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## Program Management Model Study

by

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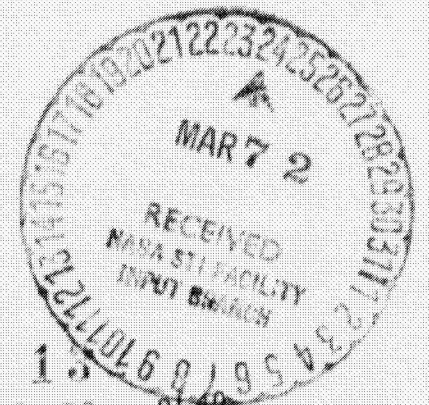
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## FOREWORD

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## SUMMARY

### PROBLEM

To develop two models, a System Performance Model and a Program Assessment Model, that will provide trade-off information for use by NASA management in the evaluation and programming of development activities for the Earth Observation Program (EOP).

The need for such models arises because of the diverse variety of user needs for remote-sensing information and the variety of system technology which should be considered to fulfill these needs. The models should provide a formalized means for: (1) structuring user remote-sensing needs, (2) identifying the capabilities of alternative EOP systems, (3) determining the extent to which each alternative EOP system satisfies sets of user remote-sensing needs, and (4) providing summary displays showing the cost, timing, and anticipated systems performance of alternative programs for earth observation.

### FACTS

The study was conducted by the Research Analysis Corporation, under Contract NAS-5-11398, during the period February-December 1971. NASA provided information on the structure of the EOP and on remote-sensing technology and needs.

The work resulted in the design, programming, test, demonstration, and documentation of the Systems Performance and Program Assessment Models, designated as the EOP Management Model or more briefly, the EOP Model. The EOP Model, described herein, is operational on the Goddard Space Flight Center (GSFC) IBM 360/91 computer.

## DISCUSSION

The NASA Earth Observation Program encompasses a variety of current and proposed spacecraft/aircraft missions, as well as missions yet to be defined. These activities are conducted as an integrated program of analysis and experimentation, shared with the user community, to develop specific applications for remotely-sensed information. The programming of resources for the EOP must take into account user needs, capabilities, and costs of evolving technology, and equally important, the uncertainties associated with the statements of the need and the developmental character of the technology involved.

A variety of alternatives for implementing the program exists both with respect to system configurations and orbital parameters. To assist in comparing alternative programs a System Performance Model and Program Assessment Model, were developed. Although these two models can be operated separately, normally they will be operated sequentially as a paired model system, the EOP Model.

The EOP Model is organized to accept as input a pre-selected set of user needs to be served by the system(s) and a pre-selected identification of system configuration alternatives. The model calculates values for system performance and determines the extent to which this system performance satisfies the needs of the users. Additionally, the model extracts, from a data base, the development program costs and timing associated with implementing the system configuration. When this information is generated for a family of alternative system configurations, it provides the basis for: (1) an assessment of tradeoffs among alternative configurations, and (2) a detailed examination of the performance of each alternative system and development program. A set of EOP model outputs illustrative of the information available from the model was produced on the GSFC IBM 360/91 as a demonstration of the model operation.

The model is designed to assist in a four-step EOP evaluation process. The first step provides for an analysis of the compatibility of sets of user needs. The technical characteristics of data from remote sensors needed by one potential systems user can differ considerably from the technical characteristics of data needed by other users. These differences can arise from the required time interval between

observations, the spectral range of the sensor, the ground resolution required, the amount of area to be covered, the need for near-constant sunlight between observations and from other characteristics. The model user may: (1) examine the technical characteristics of various sets of user needs, (2) evaluate the compatibility of various combinations of these sets, and (3) select sets of user needs to be met by a common experimental or operational satellite system.

The second step in the process, System Performance Evaluation provides for the evaluation of information on system performance. The model user may examine the technical performance of various system configurations as operated under various orbital conditions. The examination will indicate individual sensor performance and permit comparison of sensor operation in multi-sensor systems. Information is also provided on the utilization of the data bandwidth and data storage capacity of the data transmission portions of the system. Using this information the model user may examine and redefine alternative systems.

The third step in the process, Program Performance Evaluation, brings together the work completed in the first two steps. The model user, by selecting specific sets of user needs and a specific system configuration may, using the resultant model output, examine the extent to which the designated system satisfies the designated needs. Using this information, the model user may identify the specific instances where the system fails to serve particular needs. Based upon this evaluation he may determine that a particular system capability should be redefined or specific user needs accommodated by other system approaches.

The fourth step, the process Program Alternative Evaluation, provides for summary comparisons of the various need/system combinations selected by the model user. Using this information, the model user may conduct sensitivity studies where either the needs are examined in terms of alternative system configurations, or where a system is examined in terms of alternative sets of users. With this flexibility incremental differences in performance can be noted and compared with incremental differences in system costs and schedules. These differences may be weighted by the model user to form a basis for system selection. Using a similar approach, with uncertainties substituted as design variations, the effects of the uncertainties in both needs and system parameters may be demonstrated and included in the planning process.

PROGRAM MANAGEMENT MODEL STUDY

## Chapter 1

### INTRODUCTION

The needs for earth observations from satellites are evolving rapidly in the areas of agriculture, forestry, wildlife management, geodesy, cartography, geology, mining, oceanography, hydrology, and others. A variety of different types of data from ground, airborne, and satellite remote sensors are required to fulfill the needs arising in these separate resource areas. Within the area of satellite systems many needs and systems capabilities to fulfill them are not yet well understood. Many combinations of satellites, orbital altitudes, inclinations, sensors, on-board data processing, data transmission links, and ground stations are possible. Experiments, such as those planned for the Earth Resource Technology Satellite (ERTS), are required to verify system capabilities and the usefulness of data. The choices of experiments to be conducted under the Earth Observation Program (EOP) are based upon an assessment of user needs and benefits against alternative systems capabilities and costs.

In recognition of the variety of possible system and program alternatives, and the broad scope of user needs the National Aeronautics and Space Administration (NASA) sought development of computer models to serve as management tools in the evaluation of programming alternatives for the EOP.

This report describes the resultant work performed by the Research Analysis Corporation, under Contract NAS-5-11398, System Performance and Program Assessment Models. The work has resulted in a set of computer programs that are designated as the EOP Model.

The EOP Model is designed to address a variety of important programming issues. These are:

. How can the needs of different users best be aggregated into compatible sets (sets that can readily be served by one satellite program)?

. What level of performance can be achieved by EOP systems using current, developmental, or proposed capabilities of sensors, data storage devices, data links, and ground stations?

. To what extent does a particular EOP system configuration satisfy a given set of user needs?

. What are the developmental costs and the prospective availability of such a configuration?

. What are the feasible tradeoffs in performance, cost, and timing between program alternatives?

Use of the model requires loading a data base with information on user needs and on sensor technology, costs, and schedules of availabilities for different developments. The model calculates various measures of sensor coverage for different orbital altitudes. Calculated and retrieved data are provided in computer print-outs. The EOP Model is programmed in Mark IV language and has been run\* on the IBM 360/91 computer at the Goddard Space Flight Center Computer Facility.

The model has the potential for making the following contributions to the management of the Earth Observations Program:

. Explication of Alternatives - The model can be used to compare a variety of system alternatives from the viewpoint of their performance, costs, and schedules.

. Program Selection - The model information can be used to assist in the selection of a program. Information, for example, can illustrate the extent to which user needs are incrementally satisfied by incremental increased in program costs.

. Uniform Planning Base - The model, because of its data base on remote sensing needs and on the status of remote sensing technology, will be useful as a common basis for EOP planning and evaluation.

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\*A typical run requires about  $\frac{3}{4}$  minute CPU time and 1  $\frac{3}{4}$  minutes I/O time.

The concept and characteristics of the EOP Model are described in Chapters 2, 3, and 4. The methods for using the model in a four-step EOP evaluation process (i.e., compatibility of user needs, system performance, program performance, program alternatives) are described in Chapters 5 through 8. The EOP Model input, logic, and output are described in the appendixes. Results from a model demonstration on a sample problem are shown.



## Chapter 2

### OVERVIEW OF MODEL UTILIZATION

#### MODEL CONCEPT

The EOP Model is a computer-based tool devised to assist in the definition and evaluation of earth observations systems and their associated development programs.

The model is designed to assist in the structuring of a variety of remote sensing information needs and a variety of system configurations that can be implemented to meet these needs. This variety can include specific inputs that reflect uncertainty in the definition of user needs and uncertainties in the performance that can be achieved by remote sensors.

The model enables the systematic comparison of the performance of systems against needs. The results indicate which needs are satisfied by the system, the development projects needed to implement the system, and the development costs. Incremental differences in the user specifications or system specifications will yield incremental differences in the extent of need satisfaction and the costs of development. Such information will assist the model user in the formation of value judgments on what program alternative to recommend or implement.

The use of the EOP Model is shown schematically in Fig. 2-1. The process starts with an identification of the user needs and the systems to be considered. The EOP Model operates on this input to produce information for the model user to evaluate programs. When the process yields an acceptable program, the model activity may be terminated. Typically, the process will be continued until a choice of

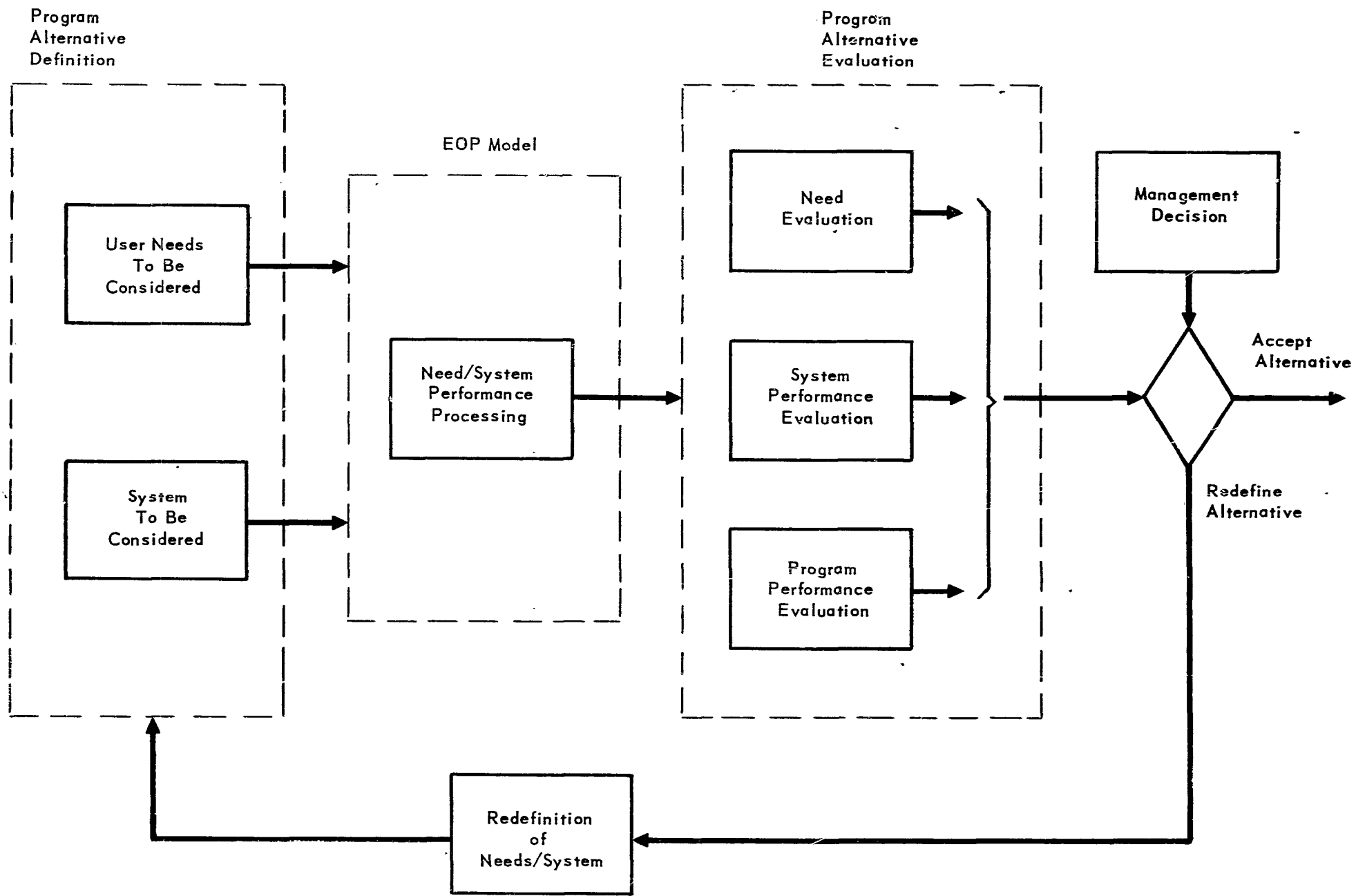


Fig. 2-1—Overview of EOP Model Utilization

alternative is made or a decision that no acceptable combinations of needs and system configurations are available.

As shown in Fig. 2-1, the use of the EOP Model requires two activities for the model user. He first defines or selects the needs and systems of interest. He later evaluates the information presented and determines a course of action.

As defined for use with the EOP Model, an earth observation system is viewed as an information flow process. The information originates with the Sensor Element\* of the configuration. The sensor information is then processed through a series of functional elements: on-board processing, data transmittal and ground processing, finally reaching storage as raw sensor data. For the purposes of the EOP Model, these functions are considered as a set whose components have been chosen to be compatible. The set is designated as a single Down-Link Element that serves to pass sensor data from the remote sensing platform to the ground, as illustrated in Fig. 2-2.

The EOP Model includes not only the physical aspects (Sensor Elements, Down-Links) associated with the mechanics of data collection. It also includes the software that makes the data accessible in appropriate form (User Program) to serve user needs (in the User Model).

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\*Refer to the Glossary for a definition of terms used in this report.

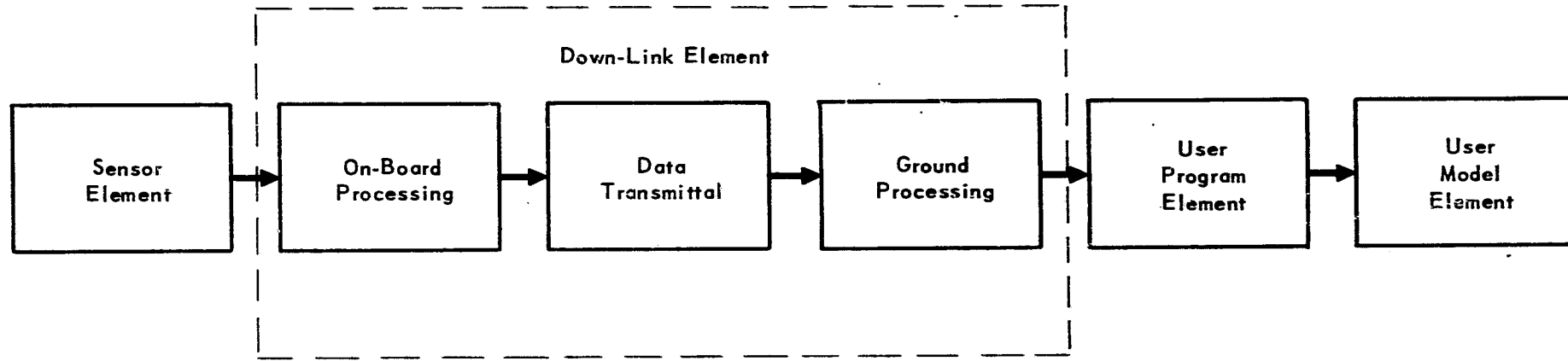


Fig. 2-2—System Element Concept

## Chapter 3

### PROGRAM DEFINITION

The definition of a program alternative for input to the EOP Model consists of the selection of: the user needs to be considered, the system configuration to be considered, and the earth coverage to be achieved. This information is recorded on a Program Definition Worksheet, Fig. 3-1.

#### USER IDENTIFICATION

The user identification is recorded in Part I of the worksheet.

The model user first defines the time period of interest. For model purposes 2-year, 4-year, and 8-year periods are standard. The later periods include the earlier periods. Only one Time Horizon value may be selected at a time.

The model user then identifies the user needs by one of two methods. He either specifies that the computer select from a subject area file of user needs, or from a file that identifies the needs of particular user agencies (and of all or specified activities within those agencies). These two methods are further described below.

- . Subject Area—a classification of needs into one of six subject areas. As adopted from Ref 2 these are: agriculture and forestry, environmental changes and cultural resources, geodesy and cartography, geology and mineral resources, oceanography and marine resources, hydrology and water management.
- . User Activity—the identification of the particular activities whose remote sensing needs are to be served. This includes specification of the user agency and a serial number identifying a particular activity of that agency. Alternatively, all the activities of an agency may be selected by checking the ALL box. A total of five activities for either the same agency or different agencies may be selected.

PROGRAM DEFINITION WORKSHEET					Option No. 01	
<b>Part 1—USER ID</b> <i>Fill in A and B or A and C.</i>						
A	B			C		
Time Horizon	User Activity Category			User Activity		
<input type="checkbox"/> Current <input type="checkbox"/> Next 2 Yrs <input checked="" type="checkbox"/> Next 4 Yrs <input type="checkbox"/> Next 8 Yrs	<input type="checkbox"/> Agri and Forestry <input type="checkbox"/> Env Chgs and Cul Res <input type="checkbox"/> Geod and Cart <input type="checkbox"/> Geol and Min Res <input type="checkbox"/> Ocean and Mar Res <input type="checkbox"/> Hydr and Water Mgmt			AGENCY	ACTIVITY	ALL
				01	-	<input checked="" type="checkbox"/>
				02	-	<input checked="" type="checkbox"/>
				03	-	<input checked="" type="checkbox"/>
				04	-	<input checked="" type="checkbox"/>
				_____	-	<input type="checkbox"/>
<b>Part 2—SYSTEM ID</b>						
Channel No.	Sensor		Down Link		No. of Daily Xmts	
	Type	Perf	Type	Perf		
1	RDM-01	PRF-01	SF-01	PRF-01	3	
2						
3						
<b>Part 3—EARTH COVERAGE ID</b> <i>Fill in A and B or A and C.</i>						
A	B		C			
Orbit Type	Min Swath	Orbit Incl	Orbit Incl	Orbit Cycle Period	Orbit Altitude	Orbit Cycle Revs
<input checked="" type="checkbox"/> Zero drift <input type="checkbox"/> Min drift <input type="checkbox"/> Selected						
Notes						

**Fig. 3-1—Program Definition Worksheet**

## SYSTEM SELECTION

The system selection consists of choosing one or more sensors and a down-link to go with each. The choice is recorded in Part 2 of the Program Definition Worksheet. The selection is identified by specifying coded values for the sensor down-links. Table 3-1 illustrates the code for two sensors at two performance levels and the input data that must be specified for each sensor. Table 3-2 shows the code and input data for two store and forward down-links. The model user, having tables such as 3-1 and 3-2 available for a variety of sensors and down-links, chooses sensors that he expects to be suited to the needs and down-links that are compatible with the sensor bandwidth. He also specifies the number of daily transmissions to the ground station(s) planned for the satellite.

## EARTH COVERAGE SELECTION

The earth coverage selection is recorded in Part 3 of the Program Definition Worksheet. This is done in terms of whether coverage is best obtained from a zero drift orbit, which provides for daily coverage of selected local areas, from a minimum drift orbit, which provides complete coverage of all or sizeable sectors of the earth on a less than daily basis, or from a selected orbit, which provides for the specific needs for which the orbit was selected. The model user also specifies the inclination of the orbit.

If the zero drift or minimum drift orbits are selected, the required entries on the worksheet are the minimum desired width of the sensor field of view (the ground swath width) and the orbit inclination. If a selected orbit is desired the user must indicate the orbit inclination and a consistent set of three parameters for the orbit. These are the Orbit Cycle Period (the number of days between passing over the same spot on the earth), the Orbit Altitude, and Orbit Cycle Revolutions (the number of revolutions in one Orbit Cycle Period).

The choice of orbit inclination is largely dependent on whether the same sun angle is desired on successive passes over the areas being observed.

Table 3-1

## SENSOR CHARACTERISTICS

Characteristic	Radiometer		Imager	
	RDM-01 PRF-01	RDM-01 PRF-02	IMG-01 PRF-01	IMG-01 PRF-02
Angular resolution ( $^{\circ}$ )	.0050 $^{\circ}$	.0025 $^{\circ}$	.002 $^{\circ}$	.001 $^{\circ}$
Field of view ( $^{\circ}$ ) (cross-track)	11.6 $^{\circ}$	11.6 $^{\circ}$	11.5 $^{\circ}$	11.5 $^{\circ}$
Spectral Limit (lower)	.5 MIC	.5 MIC	.475 MIC	.475 MIC
Spectral Limit (upper)	12.6 MIC	12.6 MIC	.830 MIC	.830 MIC
Number of Spectral Bands	4	4	3	3
Sensor Data Bandwidth	2400 KHZ	4800 KHZ	3500 KHZ	7000 KHZ

Table 3-2

## DOWN-LINK CHARACTERISTICS

Characteristic	Store and Forward	
	SF-01 PRF-01	SF-01 PRF-02
Down-link data bandwidth	4000 KHZ	7000 KHZ
Down-link data storage capacity	30 Min	30 Min
Down-link data compression factor	1.000	1.000



## Chapter 4

### MODEL CHARACTERISTICS

#### OVERVIEW

The EOP Model generates information on the capabilities, costs, and schedule of availability of EOP systems. The capabilities are measured in terms of the coverage statistics for particular user needs. The costs are those for present and proposed programs. The schedule of availability indicates the earliest date at which a system could be operative, based on development schedules.

As outlined in the preceding chapter, to use the model the model user specifies the system elements, the earth coverage, and the user needs. The model then retrieves detailed information from the data base, performs the desired processing and generates the required displays.

The model characteristics are described in the following sections in terms of inputs, logic, outputs, and computer operations. Figure 4-1 shows an overview of the model.

#### INPUTS

The inputs to the EOP Model serve to select items from a data base and define the kind of processing the items receive. The input request was illustrated in Fig. 3-1.

The data base contains detailed descriptions (resumes) of the user needs, expressed in the form of observable phenomena. The User Observable Resumes summarize the characteristics of each known application of earth observation sensors in terms of category, sponsoring agency, and specification of required observations including ground swath width, ground resolution, spectral limits, sun-synchronous requirement, etc. Appendix A describes the User Observable Resumes.

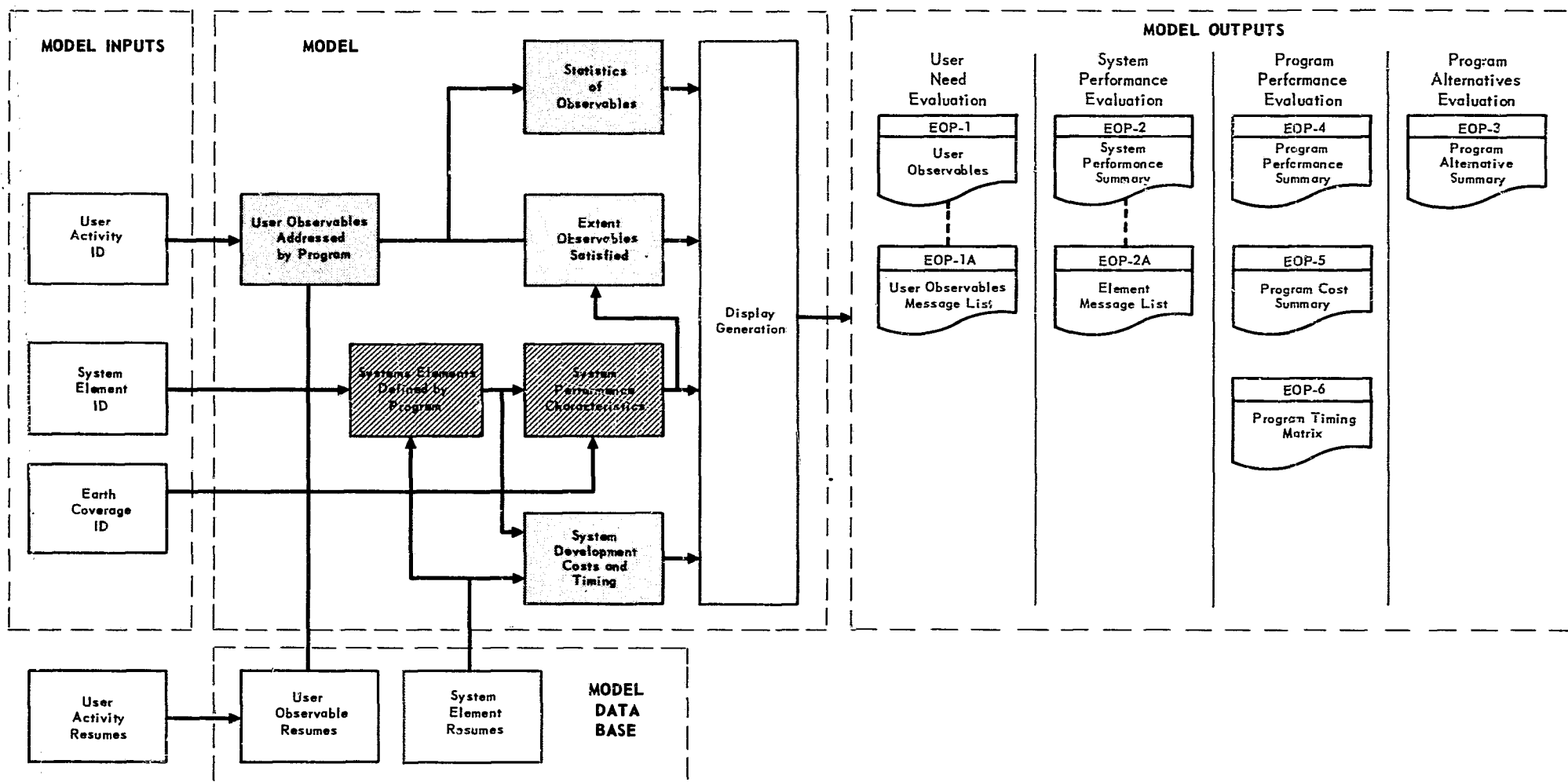


Fig. 4.1—EOP Management Model

System Performance Portion
  Program Assessment Portion

The System Element Resumes summarize the characteristics of each element including sensor field-of-view, angular resolution, physical size, weight, power requirements, cost in terms of current and future years, and availability. The resumes include information on increments of performance for the same system element to permit sensitivity evaluation of the incremental parameters and the costs associated with achieving the incremental performance. See Appendix B.

#### EOP MODEL LOGIC

The model evaluates a series of specific system element combinations for a specific set of user needs and a designated pattern of earth coverage.

Earth coverage identification may be made by orbit code in which case the model selects from stored orbit data five potential operating altitudes for the proposed systems, spaced over the range from 100 to 900 nautical miles. The five altitudes permit the evaluation of system performance to be examined at five points in the typical operating range of earth observation satellites. Where full earth coverage (minimum drift orbit) is required, the altitudes are picked such that the required ground swath width is achieved, and the Orbit Cycle Period is held to the minimum to achieve full earth coverage (in the range of 2-20 days). If local earth coverage is required, the five zero drift orbits that are possible in the altitude range from 145 to 905NM are selected.

Alternatively, the earth coverage identification may be made by designation of a specific orbit (Orbit Altitude, Orbit Cycle Period, Orbit Cycle Revolutions) in which case the model accepts these values in lieu of a table look-up.

Given the technical characteristics for the system elements and the required orbits, the model establishes by data manipulation and computation the following:

- . Spectral Range—the difference between the upper and lower limits of spectral response of the sensor.
- . Number of Bands—the number of spectral intervals built into the sensor.
- . Ground Swath Width—the cross-track distance, on the ground within the sensor's field of view, for each altitude of interest.

- . Ground Resolution—the minimum size of a point feature which can be detected, within the sensor field-of-view, for each altitude of interest.
- . Orbit Cycle Period—the number of days to generate one pattern of earth coverage.
- . Sensed Earth Fraction—the fraction of the earth surface (whole earth = 1.0) that must be viewed by a particular sensor as calculated from the coverage needs of the user activities.
- . Type Illumination—whether sun synchronous or non-sun synchronous.

The compatibility of the sensor requirements with the down-link elements is evaluated by computing:

- . Fraction of Link Input Bandwidth Utilized—a ratio of the sensor bandwidth to the input bandwidth of the down-link.
- . Fraction of Link Storage Capacity Utilized—a ratio of the time the sensor will collect data (between transmissions to a ground station) to the on-board data storage capacity.

The system orbital weight is computed by retrieving the weights of the flight elements of the system and computing the sum of these weights as a flight payload. This value is then used to identify the type of booster (Ref 4) that will lift this payload into the altitude ranges at which the system performance has been calculated.

The actual evaluation of element performance is made by comparing previously computed values with desired values of requirements. If they are met a 1 is assigned, if not a 0, giving a binary requirement by requirement evaluation of performance.

System costs are evaluated by retrieving from the data base the development costs of the individual components of the system. These individual costs are ordered by hardware and software and identified for the current fiscal year, upcoming (budget) fiscal year, prior costs, and cost-to-completion (outer fiscal years). The individual costs are then aggregated into two categories, the costs associated with on-going work and the costs associated with proposed work if the particular system involved is to be implemented. These two aggregated costs are then summed to establish a single total program costs. (The costs under discussion may or may not be totally chargeable to system under consideration depending upon the extent to which the developments

costs may be shared by other systems either programmed or proposed. The costs computed by the model are thus maximum costs.)

System timing is developed by retrieving from the data base the fiscal year of availability of each of the components of the system. The individual fiscal years of availability of hardware and software are displayed with a common time base to permit relative time comparisons of individual developments in the program. The model also identifies the development which extends the longest into the future and selects its associated fiscal year as the earliest time the system could be available for flight.

A more detailed definition of the model logic, including the analytical expressions used, is described in Appendix F.

#### OUTPUTS

The outputs of the model as shown in Fig. 4-1 are produced by the Display Generation Process and are organized to provide information in four categories as follows:

##### User Need Evaluation

Need evaluation information is provided by two display types. The User Observables (EOP-1) display summarizes by means of statistical measures of minimum, maximum, mean, and frequency count, the technical characteristics of the user needs under consideration. The User Observables Message List (EOP-1A) identifies for individual needs any special aspects, essential to its implementation, not accounted for by model operation.

##### System Performance Evaluation

System performance evaluation information is provided by two displays. The System Performance Summary (EOP-2) indicates the predicted performance of each sensor in the system for the various altitudes considered. It also indicates the predicted performance of each down-link in the system. The System Element Message List (EOP-2A) identifies for individual system elements, any special aspect, essential to its implementation, not accounted for by model operation.

##### Program Performance Evaluation

Program performance evaluation information is provided by three display types. The Program Performance Summary (EOP-4) indicates the

extent to which individual sensors in the system satisfy individual user needs at each of the altitudes under consideration. The Program Cost Summary (EOP-5) itemizes the individual development cost of system hardware and software elements for current and future years. The Program Timing Matrix (EOP-6) arrays the individual system elements against the year of their availability from the development process.

#### Program Alternative Evaluation

The program alternative evaluation is summarized in a single display type. The Program Alternative Summary (EOP-3) indicates, for the program alternative under consideration, the percent of the individual needs satisfied, the development costs, the earliest launch opportunity and the likely launch vehicle. The information is arrayed in a compact format to facilitate comparison with similar information for other alternatives under consideration.

The individual displays are illustrated at appropriate points in the discussion of the evaluation process in subsequent chapters and cataloged for general reference in Appendix E.

#### MODEL OPERATION

The EOP Model is written in MARK IV\* and is operable† on the Goddard Space Flight Center 360/91. Operation of the model is accomplished through preparation of word inputs and job execution as described in Appendix C.

#### MODEL DEMONSTRATION

The EOP Model, as exercised on a particular set of user needs for the purpose of demonstrating the overall model operating capability is described in Appendix D.

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\*A proprietary software package of Informatics, Inc., Canoga Park, Calif., available on the GSFC 360/91.

†A typical run operates with 1/4 min CPU time and 1 3/4 min I/O time.

## Chapter 5

### ANALYSIS OF COMPATIBILITY OF USER NEEDS

The key question in this chapter is: "How can the needs of different users best be aggregated into compatible sets?" It is possible to satisfy several potential users with one satellite program. In such cases the types of data and the areas of coverage desired by the users are consistent and compatible. The User Need Evaluation portion of the EOP Model is designed to help answer the above question.

#### EOP MODEL OUTPUTS USED FOR EVALUATION

To use the EOP Model for User Need Evaluation, the model user must select the particular set of needs he wishes to consider. This consists of his identifying the time horizon and the class of user needs of interest. The needs are classed either in a general way (e.g., agriculture and forestry, geodesy and cartography) or in a specific way as defined by particular users.

In response to this input specification, two outputs are produced by the EOP Model, EOP-1, entitled, "User Observables" and EOP-1A, called "User Observations Message List." EOP-1 provides statistical information on the set of observables addressed by the program. For each sensor type, it provides information on ranges, type illumination, and earth coverage requirements. The EOP-1A output is an adjunct that itemizes miscellaneous messages on file for each observable under consideration.

Table 5-1 is a composite of the information from the several computer printouts included in Report EOP-1. This shows the user requirements for two sensor types in terms of the spectral range

Table 5-1

USER NEEDS FOR REMOTE SENSING

Sensor	Spectral Range	No. of Bands	Ground Swath Width (NM)	Ground Resolution Required	Acceptable Interval Between Observations Days	Sun Synchronous	Earth Coverage	Sensed Earth Fraction
IMG01 (Imager-return beam vidicon)	.3550	2	100	100	60	Yes	Cont USA <sup>a</sup>	.014800
	.3550	2	100	100	60			
	.3550	2	100	300	60			
	.3550	2	100	300	60			
	.3550	3	100	100	60			
	.3550	3	100	100	60			
	.3550	3	100	300	60			
	.3550	3	100	300	60			
RDM01 (Radiometer-multispectral scanner)	9.4000	4	100	200	30	Yes	USA Area 9 <sup>a</sup>	.001950
	9.4000	4	100	200	30			
	9.4000	4	100	600	30			
	9.4000	4	100	600	30			
	12.1000	4	100	200	30			
	12.1000	4	100	200	30			
	12.1000	4	100	600	30			
	12.1000	4	100	600	30			
	12.1000	4	100	200	30			
	12.1000	4	100	600	30			

<sup>a</sup>As defined in Task 2 Report, Appendix D.



required, the number of bands, the width of the ground swath to be observed, the ground resolution required, the acceptable interval between observations, whether sun synchronous observations are required, the area of earth coverage required, and the fraction of the earth area this coverage represents. These data are representative and are used in the examples that carry through the remainder of the report.

Table 5-2 gives the data from an EOP-1A report, the miscellaneous comments about the observables. The first column is an identification number that codes the user agency and other information. The other columns require no explanation.

#### SUMMARY OF EVALUATION PROCESS

The basic issues facing the decision maker with respect to User Need Evaluation are:

- . What are the technical characteristics of user needs?
- . How should these needs be aggregated in the planning of EOP systems?

Behind these issues are two assumptions. First, that needs, for a variety of technical and administrative reasons, are distributed over time into the future, and thus some needs may be served before others. Second, that needs may be served by a variety of configurations. There is a problem of choice then as to the grouping of needs into sets that may be served at future times. The system configuration problem is addressed in a later chapter.

#### Evaluation Steps

The process of need evaluation is carried out in a series of basic steps that allow the model user to interpret the technical characteristics of the needs in a manner that emphasizes their consistency and compatibility. These steps consider in turn, the number of observables present, sensor type requirements, swath width needs, illumination types, earth coverage requirements, and daily transmissions necessary.

#### Possible Determinations of the Evaluation

The overall result of the need evaluation for a particular need set is a determination to do one of the following:

Table 5-2

USER OBSERVABLES MESSAGE LIST

Observable Number	Ground Swath Width At Least	Ground Resolution At Most	Status	Message
11-010101-0101	100 NM	200 Ft	Experimental	Sensor Spectral Limits Exceed Need
11-010201-0101	100 NM	200 Ft	Experimental	Sensor Spectral Limits Exceed Need
11-010301-0101	100 NM	600 Ft	Experimental	Sensor Spectral Limits Exceed Need
11-010401-0101	100 NM	600 Ft	Experimental	Sensor Spectral Limits Exceed Need
11-020101-0101	100 NM	200 Ft	Experimental	
11-020201-0101	100 NM	200 Ft	Experimental	
11-020301-0101	100 NM	600 Ft	Experimental	
11-020401-0101	100 NM	600 Ft	Experimental	
11-040101-0101	100 NM	200 Ft	Experimental	
11-040201-0101	100 NM	600 Ft	Experimental	
22-040101-0101	100 NM	100 Ft	Experimental	Sensor Number of Bands Exceed Need
22-040201-0101	100 NM	100 Ft	Experimental	Sensor Number of Bands Exceed Need
22-040301-0101	100 NM	300 Ft	Experimental	Sensor Number of Bands Exceed Need
22-040401-0101	100 NM	300 Ft	Experimental	Sensor Number of Bands Exceed Need
22-050101-0101	100 NM	100 Ft	Experimental	
22-050201-0101	100 NM	100 Ft	Experimental	
22-050301-0101	100 NM	300 Ft	Experimental	
22-050401-0101	100 NM	300 Ft	Experimental	

- Consider Need Set. The needs as aggregated are consistent and compatible and should be considered further in the planning process.
- Redefine Need Set. The needs as aggregated are not sufficiently consistent or compatible to be useful in planning. However, variations in the set composition appear feasible, and should be considered.
- Discard Need Set. The needs are too inconsistent or incompatible to be useful for planning purposes. No further consideration should be given to their implementation as a group.

#### Need Evaluation Worksheet

To assist in the evaluation process, a Need Evaluation Worksheet is provided (see Fig. 5-1)\*. The worksheet identifies, for each model output, the principle criteria for evaluation and provides space for the model user to record his assessment. In each case the criterion is given with a parameter indicating the percent of needs served. This percent value may be specified a priori, or may be established at the time of the evaluation based on the characteristics of the needs. The percent value is chosen to be appropriate for the parameter under consideration and may differ from parameter to parameter as judged by the model user.

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\*A blank copy of this and the other forms used in conjunction with operation of the EOP model are compiled for reference in Appendix J.

NEED EVALUATION WORKSHEET			OPTION NO.
			01
Model Information	Evaluation Criteria	Item	Evaluation
EOP-1 Part I  Imagery Statistics	Number of Observables	1	Type 1 <u>RDM-01</u> <u>10</u> No. of Obs
	Minimum number of sensor types of serve <u>100</u> % of observables	2	Type 2 <u>IMG-01</u> <u>8</u>
	Ground swath width to serve <u>100</u> % of observables	3	Type 3 _____ Swath Width <u>100</u> NM
EOP-1 Part II  Type Illumination Frequencies	Illumination type to serve <u>100</u> % of observables	4	<input checked="" type="checkbox"/> Sun-Sync
		5	<input type="checkbox"/> Non Sun-Sync
EOP-1 Part III  Earth Coverage Frequencies	Earth coverage type to serve <u>100</u> % of observables	6	<input checked="" type="checkbox"/> Full coverage
		7	<input type="checkbox"/> Partial coverage
EOP-1 Part IV  Sensed Earth Fraction	Fraction multiplied by <u>100</u> is estimate of daily number of transmits for <u>1</u> station ground network	8	Daily Transmits <u>1</u>
Item	Action	Evaluation Summary	
6	Restricted to Contiguous US	<input checked="" type="checkbox"/> Consider Need Set <input type="checkbox"/> Redefine Need Set <input type="checkbox"/> Discard Need Set	

Fig. 5-1—Need Evaluation Worksheet

## Chapter 6

### SYSTEM PERFORMANCE EVALUATION

#### INTRODUCTION

The key question in the System Performance Evaluation is: "What levels of performance can be achieved by EOP systems using current, developmental or proposed sensor and down-link capabilities?" An EOP system is defined by specifying the sensor elements, their associated down-link elements, and the earth coverage to be achieved by the system.

The sensors are compared at different orbital altitudes and inclinations. The altitude, for a given sensor, affects the ground swath width viewed by the sensor. The altitude and the inclination of the orbit affect the type of earth coverage provided by the system.

Also included in the System Performance Evaluation are comparisons of: (1) the amount of bandwidth that is needed vs the amount available for transferring the sensed data from satellite to ground station, and (2) the amount of data storage capacity provided on-board the satellite compared to the amount that is needed. The bandwidth comparison is to indicate whether a suitable match has been chosen between sensor and the bandwidth capacity of the down link including the operation of an on-board data compression capability if such is intended. The storage capacity comparison is a function of the sensor recording time available on the satellite and of how much of the earth is to be scanned on a sequence of orbits that occur between transmissions to a ground station. A single transmission per day, for example, simplifies the ground facility and operational requirements, but increases the on-board storage capacity.

## CHOICE OF ORBITS

The choice of orbit depends on the mission of the program. If the mission is, for example, to focus on one small sector of the earth, say the Chesapeake Bay, then a zero drift orbit\* can be chosen, that is, one in which the Bay will be observed each day. If, on the other hand, coverage of a larger sector is required, say of the entire United States, then a minimum drift† is required.

The user of the EOP Model can select either a zero drift orbit or a minimum drift orbit, or he can specify a particular orbit in terms of a consistent set of three parameters: Orbit Altitude, Orbital Cycle Period, and Orbit Cycle Revolutions. If the user does not select an orbit, the model will select five representative minimum drift orbits with altitudes ranging from about 100 to 900 nautical miles.

The inclination of the orbit is also selected by the user. If he desires that the sun angle be the same on each pass over a given point on the earth's surface (sun synchronous orbit), he will choose an inclination of approximately  $99^{\circ}$  (see Fig. 11, Ref 3).

## EVALUATION OF ORBITAL CHOICES

The EOP Model provides an output that gives measures of sensor performance. An example is given in Table 6-1 for five minimum drift orbits. In this table the first sensor (IMG01 PRF01) is an imager at performance level 1, as indicated in Table 3-1. The second sensor (RDM01 PRF01) is a radiometer. Both sensors have approximately the same field of view, as evidenced by their having substantially the same ground swath width. The imager has better resolution, as is evident in the table.

If the model user is interested in full earth coverage, only the two upper altitudes appear to satisfy the requirement. Nevertheless,

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\*Zero drift orbit - a circular orbit with a period such that the earth's coverage pattern is repeated on a daily basis (see Ref 3).

†Minimum drift orbit - an orbit with an easterly or westerly movement of the ground track such that each day's pattern of the coverage is adjacent to that of the previous day until full earth coverage is achieved (see Ref 3).

Table 6-1

SYSTEM PERFORMANCE SUMMARY  
Part 1 - Sensor Performance

Sensor and Performance Level	Variable	Altitude Range				
		1	2	3	4	5
IMG01 PRF01	Altitude NM	142	300	486	670	899
	Orbital Cycle Period, Days	13	14	15	16	18
	Revolutions/Cycle	209	211	211	209	217
	Ground Swath Width, NM	28	60	97	134	180
	Ground Resolution, FT	30.1	63.6	103.1	142.1	190.7
	Swept Earth Fraction	.27	.59	.95	1.31	1.83
RDM01 PRF01	Altitude NM	142	300	486	670	899
	Orbital Cycle Period, Days	13	14	15	16	18
	Revolutions/Cycle	209	211	211	209	217
	Ground Swath Width, NM	28	60	98	135	182
	Ground Resolution, FT	75.2	159.0	257.6	355.2	476.6
	Swept Earth Fraction	.27	.59	.96	1.32	1.85

the third orbit at 486 NM provides for a Swept Earth Fraction\* of 0.95 or 0.96 at the equator. For cases where sensor observations will be made in regions somewhat off the equator full coverage will be obtained. Hence, the user could consider this lower orbit with its better ground resolution than at the two higher altitudes. Should full coverage at the equator be desired a slightly higher orbit might be examined, or a sensor with different imagery parameters could be considered.

If the user is interested in coverage of one small area of the earth, he will specify one or more of the zero drift orbits. The ground swath width and the ground resolution will again be calculated for given sensors to compare against requirements.

The comparison of the ground resolution with the user needs is made as part of the Program Performance Evaluation. This evaluation is described in the next chapter.

Where several sensors are involved the user must evaluate whether the coverage achieved by each sensor is adequate at one or more common altitudes.

#### EVALUATION OF DOWN-LINK ELEMENTS

For the down-link associated with each sensor, the EOP Model prints a comparison of usage of bandwidth and data storage capacity. Table 6-2 identifies each down-link (SF01) with its sensor. The table shows the data compression factor, if any, the bandwidth of the data link, the fraction of the bandwidth used, the number of transmissions per Orbital Cycle Period, the number of minutes of data storage capacity, and the fraction of the link capacity that is used.

The data bandwidth is simply the ratio of sensor bandwidth (multiplied by the compression factor) divided by the link bandwidth. For efficient link usage the ratio should be in the vicinity of 0.5 to 1.0.

The usage of storage capacity is calculated from an approximate relationship found in the Task 2 report. It reflects the amount of

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\*The Swept Earth Fraction is the percent of the earth's circumference at the equator that is covered by the sensor field of view (the ground swath width) in one Orbital Cycle Period, i.e., in the interval between the times the satellite passes over the same spot on the earth.



Table 6-2

SYSTEM PERFORMANCE SUMMARY  
 Part II - Down Link Performance

Down Link	Sensor Served	Compression Factor	Link Data BW (KHZ)	Link Data BW Utilized	No. of Transmits Per Cycle	Link Data Storage	
						Capacity (min)	Fraction Used
SF01 PRF01	RDM01 PRF01	1.000	4.000	.600000	3	30	.03
SF01 PRF01	IMG01 PRF01	1.000	4.000	.875000	3	30	.23

6-9

earth area that is to be observed between down-link transmissions, the time required to observe that much area, and the amount of time (capacity) available for data storage.

In the example in Table 6-2 the radiometer shows a usage of only 3% of the storage capacity. This means that the area required to be sensed was only about one eighth (.03/.23) of that for the imager (in keeping with the sensed earth fraction shown for each of the sensors in Table 5-1).

#### SUMMARY OF EVALUATION PROCESS

The key issue with respect to System Performance Evaluation is:

What levels of performance can be achieved by EOP systems using technology as available, under development, or proposed?

The evaluation is carried out in a series of steps that consider the system performance of the sensor elements and the system performance of the down-link elements. The steps are as follows:

(1) Sensor Operating Altitude.

(a) In frequent use of the model, the system performance will be evaluated at five operating altitudes spaced uniformly across a range of altitudes from 100 to 900 nautical miles. The model user must determine that one or more of these altitudes satisfies the need for earth coverage. Where full earth coverage is needed, the user must determine, for each sensor type, the altitude(s) at which the Swept Earth Fraction equals or exceeds one. Where this condition does not occur at any altitude, the system must be redefined.

(b) Where localized earth coverage is needed, zero drift orbits will usually be specified and the model user must determine for each sensor type, the altitude(s) at which the sensor swath width equals or exceeds the minimum swath width identified in the input. Where this condition does not occur at any altitude, the system must be redefined.

(2) Common Sensor Operating Altitude. The model user must determine that the coverage (full or partial), as achieved by each sensor type, occurs at one or more common altitudes (i.e., all sensors may operate effectively in at least one orbit).

(3) Down-Link Utilization. A separate down-link is provided in the system to process the sensor data stream to the ground. The model user must determine that each down-link is effectively used. This involves a determination that, for each down-link the

(a) Data Bandwidth Utilization and

(b) Data Capacity Utilization

are approximately equal to one. In event of excessive underuse or overuse of capacity, re-specification of the system is indicated.

The overall result of the system performance evaluation is a determination of one of the following:

- . Consider System. The system, as configured, appears useful and should be further considered in the planning process.
- . Redefine System. The system, as configured, has incompatibilities either between sensor types or between a sensor and its down-link. However, variations in the configuration appear feasible and should be considered.
- . Discard System. The system, as configured, has gross incompatibilities between its elements, or fails to achieve acceptable performance and should no longer be considered.

To assist in the evaluation, a System Performance Evaluation Worksheet (Fig. 6-1) is used. The worksheet identifies the principal criteria for evaluation. To simplify the evaluation process, the judgment may be reduced to a simple go/no-go choice. If the system is unsatisfactory it may be re-specified or discarded, depending on the nature of the difficulty involved and its prospect for adjustment.

The sample System Performance Evaluation Worksheet shown in Fig. 6-1 is based on the information shown in Tables 6-1 and 6-2. The model user has determined that each sensor provides the needed full earth coverage and that this occurs at two and perhaps three altitudes. He has also determined that use of the down-link data bandwidth is adequate (0.600 and 0.875). However, the down-link data capacity, while somewhat underutilized on one down-link (0.23), is substantially underutilized (0.03) on the other. The model user might conclude that a redesign of the down-link is needed before considering it further.

SYSTEM PERFORMANCE EVALUATION WORKSHEET			OPTION NO. 01	
Model Information	Criteria	Item	Results	
EOP-2 Part I  Sensor Performance	For Full Earth Coverage:		Swept Fraction/Swath Width Condition Met?	
	(1) Does each sensor type achieve a swept fraction approximated equal unity?	1	Type 1 <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
	(2) Does this condition occur at common altitude range?	2	Type 2 <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
		3	Type 3 <input type="checkbox"/> Yes <input type="checkbox"/> No	
	For Partial Earth Coverage:		Common Altitude Condition Met?	
	(1) Does each sensor type achieve a swath width approximately equal to minimum swath width?		<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
	(2) Does this condition occur at a common altitude range?	4		
EOP-2 Part II  Down-Link Performance	Does Link Data Bandwidth Utilization of each Down-Link approximately equal unity?		Data Bandwidth Condition Met?	
		5	D-L 1 <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
		6	D-L 2 <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
			7	D-L 3 <input type="checkbox"/> Yes <input type="checkbox"/> No
	Does Link Data Storage Capacity of each Down-Link approximately equal unity?			Data Storage Capacity Condition Met?
		8	D-L 1 <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	
		9	D-L 2 <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
			10	D-L 3 <input type="checkbox"/> Yes <input type="checkbox"/> No
	Item	Action	Evaluation Summary	
	9	Conduct tradeoff with lower storage capacity unit.	<input type="checkbox"/> Consider System <input checked="" type="checkbox"/> Redefine System <input type="checkbox"/> Discard System	

Fig. 6-1—System Performance Evaluation Worksheet

## Chapter 7

### PROGRAM PERFORMANCE EVALUATION

The key question in the Program Performance Evaluation mode of EOP Model use are: (1) to what extent does a particular EOP system configuration satisfy a given set of user needs? and (2) what developmental costs and timing are associated with this configuration?

The model compares user needs with the system performance. This determines whether each user observable is satisfied. The satisfied needs are counted, and expressed as a percentage of the total number of needs. The percentage value along with the detailed results of the comparison are provided to the model user for his evaluation.

#### SAMPLE EVALUATION

The following example is of the same system as was discussed in the last chapter. The first Program Performance report is shown as Table 7-1. This lists for each of the two sensors a number of observables specified in the user needs. The observables are identified by a code that specifies the user and related information. Eight separate observables are listed for the imager, none of which are satisfied at the three lower altitudes. Six of the eight are satisfied at the two upper altitudes. The overall percentage of needs satisfied at each altitude are shown, for each sensor and collectively for the two sensors. The reasons for the sensor's not performing adequately are given on the next report.

Table 7-2 shows the details of needs and which are satisfied. The first three columns of data show whether the spectral range, the number of spectral bands, and whether the sun illumination provided by the orbit are in keeping with the need. In each case in the table

Table 7-1

PROGRAM PERFORMANCE SUMMARY  
Part I - Percent Application Satisfied

Element	Perf Incr	Observable Number	Altitude Range 1	Altitude Range 2	Altitude Range 3	Altitude Range 4	Altitude Range 5
IMG01	PRF01	22-040101-0101	0	0	0	0	0
		22-040201-0101	0	0	0	0	0
		22-040301-0101	0	0	0	1	1
		22-040401-0101	0	0	0	1	1
		22-050101-0101	0	0	0	1	1
		22-050201-0101	0	0	0	1	1
		22-050301-0101	0	0	0	1	1
		22-050401-0101	0	0	0	1	1
IMG01	PRF01		0	0	0	6	6
			8	8	8	8	8
			.00%	.00%	.00%	75.00%	75.00%
RDM01	PRF01	11-010101-0101	0	0	0	0	0
		11-010201-0101	0	0	0	0	0
		11-010301-0101	0	0	0	1	1
		11-010401-0101	0	0	0	1	1
		11-020101-0101	0	0	0	1	1
		11-020201-0101	0	0	0	1	1
		11-020301-0101	0	0	0	1	1
		11-020401-0101	0	0	0	1	1
		11-040101-0101	0	0	0	1	1
		11-040201-0101	0	0	0	1	1
RDM01	PRF01		0	0	0	8	8
			10	10	10	10	10
			.00%	.00%	.00%	80.00%	80.00%
			0	0	0	14	14
			18	18	18	18	18
	.00%	.00%	.00%	77.77%	77.77%		

Table 7-2

PROGRAM PERFORMANCE SUMMARY  
Part II - Individual Applications Satisfied

Element	Perf Incr	Observable Number	Spectral Range	No. of Bands	Illum- inatn	GS1	GR1	GS2	GR2	GS3	GR3	GS4	GR4	GS5	GR5	
IMG01	PRF01	22-040101-0101	1	1	1	0	1	0	1	0	0	1	0	1	0	
		22-040201-0101	1	1	1	0	1	0	1	0	0	1	0	1	0	
		22-040301-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		22-040401-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		22-050101-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		22-050201-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		22-050301-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		22-050401-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
IMG01	PRF01		8	8	8	0	8	0	8	0	6	8	6	8	6	
			8	8	8	8	8	8	8	8	8	8	8	8	8	
RDM01	PRF01	11-010101-0101	1	1	1	0	1	0	1	0	0	1	0	1	0	
		11-010201-0101	1	1	1	0	1	0	1	0	0	1	0	1	0	
		11-010301-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	
		11-010401-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		11-020101-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		11-020201-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		11-020301-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		11-020401-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		11-040101-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
		11-040201-0101	1	1	1	0	1	0	1	0	1	1	1	1	1	1
RDM01	PRF01		10	10	10	0	10	0	10	0	8	10	8	10	8	
			10	10	10	10	10	10	10	10	10	10	10	10	10	
			18	18	18	0	18	0	18	0	14	18	14	18	14	
			18	18	18	18	18	18	18	18	18	18	18	18	18	

7-3



the answer is, yes. The following columns list, for each of the five altitudes, whether the Ground Swath Width (GS) and the Ground Resolution (GR) is adequate. It may be recalled from Fig. 6-1 that the Ground Swath Width was less than one for the lower three altitudes. This is reflected under the GS column in Table 7-1. The table indicates for both sensors that the ground resolution is inadequate for the first two observables. Hence, the overall performance for the upper altitudes is 14 out of 18 observables satisfied, or 77.7%. It is judgemental whether the program should be accepted with the needs unsatisfied. The answer would be a function of the importance of the observables and the cost and timing of changes to provide adequate performance. The judgements may be assisted by information derived from the following model reports.

Table 7-3 gives the hardware development costs for the current year and the Budget year. It indicates that the sensors and the Down-Link Elements are in a state of advanced development, and that the development costs will be completed in the Budget year for the sensors and in the current year for the Down-Link Elements.

Table 7-4 gives the software costs for elements specified by code. This also indicates, for the example, that costs do not extend beyond the Budget Year.

Table 7-5 indicates that all of the hardware items, for the example given, will be available in Fiscal Year 72.

Table 7-6 shows that the software items that are in the status of advanced development will be ready in FY 72; however, the items that are in the "proposal" state will not be available until FY 74.

With these cost and timing data the model user can weigh whether to proceed with what are technically feasible alternatives or whether to look for other alternatives.

#### SUMMARY OF EVALUATION PROCESS

As mentioned, the key issues with respect to Program Performance Evaluation are:

- . To what extent does a particular EOP system configuration respond to a particular set of user needs?
- . What development costs and timing are associated with achieving this response?



Table 7-3

PROGRAM COST SUMMARY  
Part I - Hardware Elements

Element	Perf Incr	Number of Elements	Development Status	Cost CY	Cost BY	Cost to Date	Cost to Complete
IMG01	PRF01		Advanced Devmt	200	200		
RDM01	PRF01		Advanced Devmt	200	200		
SF01	PRF01	2	Advanced Devmt	400			

Table 7-4

PROGRAM COST SUMMARY  
Part II - Software Elements

Element	Perf Incr	Development Status	Cost CY	Cost BY	Cost to Date	Cost to Complete
PRG01		Advanced Devmt	50	50		
PRG02		Advanced Devmt	50	50		
PRG04		Proposal		50		50
PRG05		Proposal		50		50
MDL01		Advanced Devmt	50	50		
MDL02		Advanced Devmt	50	50		
MDL04		Proposal		50		50
MDL05		Proposal		50		50

7-5



Table 7-5

PROGRAM TIMING SUMMARY  
Part I - Hardware Elements

Element	Perf Incr	Number of Elements	Development Status	Curr Year	F-YR 71	F-YR 72	F-YR 73	F-YR 74	F-YR 75	F-YR 76	F-YR 77	F-YR 78
IMG01	PRF01		Advanced Devmt			XX						
RDM01	PRF01		Advanced Devmt			XX						
SF01	PRF01	2	Advanced Devmt			XX						

Table 7-6

PROGRAM TIMING SUMMARY  
Part II - Software Elements

Element	Perf Incr	Development Status	Curr Year	F-YR 71	F-YR 72	F-YR 73	F-YR 74	F-YR 75	F-YR 76	F-YR 77	F-YR 78
PRG01		Advanced Devmt			XX						
PRG02		Advanced Devmt			XX						
PRG04		Proposal					XX				
PRG05		Proposal					XX				
MDL01		Advanced Devmt			XX						
MDL02		Advanced Devmt			XX						
MDL04		Proposal					XX				
MDL05		Proposal					XX				

The evaluation steps are as follows:

(1) Observables Satisfied. The model user may judge a system based on the percentage of needs satisfied. While satisfying all needs is the ideal case, systems may be accepted that serve less than all needs. It may turn out that the unsatisfied needs can be satisfied in another program or they may be of low priority.

(2) Modifications Required. The model user may note that a particular sensor is consistently inadequate, and he may decide that a different sensor should be considered.

(3) Development Cost Limits. The model user must determine whether the development costs for hardware and software are acceptable. He will consider costs in the Budget Year (upcoming) and to bring the system to completion. Cost constraints, if known, will be included in the overall evaluation.

(4) Development Timing Limits. If a system cannot be developed in time to meet the target year, the model will identify the pacing items. The model user may then consider reprogramming of resources to meet the target date, if such will likely solve the problem.

The reprogramming decision will be influenced by the feasibility of speeding up the developments. If several system elements are involved, reprogramming may be unrealistic and the target date may have to be reconsidered.

It should be noted that while the model gives insight into possible reprogramming candidates it does not provide a basis for program change. The actual data appropriate to a reprogramming action must come from the developing agency in response to queries made by the model user based on the model outputs. As the information is made available by the developer it may be included in the model data for subsequent use in the planning process. The overall result of the program performance evaluation is a determination to do one of the following:

- . Consider Program. The program, as put together, appears useful and should be further considered in the planning process.
- . Redefine Program. The program, as presently put together, has incompatibilities between the system configuration and the user needs. However, variations in the composition of either the system or user set appear feasible and should be considered.

- . Discard Program. The program has gross incompatibilities between the system configuration and the user needs, and should no longer be considered.

To assist the model user, a Program Performance Worksheet (Fig. 7-1) is provided. The worksheet identifies for each block of model display information, the principal criteria for evaluation and provides space for the model user to record his evaluation.

The Program Performance Assessment Worksheet, as it might be completed by a model user, is illustrated in Fig. 7-1. The evaluation in this instance is with respect to the model information shown in the earlier tables.

The worksheet as completed indicates that the ground resolution parameter is the consistent source of inadequate performance. Because of this the user suggests a tradeoff study with higher resolution sensors. Further, the worksheet indicates that the costs and timing were acceptable.

PROGRAM PERFORMANCE EVALUATION WORKSHEET			OPTION NO. 01
Model Information	Evaluation Criteria	Item	Evaluation Results
EOP-4  Program Performance Summary	Are <u>100</u> % or more of observables satisfied?	1	Observables Satisfied? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
	For those unsatisfied is there a constant dissatisfying factor?	2	Dissatisfying Factor(s)? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
		3	Identify Factor(s) _____
EOP-5  Program Cost Summary	Cost Limits		Cost Limits Met?
	Hardware	4	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
	Budget Year <u>\$500 K</u>	5	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
	To Completion <u>\$250 K</u>		
Software	6	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
Budget Year <u>\$500 K</u>	7	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
To Completion <u>\$250 K</u>			
EOP-6  Program Timing Matrix	Timing Limits		Timing Limits Met?
	Hardware <u>FY 74</u>	8	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Software <u>FY 74</u>	9	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
Item	Action	Evaluation Summary	
3	Conduct tradeoff with higher angular resolution sensor types.	<input type="checkbox"/> Consider Program <input checked="" type="checkbox"/> Redefine Program <input type="checkbox"/> Discard Program	

Fig. 7-1—Program Performance Evaluation Worksheet

## Chapter 8

### PROGRAM ALTERNATIVE EVALUATION

The key question for the Program Alternative Evaluation is:  
"What are the feasible tradeoffs in performance, cost, and timing as between different program alternatives?"

The EOP Model provides a concise summary of the extent to which a program satisfies user needs, along with the costs and timing of the associated development program.

#### EVALUATION INFORMATION AND PROCESS

The program alternative information is an aggregation of the information discussed in prior chapters. The model output for four alternatives is shown in Table 8-1. For each alternative the key orbital data are given, together with the number of observables involved and the number and percent satisfied, the costs, the timing, and the launch vehicle that will put the payload into the desired orbit. The table presents a total of four alternatives. With increasing costs the complete set of user needs may be satisfied. Though not explicitly noted on the table the increased costs provide for improved sensor resolution to achieve the higher levels of user satisfaction.

The evaluation of the performance, cost, and timing factors is a subjective process. Whether the increased satisfaction of user needs is worth the amounts indicated in the table is dependent on the specifics of the situation. For example, Alternative 2 might be acceptable. The model user would know which observable had been rendered satisfactory by improving one of the sensors. He might decide that the additional coverage was well worth the additional total cost of \$1 million, but that obtaining 100% coverage with Alternative 4 was not worth the further increase of \$1.2 million.

Table 8-1

PROGRAM ALTERNATIVE SUMMARY

Alternative Number	Orbit Alt (NM)	Orbit Cycle (Days)	Number of Observables	Observables Satisfied		Development Costs (In Thous)						Launch Opportunity	
				Number	Percent	On-Going		Proposed		Total		Earliest FY	Vehicle
						BudFY	Cmpln	BudFY	Cmpln	BudFY	Cmpln		
01	142	13	18		.000	630		200	200	830	200	74	Delta
	300	14	18		.000								
	486	15	18		.000								
	670	16	18	14	77.770								
	899	18	18	14	77.770								
02	142	13	18		.000	400		600	600	1000	600	74	Delta
	300	14	18		.000								
	486	15	18		.000								
	670	16	18	16	88.880								
	899	18	18	14	77.770								
03	142	13	18		.000	400		600	600	1000	600	74	Delta
	300	14	18		.000								
	486	15	18		.000								
	670	16	18	16	88.880								
	899	18	18	16	88.880								
04	142	13	18		.000	200		1000	1000	1200	1000	74	Delta
	300	14	18		.000								
	486	15	18		.000								
	670	16	18	18	100.000								
	899	18	18	16	88.880								

Other alternatives that are not shown could also be introduced. One could be a hybrid program consisting of Alternative 1 plus another satellite with the sensors operating at lower altitudes to obtain the desired ground resolution. This might be at the sacrifice of some earth coverage (swath width), but the result might be cheaper than the other alternatives listed. The additional costs of the extra launch vehicle would be introduced into the process at this point.

In the example given in the table the timing is not a factor because all programs can be operative in the same year. Similarly the launch vehicle required and the on-going costs to completion, are constant and do not provide a basis for choice.



Appendix A  
USER NEED DOCUMENTATION

Appendix A  
USER NEED DOCUMENTATION

This appendix describes the documentation of user needs for operation of the EOP Model. The model requires detailed, quantitative statements of the needs of potential users of EOP systems. The needs are expressed in appropriate technical terms, and related to specific user activities. The information will assist the model user in aggregating user needs into groups that can be served with single EOP systems. A knowledge of the relationship also permits the model user to build a rationale for the system design around the specific user activities that will be served.

NEED STRUCTURE

Statements of needs are structured on a hierarchical basis. That is, general needs are stated and from this lower order needs are derived. The process of subdivision is continued to the point of defining specific measurements that can be made with remote sensors.

The sequence for the documentation of user needs is shown in Fig. A-1 and described in the following.

(1) User Activity Definition—A user activity includes an appreciable segment of the overall agency mission or jurisdiction. For example, the user activity might be that of water resources management in a geographic region of the U.S.

(2) Activity Component Definition—Components are principal aspects of the activity. For the water resources management example, these might include water management and pollution control.

(3) Component Information Need Definition—Associated with each activity component are required items of information. For the water

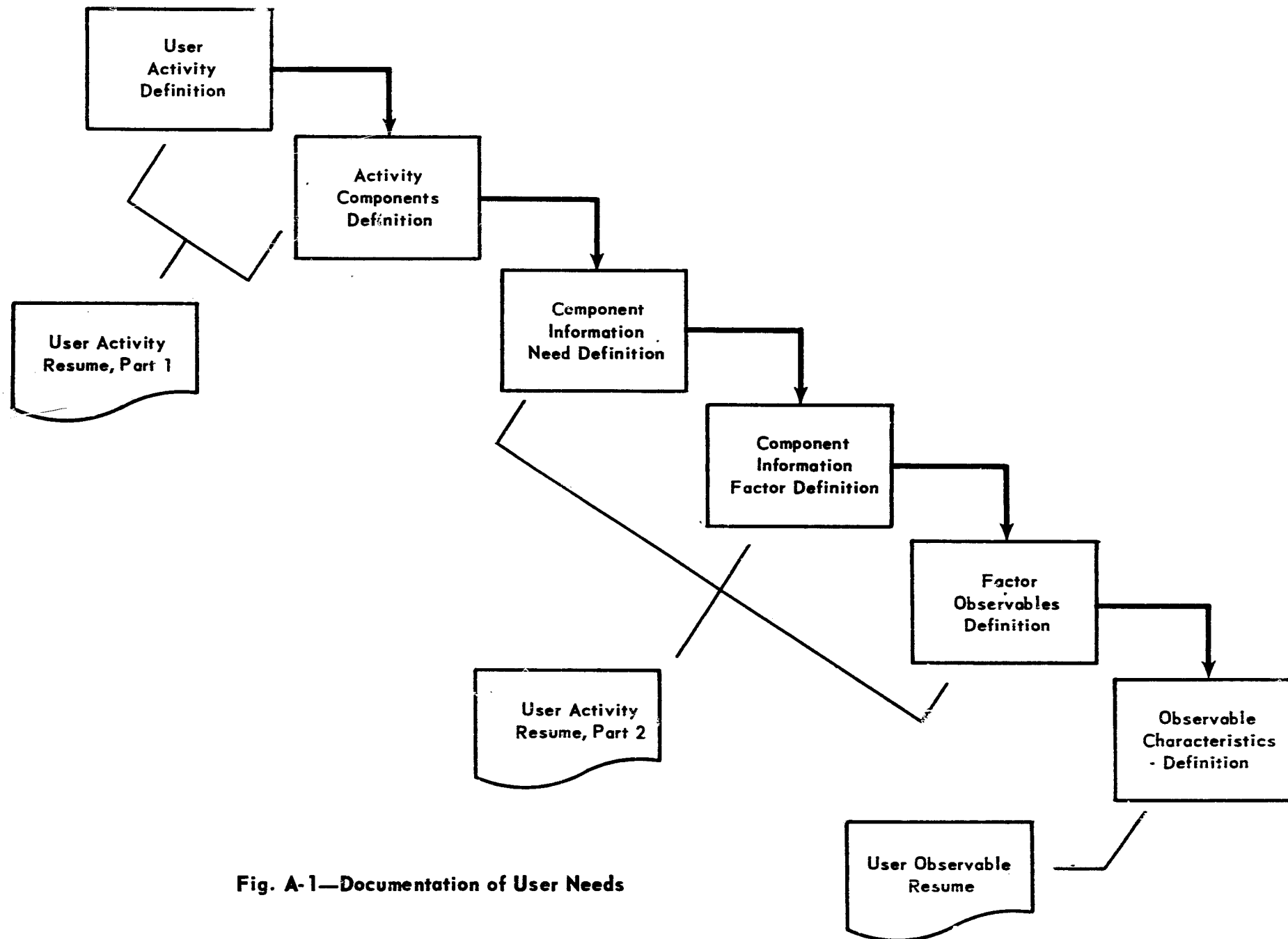


Fig. A-1—Documentation of User Needs

management example, these might include data on the distribution of surface water, flood prediction and water quality.

(4) Information Factor Definition—Associated with the information needs there are factors that describe phenomena or features that may be detected by remote sensing techniques. These factors may include color and size as well as point and area features. For measurements of surface water distribution these might include the depth of water in clear channels and the depth of water in vegetated areas.

(5) Observable Characteristics Definition—For each information factor the technical characteristics of the observation must be identified that will provide the desired information. As distinguished from the earlier definitions of need, which may be determined by the user, the definition of the Observable Characteristics requires expertise in remote sensing technology. NASA personnel would likely define the Observable Characteristics. For measuring surface water distribution and the detection of water depth in clear channels, this might involve the observation of the color of the channel water as an indication of depth.

#### NEED DOCUMENTATION

As shown in Fig. A-1, the progression in the definition of user needs from the User Activity down through the Observable Characteristics, is implemented using two documentation formats, the User Activity Resume and the User Observable Resume.

##### User Activity Resume

The User Activity Resume is organized as a 2-part document.

Part 1 of the resume is used to record the identification of the user agency, the user activity under consideration and the components of this activity. Included is an indication on whether the information needed by the activity components can be provided from other than satellite sources. Part 1 of the resume, as it might be completed by a user, is shown in Fig. A-2(a).

Part 2 of the resume is used to record the component information needs and their associated information factors. Included is an indication of how frequently this information must be made available

USER ACTIVITY RESUME		Part 1 ACTIVITY COMPONENTS		
User Agency Flood Control District		User Activity Regional Water Resources Management		
Activity Description  Water storage and release to minimize seasonal variations in availability of regional water supply.				
No.	Activity Component	Info Sources		
		EOP	Other	Both
1	Water Management			X
2	Pollution Control			X
3				
4				
5				
6				
7				
8				
9				
10				

Fig. A-2(a)—User Activity Resume (Part 1)

to meet the needs of the activity. Part 2 of the resume, as it might be completed by a user, is shown in Fig. A-2(b).

#### User Observable Resume

The User Observable Resume, as indicated in Fig. A-1, is a 1-part document which records the identity of the observable and the technical characteristics of the remote-sensing technology involved in making the observation. A separate resume is prepared for each observable. For a user activity of any size this will involve a relatively large number of observables and hence the preparation of a large number of individual resumes. To control this amount of data, an Observable Identification is assigned to each observable of the form:

N	N	-	NN	NN	NN	-	NN	NN
(1)	(2)		(3)	(4)	(5)		(6)	(7)

where:

- (1) Time Horizon of User Activity
- (2) Information Category of User Activity Number
- (3) User Agency Number
- (4) User Activity Number
- (5) User Activity Component Number
- (6) Component Information Factor Number
- (7) Observable Number

With this format it is possible to identify uniquely each observable, and at the same time maintain a correspondence with the activity involved. The resume, as it might be completed by a NASA remote-sensing expert, in response to the observable information needs as described in Part 2 of the User Activity Resume, is shown in Fig. A-3.

In completing the Observable Characteristics portion of the resume, the NASA expert records the data in a sequence and in a format compatible with reduction of data into machine readable format.

The data values may be recorded to reflect any of three conditions, minimum value, nominal value and maximum value, as determined by the NASA expert to be appropriate to the user need in question.

USER ACTIVITY RESUME		Part 2 COMPONENT INFORMATION NEEDS		
User Agency Water Resource District		Activity Component Water Management		
Component Description  Storage and timed release of water supplies throughout region to meet demands of agriculture, human water supply and conservation.				
Component Information Needs				
No.	Need	No.	Information Factor	Update Interval
1	Surface Water Distribution	1	Water Depth - Clear Channels	Weekly
		2	Water Depth - Vegetated Areas	
2	Water Quality	1	Site of Effluent Discharges	Weekly
		2	Site of Plant Stress Along Water Courses	
3	Flood Prediction	1	Heightened Water Levels	Weekly
		2	Precipitation Patterns	

Fig. A-2(b)—User Activity Resume (Part 2)

USER OBSERVABLE RESUME		User Observable Number						
		Time Hor	Act Cat	User Agny	Act Comp	Info Need	Info Fact	Obsr
		2	6	02	02	01	01	01
User Agency Water Resources District							02	
Activity Component Water Management		02	Information Need Surface Water Distribution				01	
Information Factor Water Depth in Clear Channels		01	Observable Water Color				01	
Observable Characteristics								
NO.	CHARACTERISTICS	FORMAT	VALUE					
			Minimum	Nominal	Maximum			
1	Sensor Type	3A2N		RDM01				
2	Spectral Limit-Upper	5N.5N		0.7				
3	Spectral Limit-Lower	5N.5N		0.4				
4	Spectral Units	3A		MIC				
5	Number Spectral Bands	2N		3				
6	Ground Swath Width (NM)	4N		10				
7	Ground Resolution (FT)	4N		150				
8	Area of Coverage (Code)	6N		21104				
9	Frequency of Coverage (Days)	2N		7				
10	Type Illumination (Code)	N		1				
11	Observable Status (Code)	N		2				
Message (50A Max)								

Fig. A-3—User Observable Resume



Appendix B  
SYSTEM ELEMENT RESUME



## Appendix B

### SYSTEM ELEMENT RESUME

This appendix describes the documentation by which the data base on equipment characteristics, development schedules and costs are entered for the ECP Model. The documentation is prepared for all developments in remote-sensing technology that may have potential application to earth observation systems.

Documentation is prepared for components currently available, under development and proposed. Both hardware and software developments are defined. The hardware developments include the on-board sensors and data processors, the data transmission links and the ground processors. The software developments include the programs that extract information from the sensor data, and the analytical models that relate sensor data to other variables of interest to the user.

#### RESUME PREPARATION

Preparation of the resumes calls for data from a broad range of NASA activities. The data may be taken from project information sheets and augmented by direct contact with the cognizant specialists.

There may be an advantage if the resumes are prepared by a single office. Such a procedure would provide for: (1) a consistent examination and interpretation of the source data and its subsequent translation into the resume format, and (2) a single responsible agent for monitoring of the source information and the generation of appropriate updates.

#### SYSTEM ELEMENT RESUME

The System Element Resume is organized in two parts.

### Part 1

Part 1 of the resume provides basic information identifying the development project and a brief description of the element describing the basic mode of operation. The relationship between projects is also given if more than one project is involved. Part 1 of the resume, as it might be prepared to describe a multispectral scanner type of sensor, is shown in Fig. B-1.

### Part 2

Part 2 of the resume is organized to record data on technical data and administrative data.

#### Technical Data

The technical data is divided into four sets of entries, one for each of the four types of system elements (i.e., sensor, down-link, user program, user model). The set of entries completed on any one resume is determined by the type of element being reported, as indicated at the top of the form.

#### Administrative Data

The administrative data calls for the same type of entries for all element types. Data is provided on the fiscal year the element is available for use as part of a flight program, the present status of the development and development costs as previously incurred, presently incurred, to be incurred in the upcoming (budget) year and cost to completion (outer years).

Part 2 of the resume, as it might be completed for each type of element, is shown in the following figures:

<u>Element</u>	<u>Figure</u>
Sensor	B-2 (a)
Down-Link	B-2 (b)
User Program	B-2 (c)
User Model	B-2 (d)

SYSTEM ELEMENT RESUME		Part 1 ELEMENT DESCRIPTION	
Element Category	<input checked="" type="checkbox"/> Sensor	<input type="checkbox"/> User Program	Type RDM-01
	<input checked="" type="checkbox"/> Down-Link	<input type="checkbox"/> User Model	Perf. Level PRF-01
No.	Development Title	Development Control No.	
1	Multispectral Scanner	999-99-99	
2			
3			
4			
5			
<p><b>Element Description</b></p> <p>The MSS has a 2-element cassegrain mirror system (F/3.6) with a 9-inch diameter primary and a rocking scan mirror, located in the object plane, with cross-orbital-track sweep rate of 13.6 Hz. The image is folded twice and focused on a square fiber optic matrix. Individual fibers couple the focused optical energy to a band filter and detector assembly. Bands 1, 2, &amp; 3 utilize tri-axial photomultiplier tubes while band 4 uses silicon photodiodes. Six detectors are paralleled in each of the first four bands by a row of fiber optic bundles stacked in the direction of the orbital track permitting a slower scanning motion of the rocking mirror system. Two detectors are used in the thermal band. The basic MSS scan line synchronization is provided by an optical pulse generator. A multiplexer is included in the MSS and processes the video data. The 24 (or 26) channels of video are time-division-multiplexed into a single data stream of approximately 2.4 MHz. The multiplexed signal is then converted into a 15 MB/S PCM signal by an A/D converter. Line start, PCM format information, and calibration data are included in the multiplexer output signal.</p>			

Fig. B-1—System Element Resume (Part 1)

SYSTEM ELEMENT RESUME				Part 2 ELEMENT CHARACTERISTICS		
Element Category	<input checked="" type="checkbox"/> Sensor		<input type="checkbox"/> User Program		Type RDM-01	
	<input type="checkbox"/> Down-Link		<input type="checkbox"/> User Model		Perf. Level PRF-01	
Technical Characteristics						
Sensor Element	Spectral Limit-Upper	Spectral Limit-Lower	Spectral Units	Number Spectral Bands	Sensor Data Bandwidth	Angular Resolution
	12.6	.05	MIC	4	2400	.005
	Type Field of View	Field of View, A-T	Field of View, C-T	Field Inclination	Weight	Power
	1	11.6	11.6	0	136	55
Down-Link Element	Down-Link Data Bandwidth	Data Compression Factor	Data Storage Capacity		Weight	Power
User Program Element	Number of Instructions	Number Decision Points	Number Data Values			
User Model Element	Number Activity Components	Number Information Needs	Number Information Factors	Number User Observables		
Administrative Characteristics						
All Elements	FY Available	Development Status	Cost Current FY	Cost Budget FY	Cost Prior FY	Cost Outer FY
	72	4	200	200		
Message (50A) Max						
ERTS Instrument						

Fig. B-2(a)—System Element Part 2 (Sensor)

SYSTEM ELEMENT RESUME				Part 2 ELEMENT CHARACTERISTICS		
Element Category	<input type="checkbox"/> Sensor	<input type="checkbox"/> User Program		Type SF-01		
	<input checked="" type="checkbox"/> Down-Link	<input type="checkbox"/> User Model		Perf. Level PRF-01		
Technical Characteristics						
Sensor Element	Spectral Limit-Upper	Spectral Limit-Lower	Spectral Units	Number Spectral Bands	Sensor Data Bandwidth	Angular Resolution
	Type Field of View	Field of View, A-T	Field of View, C-T	Field Inclination	Weight	Power
Down-Link Element	Down-Link Data Bandwidth	Data Compression Factor	Data Storage Capacity		Weight	Power
	4000	1.000	30		70	60
User Program Element	Number of Instructions	Number Decision Points	Number Data Values			
User Model Element	Number Activity Components	Number Information Needs	Number Information Factors	Number User Observables		
Administrative Characteristics						
All Elements	FY Available	Development Status	Cost Current FY	Cost Budget FY	Cost Prior FY	Cost Outer FY
	72	4	200			
Message (50A) Max ERTS Equipment						

Fig. B-2(b)—System Element Resume Part 2 (Down-Link)

SYSTEM ELEMENT RESUME				Part 2 ELEMENT CHARACTERISTICS		
Element Category	<input type="checkbox"/> Sensor		<input checked="" type="checkbox"/> User Program		Type PRG-01	
	<input type="checkbox"/> Down-Link		<input type="checkbox"/> User Model		Perf. Level	
Technical Characteristics						
Sensor Element	Spectral Limit-Upper	Spectral Limit-Lower	Spectral Units	Number Spectral Bands	Sensor Data Bandwidth	Angular Resolution
	Type Field of View	Field of View, A-T	Field of View, C-T	Field Inclination	Weight	Power
Down-Link Element	Down-Link Data Bandwidth	Data Compression Factor	Data Storage Capacity		Weight	Power
User Program Element	Number of Instructions	Number Decision Points	Number Data Values			
	1,000	10	1,000,000			
User Model Element	Number Activity Components	Number Information Needs	Number Information Factors	Number User Observables		
Administrative Characteristics						
All Elements	FY Available	Development Status	Cost Current FY	Cost Budget FY	Cost Prior FY	Cost Outer FY
	72	4	50	50		
Message (50A) Max						

Fig. B-2(c)—System Element Resume Part 2 (User Program)

SYSTEM ELEMENT RESUME				Part 2 ELEMENT CHARACTERISTICS		
Element Category	<input type="checkbox"/> Sensor		<input type="checkbox"/> User Program		Type MDL-01	
	<input type="checkbox"/> Down-Link		<input checked="" type="checkbox"/> User Model		Perf. Level	
Technical Characteristics						
Sensor Element	Spectral Limit-Upper	Spectral Limit-Lower	Spectral Units	Number Spectral Bands	Sensor Data Bandwidth	Angular Resolution
	Type Field of View	Field of View, A-T	Field of View, C-T	Field Inclination	Weight	Power
Down-Link Element	Down-Link Data Bandwidth	Data Compression Factor	Data Storage Capacity		Weight	Power
User Program Element	Number of Instructions	Number Decision Points	Number Data Values			
User Model Element	Number Activity Components	Number Information Needs	Number Information Factors	Number User Observables		
	2	4	8	16		
Administrative Characteristics						
All Elements	FY Available	Development Status	Cost Current FY	Cost Budget FY	Cost Prior FY	Cost Outer FY
	72	4	50	50		
Message (50A) Max						

Fig. B-2(d)—System Element Resume Part 2 (User Model)



Appendix C.  
MODEL OPERATION

Appendix C  
MODEL OPERATION

INPUT PREPARATION

The preparation of model inputs involves production of three data decks as follows:

- . Observable Resume Deck
- . System Element Resume Deck
- . Model Control Deck

A description of the input preparation for each deck is provided in the following sections. Emphasis is placed on the card format types which make up each set. Reference should be made to:

Appendix G - INPUT DATA FORMATS

Appendix H - CODE CATALOG

as appropriate, for details on format and actual parameter values.

Observable Resume Deck

Each Observable Resume consists of a 3-card set of information for each application. The first two cards of the set (Cards A1 and A2) are used to record the quantitative aspects of the observable. The third card of the set (A3) is used, as required, to record a brief (50-character) message describing any significant aspect of the observable not recorded by the quantitative information.

The card formats are shown in Appendix G in the figures identified in the following table:

Card type	Card title	Figure (Appendix G)
A1	Observable Resume I	G1
A2	Observable Resume II	G2
A3	Observable Message	G3

Refer to the Glossary for the definition of the parameters itemized in the figures.

#### System Element Resume Deck

The System Element Resume consists of a 3-card, or 4-card set of information depending on the type of element being described.

The Sensor System element uses a 4-card set. The first two cards (S1 and S2) are used to identify the element type and to record the quantitative aspects of the sensor performance. The third card (S4) is used to record the sensor development cost information and fiscal year availability of the sensor for operational use. A fourth card (S5) is used, as required, to provide a brief (50-character) qualitative statement of any significant aspect of the sensor utilization or development not recorded by the quantitative information.

The Down-Link element uses a 4-card set. The first card (S1) is used to identify the element type. The second card (S3) is used to record the quantitative aspect of the down-link performance. The third card (S4) is used to record the down-link development cost information and fiscal year availability of the sensor for operational use. A fourth card (S5) is used, as required, to provide a brief (50-character) qualitative statement on utilization or development not recorded by the quantitative information.

The User Program element and Use Model element use a 3-card set. The first card (S1) is used to identify the element type. The second card (S4) identifies the development costs and fiscal year availability of the program or model. The third card (S5) is used to provide a brief (50-character) qualitative statement on utilization or development not recorded by the quantitative information.

A summary of the card types associated with each element is shown in the following table:

Element	Card types used				
	S1	S2	S3	S4	S5
Sensor	X	X		X	X
Down-Link	X		X	X	X
User Processor	X			X	X
User Model	X				

The card formats are shown in Appendix G in the figures identified in the following table:

Card type		Figure (Appendix G)
S1	Sensor Element I	G4
S2	Sensor Element II	G5
S3	Down-Link Element	G6
S4	Element Costs	G7
S5	Element Message	G8

Refer to Glossary for the definition of the parameters itemized in the figure.

### Model Control Deck

Preparation of the model control input consists in the preparation of a 5-card set of information which provides for the identification of model run, the type of results required, and the information to be retrieved from the model data base against which the model is to be run.

The first card (P1) identifies the control conditions imposed on the run. The second card (P2) identifies the user activities against which the model is to be run. The third and fourth cards (P4, P5) identifies the system elements against which the model is to be run. The fifth card (P6) identifies the earth coverage imposed on the run. The cards are grouped into two sets to form Model Control Parts 1 and

and 2. Part 1 contains (P1), (P2), and (P6). Part 2 contains only (P5).

The card formats are shown in Appendix G in the figures identified in the following table:

Card type	Card title	Figure (Appendix G)
P1	Run ID	G9
P2	Activity ID	G10
P4	System Element ID I	G11
P5	System Element ID II	G12
P6	Earth Coverage ID	G13

Refer to the Glossary for the definition of the parameters itemized in these figures.

#### JOB CATALOGING

Prior to its use as an operational programming system, the EOP model is cataloged onto disk-pack.

Job cataloging with the EOP model is carried out using the Mark IV File Management System software package<sup>1</sup> in conjunction with the IBM 360/91 operating system JCL.

Cataloging is a 3-job process. In the first job, code is cataloged to initialize the program operation by establishing a dictionary which contains the definitions for files, transactions, and tables. In the second job, code is cataloged to identify and analyze the statistics of the applications under consideration and output the associated reports. In the third job, code is cataloged to identify the system elements under consideration, analyze the system performance of these elements, compare this system performance to the needs of the applications under consideration, and output the associated reports.

Cataloging is carried out by input of the card decks listed in the EOP Model Listing, provided separately.

<sup>1</sup>Available at the GSFC computer facility on the IBM 360/91

## JOB EXECUTION

Job execution is carried out using a procedure which assumes that the EOP model has been previously cataloged on disk-pack (see preceding section).

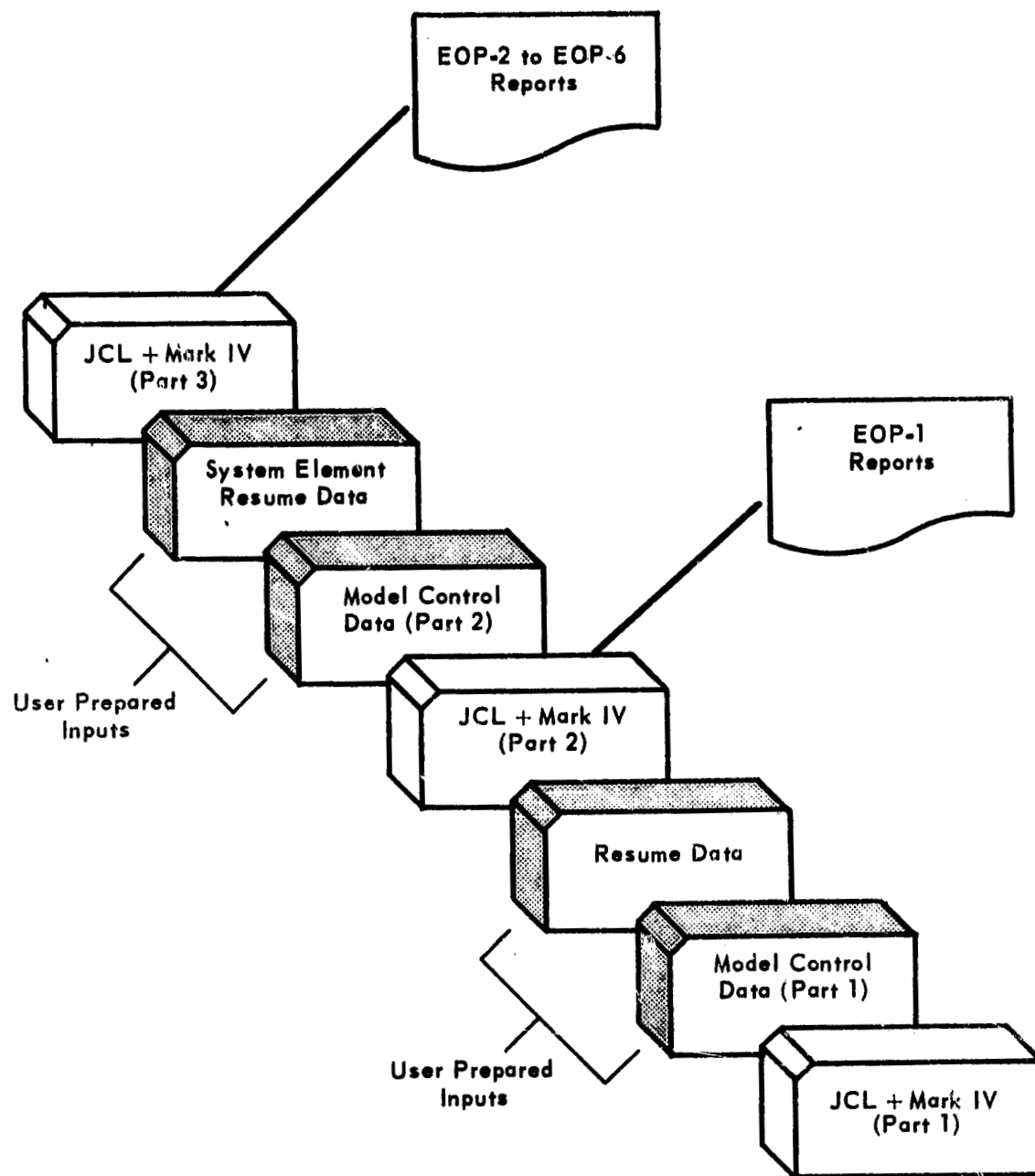
For this condition, job execution consists in the assembly of a job deck which provides for call of the appropriate processing routines from those in storage, and the input of the appropriate data against which the processing takes place.

The sequence of these individual decks as assembled into the overall run deck is shown in Fig. C-1. The JCL + MARK IV decks are individually identified, prepackaged sets of cards (see Tables C-1 to C-3) inserted in the order shown without further user attention. The user prepared inputs are inserted in the order shown subject to the following word order within the individual decks.

- . Model Control Deck - "P-card" number order
- . Observable Resumes Decks - sensor type in alphabetical order, followed by observable number in numerical order, then "A-card" number order.
- . System Element Resumes Deck - element category in numerical order, followed by element type in alphabetic order, followed by element performance in numerical order, then "S-card" number order.

As an operating convenience, the card decks may be color-coded to simplify the assembling and inspection of the overall run deck.

A run deck is prepared for each program alternative of interest, and submitted for processing as a separate entity. Any number of run decks may be submitted at a time, and will be processed independently.



**Fig. C-1—Job Execution Set-Up**

Table C-1

JCL + MARK IV

( PART 1 )

```
//WSJRS001 JOB )RJ0021685A,T,B00080,001003*,069,MSGLEVEL=1
//JOB LIB DD DSN=SYS2.MARKIV,DISP=SHR
//STEP0 EXEC PGM=IEFBR14
//M4NEW DD DSN=M4001,UNIT=SYSDA,VOL=SER=M2SCR6,DISP=)OLD,DELETE*
//STEP2 EXEC PGM=MARKIV
//M4LIB DD DSN=M2.WSJRS.D001,DISP=SHR
//M4LIST DD SYSOUT=A,DCB=)RECFM=FB,LRECL=133,BLKSIZE=7182*
//M4REPO DD UNIT=SYSDA,SPACE=)CYL,)5,5**,DISP=),PASS*,
// DCB=)RECFM=FB,LRECL=7140,BLKSIZE=7144*
//M4NEW DD DSN=M4001,UNIT=SYSDA,DISP=)NEW,KEEP*,VOL=SER=M2SCR6,
// DCB=)RECFM=FB,LRECL=400,BLKSIZE=400*,SPACE=)CYL,)5,5**
//M4SORT DD UNIT=SYSDA,SPACE=)TRK,1*,DISP=),PASS*
//M4RJCT DD DUMMY,UNIT=SYSDA,SPACE=)CYL,)5,5**,DISP=),DELETE*
//M4INPUT DD *
PUN2 RCINSTRESU U US Y
POP-ONE CRTODAY RESEARCH ANALYSIS CORP
/*
//M4TRAN DD *
```



Table C-2

JCL + MARK IV

( PART 2 )

999999999999ZZZ77

/\*

//SORT EXEC SORTN, PARM='CORE=250000,MSG=AP',

// REGION=260K,CYL=5

//SORT.SORTIN DD DSN=\*.STEP2.M4REPO,DISP=)OLD,DELETE\*

//SORT.SYSIN DD DSN=\*.STEP2.M4SORT,DISP=)OLD,DELETE\*

//SORT.SORTOUT DD DCB=)LRECL=7140,BLKSIZE=7144,RECFM=VB\*,

// UNIT=SYSDA,SPACE=)CYL, )5,5\*\*,DISP=),PASS\*

//STEP3 EXEC PGM=MARKIV

//M4LIB DD DSN=M2.WSJRS.D001,DISP=SHR

//M4LIST DD SYSOUT=A,DCB=)RECFM=FB,LRECL=133,BLKSIZE=7182\*

//M4REPI DD DSN=\*.SORT.SORT.SORTOUT,DISP=)OLD,DELETE\*

//M4INPUT DD \*

SUN3 RC S

/\*

//SYSPRINT DD SYSOUT=A

/\*

//STEP4 EXEC PGM=MARKIV,REGION=250K

//M4LIB DD DSN=M2.WSJRS.D001,DISP=SHR

//M4LIST DD SYSOUT=A,DCB=)RECFM=FB,LRECL=133,BLKSIZE=7182\*

//M4REPO DD UNIT=SYSDA,SPACE=)CYL, )5,5\*\*,DISP=),PASS\*,

// DCB=)RECFM=FB,LRECL=7140,BLKSIZE=7144\*

//M4NEW DD DUMMY,UNIT=SYSDA,SPACE=)CYL, )5,5\*\*,DISP=),DELETE\*,

// DCB=)RECFM=FB,LRECL=500,BLKSIZE=500\*

//M4CORD1 DD DSN=M4001,VOL=SER=M2SCR6,UNIT=SYSDA,DISP=)OLD,KEEP\*

//M4SORT DD UNIT=SYSDA,SPACE=)TRK,1\*,DISP=),PASS\*

//M4REJCT DD DUMMY,UNIT=SYSDA,SPACE=)CYL, )5,5\*\*,DISP=),DELETE\*

//M4INPUT DD \*

DUN2 RCINSTDATA U US Y

DUN2 RFINSTRSUUM4CORD1 ELCODE SENSKEY PERFINC

FOP-TWO CRTODAY RESEARCH ANALYSIS CORP

/\*

//M4TRAN DD \*

Table C-3

JCL + MARK IV

( PART 3 )

```
/*  
//TORT EXEC SORTN,PARM='CORE=250000,MSG=AP',  
// REGION=260K,CYL=5  
//SORT.SORTIN DD DSN=*.STEP4.M4REPO,DISP=)OLD,DELETE*  
//SORT.SYSIN DD DSN=*.STEP4.M4SORT,DISP=)OLD,DELETE*  
//SORT.SORTOUT DD DCR=)LRECL=7140,BLKSIZE=7144,RECFM=VR*,  
// UNIT=SYSDA,SPACE=)CYL, )5.5**,DISP=),PASS*  
//STEP5 EXEC PGM=MARKIV  
//M4LIB DD DSN=M2.WSJRS.D001,DISP=SHR  
//M4LIST DD SYSOUT=A,DCR=)RECFM=FB,LRECL=133,BLKSIZE=7182*  
//M4REPI DD DSN=*.TORT.SORT.SORTOUT,DISP=)OLD,DELETE*  
//M4INPUT DD *  
SUN3 RC S  
/*  
//SYSPRINT DD SYSOUT=A  
/*
```

Appendix D  
MODEL DEMONSTRATION

## Appendix D

### MODEL DEMONSTRATION

This appendix describes the exercise of the EOP model on a set of input data for the purpose of demonstrating the overall model operating capability. The input data is based, in part, on field work which sought to identify potential users and their information needs, but in the main reflects estimates produced during the course of the analysis from the remote sensing literature. The results of the demonstration, therefore, should not be literally interpreted, but may be taken as illustrative of the information products available from the model during a programming exercise.

#### DEMONSTRATION SCENARIO

##### User Needs

The demonstration illustrates a programming situation where a group of required users are to be served by a single EOP system. For this demonstration, the regional area to be served is Southern Florida. The user community is taken to consist of the following agencies:

- . USDC Geological Survey
- . Dade County Planning Dept
- . Everglades National Park
- . Central/Southern Florida  
Flood Control Districts

The interest of this group in earth observation's information was assessed and related to the following general categories of agency activities.\*

---

\*The agency activities have been inferred from their mission and constitute a simplification of the actual agency responsibilities for demonstration purposes.

- . Water Resource Management
- . Pollution Control
- . Land Use Planning
- . Mapping
- . Ecological Monitoring

The particular activities associated with each agency are shown in Table D-1.

Following the methodology for the documentation of user needs described in Appendix A, each of the activity components was related to specific information needs, as shown in Table D-2. Again following the methodology of Appendix A, each of these information needs was related to one or more information factors (which quantify the needs). The factors, in turn, were related to specific observables, that is, the phenomena which are actually sensed to provide, either directly or inferentially, the information of interest. The progression from information need to information factor to observable, is shown in Table D-3.

#### System Configuration Alternatives

The system configuration is established from consideration of the information needs of the user community as shown in Table D-3.

#### Sensor Element

As shown in Table D-3, under sensor type, all the user information needs are identified terms of multispectral scanner imagery. The choice of sensor is one of specifying the performance level to be achieved by the multispectral scanner. One possible choice is the scanner currently under development for the ERTS program. The characteristics of this unit, including development, are identified in Table D-4 (under RDM-01, PRF-01).

Further inspection of the information needs, as shown in Table D-3 however, includes a number of requirements for ground resolutions of 150 feet. Typically, the ERTS scanner will provide on the order of 250 feet at a 500 mile operating altitude. In terms of alternative configurations therefore, consideration should be given to a scanner unit with improved resolution. For the purposes of the demonstration, a proposed development

Table D-1

ACTIVITY COMPONENTS

USER	ACTIVITY COMPONENTS				
	Water Resource Mgmt	Pollution Control	Land Use Planning	Mapping	Ecological Monitoring
Geological Survey				X	
Flood Control Districts	X	X			
Dade County Planning Dept.	X	X	X	X	
Everglades National Park	X			X	X

D-3

Table D-2  
INFORMATION NEEDS

INFORMATION NEEDS	ACTIVITY COMPONENTS				
	Water Resource Mgmt	Pollution Control	Land Use Planning	Mapping	Ecology Balance
Fire Detection					X
Flood Damage	X		X	X	X
Flood Prediction	X				X
Geological Features	X		X	X	X
Housing Development			X		
Hydrological Features	X		X	X	X
Salt Water Intrusion	X	X			
Surface Water Distr	X		X		X
Soil Moisture					X
Vegetation Devmt		X	X		X
Water Quality	X	X			X

Table D-3

## USER OBSERVABLES

Information Needs	Information Factor	User Observable	BASIC OBSERVABLE CHARACTERISTICS						
			Sensor Type	Spectral Range (Microns)	Ground Swath (NM)	Ground Resolution (Ft)	Area of Coverage	Frequency of Coverage (Days)	Illumination
Fire Detection	Smoke Presence Fire Site	Smoke Color Surface Temp	MSS <sup>1</sup>	0.4-0.8	50	150	Southern Florida	1	Sun-Sync
				10.0-12.0	100	300		1	
Flood Damage	Veg Damage Land Form Chgs	Veg Color Surface Color		0.5-0.9	100	300		7	
				0.4-1.1	100	300		7	
Flood Prediction	High Water Level Precip Patterns	Water Color Cloud Cover		0.4-0.7	100	300		15	
				0.4-1.1	100	2500		1	
Geological Feat	Land Form Struct Geothermal Activ	Surface Color Surface Temp		0.4-1.1	100	500		Annual	
				10.0-12.0	100	500		Annual	
D-5 Housing Devmt	New Constr	Surface Color		0.4-0.7	50	150		90	
Hydrological Feat	Water Courses	Water Temp		10.0-12.0	50	150		90	
Salt Water Intrusion	Intrusion Extent	Water Color		0.4-0.7	50	150		7	
Surf Water Distr	Depth Clr Chann Depth Veg Area	Water Color Veg Color		0.4-0.7	50	150		7	
				0.4-1.1	50	150		7	
Soil Moisture	Veg Extent Bare Soil Extent	Veg Color Soil Color		0.4-1.1	100	300		7	
				1.5-1.7	100	300		7	
Veg Devmt	Veg Vigor	Veg Color		0.4-1.1	100	300		30	
Water Quality	Effluent Discharges Plant Stress	Effluent Plumes Plant Color	↓	0.4-1.1	50	150	↓	30	↓
				0.5-0.9	100	300		30	



is assumed to be available which can develop a scanner with improved resolution within the next two years. The characteristics of this unit are also identified in Table D-4 (under RDM-01, PRF-02).

Table D-4  
SENSOR CHARACTERISTICS

Characteristic <sup>a</sup>	Radiometer Unit	
	RDM-01 PRF-01	RDM-01 PRF-02
Angular resolution (°)	.0050°	.0025°
Field of view (°) (cross-track)	11.6°	11.6°
Spectral Limit (lower)	.5 MIC	.5 MIC
Spectral Limit (upper)	12.6 MIC	12.6 MIC
Number of Spectral Bands	4	4
Sensor Data Bandwidth	2400 KHZ	4800 KHZ
Costs - Current Year <sup>b</sup>	\$200K	
Costs - Budget Year <sup>b</sup>	\$200K	\$200K
Costs - Outer Years <sup>b</sup>	-	\$200K

<sup>a</sup> See Glossary (Appendix J) for definition of terms.

<sup>b</sup> Assigned values for demonstration purposes.

#### Down-Link Element

In addition to the sensor complement of the system configuration, provision must be made for the down-link portion of the system. For the purposes of the demonstration it is assumed that the down-link associated with each sensor type is prescribed (i.e., no alternatives). The choice of down-link is such as to provide compatibility between the sensor data bandwidth and the link bandwidth. A store and forward technique is used.

The down-link characteristics selected for the demonstration, reflecting these criteria are shown in Table D-5.

Table D-5

## DOWN-LINK CHARACTERISTICS

Characteristic <sup>a</sup>	Store and Forward Unit	
	SF-01 PRF-01	SF-01 PRF-02
Down-link data bandwidth	4000 KHZ	7000 KHZ
Down-link data storage capacity	30 min	30 min
Down-link data compression factor	1.000	1.000
Costs - Current Year <sup>b</sup>	\$200K	
Costs - Budget Year <sup>b</sup>	-	\$200
Costs - Outer Years <sup>b</sup>	-	\$200

<sup>a</sup> See Glossary (Appendix J) for definition of terms.

<sup>b</sup> Assigned values for demonstration purposes

#### User Program and User Model Elements

In addition to the sensor and down-link elements of the system, provision is also made for the software elements of the system. These involve for each user, a User Program which extracts the appropriate user information from the sensor imagery and a User Model, which defines analytically the manner in which the information is employed in the user activity.

For the purposes of the model, each user agency is assumed to be supported by one development program to produce a single integrated User Program, and another to produce a single integrated User Model.

For demonstration purposes the four user agencies are assumed to have identical User Program and User Model characteristics.\* A summary of the User Program and User Model characteristics is shown in Table D-6 and Table D-7, respectively.

---

\*The characteristics are meant as a guide to the scope of the effort involved in the development, to provide a basis for time and cost estimates; they do not uniquely define the development product.

Table D-6

## USER PROGRAM CHARACTERISTICS

Characteristic	User Program <sup>a</sup>			
	PRG-01	PRG-02	PRG-03	PRG-04
Number of Instructions	1000	1000	1000	100
Number of Decision Points	10	10	10	10
Number of Data Values	10 <sup>6</sup>	10 <sup>6</sup>	10 <sup>6</sup>	10 <sup>6</sup>
Costs - Current Year	\$50K	\$50K	\$50K	\$50K
Costs - Budget Year	\$50K	\$50K	\$50K	\$50K
Costs - Outer Years	-	-	-	-

<sup>a</sup>Assigned values for demonstration purposes.

Table D-7

## USER MODEL CHARACTERISTICS

Characteristic	User Model <sup>a</sup>			
	MDL-01	MDL-02	MDL-03	MDL-04
Number of:				
Activity Components	2	2	2	2
Information Needs	8	8	8	8
Information Factors	16	16	16	16
Observables	16	16	16	16
Costs - Current Year	\$50K	\$50K	\$50K	\$50K
Costs - Budget Year	\$50K	\$50K	\$50K	\$50K
Costs - Outer Years	-	-	-	-

<sup>a</sup>Assigned values for demonstration purposes.

### Orbit Type Alternatives

The EOP Model provides for two basic types of orbit, zero drift and minimum drift. The zero drift orbit, repeats its pattern of coverage daily, and provides near real time information. It is limited however to providing limited coverage of the earth, namely, that provided by the sub-satellite bands which can be generated in the 24-hour period. Minimum drift coverage, by definition, provides for complete coverage of the earth by allowing a progression in the coverage of each 24-hour period, such that the interlace over a period of days generates the complete pattern of coverage.

Additionally, the EOP Model provides for designation of the angle of inclination of the orbit, with the anticipation that the sun-synchronous orbit of  $99^{\circ}$  will dominate the choice of orbit angles considered.

For the South Florida regional example under consideration, an inspection of the user needs as shown in Table D-3 yields the following factors pertinent to orbit type selection.

1. Southern Florida area coverage
2. Frequency of coverage from 1 to 90 days
3. Sun-synchronous operation

The sun-synchronous requirement can be met with either the zero drift or minimum drift orbit. The frequency of observation requirement can be met (in all cases) only by the zero drift orbit which provides daily coverage.

The area coverage as restricted to Southern Florida presents a somewhat unique situation with respect to the zero drift orbit.

The Florida peninsula is oriented, to a first order approximation, directly along a sub-satellite track for a sun-synchronous orbit. In addition, the width of the peninsula approximates that achievable by the current ERTS scanner.

Thus a zero drift orbit may provide the desired coverage, under sun-synchronous conditions, on a daily basis.

The orbit choice for the demonstration is thus a zero drift,  $99^{\circ}$  orbit, which under operational conditions\* would be aligned to pass over the Florida peninsula.

---

\*The model logic does not include consideration of a ground reference point for the orbit considered.

## DEMONSTRATION RESULTS

As indicated in the description of the demonstration scenario, two system configurations were selected as alternatives to be considered in satisfying the remote sensing needs of the regional user community. One system employs a radiometer with twice the resolution capability of the other, but in all other respects, including orbit, the systems are identical. A comparison of the basic model output (Program Alternative Summary, EOP 3) for each configuration is shown in Table D-8.

As shown in Table D-8, the system with the lower resolution (Alternative 01), satisfies only 25% (25.310) of the 79 individual user needs of the user community. Alternative 02, with the higher resolution, achieves a 61% (60.750) satisfaction of the needs.

This difference in program performance, however, is achieved at a development cost of \$1,400,000 (800 + 600) for Alternative 2, compared with a development cost of \$800,000 (600 + 200) for the lower resolution system.

From a launch perspective, both systems involve the use of a DELTA booster to achieve their maximum user satisfaction. Alternative 02, however, can provide a 39% (39.240) user satisfaction in a lower orbit (485 NM) which can be achieved by the smaller SCOUT booster.

The EOP Model has thus provided the decision-maker with quantitative information to support the following types of judgments.

- . Is the size of the user community (as measured by the total number of needs served) in this case 79 appropriate to the level of investment being considered, in this case \$800,000 to \$1,400,000 plus a DELTA or SCOUT launch?
- . Is the fraction of needs actually satisfied a reasonable return, perhaps based upon the benefits\* which accrue?
- . Is the commitment to new work in the form of development of proposed projects, rather than the continued development of on-going work, the preferred course of action in terms of the overall development of remote-sensing technology?

---

\*See Appendix K for a discussion of the benefits associated with map preparation.

Table D-8

PROGRAM ALTERNATIVE SUMMARY

ALTER NATIVE NUMBER	ORBIT ALT (NM)	ORBIT CYCLE (DAYS)	NUMBER OF OBSERS	OBSERVATIONS SATISFIED NUMBER PERCENT	-----DEVELOPMENT COSTS (IN THOUS)-----				LAUNCH OPPORTUNITY			
					-ON-GOING-	-PROPOSED-	---TOTAL---		EARLIEST	VEHICLE		
					BUDFY	CMPLN	BUDFY	CMPLN	BUDFY	CMPLN	FY	
01	145	1	79	.000	500	100	100.	100	600	200	74	SCOUT
	305	1	79	.000								SCOUT
	485	1	79	.000								SCOUT
	680	1	79	20 25.310								DELTA
	945	1	79	4 5.060								DELTA
02	145	1	79	.000	300	100	500	500	800	600	74	SCOUT
	305	1	79	31 39.240								SCOUT
	485	1	79	31 39.240								SCOUT
	680	1	79	48 60.750								DELTA
	945	1	79	48 60.750								DELTA

D-11



Should a commitment be made to a SCOUT launch over a DELTA launch as part of a program to expedite the response to user needs by using simpler, less costly resources?

It should be noted that the answers to these questions are not directly obtainable from the model output. The model in each instance provides a set of values which can be consistently compared to values from other runs. The decision-maker must make the final determination based upon the importance he attaches to the difference values.

For the particular values determined in the model demonstration, one possible interpretation is that a SCOUT launched satellite is the desired mission but that a large percentage of user needs must be served. Assuming that the technology cannot be pressed to achieve a higher level of resolution, and thereby increase the user percentage satisfied, the decision may be one to expand the size of the user community. This would involve a further inquiry into the regional needs. In addition, consideration could be given to the needs of potential users within the subsatellite track of the Florida-positioned orbit over the balance of the United States.

Appendix E  
EOP MODEL OUTPUTS



<b>DISPLAY TYPE</b> EOP-1	<b>DISPLAY TITLE</b> USER OBSERVABLES
<b>DESCRIPTION</b> <p>This display, which comes in four parts, provides statistical information on the set of observables addressed by the program. Part I provides for each sensor type measures of the range (minimum value, maximum value) and mean (average value) for each observable characteristic for which such measures are applicable. Part II provides a frequency count of the Type Illumination (i.e., sun-synchronous, non-sun-synchronous). Part III provides a frequency count of the Earth Coverage. Part IV provides information on the amount of the earth's surface which must be sensed by each sensor to meet the needs of all the observables under consideration.</p>	
<b>USE: EVALUATION OF</b> <input type="checkbox"/> Program Alternatives <input type="checkbox"/> Program Performance <input type="checkbox"/> System Performance <input checked="" type="checkbox"/> User Needs	<b>FORMAT</b>  See Fig. E-2

Fig. E-1—EOP-1 Summary

RAC

USER-OBSERVABLES

PART 3 IMAGERY STATISTICS

OPTION 01 SENSOR IMG01

		SPECTRAL RANGE	NO OF BANDS	GROUND SWATH	UN TS	GROUND RESOLTN	UN TS	FREQ OF CIV
		.3550	2	100	NM	100	FT	60
		.3550	2	100	NM	100	FT	60
		.3550	2	100	NM	300	FT	60
		.3550	2	100	NM	300	FT	50
		.3550	3	100	NM	100	FT	60
		.3550	3	100	NM	100	FT	60
		.3550	3	100	NM	300	FT	50
		.3550	3	100	NM	300	FT	60
OP	COUNT		8					
	MAX.	.3550	3	100		300		60
	MIN.	.3550	2	100		100		60
	AVG.	.3550	2	100		200		60

E-2

Fig. E-2 (a)—Report EOP-1

USER OBSERVABLES

PART I IMAGERY STATISTICS

OPTICN 01 SENSOR RDM01

SPECTRAL RANGE	NO OF BANDS	GROUND SWATH	JN TS	GROUND RESOLTN	UN TS	FREQ JF C3V
9.4000	4	100	NM	200	FT	30
9.4000	4	100	NM	200	FT	30
9.4000	4	100	NM	600	FT	30
9.4000	4	100	NM	600	FT	30
12.1000	4	100	NM	200	FT	30
12.1000	4	100	NM	200	FT	30
12.1000	4	100	NM	600	FT	30
12.1000	4	100	NM	600	FT	30
12.1000	4	100	NM	200	FT	30
12.1000	4	100	NM	600	FT	30

OP	COUNT					
	10					
MAX.		12.1000	4	100	600	30
MIN.		9.4000	4	100	200	30
AVG.		11.0200	4	100	400	30

E-3

Fig. E-2 (b)—Report EOP-1

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USER OBSERVABLES

PART II - TYPE OF ILLUMINATION FREQUENCIES

OPTION 01

SENSOR	SUN	NON-SUN	TOTAL
	SYNCHRONOUS	SYNCHRONOUS	
IMG01	8		8
RDM01	10		10

Fig. E-2 (c)—Report EOP-1

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USER OBSERVABLES

PART III EARTH COVERAGE FREQUENCIES

OPTION 01

SENSOR	GLBE	CONT	NORTH	CONT	FEDERAL ADMINISTRATIVE AREA										ALASKA
			AMER	USA	1	2	3	4	5	6	7	8	9	10	
IMG01									8						
EDM01														10	

Fig. E-2 (d)—Report EOP-1



USER OBSERVABLES

PART IV SENSED EARTH FRACTION

OPTION 01

	SENSOR	SENSED EARTH FRACTION
ISENSTYPE MAX.	IMG01	.014800
ISENSTYPE MAX.	RDM01	.001950
OP MAX.		.014800

11-6

Fig. E-2 (c)—Report EOP-1

<b>DISPLAY TYPE</b>  EOP-1A	<b>DISPLAY TITLE</b>  USER OBSERVABLES
<b>DESCRIPTION</b>  <p>This display is an adjunct to display EOP-1. It itemizes the messages on file for each observable under consideration. These messages consist of a line of text, which alert the model user to some particular aspect of the observable, essential to its implementation which is not accounted for by the model operation. The information in these messages may or may not affect the implementation of the observables as part of the set of observables under consideration; this is a determination to be made by the model user.</p> <p>In addition, the display indicates the status of each observable as a verified source of information by use of one of three status levels; proposed, experimental, established.</p>	
<b>USE: EVALUATION OF</b>  <input type="checkbox"/> Program Alternatives <input type="checkbox"/> Program Performance <input type="checkbox"/> System Performance <input checked="" type="checkbox"/> User Needs	<b>FORMAT</b>  See Fig. E-4

**Fig. E-3—EOP-1A Summary**



USER OBSERVABLES MESSAGE LIST

E-4

OBSERVABLE NO	OBSERVABLE	STATUS	MESSAGE
OPTION 01			
11-010101-0101	GS GE 100NM, GR LE 200FT	EXPERIMENTAL	SENSOR SPECTRAL LIMITS EXCEED NEED
11-010201-0101	GS GE 100NM, GR LE 200FT	EXPERIMENTAL	SENSOR SPECTRAL LIMITS EXCEED NEED
11-010301-0101	GS GE 100NM, GR LE 600FT	EXPERIMENTAL	SENSOR SPECTRAL LIMITS EXCEED NEED
11-010401-0101	GS GE 100NM, GR LE 600FT	EXPERIMENTAL	SENSOR SPECTRAL LIMITS EXCEED NEED
11-020101-0101	GS GE 100NM, GR LE 200FT	EXPERIMENTAL	
11-020201-0101	GS GE 100NM, GR LE 200FT	EXPERIMENTAL	
11-020301-0101	GS GE 100NM, GR LE 600FT	EXPERIMENTAL	
11-020401-0101	GS GE 100NM, GR LE 600FT	EXPERIMENTAL	
11-040101-0101	GS GE 100NM, GR LE 200FT	EXPERIMENTAL	
11-040201-0101	GS GE 100NM, GR LE 600FT	EXPERIMENTAL	
22-040101-0101	GS GE 100NM, GR LE 100FT	EXPERIMENTAL	SENSOR NUMBER OF BANDS EXCEED NEED
22-040201-0101	GS GE 100NM, GR LE 100FT	EXPERIMENTAL	SENSOR NUMBER OF BANDS EXCEED NEED
22-040301-0101	GS GE 100NM, GR LE 300FT	EXPERIMENTAL	SENSOR NUMBER OF BANDS EXCEED NEED
22-040401-0101	GS GE 100NM, GR LE 300FT	EXPERIMENTAL	SENSOR NUMBER OF BANDS EXCEED NEED
22-050101-0101	GS GE 100NM, GR LE 100FT	EXPERIMENTAL	
22-050201-0101	GS GE 100NM, GR LE 100FT	EXPERIMENTAL	
22-050301-0101	GS GE 100NM, GR LE 300FT	EXPERIMENTAL	
22-050401-0101	GS GE 100NM, GR LE 300FT	EXPERIMENTAL	

Fig. E-4—Report EOP-1A



<b>DISPLAY TYPE</b> EOP-2	<b>DISPLAY TITLE</b> SYSTEM PERFORMANCE SUMMARY
<b>DESCRIPTION</b> <p>This display, which comes in two parts, provides information of the performance of the system at each of the orbit altitudes identified in the Earth Coverage input. Part I of the display provides information on the instrumentation. The value for ground swath and ground resolution for each sensor type in the system is provided at each altitude, along with the values of orbit cycle period and number of revolutions per cycle. Part II of the display provides data on the down-link elements of the system, in processing the sensor data from the sensor output to the ground station. For each down-link, performance data is provided which indicates the fraction of down-link channel input bandwidth and the fraction of down-link storage capacity which is utilized during the course of sensor operation. Included in the identification of bandwidth utilization is the bandwidth compression factor. This factor is used to compute an effective sensor bandwidth, as input to the down-link, to account for data stream reduction, if the on-board processing includes real-time data reduction.</p>	
<b>USE: EVALUATION OF</b> <input type="checkbox"/> Program Alternatives <input type="checkbox"/> Program Performance <input checked="" type="checkbox"/> System Performance <input type="checkbox"/> User Needs	<b>FORMAT</b>  See Fig. E-6

**Fig. E-5—EOP-2 Summary**



SYSTEM PERFORMANCE SUMMARY

PART I SENSOR PERFORMANCE

SENSOR PER VARIABLE ALTITUDE RANGE 1 ALTITUDE RANGE 2 ALTITUDE RANGE 3 ALTITUDE RANGE 4 ALTITUDE RANGE 5

OPTION 01

IMG01 PRF01	A_TITUDE_NM	142	300	486	670	899
	CYCLE PE DY	13	14	15	16	18
	REVS/CYC	209	211	211	209	217
	GRND SWT NM	28	60	97	134	180
	GRND RES FT	30.1	63.6	103.1	142.1	190.7
	S#PT FRC	.27	.59	.95	1.31	1.83
RDM01 PRF01	A_TITUDE_NM	142	300	486	670	899
	CYCLE PE DY	13	14	15	16	18
	REVS/CYC	209	211	211	209	217
	GRND SWT NM	28	60	98	135	182
	GRND RES FT	75.2	159.0	257.6	355.2	476.6
	S#PT FRC	.27	.59	.96	1.32	1.85

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Fig. E-6 (a)—Report EOP-2

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SYSTEM PERFORMANCE SUMMARY

PART II - DOWN LINK PERFORMANCE

DOWN LINK	SENSOR SERVED		COMPR FACTR	LINK DATA BW (KHZ)	LINK DATA BW UTILIZED	NO OF TRNSM	LINK DATA STOP CAPY (MIN)	LINK DATA STOP CAPY UTILIZED		
OPTION 01	SF01	PRF01	RDM01	PRF01	1.000	4.000	.600000	3	30	.42
	SF01	PRF01	IMG01	PRF01	1.000	4.000	.875000	3	30	.23

E-11

Fig. E-6 (b)--Report EOP-2

<b>DISPLAY TYPE</b>  EOP-2A	<b>DISPLAY TITLE</b>  SYSTEM ELEMENT MESSAGE LIST
<b>DESCRIPTION</b>  <p>This display is an adjunct to display EOP-2 and itemizes the messages on file for each system element provided for in the program. These messages consist of a line of text, which alerts the model user to some particular aspect of the system element, essential to its operation which is not accounted for by the model operation. The information in these messages may or may not affect the implementation of the system under consideration; this is a determination to be made by the model user.</p>	
<b>USE: EVALUATION OF</b>  <input type="checkbox"/> Program Alternatives <input type="checkbox"/> Program Performance <input checked="" type="checkbox"/> System Performance <input type="checkbox"/> User Needs	<b>FORMAT</b>  See Fig. E-8

Fig. E-7—EOP-2A Summary

SYSTEM ELEMENT MESSAGE LIST

SENSOR PERFORMANCE MESSAGE

OPTION 01

IMG01	PRF01	ERTS INSTRUMENT
PDM01	PRF01	ERTS INSTRUMENT

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Fig. E-8—Report EOP-2A



<b>DISPLAY TYPE</b> EOP-3	<b>DISPLAY TITLE</b> PROGRAM ALTERNATIVE SUMMARY
<b>DESCRIPTION</b> <p>This display provides a short summary of the program under consideration. Three basic sets of information are provided. The first set of information describes program performance and measures the number of applications satisfied by the program. The number is expressed both as a numeric and as a percent of the total number of applications under consideration. To the extent that the program ability to satisfy some needs (i.e., ground swath, ground resolution) varies with altitude, the program performance is shown for each altitude considered.</p> <p>The second set of information shown in the display presents development cost. The overall cost for development of all system elements requiring development is shown. A breakdown is shown to distinguish between costs to be incurred in the (upcoming) budget year and the balance of the cost to completion. A further breakdown is shown to identify those development efforts which are presently underway in the current year (on-going) and those which represent new work (proposed).</p> <p>The third set of information in the display identifies an indicated launch opportunity. While other factors would enter into the commitment to an actual launch, the data display indicates the earliest fiscal year the launch could take place, and the booster type necessary to place the payload into orbit.</p>	
<b>USE: EVALUATION OF</b> <input checked="" type="checkbox"/> Program Alternatives <input type="checkbox"/> Program Performance <input type="checkbox"/> System Performance <input type="checkbox"/> User Needs	<b>FORMAT</b> See Fig. E-10 (information from four alternatives shown to illustrate basic tradeoffs provided by summary)

Fig. E-9—EOP-3 Summary

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REPORT EOP-3

PROGRAM ALTERNATIVE SUMMARY

ALTER NATIVE NUMBER	ORBIT ALT (NM)	ORBIT CYCLE (DAYS)	NUMBER OF OBSERS	OBSERVATIONS		DEVELOPMENT COSTS (IN THOUS)				LAUNCH OPPORTUNITY EACH TEST VEHICLE FY			
				SATISFIED NUMBER	PERCENT	-ON-GOING- RDYFY	-PROPOSED- CMLN	-TOTAL- RDYFY	-TOTAL- CMLN				
01	142	13	18			600		200	200	800	200	74	DELTA
	300	14	18										DELTA
	486	15	18										DELTA
	670	16	18	14	77.770								DELTA
	899	18	18	14	77.770								DELTA
02	142	13	18			400		600	600	1000	600	74	DELTA
	300	14	18										DELTA
	486	15	18										DELTA
	670	16	18	16	88.880								DELTA
	899	18	18	14	77.770								DELTA
03	142	13	18			400		600	600	1000	600	74	DELTA
	300	14	18										DELTA
	486	15	18										DELTA
	670	16	18	16	88.880								DELTA
	899	18	18	16	88.880								DELTA
04	142	13	18			200		1000	1000	1200	1000	74	DELTA
	300	14	18										DELTA
	486	15	18										DELTA
	670	16	18	18	100.000								DELTA
	899	18	18	16	88.880								DELTA

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Fig. E-10—Report EOP-3

<b>DISPLAY TYPE</b> EOP-4	<b>DISPLAY TITLE</b> PROGRAM PERFORMANCE SUMMARY
<b>DESCRIPTION</b> <p>This display, which comes in two parts, provides information on the extent to which a given program has satisfied applications. Part I of the display is sensor-oriented and indicates the percentage of the applications satisfied by each sensor type as broken down by application characteristics. This display provides insight into which application characteristics, if any, are not being met by the program down to the level of sensor type. Part II of the display breaks down the summary shown in Part I by individual applications. It identifies the individual applications that are not being satisfied by the program.</p>	
<b>USE: EVALUATION OF</b> <input type="checkbox"/> Program Alternatives <input checked="" type="checkbox"/> Program Performance <input type="checkbox"/> System Performance <input type="checkbox"/> User Needs	<b>FORMAT</b> See Fig. E-12

Fig. E-11—EOP-4 Summary



PROGRAM PERFORMANCE SUMMARY

PART I PERCENT APPLICATIONS SATISFIED

OPTION 01

E-17

OBSERVATION NUMBER	ALTITUDE RANGE 1	ALTITUDE RANGE 2	ALTITUDE RANGE 3	ALTITUDE RANGE 4	ALTITUDE RANGE 5
IMG01 PRF01 22-040101-0101	0	0	0	0	0
22-040201-0101	0	0	0	0	0
22-040301-0101	0	0	0	1	1
22-040401-0101	0	0	0	1	1
22-050101-0101	0	0	0	1	1
22-050201-0101	0	0	0	1	1
22-050301-0101	0	0	0	1	1
22-050401-0101	0	0	0	1	1
IMG01 PRF01	0	0	0	6	6
	8	8	8	8	8
	.00%	.00%	.00%	75.00%	75.00%
RDM01 PRF01 11-010101-0101	0	0	0	0	0
11-010201-0101	0	0	0	0	0
11-010301-0101	0	0	0	1	1
11-010401-0101	0	0	0	1	1
11-020101-0101	0	0	0	1	1
11-020201-0101	0	0	0	1	1
11-020301-0101	0	0	0	1	1
11-020401-0101	0	0	0	1	1
11-040101-0101	0	0	0	1	1
11-040201-0101	0	0	0	1	1
RDM01 PRF01	0	0	0	8	8
	10	10	10	10	10
	.00%	.00%	.00%	80.00%	80.00%
	0	0	0	14	14
	18	18	18	18	18
	.00%	.00%	.00%	77.77%	77.77%

Fig. E-12 (a)—Report EOP-4



PROGRAM PERFORMANCE SUMMARY

PART II INDIVIDUAL APPLICATIONS SATISFIED

OPTION 01

ELEMENT	REF INCR	OBSERVABLE NUMBER	SPECTRAL RANGE	NO. OF BANDS	ILLUM INATN	GS1 GR1	GS2 GR2	GS3 GR3	GS4 GR4	GS5 GR5
IMG01	PPF01	22-040101-0101	1	1	1	0 1	0 1	0 0	1 0	1 0
		22-040201-0101	1	1	1	0 1	0 1	0 0	1 0	1 0
		22-040301-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		22-040401-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		22-050101-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		22-050201-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		22-050301-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		22-050401-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
IMG01	PRF01		8	8	8	0 8	0 8	0 6	8 6	8 6
			8	8	8	8 8	8 8	8 8	8 8	8 8
RDM01	PRF01	11-010101-0101	1	1	1	0 1	0 1	0 0	1 0	1 0
		11-010201-0101	1	1	1	0 1	0 1	0 0	1 0	1 0
		11-010301-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		11-010401-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		11-020101-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		11-020201-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		11-020301-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		11-020401-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
		11-040101-0101	1	1	1	0 1	0 1	0 1	1 1	1 1
11-040201-0101	1	1	1	0 1	0 1	0 1	1 1	1 1		
RDM01	PRF01		10	10	10	0 10	0 10	0 8	10 8	10 8
			10	10	10	10 10	10 10	10 10	10 10	10 10
			18	18	18	0 18	0 18	0 14	18 14	18 14
			18	18	18	18 18	18 18	18 18	18 18	18 18

E-18

Fig. E-12 (b)—Report EOP-4

<b>DISPLAY TYPE</b>  EOP-5	<b>DISPLAY TITLE</b>  PROGRAM COST SUMMARY
<b>DESCRIPTION</b>  <p>This display, which comes in two parts, provides information on the development costs of individual system elements. Part I provides information on the hardware elements of the system (sensors, down-links). Part II provides information on the software elements of the system (application programs, application models). A breakdown is shown to distinguish between costs which are currently being incurred (current costs), costs to be incurred in the coming year (budget year costs), and the balance of cost to completion (outer year costs).</p> <p>In addition to the cost information, the display indicates, for each element, the status of the developmental process by use of one of six status levels: proposal, feasibility study, preliminary development, advanced development, operational system, post-operational system.</p>	
<b>USE: EVALUATION OF</b>  <input type="checkbox"/> Program Alternatives <input checked="" type="checkbox"/> Program Performance <input type="checkbox"/> System Performance <input type="checkbox"/> User Needs	<b>FORMAT</b>  See Fig. E-14

Fig. E-13—EOP-5 Summary



PROGRAM COST SUMMARY

PART I - HARDWARE ELEMENTS

OPTION 01

ELEMENT	PERF INCR	NUMBER OF ELEMENTS	DEVELOPMENT STATUS	COST BY	COST BY	COST TO DATE	COST TO COMPLETE
IMG01	PRF01		ADVANCED DEVMT	200	200		
RDM01	PRF01		ADVANCED DEVMT	200	200		
SFO1	PRF01	2	ADVANCED DEVMT	400			

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Fig. E-14 (a)—Report EOP-5

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REPORT EOP-5

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PROGRAM COST SUMMARY

PART II SOFTWARE ELEMENTS

OPTION 01

ELEMENT	PERF INCR	DEVELOPMENT STATUS	COST CY	COST BY	COST TO DATE	COST TO COMPLETE
PRG01		ADVANCED DEVMT	50	50		
PRG02		ADVANCED DEVMT	50	50		
PRG04		PROPOSAL		50		50
PRG05		PROPOSAL		50		50
MDL01		ADVANCED DEVMT	50	50		
MDL02		ADVANCED DEVMT	50	50		
MDL04		PROPOSAL		50		50
MDL05		PROPOSAL		50		50

E-21

Fig. E-14 (b)—Report EOP-5



<b>DISPLAY TYPE</b> EOP-6	<b>DISPLAY TITLE</b> PROGRAM TIMING MATRIX
<b>DESCRIPTION</b>  <p>This display, which comes in two parts, uses a matrix arrangement to indicate the fiscal year availability as each system element against a common time scale. Part I provides information on the hardware elements of the system (sensors, down-links). Part II provides information on the software elements of the system (application programs, applications models).</p>	
<b>USE: EVALUATION OF</b>  <input type="checkbox"/> Program Alternatives <input checked="" type="checkbox"/> Program Performance <input type="checkbox"/> System Performance <input type="checkbox"/> User Needs	<b>FORMAT</b>  See Fig. E-16

Fig. E-15—EOP-6 Summary

PROGRAM TIMING SUMMARY

PART I - HARDWARE ELEMENTS

OPTION 01

ELEMENT	PERF INCR	NUMBER OF ELEMENTS	DEVELOPMENT STATUS	CURR YEAR	F-YR -71-	F-YR -72-	F-YR -73-	F-YR -74-	F-YR -75-	F-YR -76-	F-YR -77-	F-YR -78-
IMG01	PRF01		ADVANCED DEVMT							XX		
RDY01	PRF01		ADVANCED DEVMT							XX		
SF01	PRF01	2	ADVANCED DEVMT							XX		

E-23



Fig. E-16 (a)—Report EOP-6



PROGRAM TIMING SUMMARY

PART II SOFTWARE ELEMENTS

OPTION 01

ELEMENT	PERF INCR	DEVELOPMENT STATUS	CURR	F-YR	F-YR	F-YR	F-YR	F-YR	F-YR	F-YR	F-YR
			YEAR	-71-	-72-	-73-	-74-	-75-	-76-	-77-	-78-
PRG01		ADVANCED DEVMT			XX						
PRG02		ADVANCED DEVMT			XX						
PRG04		PROPOSAL					XX				
PRG05		PROPOSAL					XX				
MDL01		ADVANCED DEVMT			XX						
MDL02		ADVANCED DEVMT			XX						
MDL04		PROPOSAL					XX				
MDL05		PROPOSAL					XX				

Fig. E-16 (b)—Report EOP-6



Appendix F  
PROCESSING FLOW DIAGRAMS

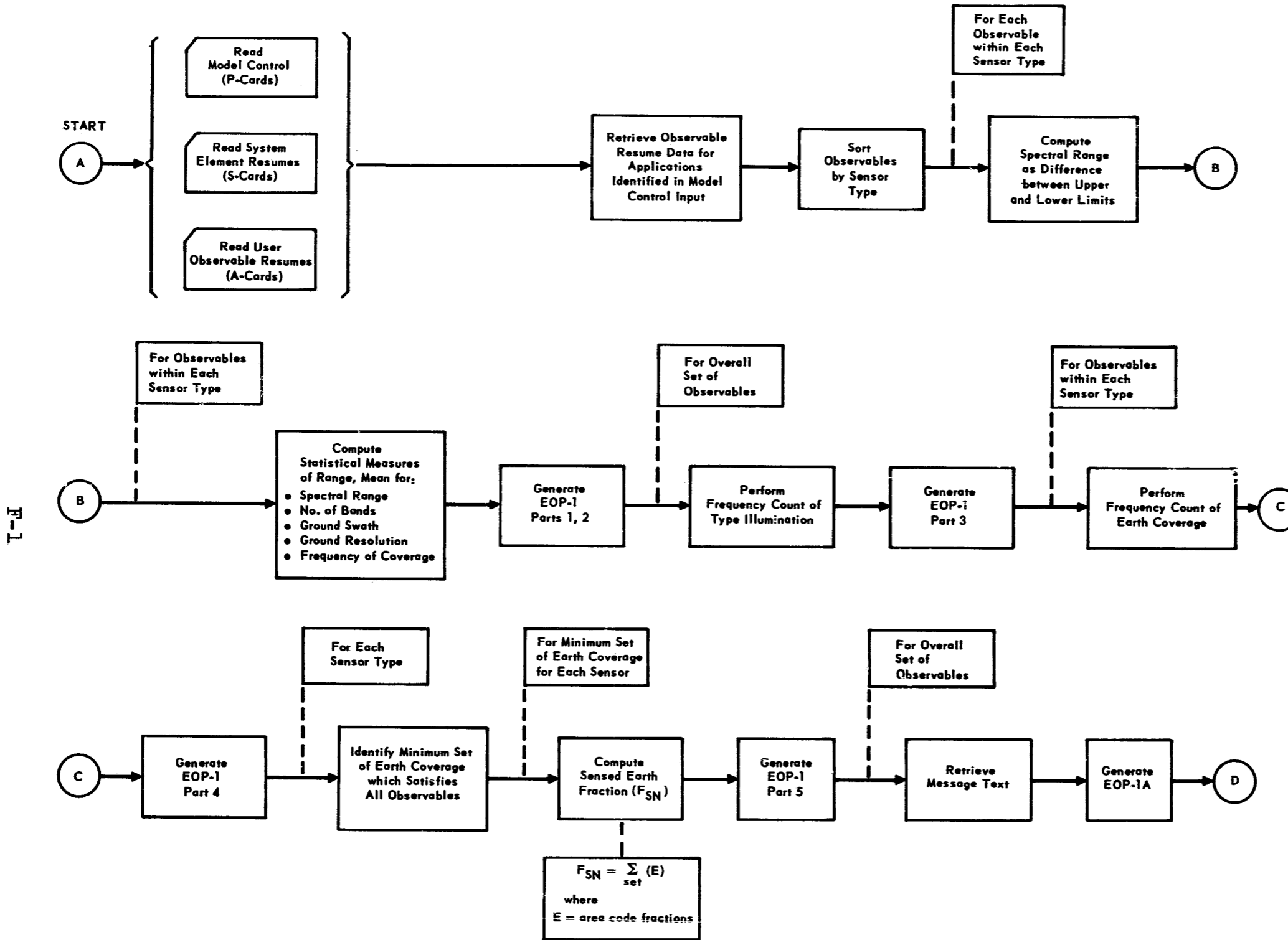


Fig. F1—EOP Model Processing Flow (Block 1)

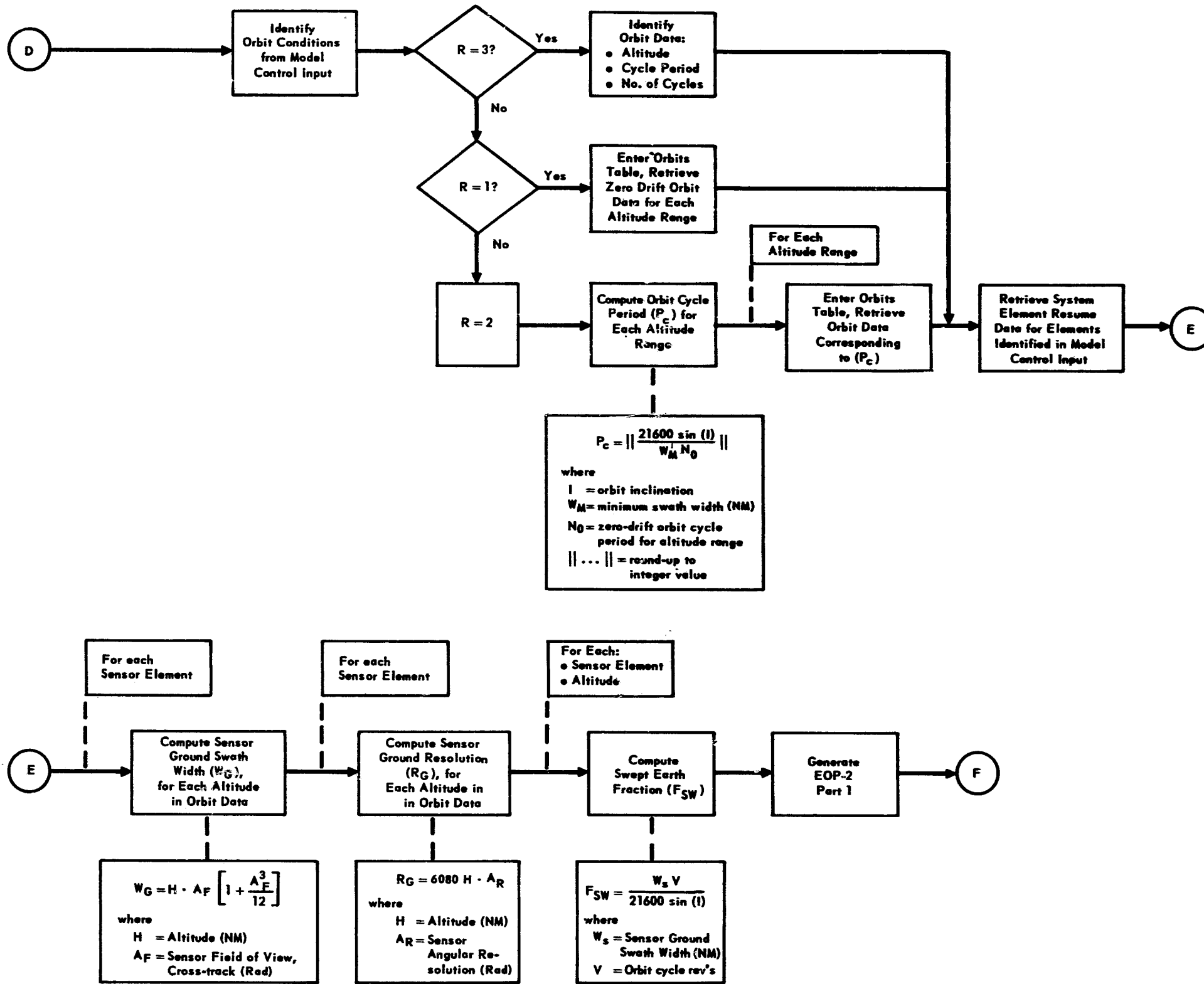
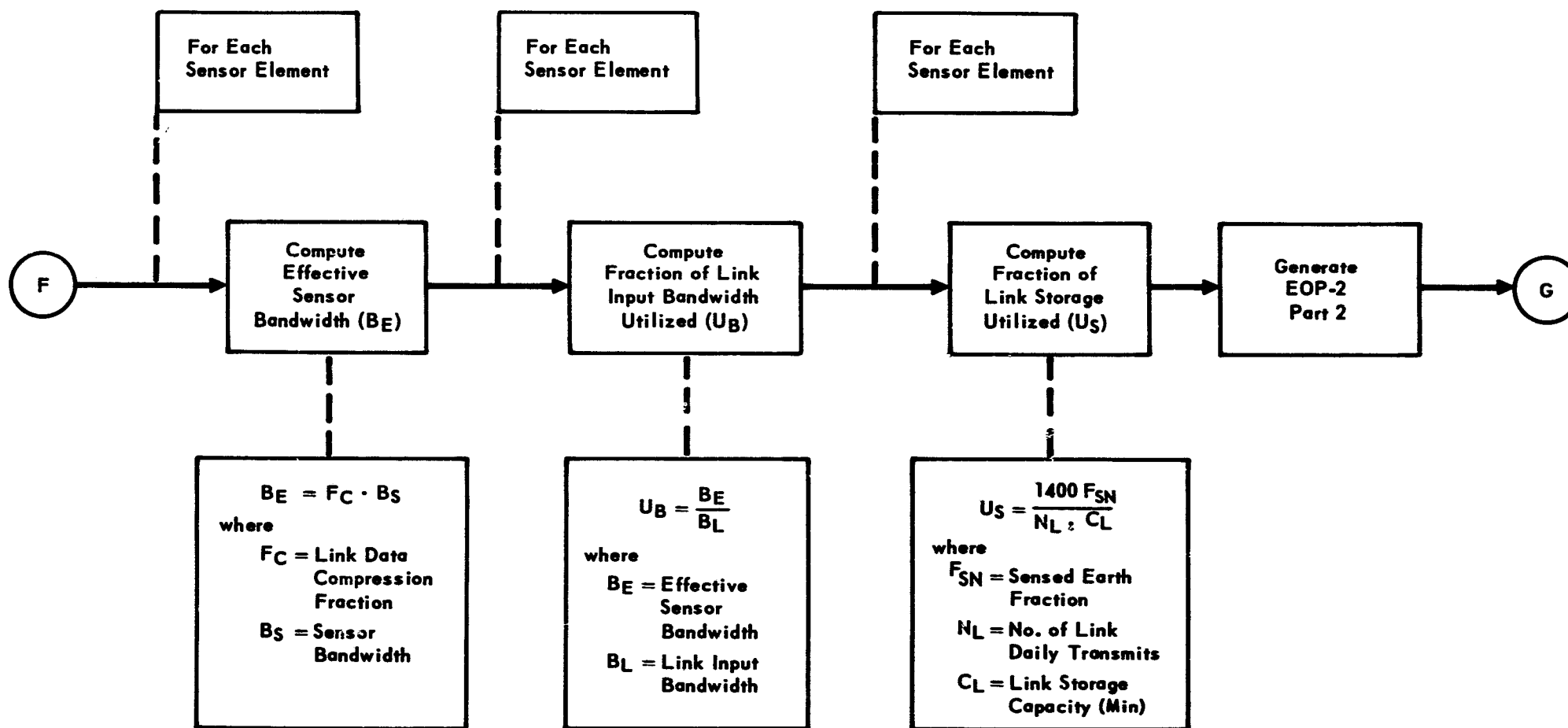


Fig. F2—EOP Model Processing Flow (Block 2)



F-3

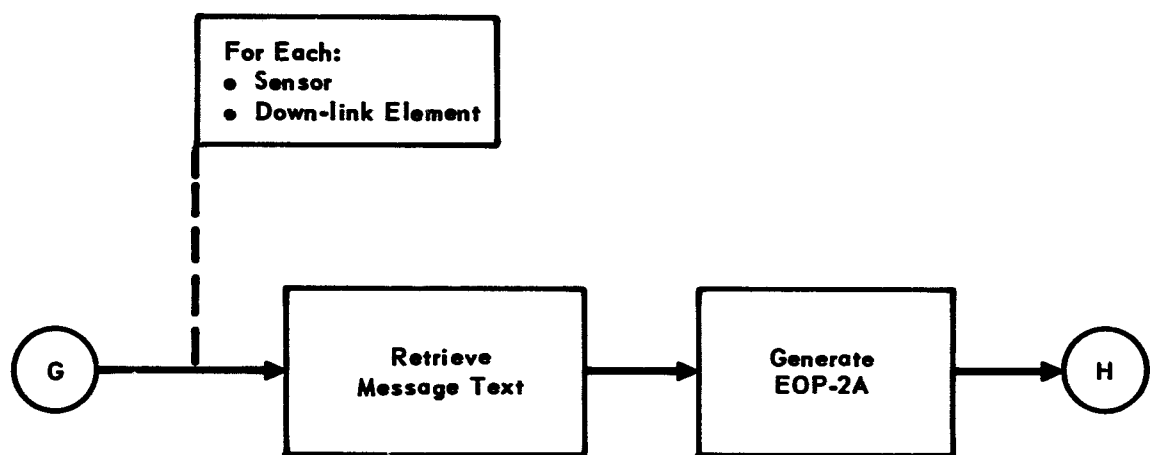


Fig. F3—EOP Model Processing Flow (Block 3)

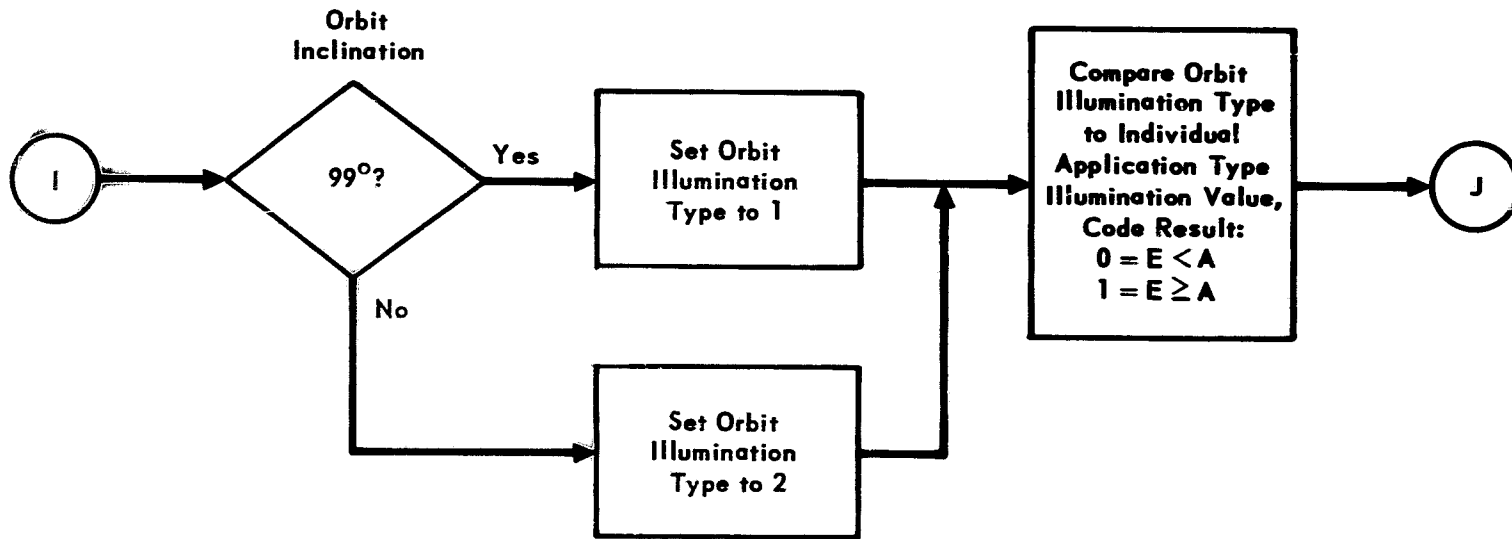
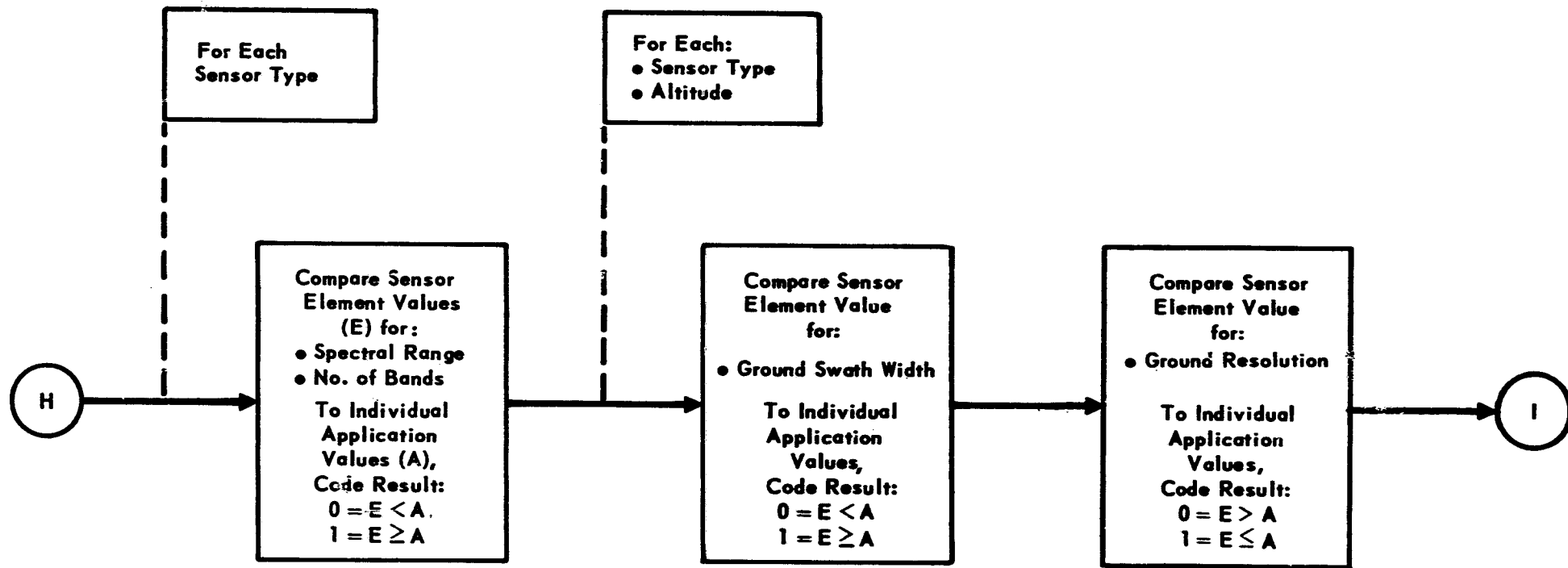


Fig. F4—EOP Model Processing Flow (Block 4)

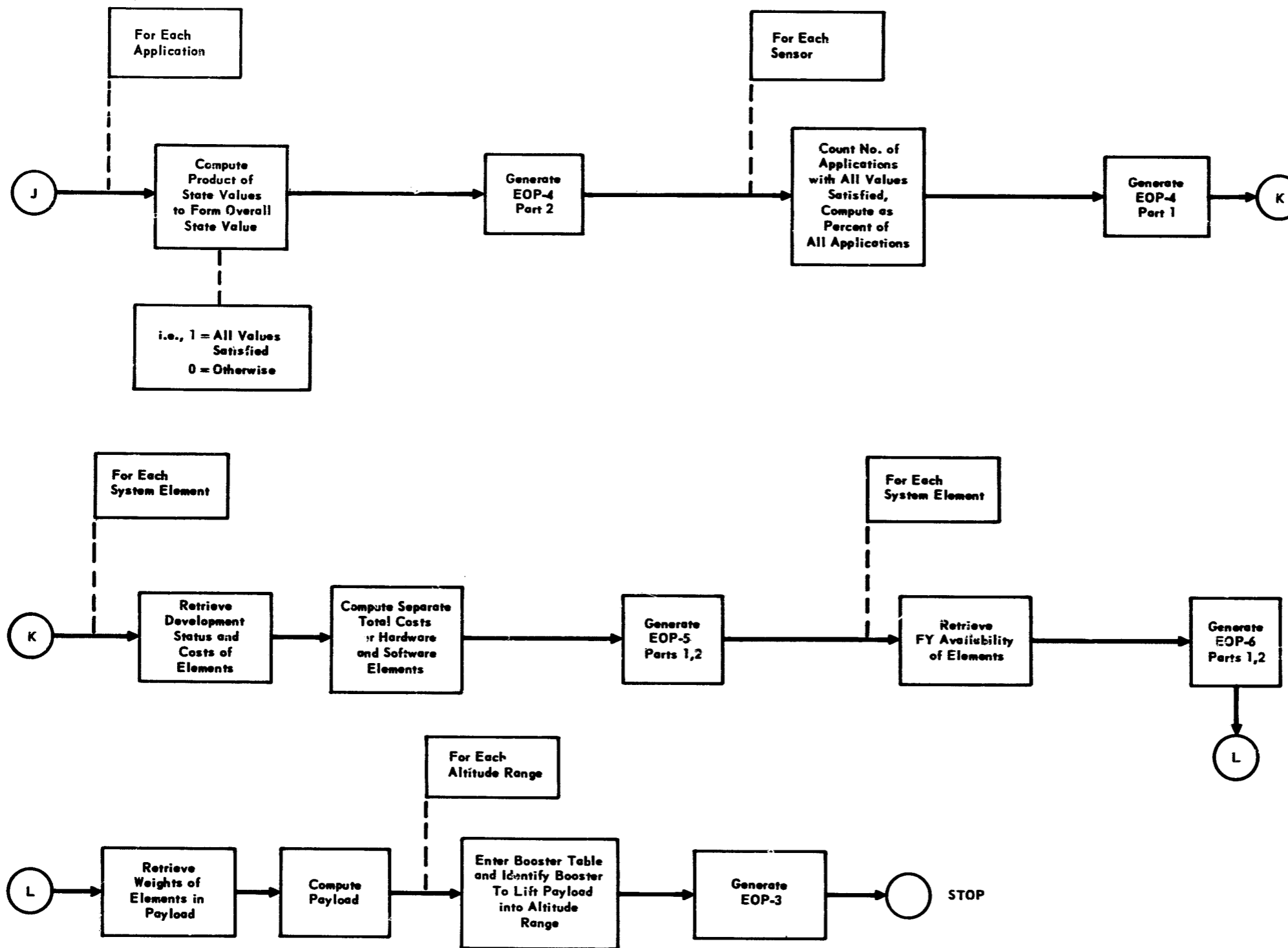


Fig. F5—EOP Model Processing Flow (Block 5)

Appendix G  
INPUT DATA FORMATS<sup>1</sup>

<u>Card Type</u>	<u>Figure</u>	<u>Page</u>
A-1	G-1 User Observable Resume I	G-1
A-2	G-2 User Observable Resume II	G-2
A-3	G-3 User Observable Message	G-3
S1	G-4 Sensor Element I	G-4
S2	G-5 Sensor Element II	G-5
S3	G-6 Down Link Element	G-6
S5	G-7 System Element Costs	G-7
S6	G-8 System Element Message	G-8
P1	G-9 Run Identification	G-9
P2	G-10 Activity Identification	G-10
P4	G-11 System Element Identification I	G-11
P5	G-12 System Element Identification II	G-12
P6	G-13 Earth Coverage Identification	G-13

<sup>1</sup>See Glossary for the definition of the parameters used in the figures.

CARD TITLE				
User Observable Resume I				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Time Horizon	H	N	1
2	Activity Category No.	C	N	2
3	User Agency No.	G	2N	3,4
4	Activity Component No.	G	2N	5,6
5	Information Need No.		2N	7,8
6	Information Factor No.		2N	9,10
7	Observable No.		2N	11,12
8	Sensor Type		3A2N	13,17
9	Observable		40A	20,59
10	Earth Coverage	E	5N	62,66
11	Frequency of Coverage		2N	68,69
12	Observable Status	L	N	72
	CARD ID		1A1	78,80

Fig. G-1—User Observable Resume I



CARD TITLE				
User Observable Resume II				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Time Horizon	H	N	1
2	Activity Category No.	C	N	2
3	User Agency No.	G	2N	3,4
4	Activity Component No.	G	2N	5,6
5	Information Need No.		2N	7,8
6	Information Factor No.		2N	9,10
7	Observable No.		2N	11,12
8	Sensor Type		3A2N	13,17
9	Sensor Type		3A2N	20-24
10	Spectral Units		3A	27-29
11	Spectral Limit (Lower)		5N.4N	31-40
12	Spectral Limit (Upper)		5N.4N	45-54
13	Number Spectral Bands		2N	57,58
14	Type Illumination	I	N	61
15	Ground Swath (NM)		3N2A	64-68
16	Ground Resolution (feet)		4N2A	61-76
	CARD ID		1A2	78-80

Fig. G-2—User Observable Resume II

CARD TITLE				
User Observable Message				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Time Horizon	H	N	1
2	Activity Category No.	C	N	2
3	User Agency No.	G	2N	3,4
4	Activity Component No.	G	2N	5,6
5	Information Need No.		2N	7,8
6	Information Factor No.		2N	9,10
7	Observable No.		2N	11,12
8	Sensor Type		3A2N	13,17
9	Observable Message		50A	20-69
	CARD ID		1A3	78-80

Fig. G-3—User Observable Message

CARD TITLE				
Sensor Element I				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Sensor Type	T	3A2N	1-5
2	Sensor Performance Increment		3A2N	8-12
3	System Element Category		N	15
4	Spectral Units		3A	28-30
5	Spectral Limit (Lower)		5N.4N	32-41
6	Spectral Limit (Upper)		5N.4N	46-55
7	Number Spectral Bands		2N	58-59
8	Angular Resolution		4N.4N	67-75
	CARD ID		1S1	78-80

Fig. G-4—Sensor Element I

CARD TITLE				
Sensor Element II				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Sensor Type		3A2N	1-5
2	Sensor Performance Increment		3A2N	8-12
3	System Element Category	T	N	15
4	Sensor Band Width <sup>a</sup>		4N2A	20-25
5	Field-of-View (Cross Track) (Deg's)		4N.2N	32-38
6	Field-of-View (Cross Track) (Deg's)		4N.2N	43-49
7	Type Field-of-View	V	N	53
8	Field Inclination (Deg's)		2N	56,57
9	Weight (lbs)		4N	60-63
10	Power (Avg Watts)		4N	66-69
	<sup>a</sup> Expressed in same units as those used to specify applications (see card A2, item 10).			
	CARD ID		1S2	78-80

Fig. G-5—Sensor Element II

CARD TITLE				
Down-Link Element				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Down-Link Type	T	3A2N	..1-5
2	Down-Link Performance Increment		3A2N	8-12
3	System Element Category		N	15
4	Down-Link Data Bandwidth (KHz)		4N2A	20-25
5	Down-Link Storage Capacity (min)		4N2A	30-35
6	Down-Link Data Compression Factor		N.3N	40-44
7	Weight (lbs)		4N	60-63
8	Power (avg watts)		4N	66-69
	CARD ID		1S3	78-80

Fig. G-6—Down-Link Element

CARD TITLE				
System Element Costs				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	System Element Type		3A2N	1-5
2	System Element Performance Increment		3A2N	8-12
3	System Element Category	T	N	15
4	FY Available		2N	39,40
5	Costs - Current FY (in thousands)		5N	45-49
6	System Element Status	D	N	43
7	Costs - Budget FY (in thousands)		5N	53-57
8	Costs - Prior FY (in thousands)		6N	62-67
9	Costs - Outer FY (in thousands)		6N	71-76
	CARD ID		1S4	78-80

Fig. G-7—System Element Costs

CARD TITLE				
System Element Message				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	System Element Type		3A2N	1-5
2	System Element Performance Increment		3A2N	8-12
3	System Element Category	T	N	15
4	Message Text		50A	20-69
	CARD ID		1S5	78-80

Fig. G-8—System Element Message

CARD TITLE				
Run Identification				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Card ID		AAA01	13-17
2	Run Number		2N (Note 1)	18,19
Note 1: Each run in a sequence is numbered sequentially starting with "01."				
	CARD ID		1P1	78-80

Fig. G-9—Run Identification



CARD TITLE				
Activity Identification				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Card ID		AAA01	13-17
2	Run Number		2N	18-19
3	Activity Identifier Select	P	3A	21-23
4	User Agency No.		2N	25-45 (Note 1)
5	Activity Component No.		2N	
6	Time Horizon Select	H	N	70
Note 1: Five groups of 4N Max, with groups separated by commas.				
	CARD ID		1P2	78-80

Fig. G-10—Activity Identification

CARD TITLE				
System Element Identification I				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Card ID		AAA01	13-17
2	Run Number		2N	18-19
3	Sensor Type Select		3A2N	21-25
4	Sensor Performance Increment Select		3A2N	28-32
5	Down-Link Type Select		3A2N	40-44
6	Down-Link Performance Increment Select		3A2N	47-51
7	Down-Link Type Count		N	54
8	Daily Transmits Select		N	70
	Note 1: A separate P4-card is prepared for each sensor/down-link combination in system and consecutively numbered from 1 to n.			
	CARD ID		nP4 (Note 1)	78-80

Fig. G-11—System Element Identification I

CARD TITLE				
System Element Identification II				
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS
1	Card ID		AAAON	1-5
2	System Element Category (for sensor element)		I	15
3	Sensor Type Select		3A2N	20-24
4	Sensor Performance Increment Select		3A2N	27-31
5	Down-Link Type Select		3A2N	40-44
6	Down-Link Performance Increment Select		3A2N	47-51
7	Down-Link Type Count		N	54
	<p>Note 1:</p> <p>A separate P5-card is prepared for each sensor/down-link combination in system and consecutively numbered from 1 to n.</p>			
	CARD ID		nP5 (Note 1)	Not Punched

Fig. G-12—System Element Identification II

CARD TITLE										
Earth Coverage Identification										
ITEM NO.	PARAMETER	CODE GROUP	FORMAT	COLUMNS						
1	Card ID		AAA01	13-17						
2	Run Number		2N (Note 1)	18,19						
3	Orbit Type Select (Note 2)	R	N	22						
4	Minimum Swath Width Select (NM)		3N	24-26						
5	Orbit Inclination Select (Deg)		3N	28-30						
6	Sine (Inclination)		N.3N	33-37						
7	Orbit Cycle Period Select		2N	39-40						
8	Orbit Altitude Select		4N	42-45						
9	Orbit Revolutions Select		3N	48-50						
<p>Note 1: Each run in a sequence is numbered sequentially starting with "01."</p> <p>Note 2: Specify remaining parameters per table.</p> <table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th><u>Orbit Type</u></th> <th><u>Item Nos.</u></th> </tr> </thead> <tbody> <tr> <td>R3</td> <td>4-8</td> </tr> <tr> <td>R1, R2</td> <td>3-5</td> </tr> </tbody> </table>					<u>Orbit Type</u>	<u>Item Nos.</u>	R3	4-8	R1, R2	3-5
<u>Orbit Type</u>	<u>Item Nos.</u>									
R3	4-8									
R1, R2	3-5									
	CARD ID		1P6	78-80						

Fig. G-13—Earth Coverage Identification

Appendix H  
CODE CATALOG

<u>Code Letter</u>	<u>Table</u>	<u>Page</u>
C	H-1 Activity Category	H-1
D	H-2 Element Status	H-1
G	H-3 Agency Programs	H-1
H	H-4 Time Horizon	H-2
I	H-5 Illumination Type	H-2
L	H-6 Observable Status	H-2
P	H-7 Activity Identifier	H-3
R	H-8 Orbit Type	H-3
T	H-9 System Element Category	H-3
V	H-10 Field-of-View Type	H-3

TABLE H-1

ACTIVITY CATEGORY CODES

C-CODES	TE	0	NONE
C-CODES	TE	1	AGRI - FORESTRY
C-CODES	TE	2	ENV CHGS - CULT RES
C-CODES	TE	3	GEODESY - CAR
C-CODES	TE	4	GEOLOGY - MIN RES
C-CODES	TE	5	OCEAN - MAR RES
C-CODES	TE	6	HYDR - WATER MGM
C-CODES	TE	9	ALL CATEGORIES

TABLE H-2

ELEMENT STATUS CODES

D-CODES	TE	1	PROPOSAL
D-CODES	TE	2	FEASIBILITY STUDY
D-CODES	TE	3	PRELIMINARY DEVMT
D-CODES	TE	4	ADVANCED DEVMT
D-CODES	TE	5	OPERATIONAL SYSTEM
D-CODES	TE	6	POST-OPNL SYSTEM

TABLE H-3

AGENCY PROGRAMS

G-CODES TE (TO BE DEFINED)

TABLE H-4

TIME HORIZON CODES

H-CODES TE	0	CURRENT
H-CODES TE	1	2 YEARS
H-CODES TE	2	4 YEARS
H-CODES TE	3	8 YEARS

TABLE H-5

ILLUMINATION TYPE CODES

I-CODES TE	1	SUN-SYNCHRONOUS
I-CODES TE	2	NON SUN-SYNCHRONOUS

TABLE H-6

OBSERVABLE STATUS CODES

L-CODES TE	1	PROPOSED
L-CODES TE	2	EXPERIMENTAL
L-CODES TE	3	ESTABLISHED

TABLE H-7

ACTIVITY IDENTIFIER CODES

CAT PRG	ACTIVITY CATEGORY AGENCY PROGRAM
------------	-------------------------------------

TABLE H-8

ORBIT TYPE CODES

D-CODES TE 1	ZERO PRIFT
D-CODES TE 2	MINIMUM PRIFT
D-CODES TE 3	SELECTED ORBIT

TABLE H-9

SYSTEM ELEMENT CATAGORY CODES

T-CODES TE 1	SENSOR
T-CODES TE 2	DOWN-LINK
T-CODES TE 3	USFR PROGRAM
T-CODES TE 4	USER MODEL

TABLE H-10

FIELD OF VIEW TYPE CODES

V-CODES TE 0	CIRCULAR
V-CODES TE 1	RECTANGULAR
V-CODES TE 2	SCANNING



Appendix I  
MODEL PARAMETER TABLES

	<u>Table</u>	<u>Page</u>
I-1	Earth Orbits	I-1
I-2	Earth Coverage	I-4
I-3	Booster Payload	I-6
	<u>Figure</u>	
I-1	Federal Administrative Areas	I-5

Table I-1

## EARTH ORBITS TABLE

## ZERO DRIFT ORBITS

ALTITUDE RANGE	ORBIT ALTITUDE	ORBIT PERIOD	CYCLE PERIOD	REVS PER CYC	ORBIT DRIFT
R1	145	090.0	01	16	0
R2	305	096.0	01	15	0
R3	485	103.0	01	14	0
R4	680	110.7	01	13	0
R5	905	120.0	01	12	0

## MINIMUM DRIFT ORBITS

ALTITUDE RANGE	ORBIT ALTITUDE	ORBIT PERIOD	CYCLE PERIOD	REVS PER CYC	ORBIT DRIFT
R1	110	088.7	04	065	E
R1	120	089.0	05	081	E
R1	125	089.1	06	097	E
R1	130	089.3	07	113	E
R1	137	089.5	08	129	E
R1	139	089.7	09	145	E
R1	139	089.8	10	161	E
R1	140	089.8	11	177	E
R1	140	089.8	12	193	E
R1	142	089.9	13	209	E
R1	143	089.9	14	225	E
R1	144	090.0	15	241	E
R1	146	090.0	16	257	E
R1	147	090.0	17	273	E
R1	150	090.0	18	289	E
R1	152	090.2	19	305	E
R1	153	090.3	20	321	E
R2	220	093.0	02	031	F
R2	267	094.0	03	046	E
R2	275	094.5	04	061	E
R2	279	094.9	05	076	E
R2	290	095.0	06	091	E
R2	293	095.1	07	106	E
R2	295	095.3	08	121	E
R2	297	095.5	09	136	E
R2	297	095.5	10	151	E
R2	298	095.6	11	166	E
R2	298	095.6	12	181	E
R2	299	095.7	13	196	E
R2	300	095.8	14	211	E
R2	300	095.8	15	226	E
R2	301	095.8	16	241	E
R2	305	095.9	17	256	E
R2	307	095.9	18	271	E

R2	309	096.0	19	286	E
R2	310	096.0	20	301	E
R3	395	099.3	02	029	E
R3	422	100.5	03	043	E
R3	439	101.1	04	057	E
R3	443	101.3	05	071	E
R3	465	101.6	06	085	E
R3	478	101.9	07	099	E
R3	480	102.0	08	113	E
R3	481	102.0	09	127	E
R3	482	102.1	10	141	E
R3	483	102.1	11	155	E
R3	485	102.2	12	169	E
R3	485	102.2	13	183	E
R3	485	102.3	14	197	E
R3	486	102.3	15	211	E
R3	486	102.3	16	225	E
R3	487	102.4	17	239	E
R3	487	102.4	18	253	E
R3	488	102.5	19	267	E
R3	488	102.5	20	281	E
R4	575	106.7	02	027	E
R4	617	108.0	03	040	E
R4	630	108.8	04	053	E
R4	639	109.0	05	066	E
R4	643	109.3	06	079	E
R4	650	109.7	07	092	E
R4	659	109.8	08	105	E
R4	667	109.8	09	118	E
R4	660	109.8	10	131	E
R4	662	110.0	11	144	E
R4	665	110.1	12	157	E
R4	667	110.2	13	170	E
R4	667	110.2	14	183	E
R4	668	110.3	15	196	E
R4	670	110.4	16	209	E
R4	670	110.4	17	222	E
R4	672	110.4	18	235	E
R4	675	110.4	19	248	E
R4	677	110.4	20	261	E
R5	790	115.1	02	025	E
R5	827	116.5	03	037	E
R5	845	117.7	04	049	E
R5	860	118.0	05	061	E
R5	869	118.3	06	073	E
R5	878	118.8	07	085	E
R5	880	118.9	08	097	E
R5	881	119.0	09	109	E
R5	883	119.0	10	121	E
R5	885	119.1	11	133	E
R5	890	119.2	12	145	E

R5	893	119.3	13	157	F
R5	895	119.3	14	169	E
R5	897	119.5	15	181	E
R5	898	119.5	16	193	E
R5	898	119.6	17	205	E
R5	899	119.6	18	217	E
R5	899	119.7	19	229	E
R5	901	119.8	20	241	E

Table I-2

EARTH COVERAGE TABLE

CODE	EARTH SURFACE FRACTION	AREA
E10000	1.000000	GLOBE
E20000	.287000	CONTINENTS
E21000	.047300	NORTH AMERICA
E21100	.014800	CONTIGUOUS U.S.
E21101	.000334	FAA 1 (FED ADMIN AREA)*
E21102	.000294	FAA 2
E21103	.000624	FAA 3
E21104	.001950	FAA 4
E21105	.001680	FAA 5
E21106	.002850	FAA 6
E21107	.001450	FAA 7
E21108	.002450	FAA 8
E21109	.001950	FAA 9 (LESS HAWAII)
E21110	.001260	FAA10 (LESS ALASKA)
E21200	.002980	ALASKA

\* See Fig. D-1 for definition of areas



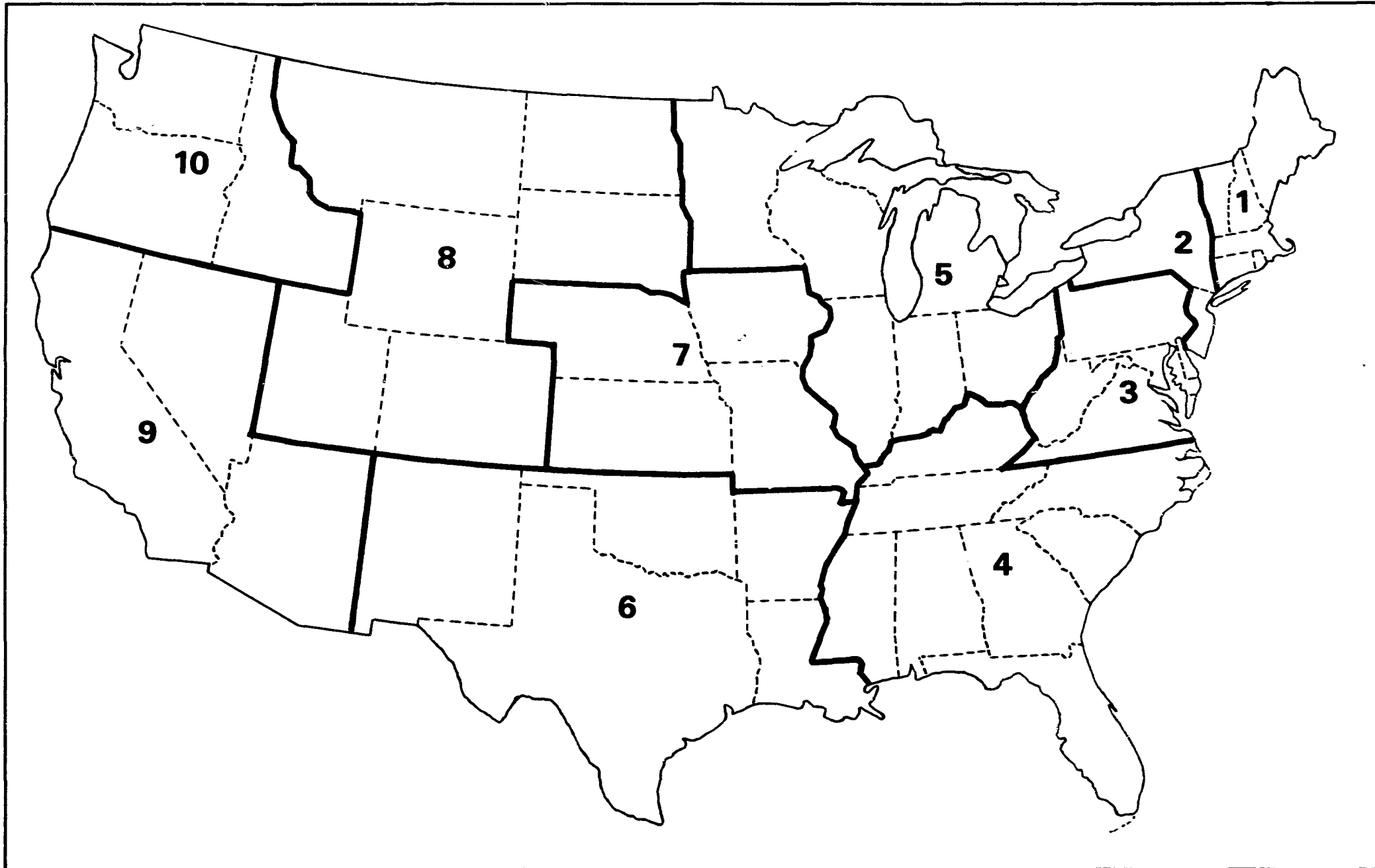


Fig. I-1—Federal Administrative Areas

SOURCE: The National Atlas of the United States of America,  
U.S. Geological Survey, 1970.

Table I-3

BOOSTER PAYLOAD TABLE

BOOSTER TYPE	PAYLOAD LIMIT (LBS) BY ALTITUDE RANGE				
	R1	R2	R3	R4	R5
SCOUT	400	325	250	200	125
DELTA	3850	3350	2650	1950	1100

Appendix J  
MODEL DATA FORMS

NOTE:

The material in this appendix has been left untitled and unpaginated to permit reproduction and individual blank forms for use on an experimental basis.



<b>PROGRAM DEFINITION WORKSHEET</b>	Option No.
-------------------------------------	------------

**Part 1—USER ID**  
*Fill in A and B or A and C.*

A	B	C		
Time Horizon	User Activity Category	User Activity		
<input type="checkbox"/> Current <input type="checkbox"/> Next 2 Yrs <input type="checkbox"/> Next 4 Yrs <input type="checkbox"/> Next 8 Yrs	<input type="checkbox"/> Agri and Forestry <input type="checkbox"/> Env Chgs and Cul Res <input type="checkbox"/> Geod and Cart <input type="checkbox"/> Geol and Min Res <input type="checkbox"/> Ocean and Mar Res <input type="checkbox"/> Hydr and Water Mgmt	AGENCY _____ _____ _____ _____ _____	ACTIVITY _____ _____ _____ _____ _____	ALL <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>

**Part 2—SYSTEM ID**

Channel No.	Sensor		Down Link		No. of Daily Xmts
	Type	Perf	Type	Perf	
1					
2					
3					

**Part 3—EARTH COVERAGE ID**  
*Fill in A and B or A and C.*

A	B		C			
Orbit Type	Min Swath	Orbit Incl	Orbit Incl	Orbit Cycle Period	Orbit Altitude	Orbit Cycle Revs
<input type="checkbox"/> Zero drift <input type="checkbox"/> Min drift <input type="checkbox"/> Selected						

Notes

NEED EVALUATION WORKSHEET			OPTION NO.
Model Information	Evaluation Criteria	Item	Evaluation
EOP-1 Part 1  Imagery Statistics	Number of Observables		No. of Obs
	Minimum number of sensor types of serve _____ % of observables	1	Type 1 _____
	Ground swath width to serve _____ % of observables	2 3	Type 2 _____ Type 3 _____ Swath Width _____ NM
EOP-1 Part II  Type Illumination Frequencies	Illumination type to serve _____ % of observables	4	<input type="checkbox"/> Sun-Sync
		5	<input type="checkbox"/> Non Sun-Sync
EOP-1 Part III  Earth Coverage Frequencies	Earth coverage type to serve _____ % of observables	6	<input type="checkbox"/> Full coverage
		7	<input type="checkbox"/> Partial coverage
EOP-1 Part IV  Sensed Earth Fraction	Fraction multiplied by _____ is estimate of daily number of transmits for _____ - station ground network	8	Daily Transmits _____
Item	Action	Evaluation Summary	
		<input type="checkbox"/> Consider Need Set <input type="checkbox"/> Redefine Need Set <input type="checkbox"/> Discard Need Set	

SYSTEM PERFORMANCE EVALUATION WORKSHEET			OPTION NO.
Model Information	Criteria	Item	Results
EOP-2 Part I  Sensor Performance	For Full Earth Coverage:		Swept Fraction/Swath Width Condition Met?
	(1) Does each sensor type achieve a swept fraction approximated equal unity?	1	Type 1 <input type="checkbox"/> Yes <input type="checkbox"/> No
	(2) Does this condition occur at common altitude range?	2	Type 2 <input type="checkbox"/> Yes <input type="checkbox"/> No
		3	Type 3 <input type="checkbox"/> Yes <input type="checkbox"/> No
	For Partial Earth Coverage:		Common Altitude Condition Met?
	(1) Does each sensor type achieve a swath width approximately equal to minimum swath width?		<input type="checkbox"/> Yes <input type="checkbox"/> No
	(2) Does this condition occur at a common altitude range?	4	
EOP-2 Part II  Down-Link Performance	Does Link Data Bandwidth Utilization of each Down-Link approximately equal unity?	5	Data Bandwidth Condition Met? D-L 1 <input type="checkbox"/> Yes <input type="checkbox"/> No
		6	D-L 2 <input type="checkbox"/> Yes <input type="checkbox"/> No
		7	D-L 3 <input type="checkbox"/> Yes <input type="checkbox"/> No
	Does Link Data Storage Capacity of each Down-Link approximately equal unity?	8	Data Storage Capacity Condition Met? D-L 1 <input type="checkbox"/> Yes <input type="checkbox"/> No
		9	D-L 2 <input type="checkbox"/> Yes <input type="checkbox"/> No
		10	D-L 3 <input type="checkbox"/> Yes <input type="checkbox"/> No
Item	Action	Evaluation Summary	
		<input type="checkbox"/> Consider System <input type="checkbox"/> Redefine System <input type="checkbox"/> Discard System	

USER ACTIVITY RESUME		Part 1 ACTIVITY COMPONENTS		
User Agency		User Activity		
Activity Description				
No.	Activity Component	Info Sources		
		EOP	Other	Both
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

<b>USER ACTIVITY RESUME</b>		<b>Part 2 COMPONENT INFORMATION NEEDS</b>		
User Agency		Activity Component		
Component Description				
Component Information Needs				
No.	Need	No.	Information Factor	Update Interval



PROGRAM PERFORMANCE EVALUATION WORKSHEET			OPTION NO.
Model Information	Evaluation Criteria	Item	Evaluation Results
EOP-4  Program Performance Summary	Are _____% or more of observables satisfied?	1	Observables Satisfied? <input type="checkbox"/> Yes <input type="checkbox"/> No
	For those unsatisfied is there a constant dissatisfying factor?	2	Dissatisfying Factor(s)? <input type="checkbox"/> Yes <input type="checkbox"/> No
		3	Identify Factor(s) _____
EOP-5  Program Cost Summary	<b>Cost Limits</b>		<b>Cost Limits Met?</b>
	Hardware	4	<input type="checkbox"/> Yes <input type="checkbox"/> No
	Budget Year _____ To Completion _____	5	<input type="checkbox"/> Yes <input type="checkbox"/> No
	Software	6	<input type="checkbox"/> Yes <input type="checkbox"/> No
	Budget Year _____ To Completion _____	7	<input type="checkbox"/> Yes <input type="checkbox"/> No
EOP-6  Program Timing Matrix	<b>Timing Limits</b>		<b>Timing Limits Met?</b>
	Hardware _____	8	<input type="checkbox"/> Yes <input type="checkbox"/> No
	Software _____	9	<input type="checkbox"/> Yes <input type="checkbox"/> No
Item	Action	Evaluation Summary	
		<input type="checkbox"/> Consider Program <input type="checkbox"/> Redefine Program <input type="checkbox"/> Discard Program	

USER OBSERVABLE RESUME		User Observable Number						
		Time Hor	Act Cat	User Agny	Act Comp	Info Need	Info Fact	Obsr
User Agency								
Activity Component			Information Need					
Information Factor			Observable					
Observable Characteristics								
NO.	CHARACTERISTICS	FORMAT	VALUE					
			Minimum	Nominal	Maximum			
1	Sensor Type	3A2N						
2	Spectral Limit-Upper	5N.5N						
3	Spectral Limit-Lower	5N.5N						
4	Spectral Units	3A						
5	Number Spectral Bands	2N						
6	Ground Swath Width (NM)	4N						
7	Ground Resolution (FT)	4N						
8	Area of Coverage (Code)	6N						
9	Frequency of Coverage (Days)	2N						
10	Type Illumination (Code)	N						
11	Observable Status (Code)	N						
Message (50A Max)								

**SYSTEM ELEMENT RESUME****Part 1  
ELEMENT DESCRIPTION**

Element Category	<input type="checkbox"/> Sensor	<input type="checkbox"/> User Program	Type
	<input type="checkbox"/> Down-Link	<input type="checkbox"/> User Model	Perf. Level
No.	Development Title	Development Control No.	
1			
2			
3			
4			
5			

Element Description



SYSTEM ELEMENT RESUME				Part 2 ELEMENT CHARACTERISTICS		
Element Category	<input type="checkbox"/> Sensor <span style="margin-left: 150px;"><input type="checkbox"/> User Program</span>				Type	
	<input type="checkbox"/> Down-Link <span style="margin-left: 150px;"><input type="checkbox"/> User Model</span>				Perf. Level	
Technical Characteristics						
Sensor Element	Spectral Limit-Upper	Spectral Limit-Lower	Spectral Units	Number Spectral Bands	Sensor Data Bandwidth	Angular Resolution
	Type Field of View	Field of View, A-T	Field of View, C-T	Field Inclination	Weight	Power
Down-Link Element	Down-Link Data Bandwidth	Data Compression Factor	Data Storage Capacity		Weight	Power
User Program Element	Number of Instructions	Number Decision Points	Number Data Values			
User Model Element	Number Activity Components	Number Information Needs	Number Information Factors	Number User Observables		
Administrative Characteristics						
All Elements	FY Available	Development Status	Cost Current FY	Cost Budget FY	Cost Prior FY	Cost Outer FY
Message (50A) Max						

Appendix K

THE MEASURE OF ECONOMIC BENEFITS  
FROM REMOTE SENSING

This report represents the independent findings of Mathematica, Inc., of Princeton, New Jersey on one particular aspect of the information needs of a regional community of users.

## Appendix K

### THE MEASURE OF ECONOMIC BENEFITS FROM REMOTE SENSING<sup>1</sup>

In addressing the potential benefits of Remote Sensing applied to southern Florida water management, one should first consider what is currently being done by conventional means. The benefits derived from replacing or complementing current techniques are then evaluated in light of most probable current capabilities and likely capability improvements in Earth Resources Observation Satellites (EROS).

As has been summarized in this paper, it has been demonstrated that there will be major benefits to hydrology from interdisciplinary programs of space technology that include improved weather forecasts, improved land-use mapping and classification, topographic and geologic mapping, precipitation reporting on a real-time basis, and aerial estimates of soil temperature. As reported by the National Academy of Sciences' National Research Council,<sup>2</sup> "Space technology applied to hydrology should be evaluated and exploited in the interest of the users, taking into consideration the following: the transfer of data from ground stations or sensors finally to the users; the impact of economic, social or political factors on water resources development and the need for hydrologic data; and the administrative structures to coordinate and integrate all space programs regarding applications in hydrology."

In the following pages the method and estimates of how to measure the economic benefits from topographic surveys and identification in southern Florida is given.

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<sup>1</sup>Excerpt from: "An Investigation into the Economic Benefits of Remote Sensing by the Earth Resources Observation Satellite (EROS) Applied to Southern Florida Water Management," prepared under sub-contract to Research Analysis Corporation by Mathematica, Inc., Nov 4, 1971.

<sup>2</sup>Summer Study on Space Applications. Division of Engineering. National Research Council. Useful Applications of Earth-Oriented Satellites: Hydrology. Washington, D. C. National Academy of Sciences. 1969

In fiscal 1968, the Geological Survey of the Department of the Interior spent approximately \$27 million for topographic surveying and mapping.<sup>1</sup> Of this, \$600,000 was expended on 200,000 square miles of aerial photographs. According to estimates obtained, topographical maps are replaced about once in twenty years.<sup>2</sup> One-twentieth of the United States land area (excluding Alaska) is equivalent to about 150,000 square miles. This bears up quite well with the 200,000 square mile aerial photograph figure considering that there is a real area loss of about 30 to 40 percent due to edge distortion.<sup>3</sup> Dividing 150,000 square miles into \$27,000,000, we obtain an average topographical mapping cost of approximately \$180 per square mile.<sup>4</sup> This represents topographical maps of all scales ranging from the 1:2,400 to the 1:5,000,000 series. A quadrangle map of the basic 1:24,000 series (covering from 49 to 70 square miles) costs between \$12,000 and \$15,000 to update. Using averages, this comes to an average cost for this series

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<sup>1</sup>This figure and many that follow have been derived by linearly interpolating for 1968 having been given actual expenditures for fiscal 1963, 1964 and anticipated fiscal 1973. Source: Office of Science and Technology. Committee on Natural Resources. Research and Development on Natural Resources. Federal Council for Science and Technology. 1964.

<sup>2</sup>This excludes Alaska which, for the most part, is uncharted.

<sup>3</sup>It is the practice of the Geological Survey to take aerial photographs of an area when topographic maps are being updated.

<sup>4</sup>Aerial photography is only a small percentage of topographic mapping costs. A major component is the cost of the orthographic rectification process required for the construction of a mosaic from the many aerial photographs taken from various angles. Because satellite pictures will be taken at constant sun angles and from altitudes which will almost eliminate edge distortion, this process could be virtually eliminated, greatly reducing the costs of map updating for the technically feasible scales.

of \$225 per square mile.<sup>1</sup>

The southern Florida land area as shown in Figure 1 is about 250 thousand square miles. As shown, this includes the land area extending southward from Lake Okechobee. Assuming that the area that is now being updated by aerial surveying is proportional to the continental U.S. as a whole, 12,500 square miles in southern Florida are updated each year.<sup>2</sup>

Estimates of the average costs of these map series have been derived from: U.S. Department of the Interior, Geological Survey, "Topographic Maps," Geological Survey, Map Information Service, and Lowell E. Starr and Winston Siebert, "Potential Time-Cost Benefits from Use of Orbital-Height Photographic Data in Cartographic Programs. Technical Letter NASA-54, August 1966.

In Figure 4, the area enclosed by OEFA represents the actual topographical mapping that by assumption is currently being done in southern Florida: twelve and one-half thousand square miles at a cost of \$2,250,000.<sup>3</sup> Were the EROS system able to replace conventional methods for updating this amount of maps, the market value provided would be \$2,250,000. This is depicted by the area of the rectangle, OEFA.

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<sup>1</sup>The Geological Survey embarked on a program in 1964 to cover the entire United States (excluding Alaska) with 1:24,000 maps by 1981. The Geological Survey is currently also engaged in the compilation of a 1:1,000,000 series of the United States' coastal and continental shelf areas, which they hope to complete within the next five years. They also want to embark on a 10 to 20 year program to generate a 1:250,000 scale series of maps of the same areas. Estimated annual funding for this last task is from \$5 million to \$20 million.

<sup>2</sup>This would seem to be an overestimation, but more precise information has not been obtained and the argument is not distorted by it.

<sup>3</sup>For this estimate, \$180, the average topographic cost per square mile for all series, is used.

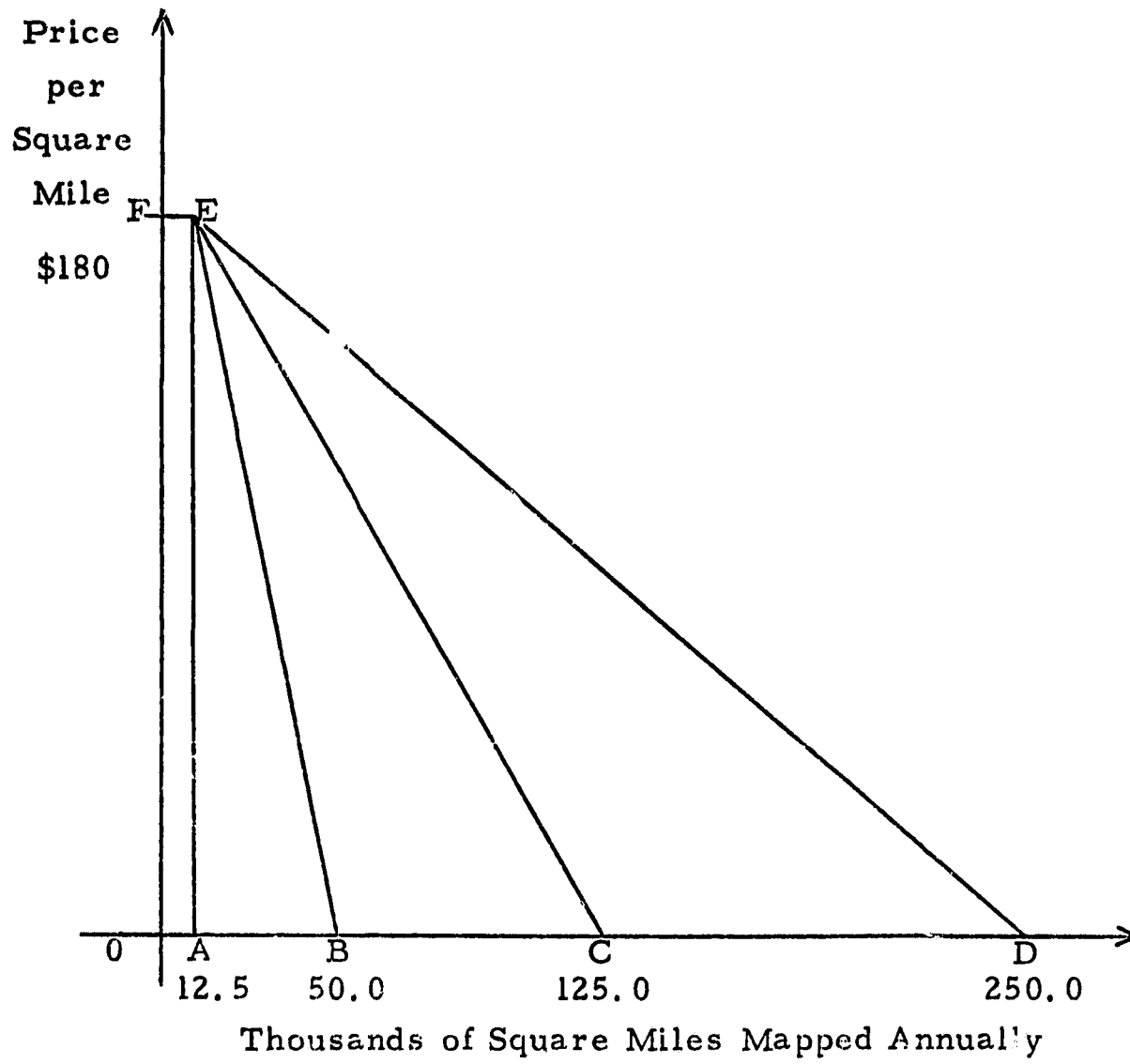


Fig. K-1—Annual Potential Demand for Mapping

Table 1 summarizes the estimated annual potential EROS market values (demand) from satellite cartography reflecting the assumptions and information presented above.

Table 1: Estimated Undiscounted Annual Demand for Cartography in Southern Florida (millions of 1963 dollars)

Replacement Rate	<u>Potential Benefits of EROS Applications</u>			
	Full Benefit	Current Resolutions (10%)	After 5 Years (40%)	After 10 years (90%)
Every five years	5.6	0.5	2.1	4.7
Biannually	12.4	1.2	6.0	11.2
Annually	23.4	2.3	9.3	20.9

At the present time, the annual EROS market values for cartography in the 240 thousand square mile area shown in Table 1 are for the reasons just given on the order of \$1.2 million. Referring to Figure 1, this anticipates demand for biannual replacement and present EROS capability.

Although this estimate is based on hypothetical demand function FB, it is expected that there will be a shift in demand to FC or DF, indicating market values after ten years on the order of \$11 million to \$21 million. This is because it is anticipated (from interviews with potential users) that as the program grows the uses of the data will become more apparent. It has been suggested, for example, by the U.S. Geological Survey, the U.S. Federal Water Pollution Control Agency, the U.S. Fish and Wildlife Service and the Central and Southern Florida Flood Control District that annual, or even more often, updating of certain coastal and estuarine regions would be very helpful to the scientific research effort in these areas.

The next procedure is to address the market value of additional maps provided at lower cost.<sup>1</sup> A major problem for the analysis is the consideration of at what point the demand function intersects the abscissa, the point at which users would cease to demand additional maps at reduced cost, i. e., a price greater than zero.

If the nature of demand were such that an annual replacement would have economic value, the function would intersect the abscissa at "D," representative of 250,000 square miles. Point "C" represents biannual replacement and "B," once every five years.<sup>2</sup> The areas contained by the triangles AFD, AFC, and AFB represent the benefits of additional maps corresponding to the above orders of replacement.<sup>3</sup> The area under the triangle AFD is calculated by  $1/2 AF \times AD = \frac{\$180 \times 235,500}{2} = \$21,195,000$ . The areas under the triangles AFC and AFB are<sup>2</sup> calculated by  $1/2 AF \times AC$ , and  $1/2 AF \times AB$  and they equal \$10,125,000 and \$3,375,000, respectively.

EROS technology cannot, however, provide alone the market values depicted under the rectangle and the various triangles. This is for the

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<sup>1</sup>It is assumed that topographic maps are a normal economic good; at a lower price, more will be demanded.

<sup>2</sup>The reader is referred to the GLM study for a more detailed description of the methodology.

<sup>3</sup>An alternative way of presenting the demand function for these maps is to assume that it is nonlinear and concave to the origin. Its terminal points would be F, the square rules currently replaced, and D, annual replacement of all areas of interest. We do not, however, have enough observations to approximate the shape of the curve since at least three are required.



following reasons:

- (1) The market values in each example represent complete replacement of what is currently being done plus the values derived from the additional coverage.
- (2) Given current capabilities, EROS cannot serve as a full replacement of existing technology. For small and medium scale maps, scales from 1:5,000,000 to 1:250,000, EROS should at current capabilities be a preferred substitute for the conventional methods of updating. This is because images taken from the proposed 500 nautical mile orbit would be virtually distortion free, eliminating the need for the orthographic rectification process now required.
- (3) The use of photographs for base and field maps would require resolutions of 20 feet or less.<sup>1</sup> Until such resolutions are achievable by EROS satellite photographs, they will not be complete substitutes for aerial photos, but will complement them for mapping purposes. This is particularly true for the important 1:24,000 scale series.<sup>2</sup>
- (4) Assuming improvements in resolution capabilities over the next 10 years, EROS will operate during the first years with resolutions between 100 and 200 feet; after five years between 20 and 100 feet; and after the first ten years, at a resolution approximating 20 feet.<sup>3</sup>
- (5) Currently, maps of scales 1:250,000 and smaller account for 10 to 15 percent of the entire map program.

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<sup>1</sup> Assuming that aerial photographs have scales of 1-20,000 to 1-60,000. See: Bill Mullins. Factors and Procedures Influencing the Reliability of Agricultural Data from Earth Orbiting Sensor Systems. Dallas, Texas. Systems Technology Applied Research Corporation prepared for U.S. Department of Agriculture. Economic Research Service. June 27, 1967.

<sup>2</sup> Actually, resolutions of 20 feet or less are not something beyond the "state of the art." Higher resolutions are achieved today from satellite altitudes similar to EROS. Although a different and more costly technique is involved in these applications, we believe that EROS technology will progress to similar levels over the next 10 years.

<sup>3</sup> Indeed, it is most likely that eventually the cameras will have the ability to shoot at variable scales. In other words, in some areas perhaps 1:250,000 will be needed, for others maximum detail would be required. The ability to adjust for these requirements would economize on data handling operations.

- (6) From early results with pictures taken on NASA's Apollo missions it is certain that the planimetric features that the satellite pictures will deliver are sufficient to update topographic map series of 1:250,000 and smaller. This is because at these scales, the topographic features do not change to a significant degree. For series of 1:24,000 and larger, in which topographic features are unstable, the EROS pictures could not be used for map updating in the same way. EROS information would be used to reduce the number of control points currently required for this series. Starr and Siebert estimate that a 10 percent efficiency saving would be realized by the reduction of the number of data-bits handled.<sup>1</sup>

Based on this, it is proposed that the actual market values accruing from EROS operations will increase from 10% of potential benefits initially to 40% after five years and to 90% after ten years.

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<sup>1</sup>"Potential Time-Cost Benefits from Use of Orbital-Height Photographic Data in Cartographic Programs," op. cit., p. 11.

Land-use maps provided on a frequent basis will be useful to county and local governments faced with the task of providing for an expected population growth of about 5 percent per year over the next 20 years.

The market values that were estimated in the above analysis are feasible by EROS or other high output techniques that have been advanced. Using conventional methods, the assembling required to make photo-mosaics places a time constraint upon the rate of map replacement. According to Starr and Siebert: "Present-day techniques generally restrict map maintenance intervals to 5 to 10 years for urban areas and 10 to 15 years for farming areas. The use of orbital photographic data would allow map maintenance intervals of 1 to 2 years for urban areas and 2 to 3 years for farming areas, thereby permitting continuing annual dollar benefits, and, more importantly, providing a basis for keeping pace with the nation's rapidly expanding economy."<sup>1</sup>

In order to make an assessment of the economic benefits of the EROS program, an efficiency estimate -- cost reduction over conventional methods -- is required. This has been estimated by Starr and Siebert to be 35 percent for maps in the 1:250,000 series with some smaller spill-overs to the higher series.<sup>2</sup> This assumes, therefore, an overall cost reduction efficiency savings of 40 percent.<sup>3</sup> In order to derive a table

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<sup>1</sup> Potential Time-Cost Benefits from Use of Orbital-Height Photographic Data in Cartographic Programs. op. cit., p. 12.

<sup>2</sup> Ibid., p. 12.

<sup>3</sup> In support of this, it has been advanced that EROS would save 200 of the currently required 500 man hours, i. e., 40%, to update one map of the 1:250,000 series.

of net potential EROS benefits, i. e. the economic benefits attributable to EROS, 60 percent of the potential market values must be allocated to the other processes required for map updating.

The total annual and average annual discounted economic benefit stream can now be calculated from the figures of Table 1 and the above hypotheses. The following Tables 2 and 3 show the present worth of all future expected economic benefits attributable to EROS in southern Florida under the additional, very conservative assumption that the benefit increases will not accrue gradually, but rather at the end of each of the considered improvement periods (6 years and 10 years). Arguments for a gradual improvement from 10 percent to 90 percent during these 10 years can be made. Technological change is likely to take place continuously, not at the end of each period as assumed. There will be, however, other factors counteracting a realization of the full benefits: the usefulness of satellite data for identification and mapping purposes will largely depend on the extent to which this information is disseminated and utilized. The value of these maps and photographs would be greatly increased if the software part of EROS, i. e., data processing for different user oriented purposes, and the distribution systems, is set up in an effective way. Finally, the capabilities of potential users to interpret and use the provided data has to be considered and strengthened if necessary. This concurrent development of EROS related services cannot be stressed enough. Considerable investment will have to be made in these user oriented services.

Table 2 represents an adjustment of Table 1, which takes this into account.

Table 2: Estimated Annual Economic Benefits Attributable to EROS in Southern Florida (millions of 1963 dollars)

Replacement Rate	Full Benefit	Current Resolutions	After 5 Years	After 10 Years
Every five years	2.2	0.2	0.8	1.9
Biannually	5.0	0.5	2.4	4.5
Annually	9.4	0.9	3.7	8.4

Table 3: Present Value of Benefits of EROS in Southern Florida Applications (millions of 1963 dollars)

Replacement Rate	Discount Rates				
	5%	7.5%	10%	12.5%	15%
Every five years	\$ 27.4	\$ 15.3	\$ 9.9	\$ 7.0	\$ 5.2
Biannually	64.8	37.4	24.6	17.6	13.0
Annually	118.2	67.8	44.2	31.3	22.9

From Table 3 it may be seen that for mapping and identification purposes the total present value of future benefits of EROS applications in southern Florida vary considerably depending upon the assumed intensity of coverage and the rate of discount applied. Most of the variation in the benefit levels can be explained by differences in coverage -- changes in assumed discount rates explained only half as much variation.

For a rational economic evaluation of EROS, it is necessary to compare the total present value of benefits as shown in Table 2 with the expected present value of system costs as estimated by NASA and commercial contractors. If we were only to judge the program on the basis of the undiscounted benefits presented in Table 1, foregone economic alternatives -- opportunities which are lost due to waiting -- would not be included in the investment decision. Not to include these opportunity costs (the cost of time), would result in an overinvestment of resources in the EROS program.

For the reasons given, it is believed that in the future various data users will call for annual coverage. First, however, the system must demonstrate its capabilities.

It is emphasized that the economic benefits described above only include possible cost savings over conventional technology vis-a-vis replacement and additions to what is being done. This does not include benefits derived from new devices and techniques that may arise from the program.

## GLOSSARY

activity category - A categorization of user activities into one of six functional/disciplinary categories. As adopted from Ref 2, these are: agriculture and forestry, environmental changes and cultural resources, geodesy and cartography, geology and mineral resources, oceanography and marine resources, hydrology and water management.

activity component - A sub-segment of user activity defined to encompass a particular program or related group of operations.

activity component number - A 2-digit serial number assigned to identify a particular activity component.

activity identifier select - A choice by the model user of whether activity categories or individual activities are to be used to designate the user needs of interest.

angular resolution - The angle, as measured at the sensor which subtends the least dimension of a point feature.

BUDFY - budget fiscal year (upcoming budget year)

BY - budget year

CMPLN - to completion (see also costs-outer)

compr factr - see down-link data compression factor

costs-budget FY - The costs of development of an element in the upcoming fiscal year.

costs-current FY - The costs of development of an element in the current fiscal year.

costs-outer FY - The costs of development, of an element in the years beyond the budget FY to completion.

costs-prior FY - The costs of development to date exclusive of the current FY.

CY - current year

cycle pe - see orbit cycle period

daily transmits select - A choice by the model user, of the number of daily transmits to occur, on the average, for each down-link.

development status - A categorization of the state of development of a project. The levels are: proposal, feasibility study, preliminary development, advanced development, operational system, post-operational system.

down-link data bandwidth - the down-link bandwidth expressed in terms of the sensor data bandwidth to be passed and processed to ground storage. It is distinct from the bandwidths associated with modulation techniques used to accomplish transmission. Where on-board DAIA compression is used to effectively reduce the sensor data bandwidth, the bandwidth is that after compression.

down-link data compression factor - the amount, expressed as a value between 0 and 1, by which the down-link can effectively reduce the sensor data bandwidth using data compression. A value of 1 is assigned if no data compression is present, and an appropriate value less than 1 is assigned if data compression is present.

down-link data storage capacity - The maximum recording time available for on-board storage of the sensor data, as operated at a recording speed compatible with the sensor data bandwidth.

down-link element - A data channel associated with each sensor consisting of on-board processing, data transmittal, and ground processing.

down-link performance increment - An alpha-numeric code used to distinguish among the several levels of performance which may be achieved by a particular down-link type depending upon the particular development program selected for its implementation.

down-link performance increment - A choice by the model user of the performance level to be associated with each choice of down-link.

down-link type - An alpha-numeric code used to characterize the down-link by its basic mode of operation (e.g., SF01-store and forward, type 1/PSF01-preprocess, store and forward, type 1).

down-link type count - A sequential count of the number of down-links of the same type (and same performance increment) in a system.

down-link type select - A choice by the model user, of the down-link(s) to be associated with each choice of sensor type.

earliest FY - the earliest fiscal year in which the system could be flown as determined by the availability of the pacing developments.



earth coverage - A categorization of the earth's surface into areas for remote sensing purposes. Major surface areas are identified and then sub-divided into regions of interest (see earth coverage table in Appendix I.

field inclination - The angle off the vertical by which the sensor sight line is displaced to achieve a side-looking field-of-view.

field-of-view (along-track) - The angle as measured at the sensor which subtends the scene being viewed in the along-track direction.

field-of-view (cross-track) - The angle as measured at the sensor which subtends the scene being viewed in the cross-track direction.

frequency of coverage - The time period between repeated sensing of a given area, to meet the information needs of a given application.

ft - feet

FY available - The fiscal year in which a development is available for incorporation in a flight system.

GRI - ground resolution in altitude range 1

GRND RES - see ground resolution

ground resolution - The minimum size of a point feature on the ground which can be detected by a sensor at a given altitude.

ground swath width - The cross-track distance on the ground, within the sensor field-of-view at a given altitude.

ground swath width select - A choice by the model user of a value of ground swath width to be used by the model to establish a set of specific altitudes which provide full earth coverage.

GRND SWT - see ground swath width

GSI - ground swath width in altitude range 1

illumination - see type illumination

IMG01 - Imager, type 01 - in this document taken to designate a multi-spectral scanner.

information factor - A particular parameter which singly, or in combination with other factors defines the variable aspects of an information need (e.g., water depth as a parameter of surface water distribution).

information factor number - A 2-digit serial number assigned to identify a particular information factor with respect to its associated information need.

information need - A particular set of information which is related to decision-making within an activity component (e.g., a knowledge of surface water distribution).

information need number - A 2-digit serial number assigned to identify a particular information need with respect to its associated activity component.

link data BW - see down-link data bandwidth

link data stor capy - see down-link data storage capacity

MDLO1 - User model for agency 01. Each user agency is assumed to have all its analytical modeling needs implemented in a single modeling effort:

minimum drift - see orbit type

NM - nautical miles

no. of bands - see number spectral bands

no. of trnsmts - see daily transmits

number specral bands - For a single sensor, the number of sets of imagery which depict a common field-of-view as sensed over different spectral ranges.

observable - A term or phrase descriptive of the phenomena to be sensed, to satisfy the information needs of a particular application component.

observable message - A single line of text (50A MAX) which describes some aspect of the observable essential to its implementation, which is not accounted for by model operation (e.g., the actual value of sun-angle illumination).

observable number - A 2-digit serial number assigned sequentially to each observable which must be sensed to meet the information needs of an activity component.

observable status - A categorization of the level of experience with a given observable. The levels are: proposed, experimental and established.

orbit altitude - The height of the orbit, taken as circular, in nautical miles.

orbit altitude select - A choice by the model user, of a particular orbit altitude as selected from available orbit data (Appendix I, Table I-1) or otherwise determined.

orbit cycle period - The number of days required to complete one pattern of coverage of the earth, i.e., to return to a particular point over the earth.

orbit cycle period select - A choice by the model user, of a particular cycle period as selected from available orbit data (Appendix I, Table I-1) or otherwise determined.

orbit cycle revolutions - The number of revolutions required to generate one pattern of coverage of the earth.

orbit inclination - The angle the orbital plane makes with the equatorial plane.

orbit inclination select - A choice by the model user of the value of orbit inclination of interest.

orbit revolutions select - A choice by the model user, of a particular number of orbit revolutions per orbit cycle as determined from available orbit data (Appendix I, Table I-1) or otherwise determined.

orbit type - The configuration of the orbit with respect to the manner in which it generates coverage over the earth. Two basic orbit types are defined, minimum drift and zero drift. The minimum drift orbit is configured with an apparent easterly or westerly movement, such that each day's pattern of coverage is adjacent to that of the previous day until full earth coverage is complete. The zero drift orbit is configured to repeat its coverage pattern on a daily basis and in general provides coverage in bands over the earth surface.

orbit type select - A choice by the model user, of the type of orbits of interest (see Appendix H, Table H-8).

performance - Two types of performance are defined as identified from the context of usage, system performance and program performance, system performance describes system capability with respect to particular technical characteristics (e.g., resolution). Program performance describes, for a particular system and particular set of users, the ability of the system to satisfy the information needs of the users (e.g., the percent of needs satisfied).

power - The average power consumed by the element as operated in a flight system.

PRG01 - User program for user agency 01. Each user agency is assumed to have all its remote sensing computer processing needs implemented in a single programming effort.

program performance - A quantitative measure of the extent to which a particular system development program satisfies the information needs of a particular set of applications.

RDM01 - Radiometer, TYPE01 - in this document taken to designate a multi-spectral scanner type of sensor.

REVS/CYC - see orbit cycle revolutions

run number - A 2-digit serial number assigned to identify each run of the model, for use particularly when a number of runs are made during a single exercise period.

sensed earth fraction - The fraction of the earth surface (whole earth = 1.0) which must be sensed to meet the information needs of a particular set of users.

sensor data bandwidth - The bandwidth necessary to pass the sensor output.

sensor element - A transducer which converts a scene into an imagery data stream.

sensor performance increment - An alpha-numeric code used to distinguish among the several levels of performance which may be achieved by a particular sensor type, depending upon the particular development program selected for its implementation.

sensor performance increment select - A choice by the model user of the performance level to be associated with each choice of sensor type.

sensor type - An alpha-numeric code used to characterize the sensor by its basic mode of operation (e.g., ROM01-radiometer, type 1/IMG01-imager, type 1).

sensor type select - A choice by the model user, of the sensor type(s) of interest.

sine (inclination) - The decimal value of the sine function for the chosen angle of orbit inclination.

spectral limit (lower) - The low end of the sensor frequency response.

spectral limit (upper) - The high end of the sensor frequency response.

spectral range - The difference between the upper and lower spectral limits of a sensor.

spectral units - The units in which the sensor frequency response is measured (e.g., microns, kilohertz, angstroms).

swept earth fraction - The fraction of the earth surface (whole earth = 1.0) which is included in the pattern of coverage for a particular orbit configuration and particular swath width. It measures the extent of the earth surface which could be sensed if the sensor operates continuously.

SWPT FRC - see swept earth fraction

system element category - A code number assigned to distinguish among the four types of elements which constitute the earth observations information system (i.e., sensor element-1, down-link element-2, user program-3, user model-4).

system element message text - A single line of text which describes some aspect of element operation, essential to realizing its performance, which is not accounted for by the model operation (e.g., thermal sensitivity).

system element performance increment - An alpha-numeric code used to distinguish among the several levels of performance which may be achieved by a particular element type depending upon the particular development program selected for its implementation.

system element status - A categorization of the level of development of the element. For model purposes these levels are: proposal, feasibility study, preliminary development, advanced development, operational system, post-operational.

system element type - An alpha-numeric code used to characterize the element by its basic mode of operation.

system performance - A quantitative measure of selected technical values associated with system operation.

time horizon - The time period into the future over which the user has an interest in the application he has defined. For model purposes, 2-year, 4-year, and 8-year periods are taken as standard.

time horizon select - A choice by the model user, of a code designating the time period of interest (see Appendix H, Table H-4).

type field-of-view - A categorization of sensor field-of-view into one of four categories (e.g., circular, rectangular, scanning, inclined) for purposes of selection of the manner of ground coverage calculation.

type illumination - A categorization of sun illumination for remote sensing into sun-synchronous and non-sun-synchronous.

UN TS - Units, the units in which the parameter is measured

user activity - An appreciable segment (resourcewise) of an overall agency mission of jurisdiction (e.g., water resources management for a region of U.S.).

user agency - The organizational affiliation of the user.

user agency number - A 2-digit serial number assigned to identify a particular agency.

user model element - An analytical structure which relates user information needs to user decision-making.

user observable number - A 12-digit serial number used to completely characterize a factor observable with respect to the activity component, as follows:

<u>Digit Position</u>	<u>Number Corresponding To</u>
1	time horizon
2	activity category
3,4	user agency number
5,6	activity component
7,8	information need
9,10	information factor
11,12	factor observable

weight - The weight of the element as ready for installation.

zero drift - see orbit type

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