analyses tend to become an integral part of the decision-making process and frequently do not result in the more formal kind of reports or studies that are typical of Benefit/Cost Analyses.

Richard C. McCurdy
Associate Administrator for
Organization and Management