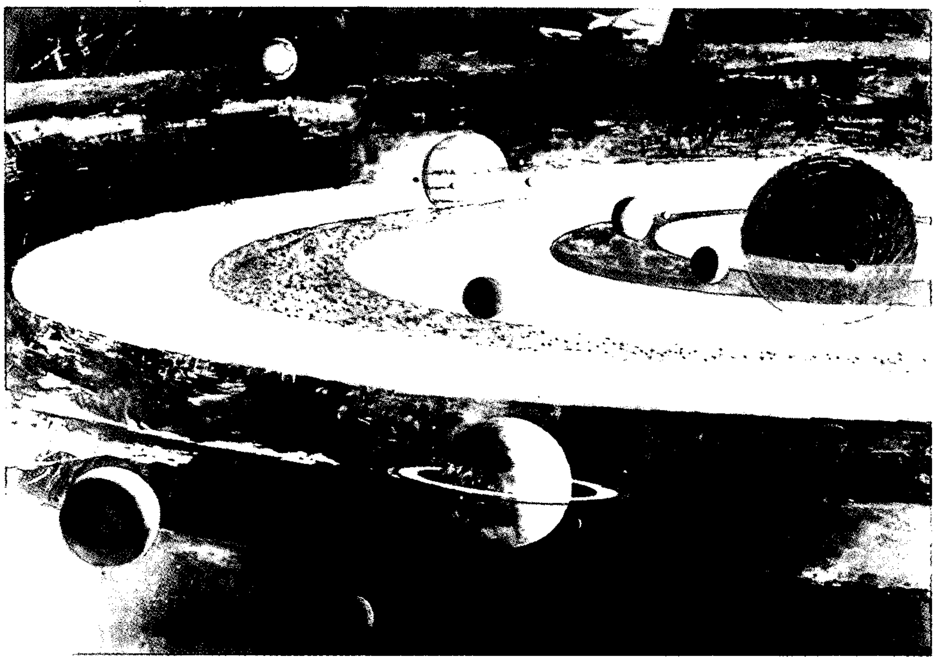


Support Requirements For Remote Sensor Systems On Unmanned Planetary Missions

SD 70-375-1

Space Division
North American Rockwell

SD 70-375-1

Support Requirements For Remote Sensor Systems On Unmanned Planetary Missions

Phase III of Contract NAS2-5647

June 1971

Prepared for

Advanced Concepts and Missions Division
National Aeronautics and Space Administration

Space Division
North American Rockwell

FOREWORD

This report presents the results of a study to determine the support requirements for remote sensor systems on unmanned planetary missions and to establish sensor and experiment groupings for selected missions. Computer programs were developed to relate measurement requirements to support requirements. Support requirements were determined for sensors capable of performing required measurements at various points along the trajectories of specific selected missions.

This study represents Phase III of a three-phase program conducted by North American Rockwell for the National Aeronautics and Space Administration, Office of Advanced Research and Technology, Advanced Concepts and Missions Division, under contract NAS2-5647. Phase I of the program, which is covered in Report SD 70-24, established the scientific and engineering objectives for planetary exploration and identified the measurement requirements needed to fulfill these objectives. Phase II, covered in Report SD 70-361, defined candidate sensor types suitable for future planetary missions and developed scaling laws depicting the relationships between the sensors, the measurements, and the sensor support requirements.

A summary of the entire three-phase program is presented separately in Report SD 71-487.

PRECEDING PAGE BLANK NOT FILMED

ACKNOWLEDGEMENTS

This study was conducted under the direction of A.C. Jones, Study Manager for the entire three-phase program, who was assisted in coordination of the program and integration of reports by A.E. Wheeler. Dr. J.B. Weddell and D.G. Brundige were responsible for the development and application of computer programs to establish the support requirements. Mission trajectory analysis and planetary coverage requirements were accomplished by E. Dazzo.

PRECEDING PAGE BLANK NOT FILMED

CONTENTS

PRECEDING PAGE BLANK NOT FILMED

ILLUSTRATIONS

TABLES

1.0 INTRODUCTION

Effective use of remote sensing systems on unmanned spacecraft to explore the planets of our solar system requires a knowledge of observation and measurement requirements, capabilities of sensor systems, and support requirements for the sensor systems. The scientific and engineering knowledge and measurement requirements for planetary exploration in the 1975-1985 time period were determined and evaluated previously (Reference 1). Candidate sensor types compatible with these requirements were subsequently identified, and scaling laws were developed depicting design and performance parameters versus support requirements. A Space Experiment Requirements Analysis (SERA) computer program was then developed for application of these scaling laws to determine the support requirements for each sensor at specific points along selected mission trajectories (Reference 2).

Specific study objectives covered in this report are to: (1) calculate additional flyby and orbiter trajectory parameter data required for evaluation of sensor support requirements; (2) use SERA program to apply sensor scaling laws which relate measurement requirements to sensor design characteristics and support requirements; (3) establish compatible imaging, non-imaging, and integrated sensor families for selected flyby and orbiter missions; and (4) establish support requirements for sensors included in these families.

Missions included within the scope of this study are listed in Table 1-1. This is not a mission study. Its purpose is to provide a range of reasonable operational conditions to show their effect on sensor support requirements. For each of these missions, the measurement requirements needed to meet observation objectives were established by means of computer techniques described in Reference 2. The determination of sensor support requirements through application of scaling laws developed in this reference is discussed in Section 3 of the present report, which includes tabulations of assumptions, options, and input data for each sensor type considered. Section 3 also contains a summary of the computer program used to evaluate measurement and support requirements, as well as a discussion of mission analysis methodology used to establish required trajectory data and planetary surface area coverage requirements. Sensor capabilities and support requirements at selected trajectory points are developed and summarized. In Section 4, compatible imaging, non-imaging, and integrated sensor families are developed for each of the missions indicated in Table 1-1, and the support requirements are established and tabulated.

Table 1-1. Missions Considered in Study

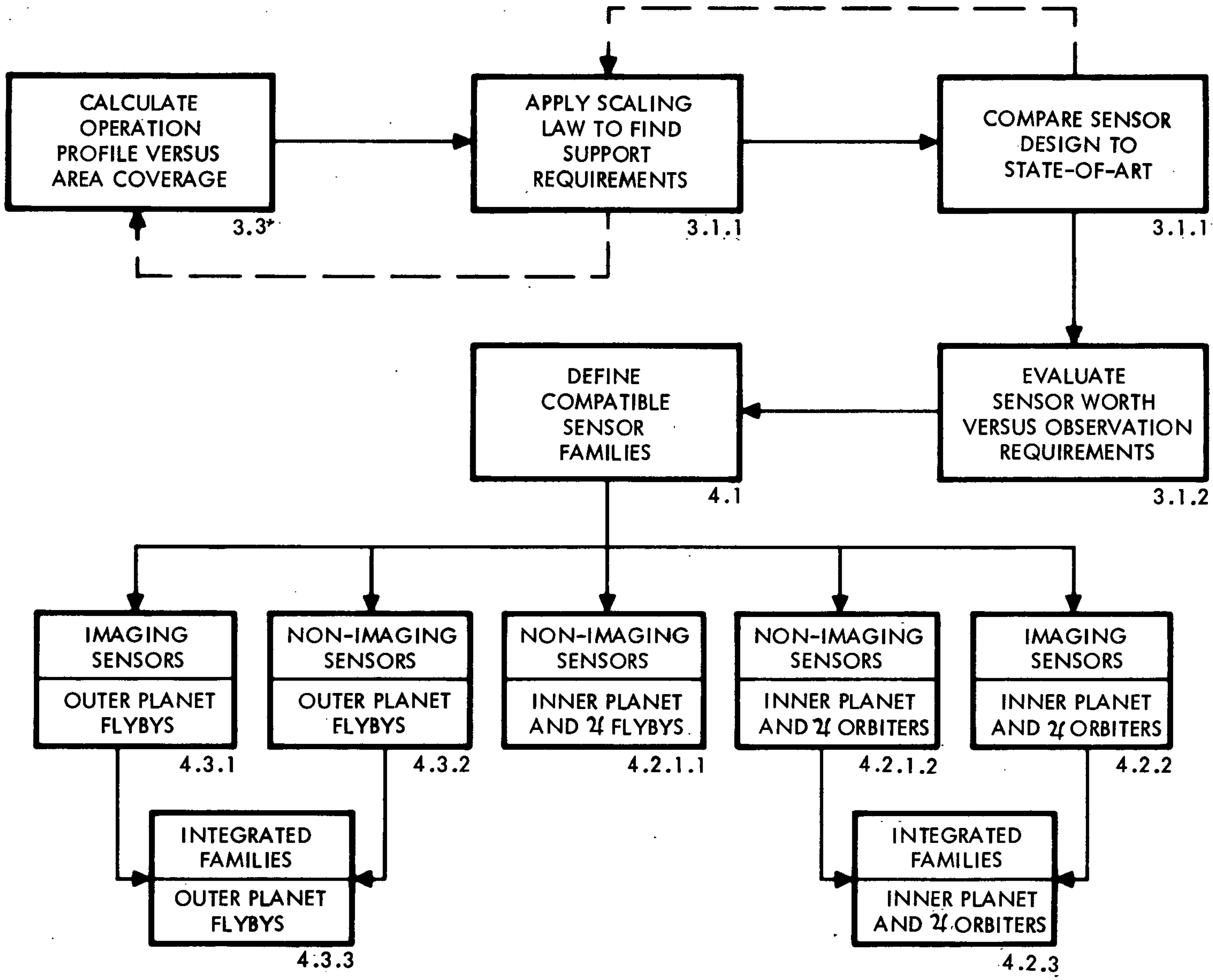
1984	Earth - Mercury
1980	Earth - Venus
1982	Earth - Venus - Mercury
1976	Earth - Jupiter - Saturn
1978	Earth - Jupiter* - Uranus - Neptune
1978	Earth - Jupiter - Saturn - Pluto**
1984	Mercury Orbit No. 1
1984	Mercury Orbit No. 10
1977	Venus Orbit No. 9
1984	Mars Orbit No. 1
1984	Mars Orbit No. 8
1978	Jupiter Orbit No. 1
1978	Jupiter Orbit No. 9
1978	Jupiter Orbit No. 11

*Sensor requirements not considered at this encounter.
**Pluto outside scope of study.

Observations of Pluto, natural satellites, and interplanetary space are not included in the study. State-of-the-art considerations are limited to sensors per se, without regard to the ability of spacecraft to meet the sensor support requirements.

A separately bound volume, Appendix A, contains sensor support requirements tables summarizing support requirements and measurement capabilities for each of the pertinent sensor types on each of the previously referenced missions. Another separate volume, Appendix B, is a computer program user's manual for the scaling law subroutine portion of the SERA program.

The logical flow of this final study phase is depicted in Figure 1-1, which indicates the procedures used to develop and integrate the data regarding sensor systems and support requirements for the specific missions considered during the study. The numbers shown in each box refer to the sections of this report where the procedures are discussed and the data presented.



*NUMBERS REFER TO SECTIONS OF THIS REPORT.

Figure 1-1. Phase III Logic

2.0 SUMMARY

This report presents results of calculations of remote sensor measurement capabilities and support requirements for unmanned planetary flyby and orbiter missions. Compatible imaging, non-imaging, and integrated sensor families are also presented for each mission. The effort reported here began with calculation of the trajectory segments on which each sensor must operate to view the required planetary surface areas on each encounter. The scaling law for the sensor type in question was used to evaluate its support requirements. Reiteration of the area coverage computation might be necessary. If the sensor design exceeded a state-of-the-art limit, the scaling law might be reapplied with a different choice of detector element, etc. The sensor worth was evaluated in terms of its capability to meet observation requirements whose intrinsic worth was given. For each mission, compatible families of imaging and non-imaging sensors were defined, and were integrated in the case of outer-planet flybys and inner-planet and Jupiter orbiters.

Twelve planetary flyby missions launched in the 1976-1984 time period were considered. Of these, the following six were selected for definition of sensor support requirements and grouping analysis:

Earth-Mercury (1984)
Earth-Venus (1980)
Earth-Venus-Mercury (1982)
Earth-Jupiter-Saturn (1976)
Earth-Jupiter-Uranus-Neptune (1978)
Earth-Jupiter-Saturn-Pluto (1978)

Observations at Pluto are outside the scope of the study, but the requirement to fly by Pluto constrains the Saturn encounter in the last of these missions. In addition, nine orbital missions to Mercury, Venus, Mars, and Jupiter were used in definition of non-imaging sensors. Imaging sensor support requirements and compatible families for these orbital missions were established earlier.

Sensor scaling laws were incorporated as subroutines of a computer program that evaluates sensor support requirements to satisfy given observation requirements from a specified trajectory. The subroutines, described

in Appendix B, represent the following sensor types by synthetic, parametric design procedures fitted to sensor state-of-art data:

Visible/UV spectrometer
TV camera
Laser radar
Far IR radiometer (thermal mapper)
Filter radiometer
Polychromatic radiometer
Scanning spectrometer
Michelson interferometer
Mapping microwave radiometer
Measuring microwave radiometer
Microwave spectrometer
Synthetic aperture radar
Radio occultation system
Radio polarimeter

In addition, point design data were used to generate support requirements for particle and field sensors.

A three-step approach was used in determining sensor planetary surface area coverage: (1) select a terminal planet flyby trajectory based on stated science objectives, (2) generate appropriate trajectory data time histories, and (3) compute surface area coverage, in percent of total planet area, based on supplied sensor start and stop altitudes.

Condensed tables of the sensor measurement capabilities and support requirements are presented in Appendix A.

Sensor families are developed for each of the above-listed flyby and orbiter missions. A sensor family is defined as a set of remote sensors that can perform required observations while on a given mission trajectory. Families are developed at two levels: (1) optimal, in which each sensor meets the maximum measurement requirements for the mission and (2) marginal, in which the sensor is designed to meet only the observation requirements representing a marginal increase of information.

For selected missions, separate families are developed for imaging and for non-imaging sensors, and also for integrated groupings consisting of both imaging and non-imaging sensors. Sensor families are established without reference to possible interference between sensors; but in cases of probable inter-sensor interference, this is appropriately annotated.

The significance and utility of the study methods and results are summarized, and recommendations are made for additional effort.

3.0 SUPPORT REQUIREMENTS

The first major effort in this study phase was the evaluation of support requirements and measurement capabilities of individual remote sensors on specific missions. This section describes the methods and assumptions adopted to perform this evaluation by means of the scaling laws developed earlier (References 2 and 3). The mission analysis methods and results are presented. Finally, the sensor capability, worth, and support requirements evaluation is illustrated by an example, and limitations on the compatibility of sensors with missions are discussed. Details of the scaling law application results are given in Appendix A.

3.1 METHODOLOGY

3.1.1 Scaling Law Applications

Remote sensor scaling laws (References 2 and 3) are procedures for the synthetic parametric design of sensors capable of satisfying given measurement requirements. The state-of-the-art (SOA) limitations on sensor instrumentation and the encounter trajectory constrain sensor capabilities and may prevent attainment of the desired quality or quantity of observations. The observation requirements have been stated (Reference 1) in terms of mission-independent planetary properties corresponding to two levels of attainment:

Level I. Optimal, i.e., the level which meets all requirements of a type of observation related to full satisfaction of the observation objectives.

Level II. Marginal, i.e., the level which barely advances present knowledge of planetary environments.

The observation requirements must be restated in terms of parameters that describe sensor capabilities (Reference 2). This restatement involves trajectory data on which the ability of a sensor to perform a specified observation or set of observations depends. Measurement requirements derived from the observation requirements and the trajectory data are inputs to the scaling law application procedure. Outputs are the capability of the sensor (expressed by the same parameters as the measurement requirements), the sensor support requirements, and the worth of the sensor (which is a measure of its support of the observation objectives and of the relative scientific importance of those objectives).

When the scaling law application proceeds from the optimal (Level I) observation requirements, one of the following situations exists in the case of any given planetary encounter or orbit:

1. One sensor type is fully capable of the required measurements.

2. Two or more sensor types in combination are fully capable of the required measurements. (This situation arises, for example, when the required spectral band is wider than the response range of a single type).

3. One or more sensor types can exceed the marginal (Level II) measurement requirements, but are prevented by SOA limits and/or the trajectory from meeting the optimal requirements.

4. One or more sensor types can just meet the marginal measurement requirements.

5. No sensor type or combination can meet the marginal measurement requirements.

6. The SOA is such that all sensors of the appropriate type satisfy the optimal measurement requirements. (This situation arises with regard to the small antenna diameters needed for some radio occultation measurements.)

   When the scaling law application proceeds from the marginal (Level II) measurement requirements, the situations of interest are 4 and 5 above, and

7. The SOA is such that all sensors of the appropriate type must exceed the marginal measurement requirements, but need not meet or exceed the optimal requirements.

   If situation 4 or 6 exists, the support requirements and sensor worth corresponding to the two levels are identical. If situation 5 exists, the support requirements are irrelevant and the sensor worth is zero.

   In relating the sensor measurement capability, worth, and support requirements to the trajectory, one of the following situations arises:

   a. The observation requires attainment of a given spatial resolution throughout a specified fraction of the planetary surface area. Often this area must satisfy limits on latitude and solar illumination. The sensor must be operated, continuously for purposes of this discussion, throughout a trajectory segment bounded by points P_1 and P_2 as shown in Figure 3-1. The sensor support requirements for the encounter are defined by the points on this segment which lead to the most stringent requirements, so that the sensor meets all capability requirements at every point on the segment. Usually a single point, often the first (highest) point, defines the support requirements for the trajectory. It is possible that some support requirements are set by one point, other requirements by a second point, etc., so that the net requirements are the outer envelope of the point-by-point requirements. If requirements set by one point are incompatible with requirements set by another point, then two sensors of the given type must be employed during the encounter, each during a different portion of the segment (P_1, P_2). (This last situation did not arise in this study). The determination of points P_1 and P_2 is discussed in Section 3.2. Their location usually depends on whether the optimal or marginal observation requirements are considered.

b. The measurement requirements can be met by an observation performed from one point P_3 on the trajectory. The location of this point usually depends on whether the optimal or marginal observation requirements are considered. Either there is no surface area coverage requirement, or the required area can be viewed at once. The sensor measurement capability, worth, and support requirements are evaluated at P_3. A related case occurs when the observation is performed at each of a finite set of discrete points selected independently of measurement requirements. The sensor support requirements are the envelope of the mutually compatible requirements at these points, as in situation (a). A radio occultation experiment, performed at entrance and exit, is an example.

c. The measurement requirements are all independent of the trajectory. An arbitrary point is selected for purposes of computing the sensor measurement capability, worth, and support requirements.

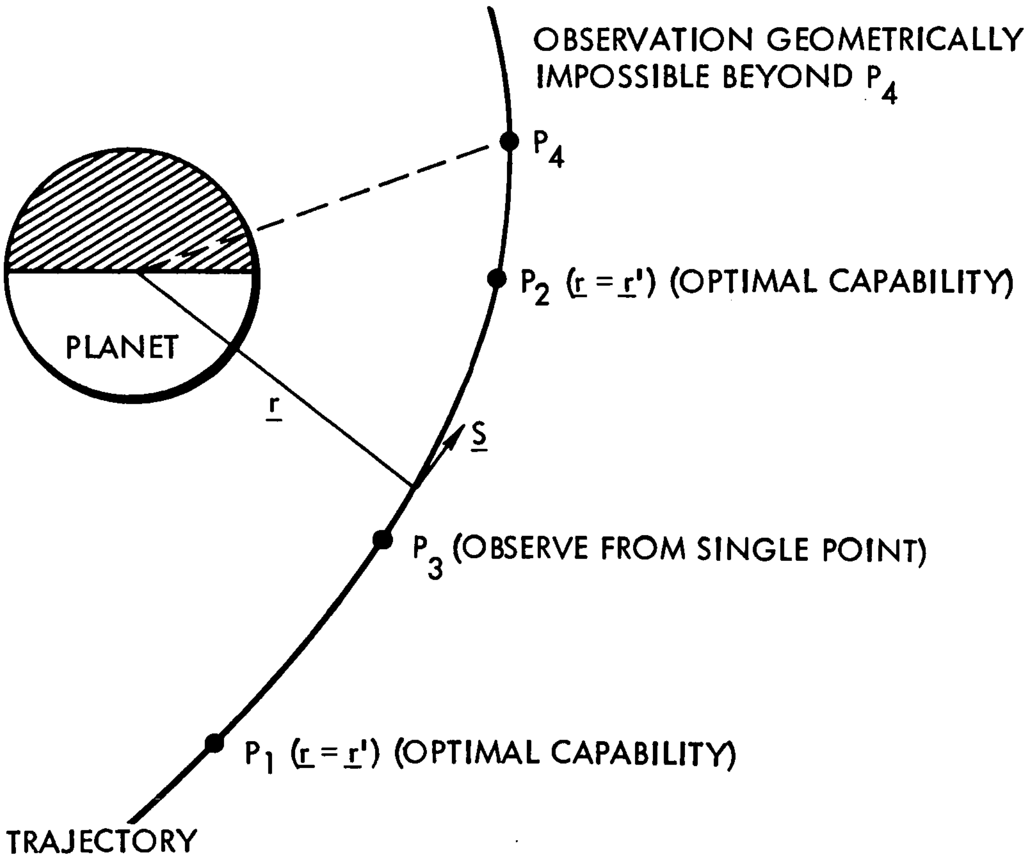


Figure 3-1. Measurement Capabilities Along a Trajectory Segment

d. A specific sensor design can meet or exceed the observation requirements, independently of the trajectory. The scaling law for this sensor type degenerates to this point design. The sensor measurement capability, worth, and support requirements are fixed.

Specific Applications

Table 3-1 summarizes application of scaling laws to specific remote sensor types and observation objectives. The scaling laws for imaging sensors are to be applied only at Saturn, Uranus, and Neptune. Support requirements of imaging sensors at Mercury, Venus, Mars, and Jupiter are discussed in Reference 3. Scaling laws for non-imaging sensors are to be applied to all planets except Earth and Pluto. Whether a sensor is imaging is indicated in Table 3-1; an imaging sensor produces a continuous two- or three-dimensional distribution of some environmental parameter (topographic height, temperature, albedo, etc.) over some part of the planet.

Additional information appears as follows:

1. Sensor Support Requirements Tables, Appendix A
2. Scaling Law Subroutines, Appendix B.
3. Output of Space Experiment Requirements Analysis computer program, copies of which are held by the NASA Technical Monitor and the NR Program Manager.

3.1.2 Measurement Requirements Computer Program

The processing of information relating to observation requirements, measurement requirements, sensor measurement capabilities, and sensor support requirements is accomplished in this study by means of a Space Experiment Requirements Analysis computer program (SERA). Since the entire SERA program requires the use of core storage exceeding that available, SERA is structured as three modules called into execution by an executive program with the use of overlay techniques. Briefly, the three modules perform the following operations:

1. Module 1 (SERA-1) stores and prints the observation requirements, stated in terms of intrinsic properties of the observed planet.
2. Module 2 (SERA-2) converts the observation requirements to measurement requirements, stated in terms of intrinsic properties

Table 3-1. Applications of Remote Sensor Scaling Laws

Sensor			Flyby Missions										Orbital Missions									
			Earth-Mercury 1984 (2)	Earth-Venus 1980 (3)	Earth-Venus-Mercury 1982 (6)		Earth-Jupiter Saturn 1976 (7)		Earth-Jupiter* Uranus-Neptune 1978 (9)		Earth-Jupiter-Saturn-Pluto** 1978 (12)		Mercury 1984 Orbit		Venus 1977 Orbit		Mars 1984 Orbit		Jupiter 1978 Orbit		
													1	10	1	9	1	8	1	9	11
No.	Name	Type	M	V	V	M	J	S	U	N	J	S	M	M	V	V	M	M	J	J	J
1.	Television camera **	○	–	–	–	–	–	○	○	○	–	○	○	○	○	○	○	○	○	○	○
2.	Camera system	○											○				○	○			
3.	Microwave radiometer, mapping **	○	–	–	–	–	–	○	○	○	–	○	○		○		○				
4.	Microwave radiometer, measuring **	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
5.	Synthetic aperture radar **	○	–	–	–	–	–	○	○	○	–	○	○		○						
6.	Noncoherent radar system	○											○		○		○				
7.	Flux-gate magnetometer	●	●			●	●	●	●	●	●	●	●	●					●	●	●
8.	Helium magnetometer	●	●			●	●	●	●	●	●	●	●	●					●	●	●
9.	Scintillation spectrometer	●	●			●							●	●			●	●			
10.	Charged-particle spectrometer †	●																			
11.	Electrostatic or Faraday cup analyzer	●	●			●							●	●							
12.	Geiger-Mueller counter array	●	●			●							●	●							
13.	Proportional counter array	●	●			●							●	●							
14.	Radio polarimeter **	●	–	–	–	–	–	–	–	–	–	–									
15.	Filter radiometer **	●	●	●	●	●	②●	②●	②●	②●	②●	②●	●	●	●	●	●	●	●	●	●
16.	Far IR radiometer **	○	–	–	–	–	–	○	○	○	–	○	○	○	○	○	○			○	
17.	Polychromator radiometer **	●	–	–	–	–	–	–	–	–	–	–									
18.	Scanning spectrometer **	○	–	–	–	–	–	–	–	–	–	–	○	○	○	○	○				
19.	Michelson interferometer **	●	–	–	–	–	①●	①●	①●	①●	①●	①●							●	●	●
20.	Visible/UV photometer **	○	–	+	+	–	+	+	+	+	+	+									
21.	Visible/UV spectrometer **	●	‡	‡	‡	‡	●	●	●	●	●	●							●	●	●
22.	Laser radar **	●	●	●	●	●	●	●	●	●	+	●	●	●	●	●	●	●			
23.	Bi-frequency radio occultation receiver **	●	×	●	●	×	●	●	●	●	●	×	●		●	●	●				
24.	Visible polarimeter **	○	–	–	–	–	–	–	–	–	–	–									
25.	Proportional counter telescope	●																			
26.	Solid-state telescope	●	●			●							●	●							
27.	Li^6I spectrometer	●	●			●							●	●							
28.	Curved plate plasma spectrometer	●	●			●							●	●							

LEGEND

- ○ Imaging sensor
- ● Nonimaging sensor
- – Not within scope of study, or requirement for sensor does not exist
- * Planetary coverage at this encounter outside scope of study
- ** Pluto outside scope of study
- † See Item 26, solid-state telescope
- ① Optimal capability
- ② Marginal capability
- ‡ Observation requirements deal with airglow emission spectra; airglow emission properties not readily available
- × No sensor designed; Earth occultation does not occur
- \+ Sensor design within state-of-art limitations not possible

of generic sensor types, at selected points on a specified planetary encounter trajectory or orbit.

3. Module 3 (SERA-3) uses sensor scaling laws to design a sensor of a given type to satisfy a set of measurement requirements, subject to state-of-the-art limitations, and then calculates the sensor support requirements.

Module 1 was described in Reference 1, Appendix D. A user's manual for the executive program and all three modules was prepared as the Appendix of Reference 2.

Module 3 calls a subroutine which embodies the set of scaling laws for the sensor type specified in input data to Module 3, as determined by the nature of the observation requirements. Subroutine names are listed in Table 3-2. The LIDAR and SPVIS subroutines were included in the Appendix of Reference 2. Listings, definitions of variables and input/output formats, array and load module maps, sample data and results, and user's instructions for the other subroutines are presented in Appendix B of this report. Appendix B also describes changes made in the main program and subroutines since issuance of Reference 2.

Table 3-2. Sensor Scaling Law Subroutines

Subroutine Name	Sensor Type
SPVIS	Visible/UV spectrometer
IMVIS	TV camera
LIDAR	Laser radar
RADIR	Far IR radiometer (thermal mapper)
SPIRD	Filter radiometer Polychromatic radiometer Scanning spectrometer Michelson interferometer
RDMIC	Mapping microwave radiometer Measuring microwave radiometer Microwave spectrometer
SNADR	Synthetic aperture radar
OCULT	Radio occultation system Radio polarimeter

3.2 MISSION ANALYSIS

A basic objective of the subject contract effort was development of suitable scaling laws relating mission support requirements to the measurement capabilities of the sensors along with the methodologies for application of these laws to representative cases. To provide meaningful observational data for these representative cases, a selected set of mission profiles and the accompanying planetary encounter trajectory data were generated.

A NASA-developed trajectory computer program was provided at the outset of the study to generate the necessary trajectory data. This program was subsequently included as a basic module in the final version, which included an automated graphical output of data along with a time-sequenced pictorial display of the encounter planet as seen from the flyby spacecraft.

NASA SP-35 formed the basic reference for heliocentric trajectory parameters related to specified mission sets, except for the mini-tours for which special trajectory data was supplied by NASA.

3.2.1 Flyby Missions

The total set of unmanned missions included in this study are flybys of Mercury and Venus (including a Venus swingby mission to Mercury), flybys of Saturn using a Jupiter swingby mode, multiplanet flybys (mini-tours) of Jupiter-Saturn-Pluto and Jupiter-Uranus-Neptune. At least two mission opportunities for each specified planetary set were evaluated.

As a consequence of the inherent planetary alignments, the time period under consideration for swingby missions to the outer planets was restricted to the latter half of the 1970 decade.

3.2.1.1 Mission Selection

A basic criterion used in this study for the selection of the mission sets was a minimal Earth departure energy commensurate with a "close" encounter with the individual encounter planets. A minimum value (1/4 planet radii) for the altitude of closest approach to Jupiter was selected to alleviate the guidance and navigation requirements, and the Saturn flybys were restricted to an external passage of the rings.

To set the character of the individual mission sets in proper perspective in terms of the planetary features and the selection rationale, the following discussion is presented for each of the mission sets:

Mercury Direct. A Mercury mission should provide a significant contribution to the knowledge of both the planet and its solar environment. Planetary mass determination, surface features, and magnetic field characteristics are but a few of several areas on which very little information is available.

At least three launch opportunities for direct flyby missions to Mercury occur during each year; these opportunities in turn occur near the date of an inferior conjunction* of Mercury. Since the orbit of Mercury has a significant inclination and a large eccentricity, only one launch opportunity yields minimal Earth departure velocity; hence, only one opportunity per calendar year is of interest.

Two mission opportunities were selected for this study corresponding to the third inferior conjunction for each of two years, 1982 and 1984, corresponding to the following respective launch dates: October 17.5, 1982 and September 16.5, 1984. The altitude of closest approach to Mercury was fixed at one planet radius; the flyby inclinations were set at 30 and 150 degrees, which is near the minimum established by the vector declination of the encounter asymptotic velocity.

Venus Direct. The orbit of Venus is characterized by a moderate inclination and a lesser eccentricity than any of the other planets. In addition to areas of interest previously mentioned regarding Mercury missions, perhaps the most significant additional area pertaining to a Venus mission is the presence of a significant atmosphere.

The two opportunities selected for the Venus mission correspond to the inferior conjunctions of 1980 and 1983; the specific launch dates were April 0.5, 1980 and May 25.5, 1983. Again the altitude of closest approach was set at one planet radius and the inclination of the hyperbolic orbit at -30 and +30 degrees, roughly the minimum permissible.

Venus Swingby to Mercury. One qualification for all swingby missions under consideration for this study is that no powered encounters are permitted; thus, in general, a somewhat restrictive set of launch windows are available for the potential missions. The opportunity for the 1980 mission

---

*Inferior conjunction is defined as that position wherein the heliocentric alignment is Sun-planet-Earth.

centers about the beginning of the year 1980 and extends about one month into 1979 and 1980. The 1982 mission has a somewhat larger launch window range centering about the early part of 1982. The selected missions for this study were December 25, 1979 and January 30.5, 1982.

The swingby about Venus for both missions is characterized by light side approaches with periapse near the terminator; the resulting altitude of closest approach for both cases is quite low, in the range of 1200 to 2000 km, which may be of concern in the guidance and control subsystems area.

Jupiter Swingby to Saturn. As stated earlier, the outer-planet missions are restricted to the 1975/1980 time period. Jupiter generally acts as a fulcrum for missions to the outer planets because of its great size. In addition to its use to add energy to the spacecraft, Jupiter itself is of considerable scientific interest. Combined with the unique character of the planet Saturn and its rings, this type of mission appears potentially to provide a wealth of scientific data.

In general, the more desirable missions occur early in the time period, due mainly to the large increase in Jupiter passage distances as time increases.

Specific mission periods chosen for this study were July 30.5, 1976 and September 3.5, 1977.

Jupiter Swingby to Uranus Swingby to Neptune. Only two launch years were considered in the study; these were the 1978 and 1979 opportunities. In general, 1978 opportunities are well behaved, i.e., the resulting swingby distances are moderate for the lower departure energies. The 1979 opportunities are characterized, in general, by a significant increase in the Jupiter swingby distance. For this study, the mission opportunities evaluated were October 8.5, 1978 and November 12.5, 1979.

Jupiter Swingby to Saturn Swingby to Pluto. The character of this mission is somewhat similar to the single swingby case previously discussed. In general, for a specific launch date, the swingby distances about Jupiter and Saturn increase with increasing target (i.e., Pluto) arrival dates. Correspondingly, the departure energy decreases as the target arrival date is extended. As a compromise which relates a minimum departure velocity commensurate with a reasonable range of swingby distances about Jupiter and Saturn, the following missions were selected: September 3.5, 1977 and October 8.5, 1978.

A summary of the mission sets evaluated in the course of the study is contained in Table 3-3.

One mission was chosen as an example for illustrative purposes in this report: the 1976 Earth-Jupiter-Saturn mission; the Saturn encounter data and a discussion of this particular case are presented in Sections 3.2.1.2 and 3.2.1.3.

3.2.1.2 Analysis Methodology

This specific mission was chosen as a representative mission; the resulting encounters with the two most massive planets of our solar system are expected to provide excellent opportunities for detailed planetary measurements. 1976 turns out to be an ideal year for this type of mission in that the best combination of minimal departure energy and close planetary encounters occur as a consequence of the favorable alignment of the planets during this time period.

For each flyby trajectory, a specific set of planetocentric parameters was generated as shown in Section 3.2.1.3. These were chosen on the basis of their expected utility in the evaluation of the complete sensor set. The first and most obvious is the altitude, followed by the spacecraft velocity magnitude and the rate of change of the radius. The latitude and longitude of the sequence of subsatellite points were likewise determined. The Earth (Sun)/spacecraft/planet included angles were considered as important parameters, as well as their rates of change. Ground speed of the subsatellite point was calculated, as well as the nadir angle rate. This latter parameter is defined as the required inertial slewing rate for a given sensor to track the instantaneous subsatellite point. Each of these parameters, along with time, was sequentially calculated using true anomaly as the independent parameter. These dependent parameters and their dimensions follow and are shown in Figure 3-2.

Altitude	(planet radii)
Latitude	(deg)
Longitude	(deg)
Radius rate	(km/sec)
Velocity	(km/sec)
Nadir angle rate	(deg/hr)
Ground speed	(km/sec)
Disk half angle	(deg)
Clock angle	(deg)
Cone angle	(deg)
Earth angle	(deg)
Phase angle	(deg)
Time	(hr)

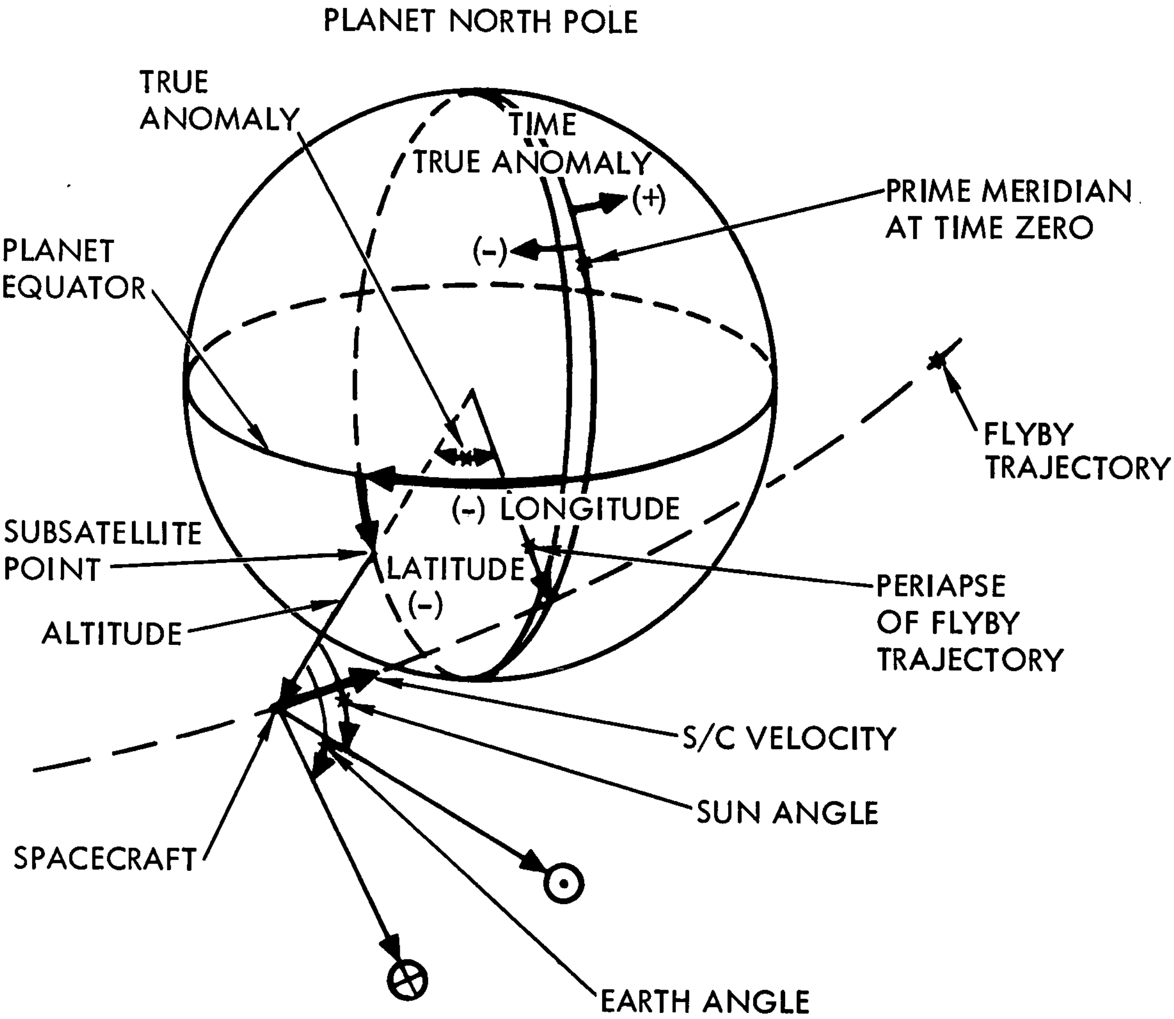


Figure 3-2. Trajectory Parameters

Table 3-3. Mission Data Summary

(1)	Earth-Mercury 1982			
		Depart	45260.0*	(October 17.5, 1982)
		Arrive	45378.0	(February 12.5, 1983)
		Trip Time 118 days		
(2)	Earth-Mercury 1984			
		Depart	45960.0	(September 16.5, 1984)
		Arrive	46080.0	(January 14.5, 1985)
		Trip Time 120 days		
(3)	Earth-Venus 1980			
		Depart	44330.0	(April 0.5, 1980)
		Arrive	44440.0	(July 19.5, 1980)
		Trip Time 110.0 days		
(4)	Earth-Venus 1983			
		Depart	45480.0	(May 25.5, 1983)
		Arrive	45640.0	(November 1.5, 1983)
		Trip Time 160.0 days		
(5)	1979 Earth-Venus-Mercury			
		Depart	44210.0	(December 2.5, 1979)
		Swgby	44466.5	(August 15, 1980)
		Arrive	44592.0	(December 18.5, 1980)
		Trip Time 256.5/125.5 = 382 days		
(6)	1982 Earth-Venus-Mercury			
		Leave	45000.0	(January 30.5, 1982)
		Swgby	45167.7	(July 17.2, 1982)
		Arrive	45304.0	(December 0.5, 1982)
		Trip Time 167.7/136.3 = 304 days		

*Julian Date - 2400000.

Table 3-3. Mission Data Summary (Cont)

(7)	1976 Earth-Jupiter-Saturn		
	Leave	42990.0	(July 30.5, 1976)
	Swgby	43725.5	(August 5.0, 1978)
	Arrive	44700.0	(April 5.5, 1981)
	Trip Time 735.5/974.5 = 1710.0 days		
(8)	1977 Earth-Jupiter-Saturn		
	Leave	43390.0	(September 3.5, 1977)
	Swgby	44133.1	(September 16.6, 1979)
	Arrive	45000.0	(January 30.5, 1982)
	Trip Time 743.1/866.9 = 1610.0 days		
(9)	Earth-Jupiter-Uranus-Neptune		
	Depart	43790.0	(October 8.5, 1978)
	Swgby	44452.0	(August 0.5, 1980)
	Swgby	46521.2	(March 31.7, 1986)
	Arrive	48000.0	(April 18.5, 1990)
	Trip Time 662.0/2069.2/1478.8 = 4210 days		
(10)	Earth-Jupiter-Uranus-Neptune		
	Depart	44190.0	(November 12.5, 1979)
	Swgby	44690.7	(March 27.2, 1981)
	Swgby	46101.7	(February 5.2, 1985)
	Arrive	47200.0	(February 8.5, 1988)
	Trip Time 500.7/1411.0/1098.3 = 3010 days		
(11)	Earth-Jupiter-Saturn-Pluto		
	Depart	43390.0	(September 3.5, 1977)
	Swgby	43837.8	(November 25.3, 1978)
	Swgby	44355.5	(April 26.0, 1980)
	Arrive	46000.0	(October 26.5, 1984)
	Trip Time 447.8/517.7/1644.5 = 2610 days		
(12)	Earth-Jupiter-Saturn-Pluto		
	Depart	43790.0	(October 8.5, 1978)
	Swgby	44229.7	(December 22.2, 1979)
	Swgby	44652.4	(February 16.9, 1981)
	Arrive	46400.0	(December 0.5, 1985)
	Trip Time 439.7/422.7/1747.6 = 2610 days		

The point of distance of closest approach is defined as time zero. A minus time or true anomaly denotes the approach phase, a plus value the departure phase. Latitude is measured in a conventional method from the planet equator; zero longitude is defined as the meridian passing through the point of closest approach at time zero.

3.2.1.3 Trajectory Data

The data determined are presented in two forms. The first is a set of time-sequenced pictorial displays of each planet as seen by the spacecraft (Figure 3-3), while the second is a set of graphs on which the selected planetocentric parameters just described are plotted with true anomaly as the independent variable (Figures 3-4 to 3-16). These data are presented in the following set of computer-generated output. Only selected pictorial displays are shown here; the full set includes 40 pictures.

3.2.2 Selection of Orbits at Inner Planets and Jupiter

In the calculation of imaging sensor support requirements for orbital missions at the inner planets and Jupiter (Reference 3), 10 orbits were considered at each inner planet and 11 at Jupiter. These orbits differ principally in eccentricity, and at Jupiter also in periapsis altitude. The inclinations are given in Table 3-5. The longitude of ascending node and argument of periapsis were not specified.

From this set of candidate orbits, certain orbits were selected in Reference 3 on the basis of maximum support of observation objectives. Table 3-4 shows the number of imaging sensor systems designed for use in each orbit in any of the orbital missions to the inner planets and Jupiter. Orbit numbers in Table 3-4 correspond to Reference 3. The tasks of computing non-imaging sensor support requirements for these missions, and of constructing integrated compatible families of imaging and non-imaging remote sensors, are greatly simplified by restricting this effort to a few orbits that best represent the distribution of Table 3-4. Table 3-5 lists the parameters of the orbits selected for evaluation of non-imaging sensor support requirements. If these requirements were calculated for the other orbits, the results would change only slightly, and the integration with compatible imaging sensor families would be trivial or meaningless.

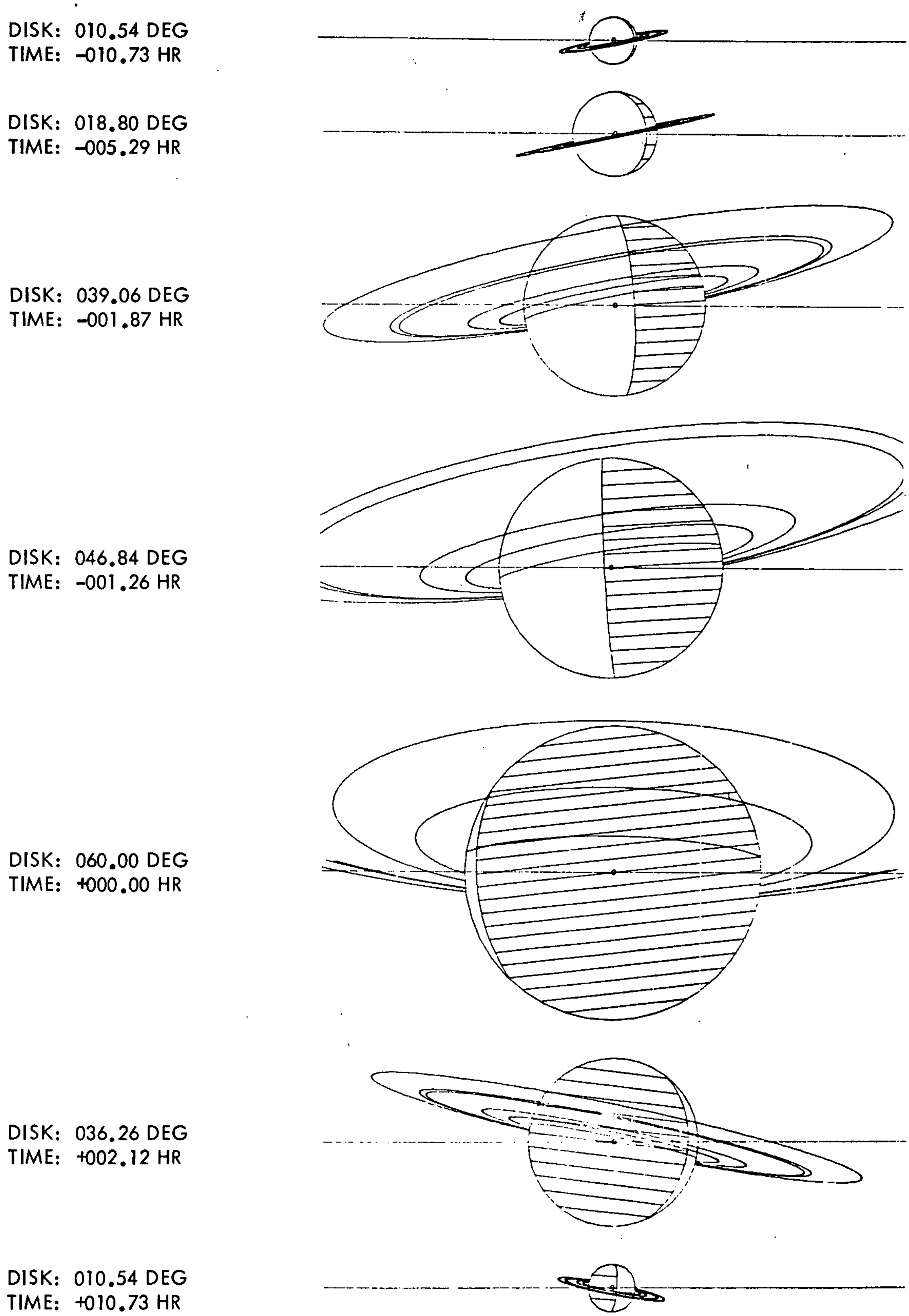


Figure 3-3. Computer-Generated Time-Sequenced Display of Planet

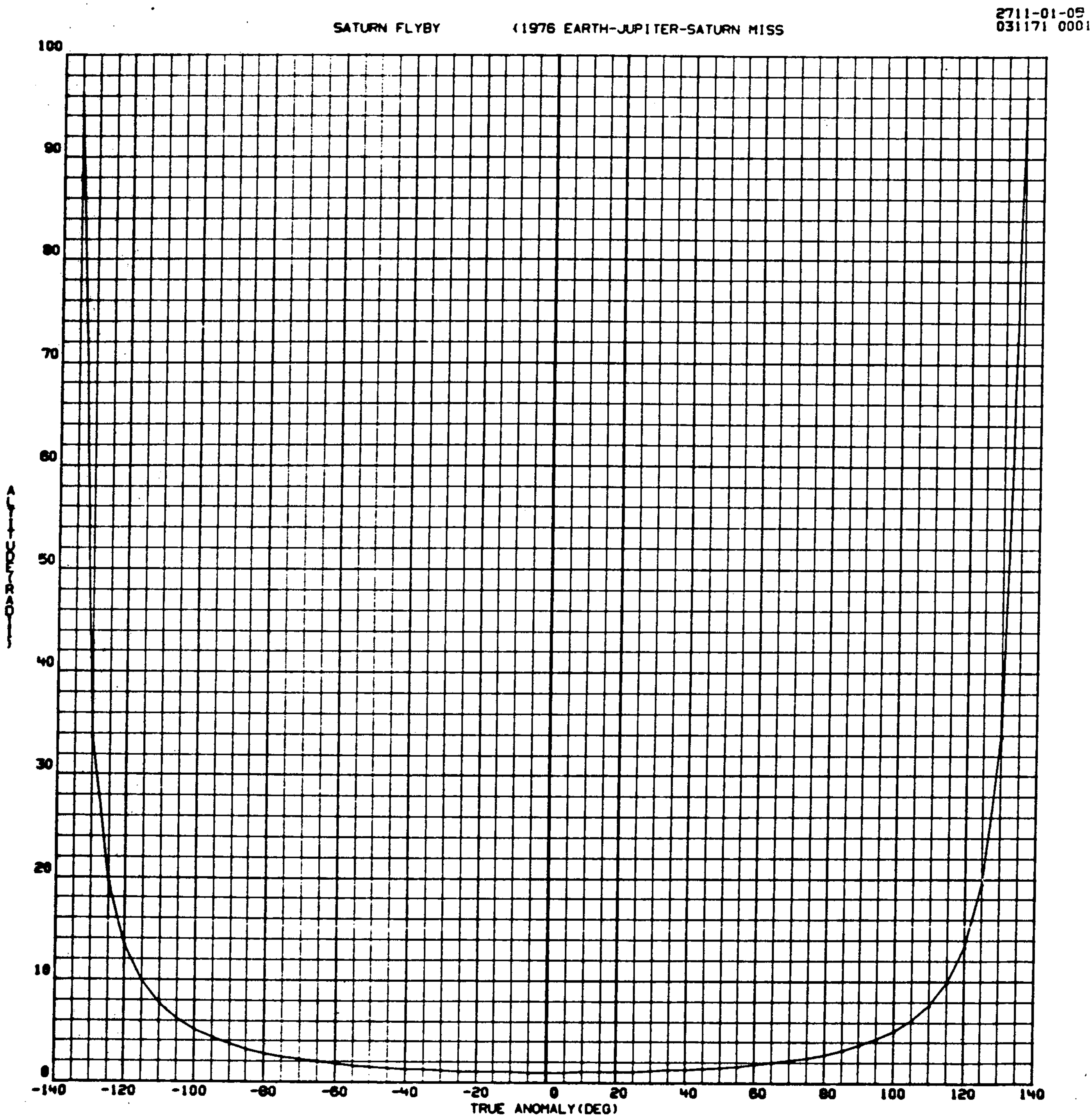


Figure 3-4. Altitude Versus True Anomaly

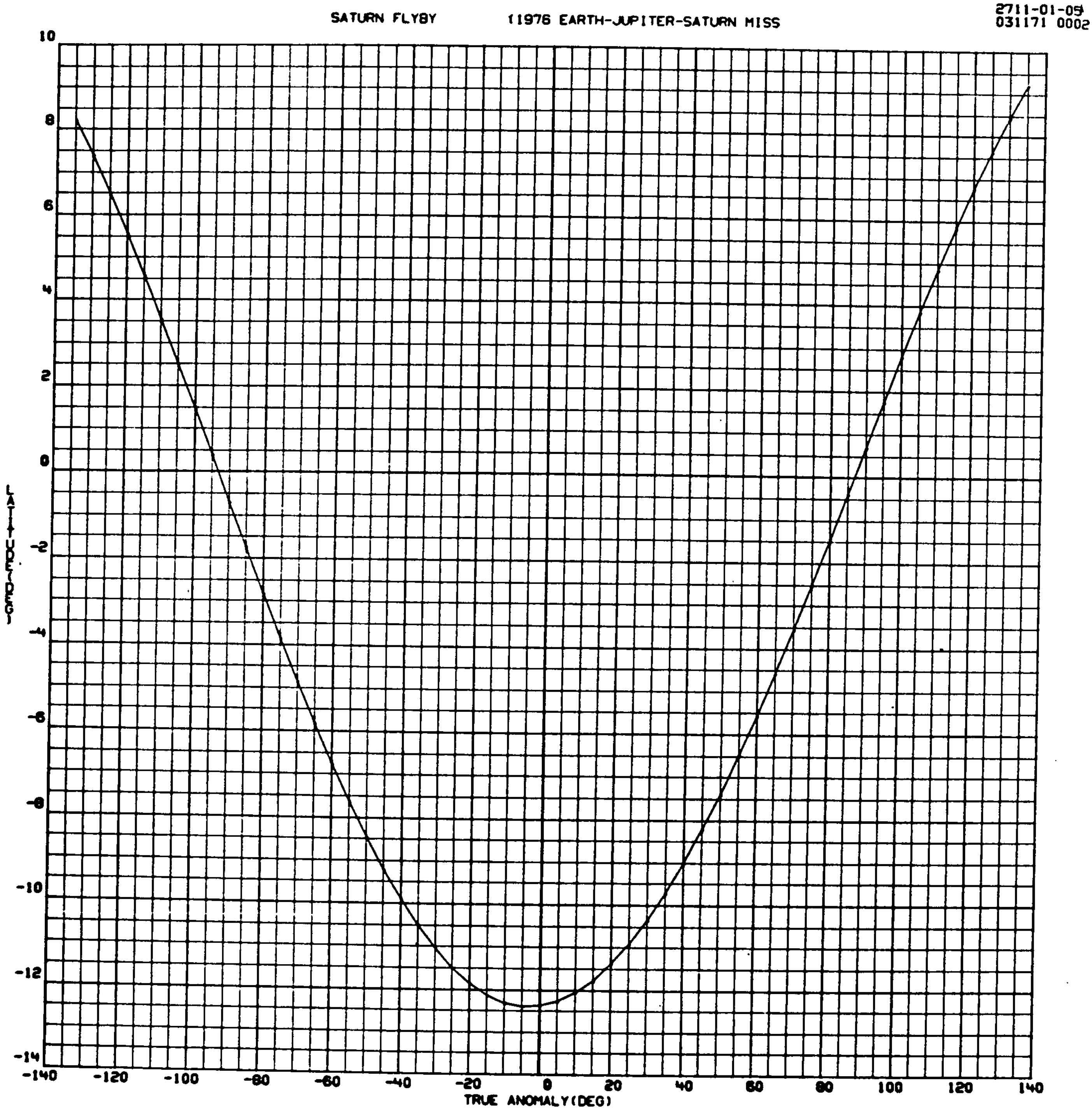


Figure 3-5. Latitude Versus True Anomaly

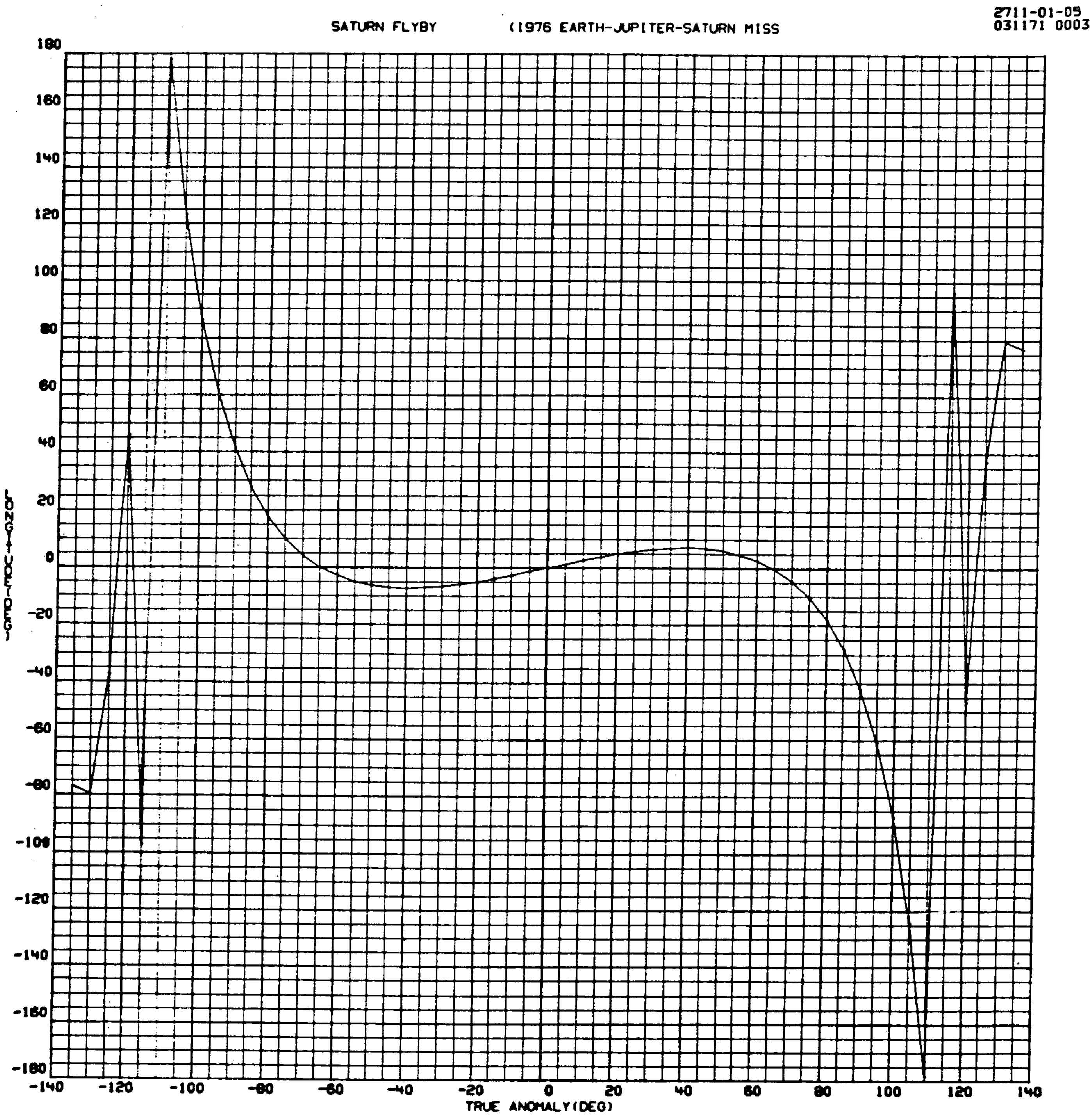


Figure 3-6. Longitude Versus True Anomaly

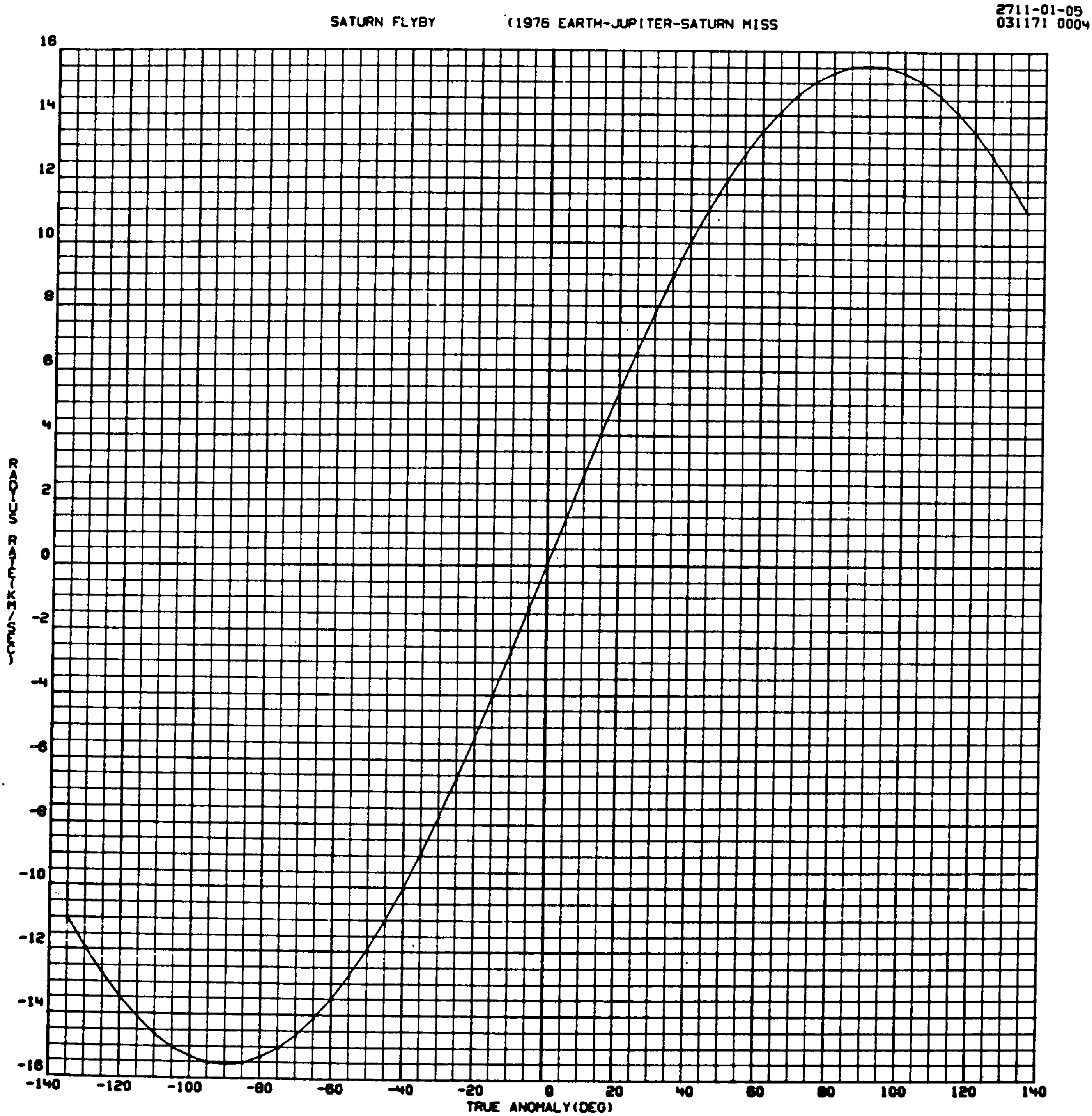


Figure 3-7. Radius Rate Versus True Anomaly

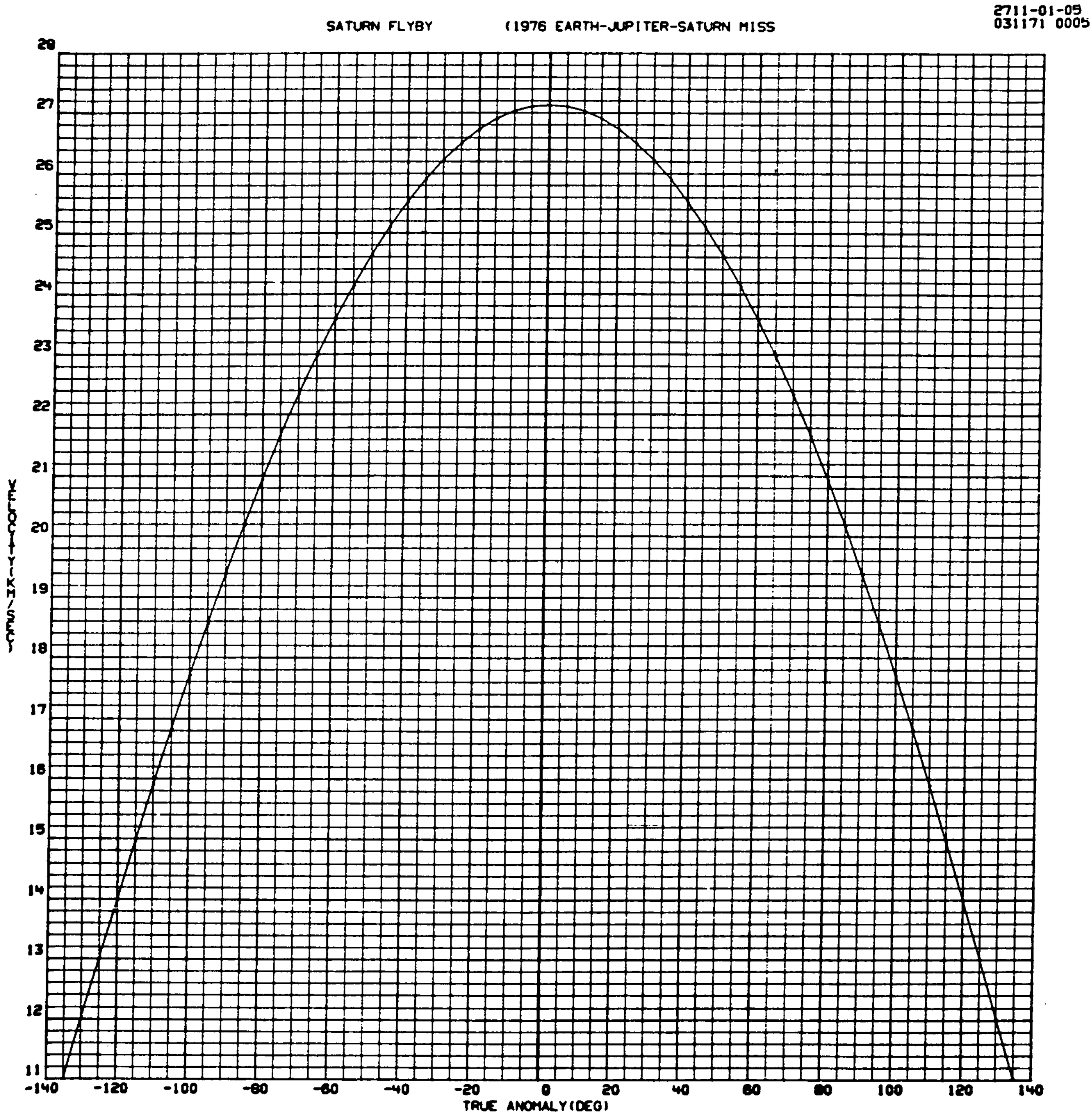


Figure 3-8. Velocity Versus True Anomaly

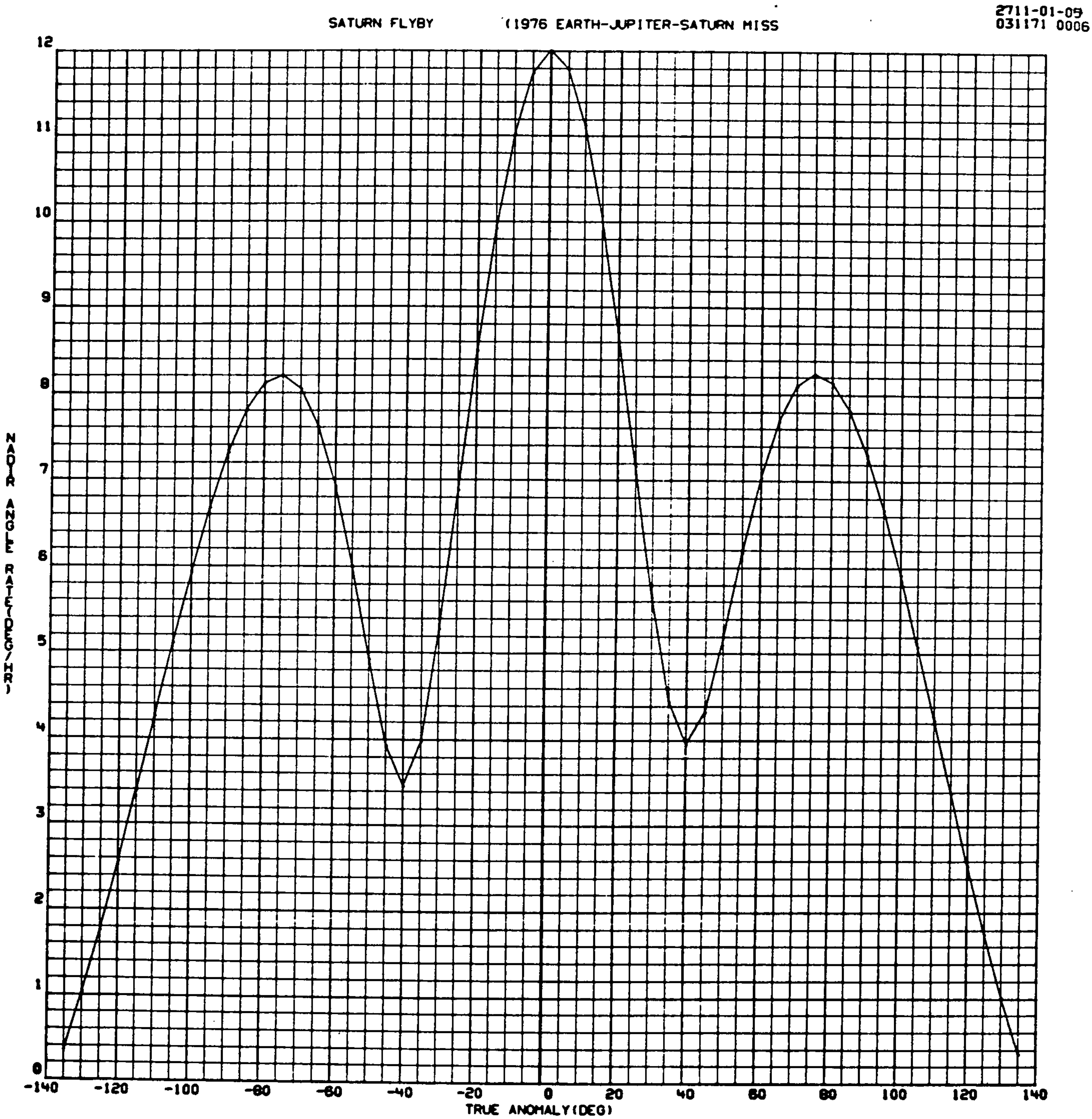


Figure 3-9. Nadir Angle Rate Versus True Anomaly

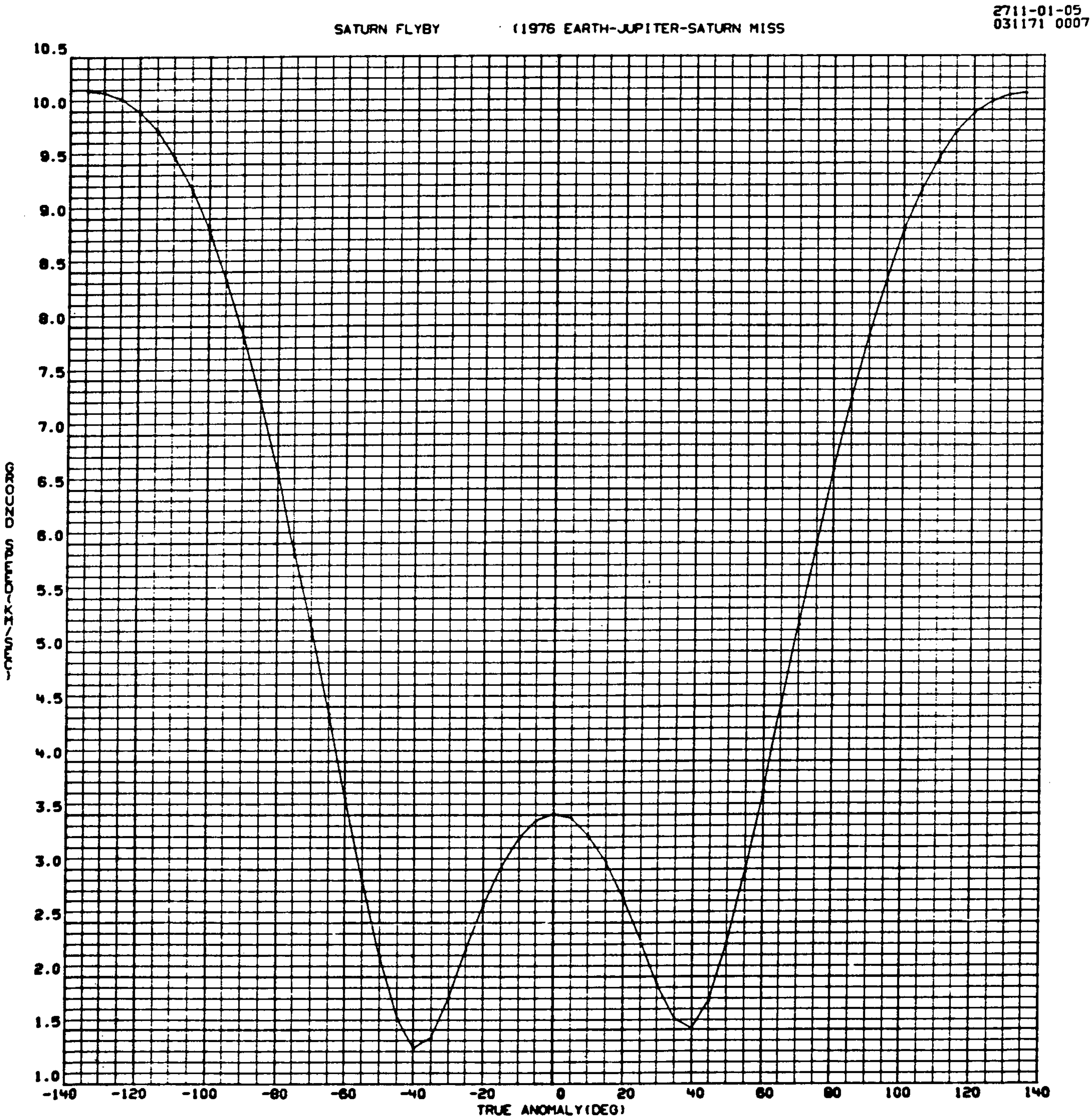


Figure 3-10. Ground Speed Versus True Anomaly

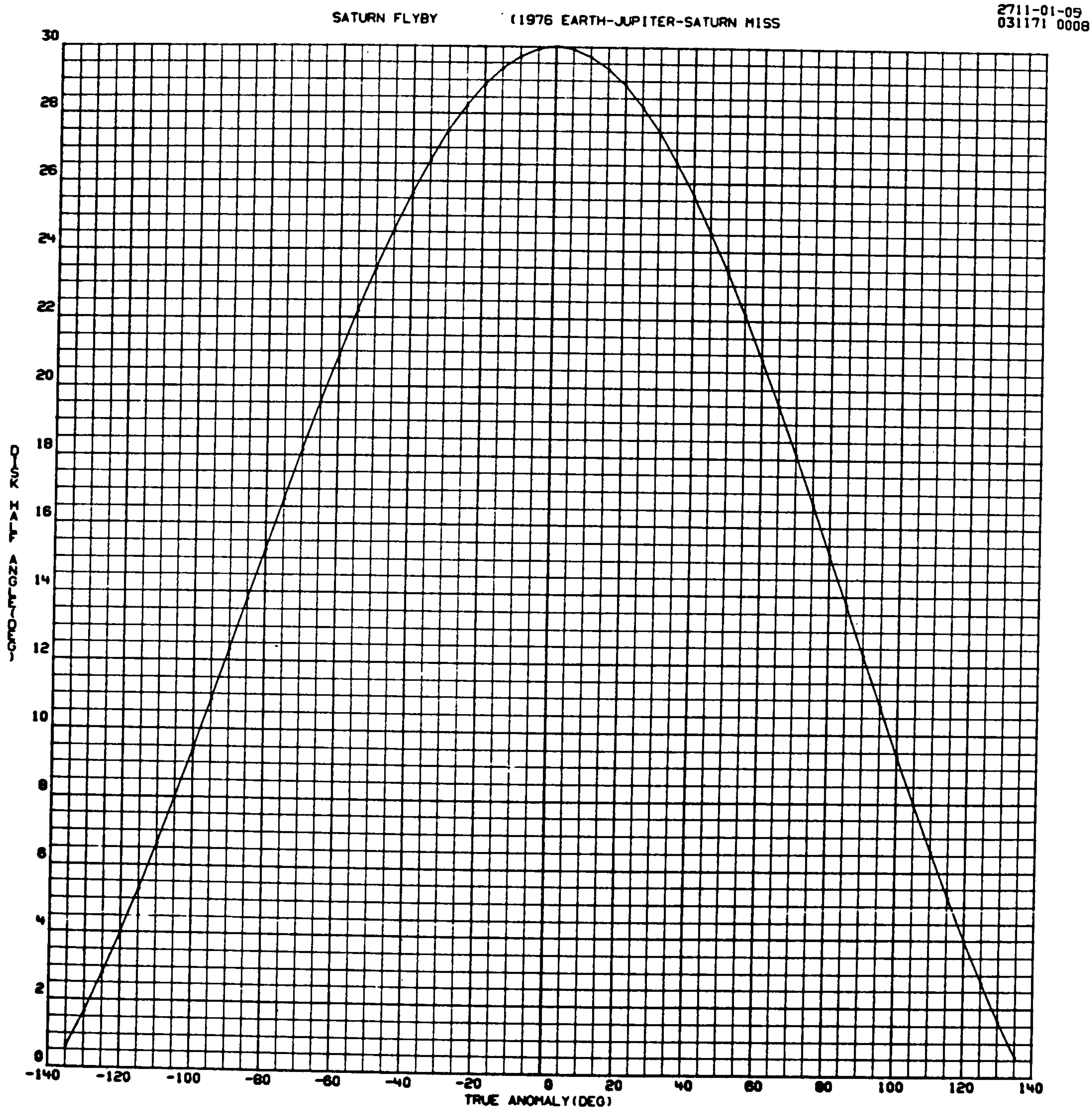


Figure 3-11. Disk Half-Angle Versus True Anomaly

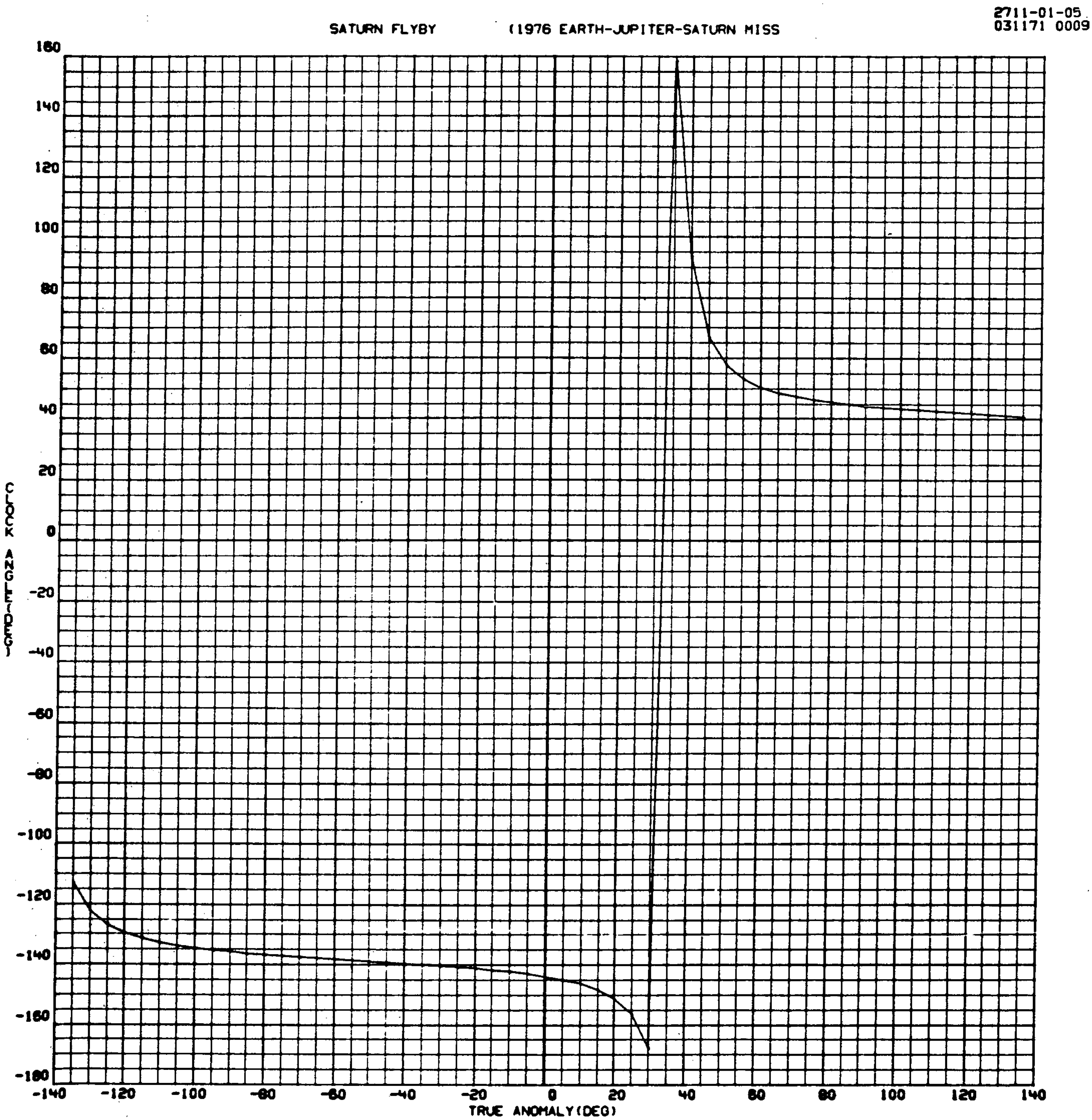


Figure 3-12. Clock Angle Versus True Anomaly

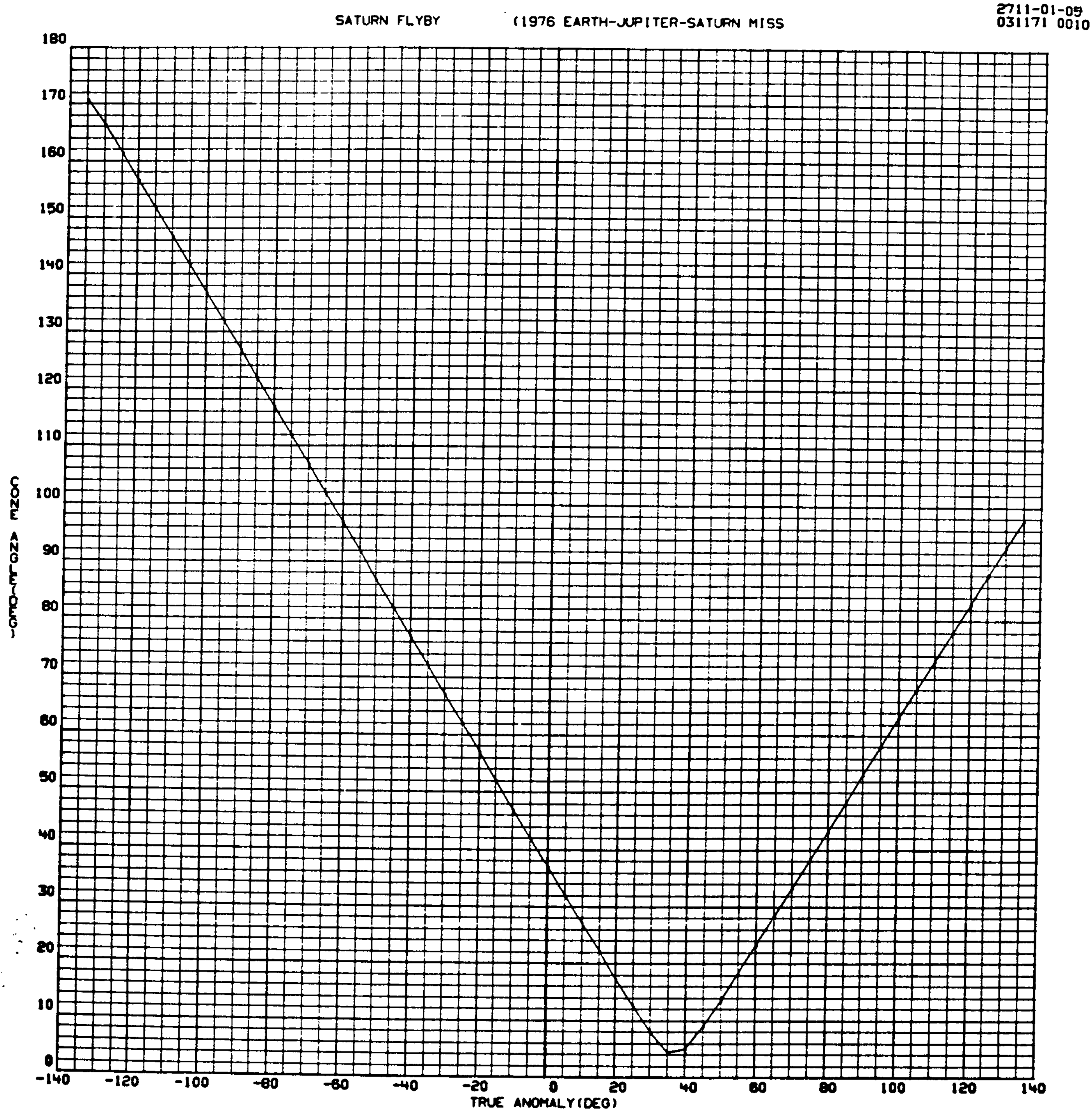


Figure 3-13. Cone Angle Versus True Anomaly

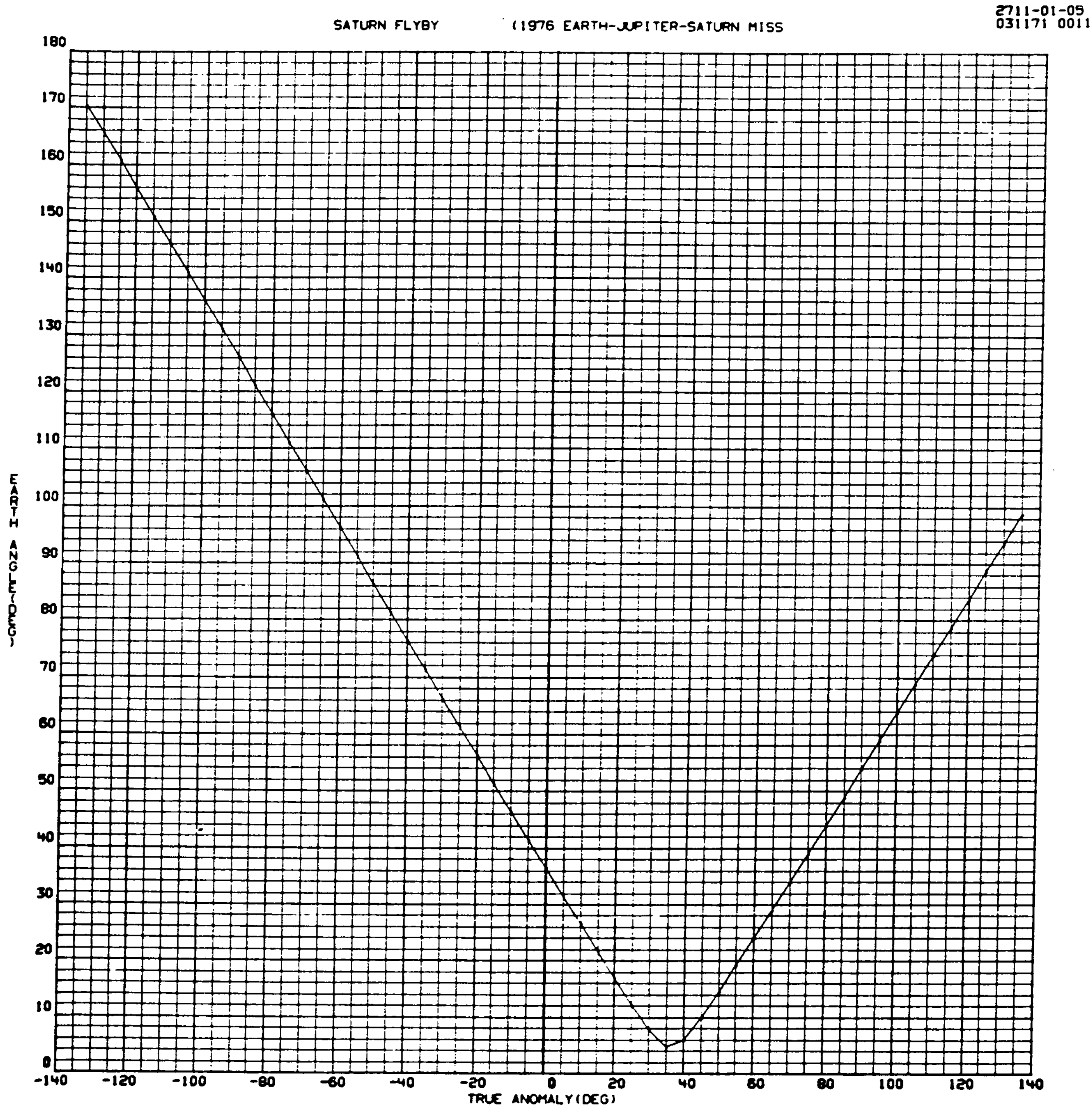


Figure 3-14. Earth Angle Versus True Anomaly

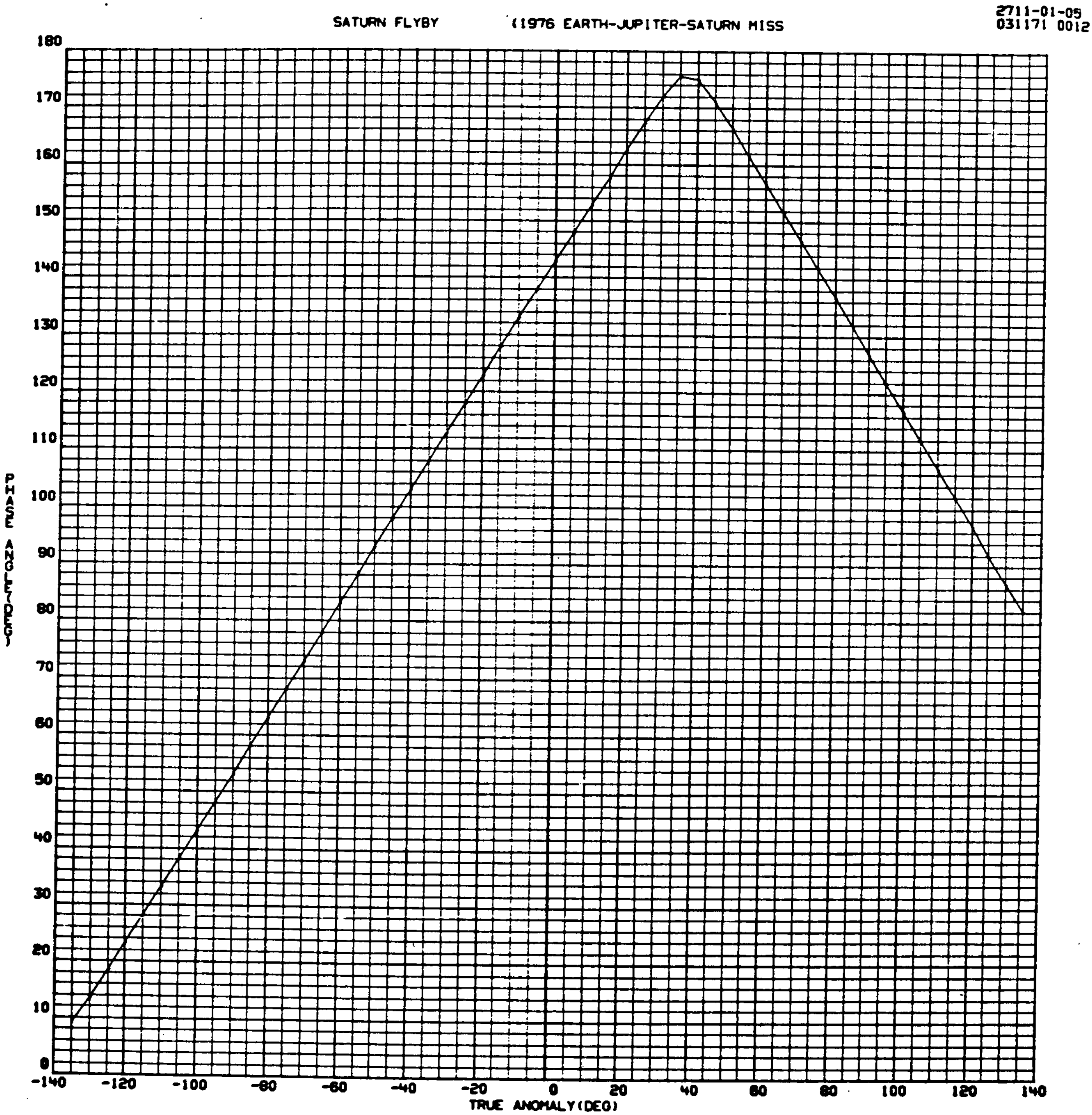


Figure 3-15. Phase Angle Versus True Anomaly

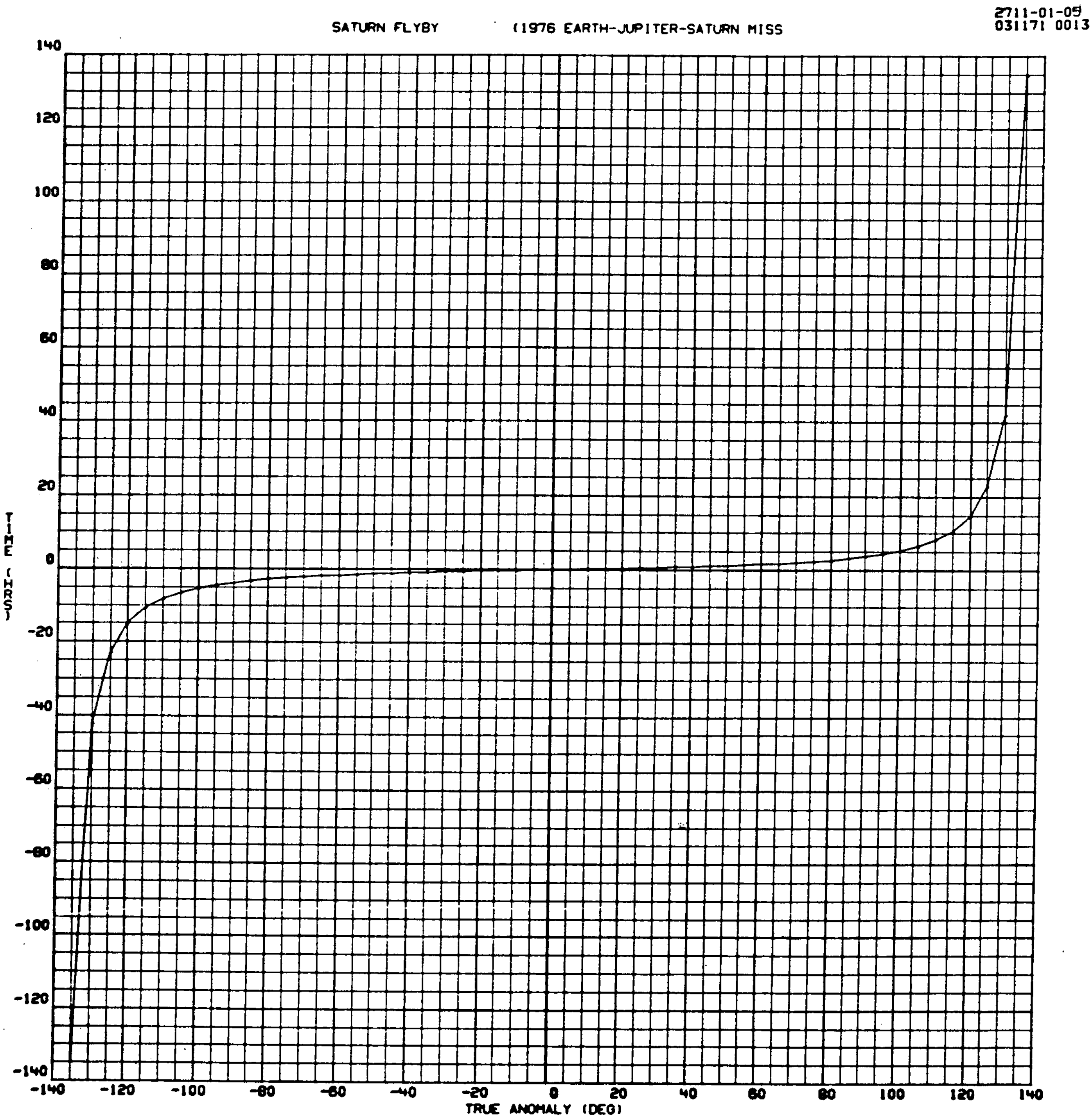


Figure 3-16. Time Versus True Anomaly

Table 3-4. Distribution of Orbits Selected for Imaging Sensor Definition

Planet	Orbit Number											Total
	1	2	3	4	5	6	7	8	9	10	11	
Mercury	66	0	0	0	0	0	0	0	0	8	-	74
Venus	58	0	0	0	0	0	0	0	9	3	-	70
Mars	48	0	0	0	0	11	3	27	0	21	-	110
Jupiter	5	0	0	0	0	0	4	0	5	4	9	27

Table 3-5. Orbits Selected for Nonimaging Experiments at Inner Planets and Jupiter

Planet	Orbit	Periapsis Altitude (km)	Apoapsis Altitude (km)	Inclination (deg)
Mercury	1	500	500	90
Mercury	10	500	53,400	90
Venus	1	454	454	90
Venus	9	255	50,400	90
Mars	1	1016	1,016	90
Mars	8	383	12,525	124
Jupiter	1	1.78×10^5	4.81×10^5	90
Jupiter	9	1.78×10^5	13.47×10^5	90
Jupiter	11	3.57×10^5	6.65×10^5	90

The orbits are assumed initially to have periapsis latitude zero, and periapsis longitude (also longitude of ascending mode) zero with respect to the subsolar meridian. At Jupiter, the insertion ΔV required for zero periapsis longitude is prohibitive, and a longitude of 90 degrees is assumed. The orbits are not large simple fractions (1/3, 1/2, etc.) or small multiples (2. 3, etc.) of the planetary rotation periods, so a few orbits will suffice for viewing all longitudes at favorable altitudes and sun angles. Precession of the apsides and regression of the nodes are ignored.

3.3 PLANETARY SURFACE AREA COVERAGE

3.3.1 Flyby Missions

A combination of several sensors, different coverage modes (i.e., optimal and marginal), numerous missions, and several target planets results in the requirement to analyze and determine planetary surface area coverage for 66 separate planetary flybys. Since the computational procedure for all these flybys are similar, only a representative sensor and planet flyby will be considered in detail, and a summary of results will be presented for the remaining 65 planet encounters.

The visible/UV spectrometer was selected for the example, with optimal area coverage on the Saturn encounter associated with the 1976 Earth-Jupiter-Saturn flyby mission.

3.3.1.1 Flyby Trajectory Selection

Saturn is the terminal planet in the mission sequence; consequently, there is a free choice of closest approach distance (periapsis) and flyby inclination (with respect to Saturn's equator). The choice of periapsis distance is constrained to avoid Saturn's rings, which are contained in the equatorial plane and extend out to an altitude of approximately 1.‿ planet radii.

The selection of flyby inclination requires, in general, a compromise between the conflicting demands of the various types of sensors. For all planetary encounters considered, the TV sensor influenced the selection of inclination the greatest; consequently, the inclination was selected to satisfy the TV requirements. The TV required that sufficient time be available to scan both north and south latitudes (avoidance of ring masking) prior to crossing the terminator from light to dark.

A graphical aid which greatly facilitates the selection of inclination is a planet stereographic projection. The stereographic projection has been known for centuries and was used by map makers in the Middle Ages. More recent analysis (Reference 4) commended its use to solve a wide variety of three-dimensional problems and delineated the detailed steps necessary for point-by-point construction. The primary advantage of this spherical projection is that all circles, great or minor, appear as circular arcs in the projection and the projection is isogonic, that is, inclination angles of planes relative to each other are preserved. A transparent coordinate overlay permits graphical solution of all spherical geometric problems.

Since for planetary imaging analyses the source of light is the Sun, a projection about the subsolar point allows the lighting angles to be displayed as concentric circles. Figure 3-17 illustrates the Saturn stereographic projection associated with the mission of interest. A 12.4-degree inclined orbit was selected to satisfy the requirement for both north and south latitude viewing on planet approach.

With the inclination fixed, trajectory data were then generated (see Section 3.2, Mission Trajectory Data) for a flyby with a periapsis altitude of 1.0 Saturn radii. The combination of selected values of periapsis altitude and flyby inclination results in a nodal (equatorial) altitude of 4.05 and 3.39 Saturn radii on approach and departure, respectively—well outside Saturn's rings.

3.3.1.2 Surface Area Computation

The first step in computing surface area required is to obtain a plot of the trajectory in terms of longitude and latitude (see Figure 3-18). Sensor on and off altitudes, as well as sensor field-of-view, were supplied by the sensor analyst (see Section 3.4.1.7). These altitudes were then equated to Saturn longitude by the available trajectory data. For the specific example, the following information resulted:

	Altitude (h, Saturn radii)	True Anomaly (degrees)	Time (hours)	Longitude (degrees)	Latitude (degrees)	Swath Width (degrees)
Sensor On	13.35	-120	14.95	46.4	5.6	118.815
Sensor Off	1.99	-65	-1.87	0.2	-5.8	17.711

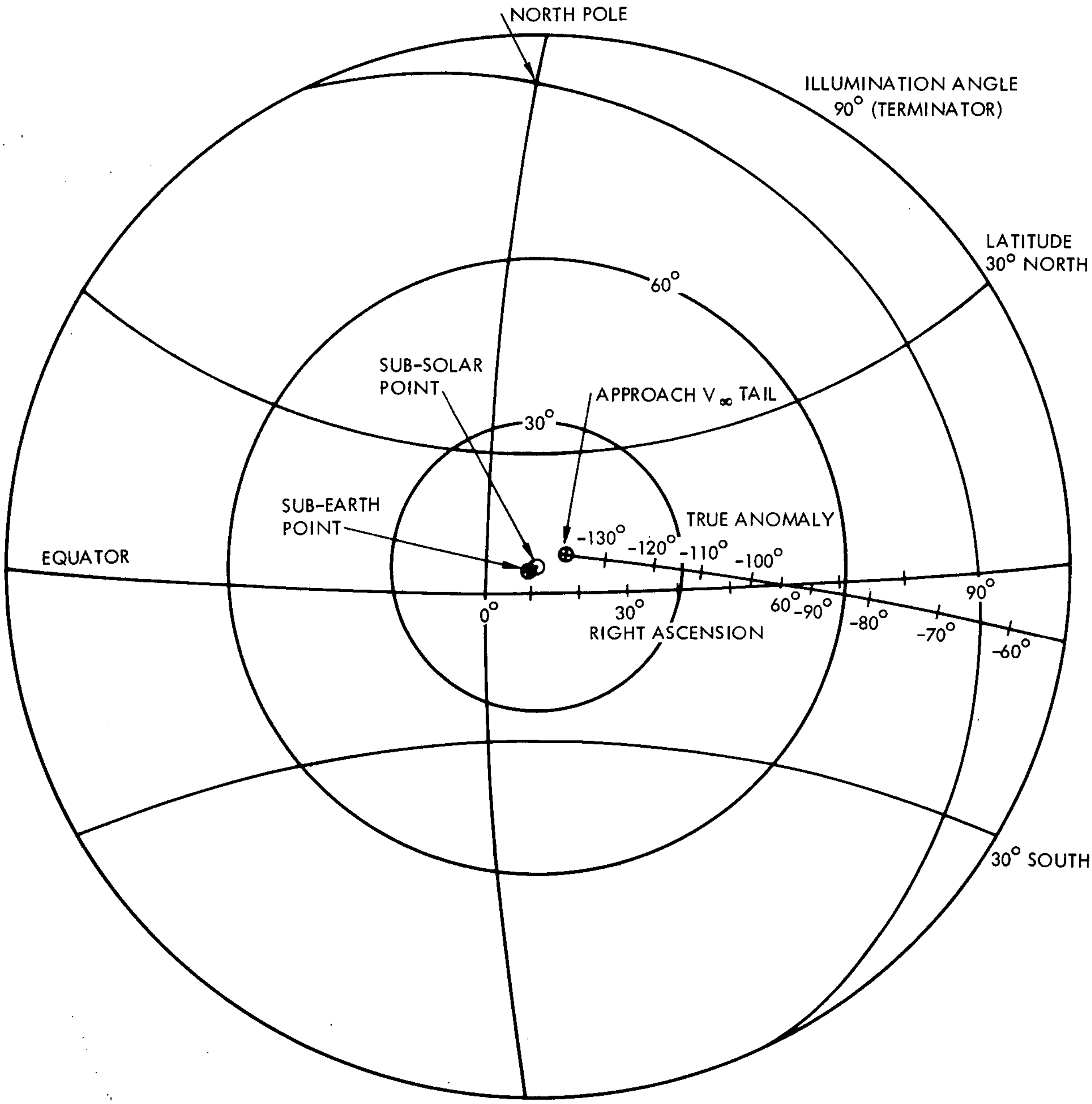


Figure 3-17. Saturn Stereographic Projection

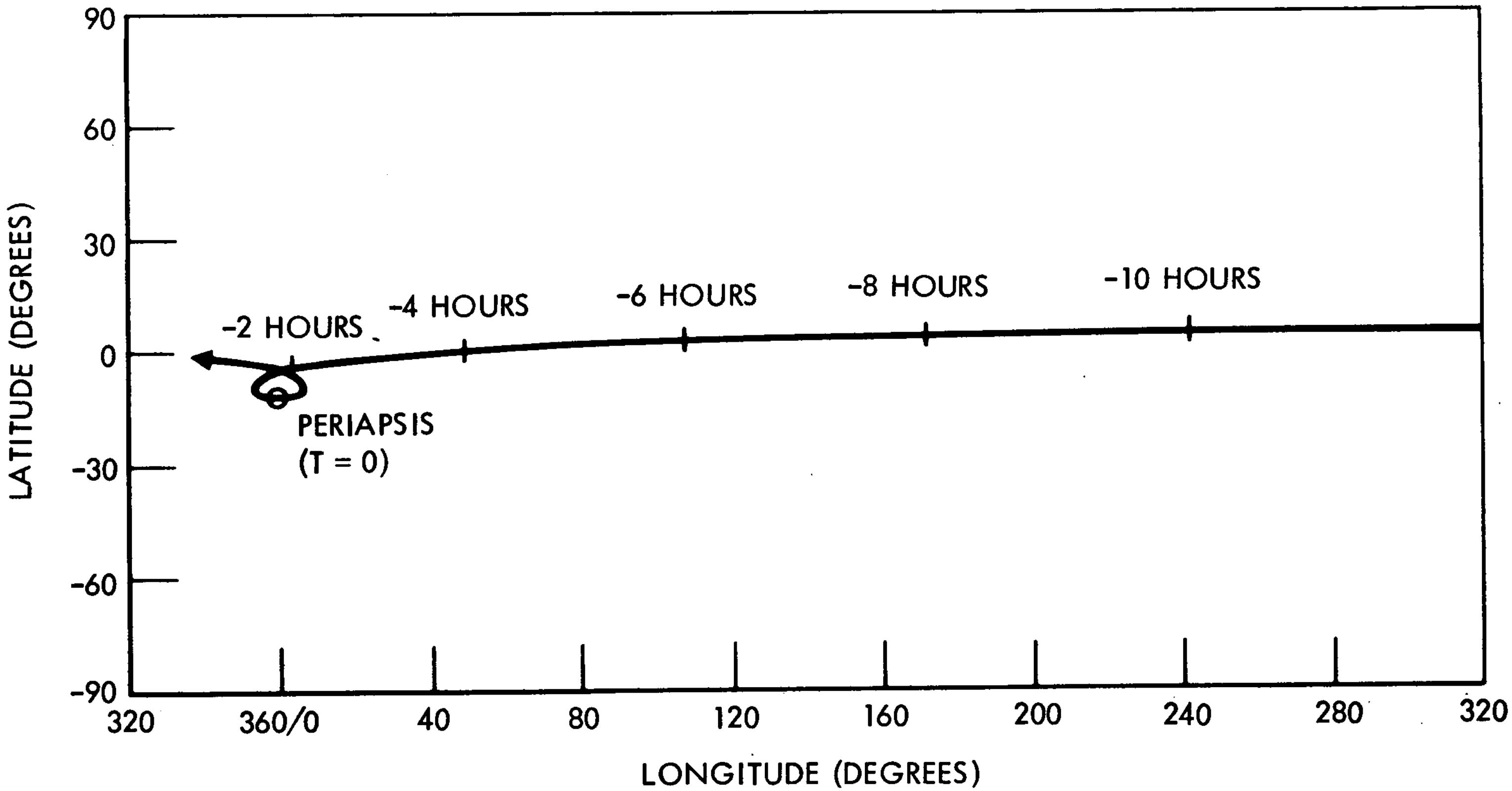


Figure 3-18. Saturn Flyby Trajectory Ground Trace

The swath width (S/W) represents a great-circle arc as determined by:

$$S/W = 2\gamma \frac{h}{r_{♄}}.$$

where $r_{♄}$ is Saturn radius, and 2γ is the aperture angle—in this example, 8.90 degrees.

Several intermediate altitudes between the sensor on and off altitudes were selected and their corresponding swath widths determined and superimposed on the longitude/latitude plot as shown in Figure 3-19. Note that the visible/UV spectrometer is used over the approach phase of the flyby only.

Simple spherical geometry was used to compute surface area coverage. The area of a zone as illustrated in Figure 3-20 is given by:

$$A\ (\text{zone}) = 2\pi\ R_{♄}^2 \sin\delta$$

where δ is zone latitude.

A latitude of 90 degrees yields the surface area of a hemisphere and twice this value is the surface area of a sphere, i.e.,

$$A\ (\text{sphere}) = 4\pi\ R_{♄}^2$$

When the area of only a portion of the zone is desired, the following relation is used:

$$A = 2\pi R_{♄} \sin\delta \left[\frac{\Delta\text{longitude (degrees)}}{360^\circ}\right]$$

Since there are no specific requirements to obtain surface area coverage better than about 5 percent, the actual sensor ground swath was approximated by zonal sections on the planet as illustrated in Figure 3-21 In this case, the ground swath was first approximated as a truncated pyramid (dashed line) and then the equivalent zonal area specified. The following expressions yield the desired surface areas:

$$A\ (\text{north}) = 2\pi\ r_{♄}^2 \left[\sin(31.573^\circ) \times \frac{319.8^\circ}{360^\circ} + \sin(62.549^\circ) \times \frac{84.6^\circ}{360^\circ}\right]$$

$$A\ (\text{south}) = 2\pi\ r_{♄}^2 \left[\sin(31.773^\circ) \times \frac{319.8^\circ}{360^\circ} + \sin(51.349^\circ) \times \frac{84.6^\circ}{360^\circ}\right]$$

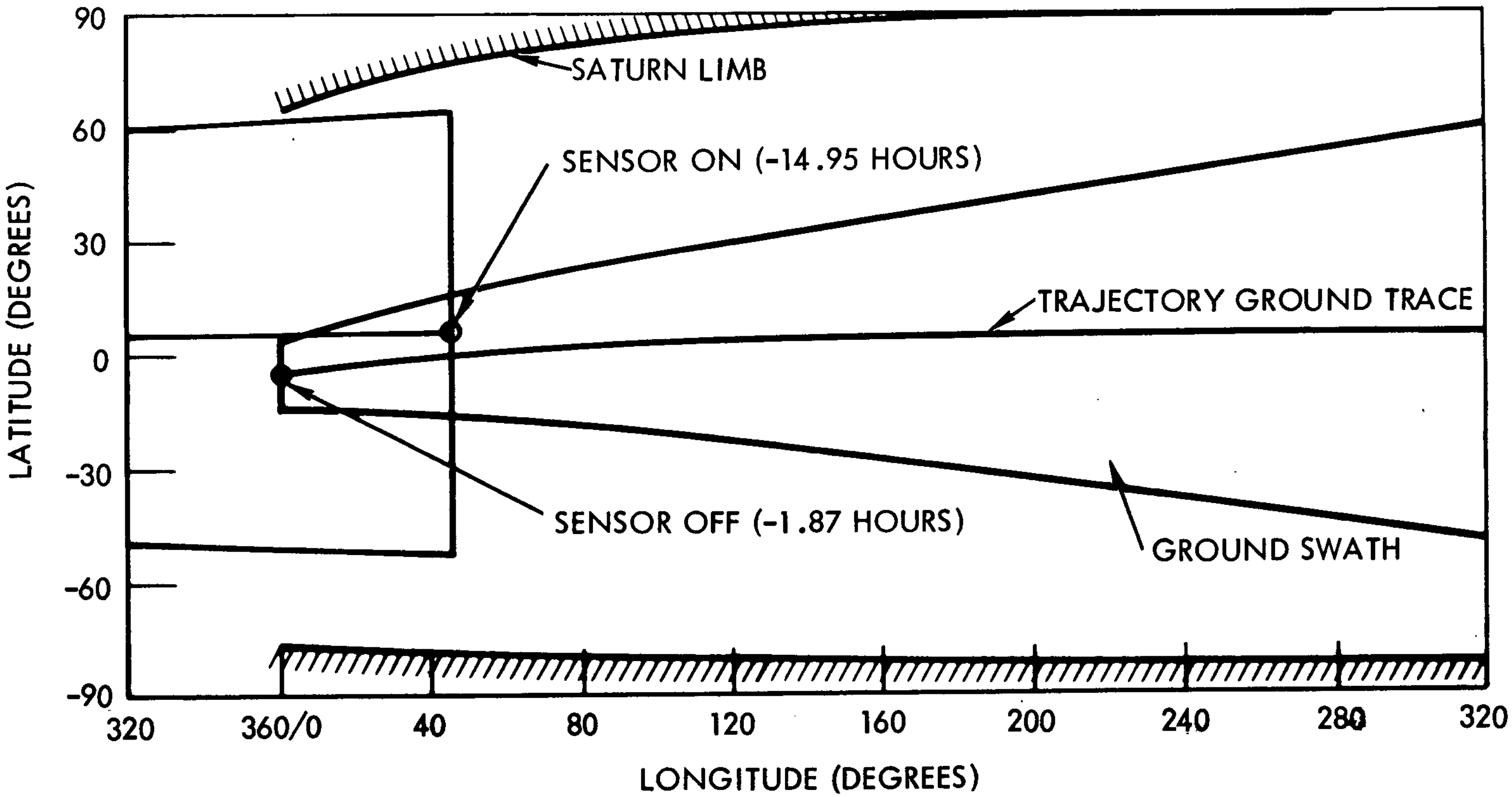
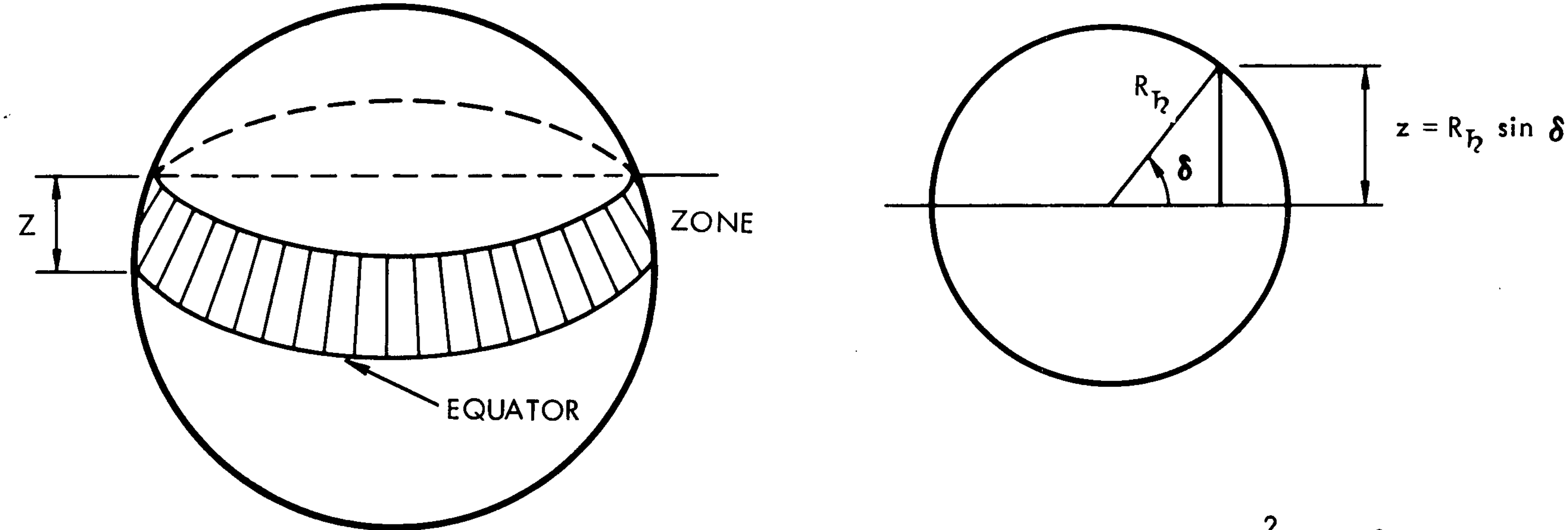


Figure 3-19. Saturn Flyby Trajectory Ground Swath



$$A\,(\text{ZONE}) = 2\,\pi\, R_{\hbar}\, z = 2\,\pi\, R_{\hbar}^2\, \sin\,\delta$$

Figure 3-20. Spherical Surface Area Computation

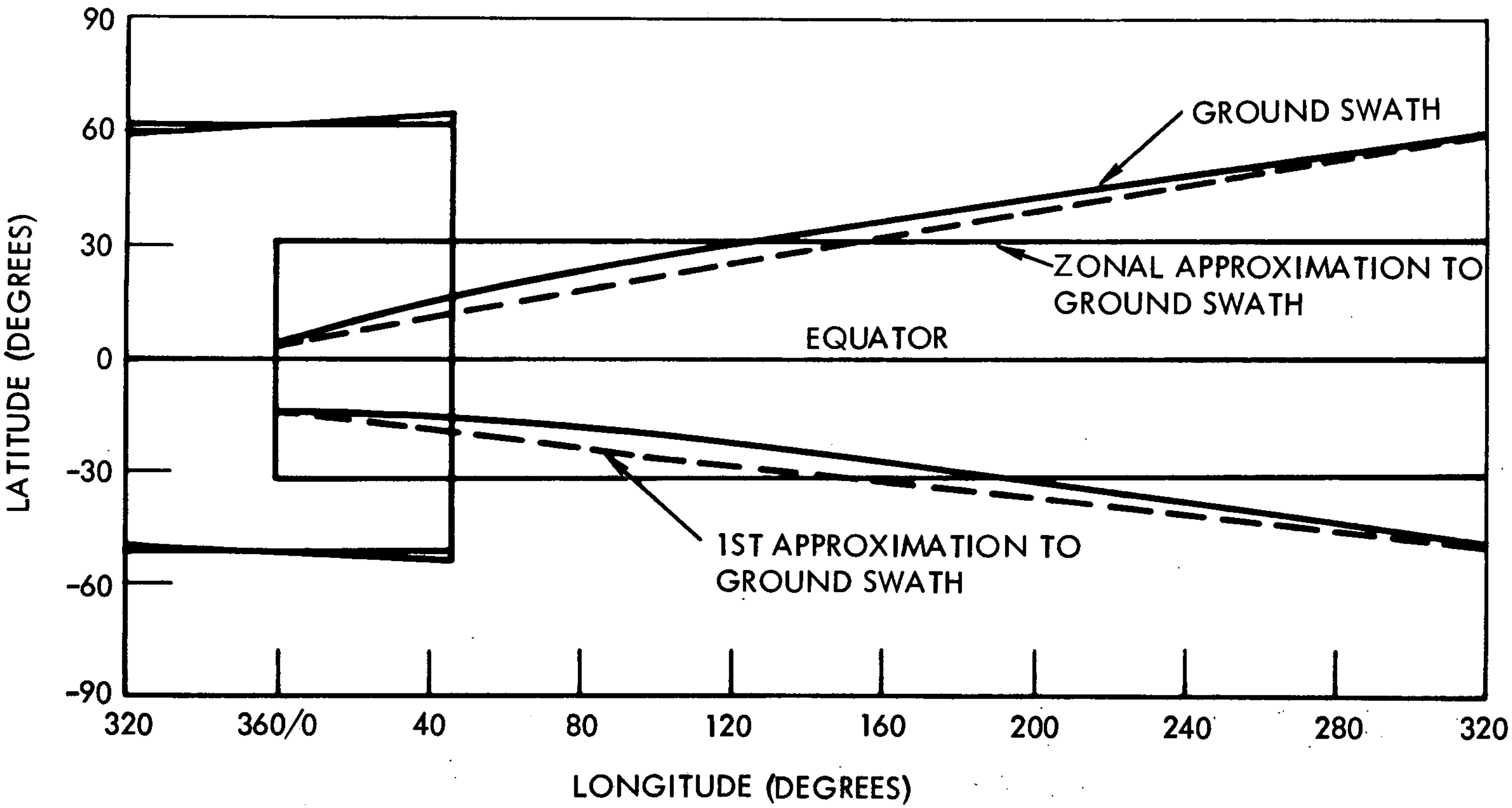


Figure 3-21. Visible/UV Spectrometer Optical Surface Coverage

Area coverage of the visible/UV spectrometer is 66.7 percent of the total surface area.

3.3.1.3 Summary of Flyby Results

Table 3-6 summarizes the planetary surface area coverage computations for the sensors and missions of interest.

3.3.2 Orbiter Missions

The computation of area coverage for the orbiter missions followed essentially the same procedure used for the flybys. In this case, trajectory data was supplied by a NR computer program (Reference 5), and the area coverage was computed automatically. This program is a second-generation interplanetary trajectory program written in Fortran II. It has the following capabilities: (1) phase-controlled choice of linked conic, Encke's or Cowell's methods using the Adams-Moulton six-order integration package; (2) up to 15 celestial bodies, 11 of which move according to JPL ephemeris tapes, while 4 use input-specified mean elements; (3) central body exchange at computed spheres of action; (4) oblateness effects up to 10th harmonic, thrust and drag forces; (5) multiple legs (phases) with selective stopping conditions and leg addressing; (6) simultaneous two-vehicle operations, each at its own optimal submultiple step size; (7) double-precision arithmetic (16 digits); (8) tracking station data, look angles to Earth, target body and Canopus, including cone and clock angles; (9) CRT 9 by 9-inch plots of any computed variables desired in any xy-axis combination; (10) a variety of input/output formats and reference systems (Earth equatorial true or mean of date or epoch, planetary equatorial, ecliptic, etc.).

At discrete time intervals (measured in minutes) swath widths (latitude distance) were determined and the surface area approximated as a truncated pyramid, where the longitude distance was obtained by multiplying ground speed by the time interval.

3.3.2.1 Summary of Orbiter Results

Table 3-7 summarizes the planetary surface area coverage computations for the sensors and missions of interest.

Table 3-6. Planetary Surface Area Coverage Summary

Sensor	Measuring Constraints	Coverage Mode	Sensor FOV (deg)	Mission	Planet	Altitude (Planet Radii) Sensor On	Altitude (Planet Radii) Sensor Off	Area Coverage (Percent of Planet)
Laser radar	Sampling performed from initiation altitude on approach to comparable altitude on departure.	N/A	0.1146	1984 M	Mercury	25.05	25.05	1.2
				1980 V	Venus	6.23	6.23	0.18
				1982 V-M	Venus	6.23	6.23	0.34
					Mercury	25.83	25.83	0.65
				1976 J-S	Jupiter	1.54	1.54	0.017
					Saturn	2.65	1.0	0.028
				1978 J-U-N	Jupiter	5.88	5.88	0.27
					Uranus	39.38	39.38	5.8
					Neptune	79.66	79.66	17.9
				1978 J-S-P	Saturn	8.11	8.11	0.42
Measuring Radiometer	Sensor used over the range from maximum altitude (sensor on) to minimum altitude (sensor off) on both approach and departure	Optimal	0.2292	1984 M	Mercury	10.0	10.0	0.48
			0.5730	1980 V	Venus	10.0	10.0	1.5
			0.2292	1982 V-M	Venus	41.0	2.69	0.31
					Mercury	10.0	10.0	0.50
			0.5730	1976 J-S	Jupiter	3.49	3.49	0.35
					Saturn	9.88	9.88	4.2
			0.4658	1978 J-U-N	Jupiter	6.86	6.86	1.5
					Uranus	16.17	16.17	4.2
					Neptune	7.58	7.58	0.59
			0.2292	1978 J-S-P	Jupiter	20.47	20.47	9.0
					Saturn	21.39	21.39	7.9
		Marginal	0.4584	1984 M	Mercury	5.13	5.13	0.48
			2.292	1980 V	Venus	28.69	28.69	22.3
			0.4584	1982 V-M	Venus	143.44	143.44	21.0
					Mercury	5.13	5.13	0.49
			0.6663	1976 J-S	Jupiter	8.36	8.36	3.2
					Saturn	9.88	9.88	4.9
			0.8186	1978 J-U-N	Jupiter	6.86	6.86	2.7
					Uranus	21.68	21.68	12.2
					Neptune	18.66	18.66	16.2
			0.4832	1978 J-S-P	Jupiter	11.70	11.70	5.8
			0.3114		Saturn	21.39	21.39	12.0
Mapping Radiometer	Sensors views up to 0.90 full angle subtended by planet. From maximum altitude to minimum altitude on both approach and departure.	Optimal	0.5730	1976 J-S	Saturn	6.19	6.19	56.6
				1978 J-U-N	Uranus	9.43	9.43	43.1
					Neptune	3.79	3.79	18.4
			0.2292	1978 J-S-P	Saturn	33.11	33.11	75.0
		Marginal	2.204	1976 J-S	Saturn	4.30	4.30	25.7
			10.81	1978 J-U-N	Uranus	2.25	2.25	6.5
					Neptune	2.37	2.37	17.1
			0.4476	1978 J-S-P	Saturn	21.19	21.19	75.0

Table 3-6. Planetary Surface Area Coverage Summary (Cont)

Sensor	Measuring Constraints	Coverage Mode	Sensor FOV (deg)	Mission	Planet	Altitude (Planet Radii) Sensor On	Sensor Off	Area Coverage (Percent of Planet)
Thermal Mapper	From maximum altitude to minimum altitude on both approach and departure.	Optimal	0.220	1976 J-S	Saturn	4.32	4.32	0.21
			0.1690	1978 J-U-N	Uranus	11.60	11.60	0.77
					Neptune	10.61	10.61	0.39
			0.00573	1978 J-S-P	Saturn	41.04	41.04	0.36
		Marginal	0.220	1976 J-S	Saturn	4.32	4.32	0.21
			0.2110	1978 J-U-N	Uranus	11.60	11.60	0.96
					Neptune	10.61	10.61	0.49
			0.0870	1978 J-S-P	Saturn	10.92	10.92	0.57
Visible/ UV Spectrometer	From maximum altitude to minimum altitude on approach only.	Optimal	8.90	1976 J-S	Jupiter	11.20	0.70	38.3
					Saturn	13.35	1.99	66.7
			14.0	1978 J-U-N	Jupiter	6.86	3.18	20.3
					Uranus	16.17	2.46	64.1
					Neptune	16.83	1.67	37.4
			8.60	1978 J-S-P	Jupiter	11.70	6.59	41.9
					Saturn	14.41	6.53	57.8
		Marginal	10.80	1976 J-S	Jupiter	14.90	(1)	36.8
					Saturn	17.70	(1)	50.0
			11.46	1978 J-U-N	Jupiter	14.10	(1)	37.3
					Uranus	24.0	(1)	50.0
					Neptune	24.0	(1)	25.2
			10.80	1976 J-S-P	Jupiter	14.9	(1)	36.8
					Saturn	17.6	(1)	50.0
Television Camera	Scan from limb-to-limb (north/ south). From maximum altitude to minimum altitude on approach only.	Optimal	0.21	1976 J-S	Saturn	7.68	1.99	24.0
			0.22	1978 J-U-N	Uranus	16.64	2.43	56.0
					Neptune	16.81	1.52	24.5
			0.22	1978 J-S-P	Saturn	30.61	6.62	99.2
		Marginal	0.21	1976 J-S	Saturn	1602	(1)	50.0
			0.21	1978 J-U-N	Uranus	403	(1)	50.0
					Neptune	403	(1)	50.0
			0.21	1978 J-S-P	Saturn	1602	(1)	50.0

(1) Single frame area coverage

Table 3-6. Planetary Surface Area Coverage Summary (Cont)

Sensor	Measuring Constraints	Coverage Mode	Sensor FOV (deg)	Mission	Planet	Altitude (Planet Radii) Sensor On	Altitude (Planet Radii) Sensor Off	Area Coverage (Percent of Planet)
IR Radiometer/ Spectrometer	Sampling performed from initiation altitude on approach to comparable altitude on departure.	Optimal	1.0	1984 M	Mercury	9.36	9.36	2.0
			6.21	1982 V-M	Venus	1.71	1.71	3.2
					Mercury	1.30	1.30	1.0
			35.0	1980 V	Venus	1.65	1.65	11.3
			18.2	1976 J-S	Jupiter	4.03	4.03	14.6
					Saturn	4.32	4.32	17.5
			9.49	1978 J-U-N	Jupiter	4.65	4.65	11.3
			2.93		Uranus	13.9	13.9	18.2
			1.21		Neptune	14.8	14.8	5.7
			2.33	1978 J-S-P	Jupiter	11.7	11.7	28.2
					Saturn	14.41	14.41	35.4
		Marginal	1.0	1984 M	Mercury	4.60	4.60	0.9
			22.9	1982 V-M	Venus	1.71	1.71	11.8
			11.4		Mercury	1.30	1.30	1.9
			34.3	1980 V	Venus	1.65	1.65	11.1
			17.2	1976 J-S	Jupiter	4.03	4.03	13.8
					Saturn	4.76	4.76	21.6
			9.84	1978 J-U-N	Jupiter	4.65	4.65	11.6
			2.07		Uranus	13.9	13.9	12.9
			1.55		Neptune	14.8	14.8	7.1
			2.38	1978 J-S-P	Jupiter	12.2	12.2	32.0
					Saturn	14.41	14.41	36.1

Table 3-7. Orbiter Missions Planetary Surface Area Coverage Summary

Sensor	Measuring Constraints	Coverage Mode	Sensor FOV (deg)	Mission	Altitude (km) Sensor On	Altitude (km) Sensor Off	Area Coverage (percent of planet/orbit)
Measuring Microwave Radiometer	Sensor is not scanned.	Optimal	0.229	1984 Mercury Orbit 1	Usage over full orbit		0.032
	Field-of-view centered at nadir.	Marginal	11.46		Usage over full orbit		1.15
	Altitude range for usage is from "sensor on" altitude to "sensor off" altitude on both ascending and descending legs of orbit.	Optimal	0.229	1984 Mercury Orbit 10	6.2×10^3	5.43×10^4	2.49
		Marginal	6.37		2.08×10^3	5.43×10^4	32.4
		Optimal	0.229	1977 Venus Orbit 1	Full orbit		0.0152
		Marginal	11.46		Full orbit		0.77
		Optimal	0.229	1977 Venus Orbit 9	9.3×10^3	5.18×10^4	0.95
		Marginal	7.74		2.29×10^3	5.18×10^4	33.9
		Optimal	0.229	1988 Mars Orbit 1	Full orbit		0.062
		Marginal	11.5		Full orbit		3.35
		Optimal	0.229	1988 Mars Orbit 8	2.31×10^3	1.26×10^4	0.526
		Marginal	4.55		8.27×10^2	1.26×10^4	10.8
		Optimal	0.229	1978 Jupiter Orbit 1	Full orbit		0.84
		Marginal	0.833		Full orbit		3.1
		Optimal	0.229	1978 Jupiter Orbit 9	1.78×10^5	1.02×10^6	0.875
		Marginal	0.298		Full orbit		1.91
		Optimal	0.229	1978 Jupiter Orbit 11	Full orbit		1.38
		Marginal	0.602		Full orbit		3.64
IR Radiometer Spectrometer	Sensor scanned if area coverage requirements not otherwise met in one orbit. If scanning used, center scan is centered at nadir.						
(F)		Optimal	5.38	1984 Mars Orbit 1	Sensor used over full orbit		1.0
(F)		Marginal	5.38				1.0
(F)		Optimal	0.088	1984 Mercury Orbit 1			1.0
(F)		Marginal	0.088				1.0
(F)		Optimal	6.12(S)	1977 Venus Orbit 1			0.41
(F)		Marginal	135.0				1.83
(F)		Optimal	2.29(S)				10.0
(F)		Marginal	6.64(S)				14.5
(F)		Optimal	39.6(S)	1988 Mars Orbit 1			10.6
(F)		Marginal	74.8				10.0
(F)		Optimal	4.56(S)	1988 Mars Orbit 8			10.8
(F)		Marginal	13.3				31.5
(M)		Optimal	1.15(S)	1978 Jupiter Orbit 1			2.06
(F)		Marginal	2.86(S)				10.7
(M)		Optimal	0.115(S)	1978 Jupiter Orbit 9			1.5
(F)		Marginal	1.64(S)				10.8
(M)		Optimal	0.776(S)	1978 Jupiter Orbit 11			4.72
(F)		Marginal	1.82(S)				10.9
		Optimal	14.8(S)	1978 Jupiter Orbit 1	4.08×10^5	2.42×10^5	15.4
Visible/UV Spectrometer	Sensor is scanned if area coverage requirements not otherwise met in one orbit. If scanning is used, center scan is centered at nadir. Altitude range for sensor usage is "sensor on" altitude to "sensor off" altitude. For 1978 J-S mission, roughly half of viewed surface is sunlit.	Marginal	11.5		4.08×10^5	2.42×10^5	12.3
		Optimal	5.8(S)	1978 Jupiter Orbit 9			11.1
		Marginal	8.6				16.3
		Optimal	11.4(S)	1978 Jupiter Orbit 11			15.8
		Marginal	13.5				18.9
Laser Radar	Sensor is not scanned. Field-of-view centered at nadir. Sensor can be used for all altitudes below altitude given.	Optimal	0.114	1984 Mercury Orbit 1	500		0.023
		Marginal			(Full orbit)		
		Optimal	0.015	1984 Mercury Orbit 10	1.37×10^4		9.2×10^{-3}
		Marginal					
		Optimal	0.0935	1977 Venus Orbit 1	454		6.3×10^{-3}
		Marginal			(Full orbit)		
		Optimal	0.0115	1977 Venus Orbit 9	3.72×10^3		9.5×10^{-4}
		Marginal					
		Optimal	0.0564	1977 Mars Orbit 1	1016		0.015
		Marginal			(Full orbit)		
		Optimal	0.0115	1977 Mars Orbit 8	1.25×10^4		0.027
		Marginal			(Full orbit)		

(F) Filter radiometer
(M) Michelson interferometer

3.4 SENSOR CAPABILITIES AND SUPPORT REQUIREMENTS

3.4.1 Visible/Ultraviolet Spectrometer Design Technique

3.4.1.1 Background

As with other sensor types considered within the scope of this study, visible/UV spectrometer design is attempted for each of the relevant planetary encounters presented in Section 3.2. The designs are accomplished with the attainment of the two basic levels of observation requirements (optimal and marginal) in mind (Reference 1). The sample case presented represents the optimal-level design of a non-imaging sensor for an outer-plan planet encounter. The visible/ultraviolet (UV) spectrometer and associated subsystem design criteria are presented in Section 4.2.6 of Reference 2.

3.4.1.2 Observation Requirements

The choice of a multi-planet mission encounter provides the initial constraint that the sensor be designed for usage at all relevant encounters. Thus, the observation requirements data sheets (ORDS) for both Jupiter and Saturn which deal with visible/UV spectroscopy must be considered for this sample case. The relevant ORDS and a summary of the specific observation requirements contained therein are provided in Table 3-8.

3.4.1.3 Sensor Design Constraints and Limitations

State-of-the-art (SOA) limitations and physical limitations often necessitate the deletion of certain ORDS, as cursory visual inspection reveals that the attainment of such ORDS requirements would cause these limitations to be violated. As can be noted in comparing the table of limitations (Table 3-9) with the requirements in Table 3-8, the lower limit wavelength coverage requirements for ORDS C-105 cannot be met and ORDS must be dropped from further consideration.

3.4.1.4 Optimal Sensor Design Requirements

Initially, sensor design is attempted with the intention of meeting the most stringent of each of the individual observation requirements taken from the collection of relevant ORDS. For the case at hand, it is desirable to design a sensor with the following capabilities:

wavelength coverage: $0.1\,\mu\,(\lambda_m') \lesssim \lambda \lesssim 1.0\,\mu\,(\lambda_M')$

spectral resolution: $\Delta\lambda' \leq 10^{-5}\,\mu$

Table 3-8. Summary of ORDS Requirements for Visible/UV Spectroscopy at Jupiter and Saturn*

ORDS (Ref. 1)	Objective/Observable	λ'_M (μ)	λ''_M (μ)	λ'_m (μ)	λ''_m (μ)	$\Delta\lambda'$ (μ)	$\Delta\lambda''$ (μ)	Λ'_N (deg)	Λ''_N (deg)	Λ'_S (deg)	Λ''_S (deg)	S' (%)	S'' (%)	$\Delta X'$ (m)	$\Delta X''$ (m)
C-65+	Trace substances in atmosphere and clouds/IR-visible-UV spectra	20.0	14.0	0.1	0.2	10^{-3}	10^{-2}	90	45	90	45	-	-	$5x10^{5}$	10^{7}
C-92	Atmospheric properties above poles/ optical photon spectrum from solar aurorae	1.0	0.1	0.1	1.0	10^{-3}	10^{-1}	90	60	90	60	-	-	-	-
C-96	Ionosphere total density profile/auroral and airglow emission spectra	1.0	0.7	0.12	0.4	10^{-4}	10^{-3}	90	80	90	80	-	-	10^{6}	10^{7}
C-97	Methane abundance/methane absorption spectra	0.8	0.7	0.5	0.6	10^{-4}	$2x10^{-3}$	90	0	90	0	100	0	10^{5}	10^{7}
C-98	H/D ratio/HD and H_2 absorption spectra	0.8	0.5	0.08	0.12	10^{-5}	10^{-4}	-	-	-	-	-	-	-	-
C-99	Same as C-98	0.8	0.5	0.09	0.12	10^{-5}	10^{-4}	-	-	-	-	-	-	10^{5}	10^{7}
C-104	Trace constituents of purines and pyromidines/UV absorption spectra	0.3	0.25	0.15	0.2	$2.5x10^{-3}$	$2x10^{-2}$	-	-	-	-	-	-	10^{6}	10^{8}
C-105	Physical properties for engineering model atmospheres/UV absorption and emission spectra	0.3	0.13	0.03	0.057	$5x10^{-6}$	10^{-4}	90	45	90	45	100	1	$5x10^{6}$	$2x10^{7}$

*All ORDS listed are applicable to both Jupiter and Saturn in this instance.
+Multi-band requirement: visible/UV band requirements are met in all instances if most stringent requirements from entire group of ORDS are met.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 3-9. Visible/UV Spectrometer Design Constraints and Limitations

Characteristic	SOA Limit[1]	Design Limit[2]
Collecting optics diameter	2.0 m	1.0 m
Number of mirror faces	10	10
Number of detectors	10	10
Photoconductor detector:		
1) waveband response range	0.01μ - 0.1μ	0.01μ - 0.1μ
2) lower limit response time	10^{-3} sec	10^{-3} sec [4]
3) peak detectivity	4.0×10^9 m-$Hz^{1/2}$/watt	4.0×10^9 m-$Hz^{1/2}$/watt
Photomultiplier detector:		
1) waveband response range	0.1 - 1.2μ	0.1 - 1.2μ [3]
2) lower limit response time	10^{-6} sec	10^{-6} sec
3) quantrum efficiency	0.25	0.20
Collecting optics aperture stop number lower limit	1.0	1.0
Grating diameter	0.2 m	0.2 m
Reciprocal grating spacing	$1.18 \times 10^6 m^{-1}$	$1.18 \times 10^6 m^{-1}$
Spectral order	5	2

(1) Reference to state-of-the-art limit at mission launch date
(2) Reference to limit used in analysis
(3) Multiple detectors required
(4) Response time is inadequate for missions considered due to excessive scan rate requirements.

In addition, it is desired that the sensor designed allow the attainment of the following measurement requirements:

(nadir) spatial resolution:	sensor angular resolution such that $\Delta X \leq 10^5$m at highest altitude for sensor usage
latitude coverage:	$0 \leq \lambda'_N \leq 90^o$; $0 \leq \lambda'_S \leq 90^o$
area coverage:	$S' = 100\%$

3.4.1.5 Trajectory Considerations

The basic objectives to be met deal with observation of spectra due to atmospheric scattering and absorption of sunlight and due to auroral emission. The useful portion of the trajectory to allow satisfaction of the latter objective is restricted to that where the polar regions are accessible to viewing, the former to that where a sunlit surface is accessible. As will be shown later, satisfaction of auroral emission objectives is regularly a direct fallout of using that portion of the trajectory segment where a sunlit surface is accessible.

3.4.1.6 Base Sensor Definition

Confinement of the range of sensor designs is provided through application of the following sensor and sensor subsystem limitation formulae (Section 4.2.6 of Reference 2):

(I) $$D_c = \frac{3 \times 10^{-12}\,(S/N)}{\Delta\phi} \left[\frac{\omega}{Q_e\,(C_p f)\,\Delta\phi}\right]^{1/2} \geq D_d \text{ and } D_c \leq D_c^*$$

(collecting optics diameter -m)

(II) $$D_d = 1.22\ \sqrt{2}\lambda_M'/\Delta\phi$$

(collecting optics diffraction-limited diameter -m)

(III) $\tau = \Delta\phi/2\omega \leq \tau_{pm}^*$ (detector response time requirement - sec)

(IV) $f\# = F/D_c \geq f_L^{\#}$ (aperture stop number)

(V) $D_g = (\lambda'_M/\Delta\lambda')/\Psi N_g \leq D_g^+$ (grating diameter -m)

(VI) $\omega = 2\pi \nu_h/(pmH\Delta\phi) \leq \omega^+ = 193/D_s$

(mirror rotation rate -rad/sec)

where:

$\Delta\phi$ - scanning beam angular size (radian)

(S/N) - signal-to-noise ratio

Q_e - quantum efficiency of photomultiplier detector cathode

C_p - available spectral radiance in the bandwidth of interest (watts/m)

f - photometric function (= cos i where i is either solar zenith angle or auroral source - planet - spacecraft angle)

F - optical focal length (= $\ell/\Delta\phi$ where ℓ is the linear detector dimension $= 10^{-3}$ m) (m)

Ψ - order of spectrum

N_g - reciprocal grating spacing (m^{-1})

v_h - apparent horizontal ground speed (m/sec)

p - number of detectors

m - number of mirror faces

H - altitude above planetary surface (m)

D_s - scanning mirror diameter (= 1.41 D_c) (m)

The upper limit usable trajectory segment can be determined in a rather straightforward fashion using Equation (I), where an upper limit value of D_c is used. Certain fixed parameter values, of course, must be assumed. Separate analysis indicates that the auroral spectral radiance at both planets is of the order of that for reflected sunlight in the bandwidth of interest; the solar values have been used. The following fixed parameter values have also been used:

Number of detectors = 2 (cesium telluride photomultiplier and silicon Schottky barrier photodiode)

Number of mirror faces = 1

Signal-to-noise ratio = 120

Typical detector quantum efficiency = 0.2

Spectral radiance at Jupiter in UV = 4.49×10^{-7} watt m^{-1}

Spectral radiance at Saturn in UV = 1.37×10^{-7} watt m^{-1}

Substituting for ω in equation (I), a more useful form results:

$$D_c = \left\{ 3 \times 10^{-12} (S/N) \left[\frac{2\pi}{pmq}\right]^{1/2} \right\} \frac{1}{(Cp)^{1/2}} \left[\frac{v_h}{fH}\right]^{1/2} \frac{1}{\Delta\phi^2}$$

or

$$D_c = \frac{\left\{1.43 \times 10^{-9}\right\}}{(C_p)^{1/2}} \frac{1}{\Delta\phi^2} \left[\frac{v_h}{fH}\right]^{1/2}$$

or

$$D_c = \frac{2.15 \times 10^{-6}}{\Delta\phi^2} \left[\frac{v_h}{fH}\right]^{1/2} \text{ at Jupiter}$$

$$D_c = \frac{3.86 \times 10^{-6}}{\Delta\phi^2} \left[\frac{v_h}{fH}\right]^{1/2} \text{ at Saturn}$$

Limiting the trajectory segment analyzed to that for which solar zenith angles are less than approximately 80 degrees, the following results are obtained:

Encounter	Minimum (H/v_h) (sec)	H (km)	v_h (km/sec)
1976 Jupiter	3.69×10^3	5.01×10^4	13.58
1976 Saturn	2.73×10^4	1.20×10^5	4.44

Encounter	Maximum $(v_h/fH)^{1/2}$ $(sec^{1/2})$	f	H (km)	v_h (km/sec)
1976 Jupiter	3.74×10^{-2}	0.194	Same	Same
1976 Saturn	1.34×10^{-2}	0.206	Same	Same

For an assumed collecting optics diameter of 1 meter, the following results then apply:

$$\Delta\phi \text{ (minimum)} = 2.81 \times 10^{-4} \text{ rd at Jupiter}$$

$$\Delta\phi \text{ (minimum)} = 1.39 \times 10^{-4} \text{ rd at Saturn}$$

or

$$\Delta\phi^* \text{ (minimum)} = 2.81 \times 10^{-4} \text{ rd for sensor usage at both encounters}$$

Checking the limits provided in equations (II)-(V), the following results are obtained:

$$\text{(II)} \quad D_d = 1.22 \sqrt{2}\ (1.0 \times 10^{-6} \text{m})/2.81 \times 10^{-4} = 6.1 \times 10^{-3} \text{m} < 1.0 \text{ m}$$

$$\text{(III)} \quad \tau = 2.81 \times 10^{-4} \text{ rd}/2(3.02 \text{ sec}^{-1}) = 4.66 \times 10^{-5} \text{ sec} > 10^{-6} \text{ sec}$$

where:

$$\omega_{max} = \left(\frac{2\pi}{pm\Delta\phi^*}\right)\left(\frac{H}{v_h}\right)^{-1}_{min} = \left(\frac{2\pi}{2 \cdot 2.81 \times 10^{-4}}\right)\left(\frac{1}{3.69 \times 10^{3}}\right) = 3.02 \text{ sec}^{-1}$$

$$\text{(IV)} \quad f^{\#} = \frac{F}{D_c} = \frac{\ell}{D_c \Delta\phi^*} = \frac{10^{-3}}{1.0\ (2.81 \times 10^{-4})} = 3.57 > 1$$

$$\text{(V)} \quad D_g = \frac{(1.0\mu/10^{-5}\mu)}{(2 \cdot 1.18 \times 10^{6} \text{ m}^{-1})} = 4.28 \times 10^{-3} \text{m} < 0.2 \text{ m}$$

where:

$$\Psi = 2 \text{ and } N_g = 1.18 \times 10^{6} \text{ m}^{-1}$$

$$\text{(VI)} \quad \omega^+ = 193/(1.41)(1.0) = 136 \frac{\text{rd}}{\text{sec}}$$

$$(= 7.82 \times 10^3 \text{ deg/sec}) > \omega_{max}$$

Thus, for a maximum-sized collecting optics system with optimal angular resolution characteristics, no design limitations have been exceeded. The final design is now restricted by the requirements that $\Delta\phi \geq \phi^*$ and $0.006\text{m} \leq D_c \leq 1.0\text{m}$ for other sensor characteristics fixed.

3.4.1.7 Trajectory Segment Definition/Sensor Capability Determination

Sensor scanning is necessary to attain latitude coverage requirements for the low-inclination trajectories involved. Because Jupiter latitudes are relatively more inaccessible than those at Saturn for this mission (lower inclination trajectory and larger planetary radius), the scanning requirements will be initially developed from analysis at Jupiter.

For approximately 2π longitude coverage at Jupiter, sensor usage should be initiated at an altitude (H_M) of the order of 8×10^5 km. For $\Delta\phi = \Delta\phi^*$, the optimal spatial resolution cannot be met at this altitude. Full planetary surface coverage cannot be met unless an extremely large scan angle is used (to allow full latitude coverage at minimum altitude) or if H_M is increased. Further tradeoff between spatial resolution and area coverage capability is not considered, and the above H_M used. It should be noted that the maximum-sized collecting optics system must be used or else spatial resolution must be further degraded.

The limb-viewing angle at H_M is of the order of 4.68 degrees. To avoid computer program complications associated with calculations performed for near-limb viewing, the total scan angle of 4.45 degrees, corresponding to a ground size viewed of 2.4 R_p (corresponding to a latitude coverage of about 68 degrees in either direction from the nadir), was used. It should be noted that in actual practice, the approximate 5 percent increase in ϕ required for limb viewing would result in relatively minimal additional subsystem support requirement penalties.

The sensor designed for the Jupiter encounter can now be analyzed at Saturn. If roughly the same initiation altitude is used (the nearest mission point available in the data book), the coarsest nadir resolution will be similar to that attained at Jupiter, and also the full planet disk can be viewed at H_M. The following results are obtained:

H_M - initiation altitude - 8.06×10^5 km

H_m - cut-off altitude - 1.20×10^5 km

$\Delta\phi$ = 2.93×10^{-4} rd = 0.0168 deg

ΔX - coarsest nadir resolution = $H\Delta\phi$ = 2.34×10^{5} m

ΔX^* - coarsest resolution at far edge of swath = 5.64×10^{5} m

where:

$$\Delta X^* = \Delta X\,(r\phi/r_o);\; r\phi/r_o = \frac{Rp}{H_M}\left\{\frac{\cos\phi'}{\left[\left(\frac{Rp}{Rp+H}\right)^2 - \sin^2\phi'\right]^{1/2}} - 1\right\}$$

Rp - planetary radius in units of H_M

ϕ^* - scan half-angle corresponding to 0.9 of limb-viewing half-angle

Maximum latitude coverage in both northern and southern hemispheres is attained at H_M for this encounter. The values represented by the computer output were obtained by using the spacecraft latitude at H_M together with the latitude coverage band which corresponds to a fixed ground size viewed. For this and most other encounters analyzed, viewing at least to within a few degrees of either pole is accomplished.

Latitude coverage and spatial resolution capability associated with the sensor designed is well within both the solar reflected and auroral observation requirements of Table 3-8. The optimal level wavelength coverage and spectral resolution requirements can be met or exceeded for nearly all ORDS. Thus, the sensor designed for observation of reflected solar emissions can also be used satisfactorily for the study of auroral spectra. The area coverage capability associated with the sensor designed (in satisfaction of the requirements for ORDS dealing with reflected solar spectra) is determined separately and is discussed in Section 3.3.1.2.

3.4.2 SERA Computer Program Data Output

The ORDS data, sensor design, and sensor support subsystem parameters, as well as related information concerning the 1976 Saturn visible/UV spectrometer, have been used in the SERA (Space Experiments Requirements Analysis) computer program. The resultant SERA program output is provided in Table 3-10. The output is effectively divided into three SERA sections as follows:

SERA 1 - Observation Requirements Output - pp 1-15 (computer program page)

SERA 2 - Measurement Requirements Output
A. Measurement Requirements by Technique for All Objectives - pp 16-19
B. Measurement Requirements by Technique and Objective - pp 20-31

SERA 3 - Sensor Capabilities and Support Requirements - pp 32-36

The observation requirements information presented in SERA 1 are effectively a duplicate of that presented in Table 3-8, while that of SERA 2 represents the conversion of observation requirements to measurement requirements as discussed in Section I of this sample case. The SERA 3 output is further subdivided according to heading as follows:

"Mission Description" - definition of usable trajectory segment per Section 3.4.1.7

"Information Requirements Supported" - summary of SERA 2 measurement requirements data

"Sensor Capabilities" - definition of actual sensor measurement capabilities per Section 3.4.1.7, including the total sensor worth at each mission point (exclusive of "Supplementary Capability" worth)

"Supplementary Capability Data" - definition of sensor measurement capabilities where analysis of data over the entire trajectory segment is required (see Section 3.4.1.7), including the individual worth of each capability for the entire encounter (the coarsest resolution value is presented for its informative value only)

"Fixed Experiment Parameters" - fixed design parameters per Section 3.4.1.6 and design constraints per Table 3-9

"Support Requirements Evaluation" - a summary of selected scaling law coefficients used and resulting sensor support subsystem requirements (per visible/UV spectrometer subroutine summary presented in the appendix of Reference 2)

A more complete list of sensor and sensor subsystem design parameters and constraints is provided in the form of a data array which follows the above output for each encounter. The "DP" data array location definitions are provided with each sensor subroutine description contained in Appendix B of this report.

3.4.3 Sensor Support Requirements Summary

A summary of sensor measurement capabilities and subsystem support requirements for the optimal level 1976 Saturn visible/UV spectrometer is presented in Table 3-11. The capability parameters listed are noted in underline in Table 3-10 under the headings "Sensor Capabilities" and "Supplementary Capability Data" in the SERA 3 output. Support requirements listed are noted in underline below the "Support Requirements" heading. Generally, the extrema ("maximum" for optimal level, "minimum" for marginal level) of all requirements are not incurred at a single mission point, but rather at various points along the trajectory segment. Often, however, the maximum values of some support requirements correspond to the first point on the segment at which the sensor is operated, and the maximum values of the other requirements correspond either to the lowest point or the last point.

Table 3-10. SERA Computer Program Data Output

VISIBLE/UV SPECTROMETER. JUPITER-SATURN FLYBY, LAUNCH 7/30/76.

Table 3-10. SERA Computer Program Data Output (Cont)


```
*** PLANETARY OBSERVATION OBJECTIVES AND REQUIREMENTS ***

OBSERVATION OBJECTIVE   12.  ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.


                 GOAL   2 UNDERSTAND ORIGIN AND EVOLUTION OF LIFE.


KNOWLEDGE REQUIREMENT   4 WHAT ARE THE PHYSICAL AND CHEMICAL PROPERTIES OF PLANETARY ATMOSPH.
                          VS. ALTITUDE, ON GLOBAL AND LOCAL BASES. WHAT IS THE ROLE OF TRACE SUB-
                          STANCES IN DETERMINING ATMOSPHERIC PROPERTIES AND VEHICLE PERFORMANCE.

OBJECTIVE WORTH = 0.50
```

Table 3-10. SERA Computer Program Data Output (Cont)


```
OBSERVABLE PROPERTY  20.  VISIBLE/ULTRAVIOLET SPECTRUM.

OBSERVATION TECHNIQUE 15.   ULTRAVIOLET SPECTROMETRY
 PLANETARY BODY  6.    SATURN(INCL. RINGS)
 OBSERVATION WORTH.  GROSS WORTH = 0.25, NET WORTH = 0.13
  OBSERVATION PARAMETER  1.    LONGEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  1.000E 00.   WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.06
   MINIMUM MEASUREMENT CAPABILITY =  1.000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  2.    SHORTEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  1.000E-01.   WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.06
   MINIMUM MEASUREMENT CAPABILITY =  1.000E 00.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  3.    SPECTRAL RESOLUTION, AT WAVELENGTH REQUIRING HIGHEST RESOLUTION(MICRON)
   DESIRED MEASUREMENT CAPABILITY =  1.000E-03.   WORTH AT D.M.C.   GROSS WORTH = 0.80, NET WORTH = 0.10
   MINIMUM MEASUREMENT CAPABILITY =  1.000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  6.    NORTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  9.000E 01.   WORTH AT D.M.C.   GROSS WORTH = 0.80, NET WORTH = 0.10
   MINIMUM MEASUREMENT CAPABILITY =  6.000E 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  7.    SOUTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY = -6.000E 01.   WORTH AT D.M.C.   GROSS WORTH = 0.80, NET WORTH = 0.10
   MINIMUM MEASUREMENT CAPABILITY = -9.000E 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER 11.    MAXIMUM ALTITUDE OF OBSERVED PHENOMENON ABOVE VISIBLE 'SURFACE' (METER)
   DESIRED MEASUREMENT CAPABILITY =  1.000E 07.   WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.06
   MINIMUM MEASUREMENT CAPABILITY =  1.000E 06.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER 12.    MINIMUM ALTITUDE OF OBSERVED PHENOMENON ABOVE VISIBLE 'SURFACE' (METER)
   DESIRED MEASUREMENT CAPABILITY =  1.000E 05.   WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.06
   MINIMUM MEASUREMENT CAPABILITY =  1.000E 06.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER 13.    NUMBER OF SAMPLES OR MEASUREMENTS
   DESIRED MEASUREMENT CAPABILITY =  1.000E 02.   WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.03
   MINIMUM MEASUREMENT CAPABILITY =  1.000E 00.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
```

Table 3-10. SERA Computer Program Data Output (Cont)

```
                                                                                          PAGE    3
OBSERVATION PARAMETER 14.   TIME ELAPSED DURING ACQUISITION OF ONE SAMPLE (SEC)
 DESIRED MEASUREMENT CAPABILITY =  1.000E 00.  WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.03
 MINIMUM MEASUREMENT CAPABILITY =  1.000E 04.
 FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
OBSERVATION PARAMETER 15.   INTERVAL BETW. COMMENCEMENT OF TWO SUCCESSIVE SAMPLE ACQUIS. PDS. (SEC)
 DESIRED MEASUREMENT CAPABILITY =  1.000E 00.  WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.03
 MINIMUM MEASUREMENT CAPABILITY =  1.000E 04.
 FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
```

Table 3-10. SERA Computer Program Data Output (Cont)

*** PLANETARY OBSERVATION OBJECTIVES AND REQUIREMENTS ***

OBSERVATION OBJECTIVE 18. NON-THERMAL ELECTROMAGNETIC EMISSION CHARACTERISTICS AND SOURCE LOCATION.

GOAL 2 UNDERSTAND ORIGIN AND EVOLUTION OF LIFE.

KNOWLEDGE REQUIREMENT 4 WHAT ARE THE PHYSICAL AND CHEMICAL PROPERTIES OF PLANETARY ATMOSPH. VS. ALTITUDE, ON GLOBAL AND LOCAL BASES. WHAT IS THE ROLE OF TRACE SUBSTANCES IN DETERMINING ATMOSPHERIC PROPERTIES AND VEHICLE PERFORMANCE.

OBJECTIVE WORTH = 0.55

Table 3-10. SERA Computer Program Data Output (Cont)


```
OBSERVABLE PROPERTY  20.  VISIBLE/ULTRAVIOLET SPECTRUM.

OBSERVATION TECHNIQUE 57.   AURORAL AND AIRGLOW (EMISSION) SPECTRA
 PLANETARY BODY  6.   SATURN(INCL. RINGS)
 OBSERVATION WORTH.  GROSS WORTH = 0.40, NET WORTH = 0.22
  OBSERVATION PARAMETER  1.   LONGEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  1.000E 00.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.11
   MINIMUM MEASUREMENT CAPABILITY =  7.000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  2.   SHORTEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  1.200E-01.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.13
   MINIMUM MEASUREMENT CAPABILITY =  4.000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  3.   SPECTRAL RESOLUTION, AT WAVELENGTH REQUIRING HIGHEST RESOLUTION(MICRON)
   DESIRED MEASUREMENT CAPABILITY =  1.000E-04.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.13
   MINIMUM MEASUREMENT CAPABILITY =  1.000E-03.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 14,  TRUNCATED EXPONENTIAL, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  4.   SPATIAL RESOLUTION AT REGION OBSERVED (METERS)
   DESIRED MEASUREMENT CAPABILITY =  1.000E 06.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.11
   MINIMUM MEASUREMENT CAPABILITY =  1.000E 07.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  6.   NORTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  9.000E 01.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.13
   MINIMUM MEASUREMENT CAPABILITY =  8.000E 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  4,  TRUNCATED EXPONENTIAL
  OBSERVATION PARAMETER  7.   SOUTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  9.000E 01.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.13
   MINIMUM MEASUREMENT CAPABILITY =  8.000E 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  4,  TRUNCATED EXPONENTIAL
  OBSERVATION PARAMETER  8.   MAXIMUM SUN ELEVATION ANGLE ABOVE HORIZON AT REGION OBSERVED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  0.0        .  WORTH AT D.M.C.   GROSS WORTH = 0.90, NET WORTH = 0.19
   MINIMUM MEASUREMENT CAPABILITY =  0.0        .
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  5,  STEP FUNCTION (R)
  OBSERVATION PARAMETER  9.   MINIMUM SUN ELEVATION ANGLE ABOVE HORIZON AT REGION OBSERVED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY = -9.000E 01.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.11
   MINIMUM MEASUREMENT CAPABILITY = -3.000E 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  2,  SINUSOID
```

Table 3-10. SERA Computer Program Data Output (Cont)

```
                                                                                                  PAGE   6
OBSERVATION PARAMETER 10.   VERTICAL (ALTITUDE) RESOLUTION (METERS)
 DESIRED MEASUREMENT CAPABILITY =  1.000E 04.  WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.06
 MINIMUM MEASUREMENT CAPABILITY =  1.000E 05.
 FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 14,  TRUNCATED EXPONENTIAL, LOG10(ARGUMENT)
OBSERVATION PARAMETER 11.   MAXIMUM ALTITUDE OF OBSERVED PHENOMENON ABOVE VISIBLE 'SURFACE' (METER)
 DESIRED MEASUREMENT CAPABILITY =  1.000E 07.  WORTH AT D.M.C.   GROSS WORTH = 0.70, NET WORTH = 0.15
 MINIMUM MEASUREMENT CAPABILITY =  1.000E 06.
 FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 14,  TRUNCATED EXPONENTIAL, LOG10(ARGUMENT)
OBSERVATION PARAMETER 12.   MINIMUM ALTITUDE OF OBSERVED PHENOMENON ABOVE VISIBLE 'SURFACE' (METER)
 DESIRED MEASUREMENT CAPABILITY =  1.000E 04.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.11
 MINIMUM MEASUREMENT CAPABILITY =  1.000E 05.
 FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
OBSERVATION PARAMETER 38.   LATITUDE INTERVAL (DEGREES)
 DESIRED MEASUREMENT CAPABILITY =  1.000E 01.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.11
 MINIMUM MEASUREMENT CAPABILITY =  2.000E 01.
 FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
```

Table 3-10. SERA Computer Program Data Output (Cont)

*** PLANETARY OBSERVATION OBJECTIVES AND REQUIREMENTS ***

OBSERVATION OBJECTIVE 12. ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.

GOAL 2 UNDERSTAND ORIGIN AND EVOLUTION OF LIFE.

KNOWLEDGE REQUIREMENT 4 WHAT ARE THE PHYSICAL AND CHEMICAL PROPERTIES OF PLANETARY ATMOSPH. VS. ALTITUDE, ON GLOBAL AND LOCAL BASES. WHAT IS THE ROLE OF TRACE SUBSTANCES IN DETERMINING ATMOSPHERIC PROPERTIES AND VEHICLE PERFORMANCE.

OBJECTIVE WORTH = 0.70

Table 3-10. SERA Computer Program Data Output (Cont)


```
OBSERVABLE PROPERTY  20.  VISIBLE/ULTRAVIOLET SPECTRUM.

OBSERVATION TECHNIQUE 14.   VISIBLE SPECTROMETRY
 PLANETARY BODY  6.   SATURN(INCL. RINGS)
 OBSERVATION WORTH.  GROSS WORTH = 0.70, NET WORTH = 0.49
  OBSERVATION PARAMETER  1.   LONGEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  8.0000E-01.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.29
   MINIMUM MEASUREMENT CAPABILITY =  7.0000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  2.   SHORTEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  5.0000E-01.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.29
   MINIMUM MEASUREMENT CAPABILITY =  6.0000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  3.   SPECTRAL RESOLUTION, AT WAVELENGTH REQUIRING HIGHEST RESOLUTION(MICRON)
   DESIRED MEASUREMENT CAPABILITY =  1.0000E-04.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.29
   MINIMUM MEASUREMENT CAPABILITY =  2.0000E-03.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  4.   SPATIAL RESOLUTION AT REGION OBSERVED (METERS)
   DESIRED MEASUREMENT CAPABILITY =  1.0000 05.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.24
   MINIMUM MEASUREMENT CAPABILITY =  1.0000 07.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  5.   FRACTION OF SURFACE AREA OF PLANET COVERED (PERCENT)
   DESIRED MEASUREMENT CAPABILITY =  1.0000 02.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.24
   MINIMUM MEASUREMENT CAPABILITY =  1.0000 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  6.   NORTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  9.0000 01.  WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.14
   MINIMUM MEASUREMENT CAPABILITY =  0.0        .
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  2,  SINUSOID
  OBSERVATION PARAMETER  7.   SOUTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  9.0000 01.  WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.14
   MINIMUM MEASUREMENT CAPABILITY =  0.0        .
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  2,  SINUSOID
  OBSERVATION PARAMETER  9.   MINIMUM SUN ELEVATION ANGLE ABOVE HORIZON AT REGION OBSERVED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  0.0        .  WORTH AT D.M.C.   GROSS WORTH = 0.10, NET WORTH = 0.04
   MINIMUM MEASUREMENT CAPABILITY =  3.0000 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
```

Table 3-10. SERA Computer Program Data Output (Cont)


```
*** PLANETARY OBSERVATION OBJECTIVES AND REQUIREMENTS ***

OBSERVATION OBJECTIVE  12.  ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.


                GOAL   2 UNDERSTAND ORIGIN AND EVOLUTION OF LIFE.


KNOWLEDGE REQUIREMENT    4 WHAT ARE THE PHYSICAL AND CHEMICAL PROPERTIES OF PLANETARY ATMOSPH.
                           VS. ALTITUDE, ON GLOBAL AND LOCAL BASES. WHAT IS THE ROLE OF TRACE SUB-
                           STANCES IN DETERMINING ATMOSPHERIC PROPERTIES AND VEHICLE PERFORMANCE.

OBJECTIVE WORTH = 0.30
```

Table 3-10. SERA Computer Program Data Output (Cont)


```
OBSERVABLE PROPERTY  20.  VISIBLE/ULTRAVIOLET SPECTRUM.

OBSERVATION TECHNIQUE 14.   VISIBLE SPECTROMETRY
 PLANETARY BODY  6.   SATURN(INCL. RINGS)
 OBSERVATION WORTH.  GROSS WORTH = 0.30, NET WORTH = 0.09
  OBSERVATION PARAMETER  1.   LONGEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  8.000E-01.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.04
   MINIMUM MEASUREMENT CAPABILITY =  5.000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  2.   SHORTEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  9.000E-02.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.04
   MINIMUM MEASUREMENT CAPABILITY =  1.200E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  3.   SPECTRAL RESOLUTION, AT WAVELENGTH REQUIRING HIGHEST RESOLUTION(MICRON)
   DESIRED MEASUREMENT CAPABILITY =  1.000E-05.  WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.02
   MINIMUM MEASUREMENT CAPABILITY =  1.000E-04.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  9.   MINIMUM SUN ELEVATION ANGLE ABOVE HORIZON AT REGION OBSERVED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  0.0       .  WORTH AT D.M.C.   GROSS WORTH = 0.10, NET WORTH = 0.00
   MINIMUM MEASUREMENT CAPABILITY =  3.000E 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
```

Table 3-10. SERA Computer Program Data Output (Cont)


```
*** PLANETARY OBSERVATION OBJECTIVES AND REQUIREMENTS ***

OBSERVATION OBJECTIVE  12.  ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.


               GOAL    2 UNDERSTAND ORIGIN AND EVOLUTION OF LIFE.


KNOWLEDGE REQUIREMENT     4 WHAT ARE THE PHYSICAL AND CHEMICAL PROPERTIES OF PLANETARY ATMOSPH.
                            VS. ALTITUDE, ON GLOBAL AND LOCAL BASES. WHAT IS THE ROLE OF TRACE SUB-
                            STANCES IN DETERMINING ATMOSPHERIC PROPERTIES AND VEHICLE PERFORMANCE.

 OBJECTIVE WORTH = 0.30
```

Table 3-10. SERA Computer Program Data Output (Cont)


```
OBSERVABLE PROPERTY  20.  VISIBLE/ULTRAVIOLET SPECTRUM.

OBSERVATION TECHNIQUE 15.   ULTRAVIOLET SPECTROMETRY
 PLANETARY BODY  6.   SATURN(INCL. RINGS)
 OBSERVATION WORTH.  GROSS WORTH = 0.40, NET WORTH = 0.12
  OBSERVATION PARAMETER  1.   LONGEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  8.0000E-01.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.06
   MINIMUM MEASUREMENT CAPABILITY =  5.0000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  2.   SHORTEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  9.0000E-02.  WORTH AT D.M.C.   GROSS WORTH = 0.50, NET WORTH = 0.06
   MINIMUM MEASUREMENT CAPABILITY =  1.2000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
  OBSERVATION PARAMETER  3.   SPECTRAL RESOLUTION, AT WAVELENGTH REQUIRING HIGHEST RESOLUTION(MICRON)
   DESIRED MEASUREMENT CAPABILITY =  1.0000E-05.  WORTH AT D.M.C.   GROSS WORTH = 0.30, NET WORTH = 0.03
   MINIMUM MEASUREMENT CAPABILITY =  1.0000E-04.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  4.   SPATIAL RESOLUTION AT REGION OBSERVED (METERS)
   DESIRED MEASUREMENT CAPABILITY =  1.0000 05.  WORTH AT D.M.C.   GROSS WORTH = 0.60, NET WORTH = 0.07
   MINIMUM MEASUREMENT CAPABILITY =  1.0000 07.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 14,  TRUNCATED EXPONENTIAL, LOG10(ARGUMENT)
  OBSERVATION PARAMETER  9.   MINIMUM SUN ELEVATION ANGLE ABOVE HORIZON AT REGION OBSERVED (DEGREES)
   DESIRED MEASUREMENT CAPABILITY =  0.0        .  WORTH AT D.M.C.   GROSS WORTH = 0.10, NET WORTH = 0.01
   MINIMUM MEASUREMENT CAPABILITY =  3.0000E 01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  1,  LINEAR
```

Table 3-10. SERA Computer Program Data Output (Cont)


```
                     *** PLANETARY OBSERVATION OBJECTIVES AND REQUIREMENTS ***

OBSERVATION OBJECTIVE  12.  ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.

                 GOAL   2 UNDERSTAND ORIGIN AND EVOLUTION OF LIFE.

KNOWLEDGE REQUIREMENT    4 WHAT ARE THE PHYSICAL AND CHEMICAL PROPERTIES OF PLANETARY ATMOSPH.
                           VS. ALTITUDE, ON GLOBAL AND LOCAL BASES. WHAT IS THE ROLE OF TRACE SUB-
                           STANCES IN DETERMINING ATMOSPHERIC PROPERTIES AND VEHICLE PERFORMANCE.

OBJECTIVE WORTH = 0.60
```

Table 3-10. SERA Computer Program Data Output (Cont)


```
OBSERVABLE PROPERTY  20.  VISIBLE/ULTRAVIOLET SPECTRUM.

OBSERVATION TECHNIQUE 15.   ULTRAVIOLET SPECTROMETRY
 PLANETARY BODY  6.    SATURN(INCL. RINGS)
 OBSERVATION WORTH.  GROSS WORTH = 0.60, NET WORTH = 0.36
  OBSERVATION PARAMETER  1.   LONGEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  3.000E-01.  WORTH AT D.M.C.   GROSS WORTH = 0.99, NET WORTH = 0.35
   MINIMUM MEASUREMENT CAPABILITY =  2.500E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  2,  SINUSOID
  OBSERVATION PARAMETER  2.   SHORTEST WAVELENGTH OF SPECTRAL BAND (MICRONS)
   DESIRED MEASUREMENT CAPABILITY =  1.500E-01.  WORTH AT D.M.C.   GROSS WORTH = 0.99, NET WORTH = 0.35
   MINIMUM MEASUREMENT CAPABILITY =  2.000E-01.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  2,  SINUSOID
  OBSERVATION PARAMETER  3.   SPECTRAL RESOLUTION, AT WAVELENGTH REQUIRING HIGHEST RESOLUTION(MICRON)
   DESIRED MEASUREMENT CAPABILITY =  2.500E-03.  WORTH AT D.M.C.   GROSS WORTH = 0.99, NET WORTH = 0.35
   MINIMUM MEASUREMENT CAPABILITY =  2.000E-02.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION =  2,  SINUSOID
  OBSERVATION PARAMETER  4.   SPATIAL RESOLUTION AT REGION OBSERVED (METERS)
   DESIRED MEASUREMENT CAPABILITY =  1.000E 06.  WORTH AT D.M.C.   GROSS WORTH = 0.40, NET WORTH = 0.14
   MINIMUM MEASUREMENT CAPABILITY =  1.000E 08.
   FORM OF WORTH VS MEASUREMENT CAPABILITY FUNCTION = 11,  LINEAR, LOG10(ARGUMENT)
```

Table 3-10. SERA Computer Program Data Output (Cont)

+ MOST STRINGENT OBSERVATION REQUIREMENT FOR EACH OBSERVATION PARAMETER +

GOAL	KNOWLEDGE REQUIREMENT	OBSERVATION OBJECTIVE	OBSERVABLE PROPERTY	PLANETARY BODY	OBSERVATION TECHNIQUE	OBSERVATION PARAMETER	OBSERVATION REQUIREMENT
2	4	18	20	6	57	1	1.000E 00
2	4	12	20	6	15	2	9.000E-02
2	4	12	20	6	15	3	1.000E-05
2	4	12	20	6	15	4	1.000E 05
2	4	12	20	6	14	5	1.000E 02
2	4	12	20	6	14	6	9.000E 01
2	4	12	20	6	14	7	9.000E 01
2	4	18	20	6	57	8	0.0
2	4	18	20	6	57	9	-9.000E 01
2	4	18	20	6	57	10	1.000E 04
2	4	18	20	6	57	11	1.000E 07
2	4	18	20	6	57	12	1.000E 04
2	4	12	20	6	15	13	1.000E 02
2	4	12	20	6	15	14	1.000E 00
2	4	12	20	6	15	15	1.000E 00
2	4	18	20	6	57	38	1.000E 01

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 16

*** MISSICN MEASUREMENT REQUIREMENTS BY TECHNIQUE FOR ALL OBJECTIVES ***

MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)CASE 1

OBS. TECH. 15. ULTRAVICLET SPECTRCMETRY

TOTAL OBSERVATICN WORTH, 2.95
ALL OBJECTIVES

OBS. OBJECTIVE 12.ATOMIC, MCLECULAR, ISCTOPIC COMPOSITICN OF ATMOSPHERE.
OBS. WORTH C.5C SD 70-24 PAGE C092

OBS. OBJECTIVE 18.NON-THERMAL ELECTROMAGNETIC EMISSION CHARACTERISTICS AND SCURCE LOCATION.
OBS. WORTH C.55 SD 70-24 PAGE C096

OBS. OBJECTIVE 12.ATOMIC, MCLECULAR, ISCTOPIC COMPOSITICN OF ATMOSPHERE.
OBS. WORTH 0.70 SD 70-24 PAGE CC97

OBS. OBJECTIVE 12.ATOMIC, MCLECULAR, ISCTOPIC COMPOSITICN OF ATMOSPHERE.
OBS. WORTH C.3C SD 70-24 PAGE C098

OBS. OBJECTIVE 12.ATOMIC, MCLECULAR, ISOTOPIC COMPOSITICN OF ATMOSPHERE.
OBS. WORTH C.30 SD 70-24 PAGE C099

OBS. OBJECTIVE 12.ATOMIC, MCLECULAR, ISCTOPIC COMPOSITICN OF ATMOSPHERE.
OBS. WORTH 0.60 SD 70-24 PAGE C1C4

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 17

CASE 1

FIXED MISSION AND EXPERIMENT PARAMETERS

1	PERIAPSIS ALTITUDE (KM)	6.0370E 04
2	INCLINATION (DEGREE)	1.2400E 01

SPECIAL CHARACTERISTICS OF SELECTED TRAJECTORY POINTS
POINT 1- MAXIMUM ALTITUDE FOR SENSOR USAGE
POINT 2- MINIMUM ALTITUDE FOR SENSOR USAGE

Table 3-10. SERA Computer Program Data Output (Cont)

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.3900E 04	6.7400E 03		
TRUE ANOMALY (DEG)	-1.2000E 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.0600E 05	1.2020E 05		
LATITUDE (DEGREE)	5.5500E 00	-5.8300E 00		
LONGITUDE (DEGREE)	4.6410E 01	1.7000E-01		
GROUND SPEED (KM/SEC)	9.9900E 00	4.4400E 00		
SPACECRAFT VELOCITY(KM/SEC)	1.4000E 01	2.2990E 01		
RADIUS RATE (KM/SEC)	-1.3480E 01	-1.4110E 01		
NADIR ANGLE RATE (DEG/HOUR)	2.5600E 00	7.6200E 00		
SUN-PLANET-S/C ANGLE (DEG)	2.3400E 01	7.8100E 01		
EARTH-PLANET-S/C ANGLE(DEG)	2.4100E 01	7.6700E 01		
SOLAR ZENITH ANGLE (DEG)	2.3400E 01	7.8100E 01		

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E 00/ 1.0000E-01	1.0000E 00/ 1.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH	0.91	0.91		
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	9.0000E-02/ 1.0000E 00	9.0000E-02/ 1.0000E 00	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH	0.93	0.93		
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E-05/ 1.0000E-01	1.0000E-05/ 1.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH	0.92	0.92		
MEASUREMENT REQUIREMENT 14 $ ANGULAR RESOLUTION (DEGREE)				
OPTIMAL/MARGINAL VALUES	7.1087E-03/ 5.7000E 01	4.7667E-02/ 5.7000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH	3.98	3.96		
MEASUREMENT REQUIREMENT 19 NUMBER OF SAMPLES OR MEASUREMENTS				
OPTIMAL/MARGINAL VALUES	1.0000E 02/ 1.0000E 00	1.0000E 02/ 1.0000E 00	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH	0.03	0.03		
MEASUREMENT REQUIREMENT 18 FRACTION OF SURFACE AREA OF PLANET IN ONE FIELD OF VIEW (PERCENT)				
OPTIMAL/MARGINAL VALUES	1.0000E 02/ 1.0000E 01	1.0000E 02/ 1.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH	0.24	0.24		

Table 3-10. SERA Computer Program Data Output (Cont)

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 12 & VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	0.C / 0.0	C.C / 0.0	0.C / 0.0	0.0 / 0.0
OPTIMAL WORTH	6.CC	6.CC		
MEASUREMENT REQUIREMENT 13 & VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	9.CCOOE 01/ 9.CCOOE 01	9.COOCE 01/ 9.0000E 01	C.0 / 0.0	C.C / 0.0
OPTIMAL WORTH	6.CC	6.CC		
MEASUREMENT REQUIREMENT 33 NORTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	9.CCOOE 01/ 0.0	9.CCCCE 01/ 0.C	C.0 / 0.C	0.C / 0.0
OPTIMAL WORTH	C.37	C.37		
MEASUREMENT REQUIREMENT 34 SOUTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	9.CCCCE 01/ -9.COOOE 01	9.COCOE 01/ -9.0000E 01	C.C / 0.0	0.C / 0.0
OPTIMAL WORTH	C.37	C.37		

	PT. 1	PT. 2
TOTAL OPTIMAL WORTH,	4.2732E-02	4.2730E-02

Table 3-10. SERA Computer Program Data Output (Cont)

*** MISSICN MEASUREMENT REQUIREMENTS BY TECHNIQUE AND OBJECTIVE ***

MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)CASE 1

OBSERVATION TECHNIQUE 15. ULTRAVIOLET SPECTROMETRY
OBS. OBJECTIVE 12. ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.50 SD 70-24 PAGE 0092

FIXED MISSION AND EXPERIMENT PARAMETERS

1	PERIAPSIS ALTITUDE (KM)	6.0370E 04
2	INCLINATION (DEGREE)	1.2400E 01

SPECIAL CHARACTERISTICS OF SELECTED TRAJECTORY POINTS
POINT 1- MAXIMUM ALTITUDE FOR SENSOR USAGE
POINT 2- MINIMUM ALTITUDE FOR SENSOR USAGE

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 20

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.3900E 04	6.7400E 03		
TRUE ANOMALY (DEG)	-1.2000E 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.0600E 05	1.2020E 05		
LATITUDE (DEGREE)	5.5500E 00	-5.8300E 00		
LONGITUDE (DEGREE)	4.6410E 01	1.7000E-01		
GROUND SPEED (KM/SEC)	9.9900E 00	4.4400E 00		
SPACECRAFT VELOCITY(KM/SEC)	1.4000E 01	2.2990E 01		
RADIUS RATE (KM/SEC)	-1.3480E 01	-1.4110E 01		
NADIR ANGLE RATE (DEG/HOUR)	2.5600E 00	7.6200E 00		
SUN-PLANET-S/C ANGLE (DEG)	2.3400E 01	7.6100E 01		
EARTH-PLANET-S/C ANGLE(DEG)	2.4100E 01	7.8700E 01		
SOLAR ZENITH ANGLE (DEG)	2.3400E 01	7.6100E 01		
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E 00/ 1.0000E-01	1.0000E 00/ 1.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.06/ 11	0.06/ 11	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E-01/ 1.0000E 00	1.0000E-01/ 1.0000E 00	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.06/ 11	0.06/ 11	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E-03/ 1.0000E-01	1.0000E-03/ 1.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.10/ 11	0.10/ 11	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 19 NUMBER OF SAMPLES OF MEASUREMENTS				
OPTIMAL/MARGINAL VALUES	1.0000E 02/ 1.0000E 00	1.0000E 02/ 1.0000E 00	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.03/ 11	0.03/ 11	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 9.0000E 01	9.0000E 01/ 9.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0

Table 3-10. SERA Computer Program Data Output (Cont)

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 33 NORTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 6.0000E 01	9.0000E 01/ 6.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.10/ 1	0.10/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 34 SOUTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	-6.0000E 01/ -9.0000E 01	-6.0000E 01/ -9.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.10/ 1	0.10/ 1	0.0 / 0	0.0 / 0

TOTAL OPTIMAL WORTH,	1.0800E-07	1.0800E-07		

Table 3-10. SERA Computer Program Data Output (Cont)


```
*** MISSION MEASUREMENT REQUIREMENTS BY TECHNIQUE AND OBJECTIVE ***

MISSION  7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76.          PLANET  6.  SATURN(INCL. RINGS)CASE   1

OBSERVATION TECHNIQUE 57. ULTRAVIOLET SPECTROMETRY
OBS. OBJECTIVE 18. NON-THERMAL ELECTROMAGNETIC EMISSION CHARACTERISTICS AND SOURCE LOCATION.
OBS. WORTH     0.55  SD 70-24 PAGE 0096

FIXED MISSION AND EXPERIMENT PARAMETERS
     1  PERIAPSIS ALTITUDE (KM)                                    6.0370E 04
     2  INCLINATION (DEGREE)                                       1.2400E 01

SPECIAL CHARACTERISTICS OF SELECTED TRAJECTORY POINTS
 POINT 1- MAXIMUM ALTITUDE FOR SENSOR USAGE
 POINT 2- MINIMUM ALTITUDE FOR SENSOR USAGE
```

NOT REPRODUCIBLE

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 22

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.39C0E C4	6.7400E 03		
TRUE ANOMALY (DEG)	-1.20C0E 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.06C0E 05	1.2020E 05		
LATITUDE (DEGREE)	5.55C0E 00	-5.830CE 00		
LONGITUDE (DEGREE)	4.641CE 01	1.70CCE-01		
GROUND SPEED (KM/SEC)	5.99C0E 00	4.440CE 00		
SPACECRAFT VELOCITY(KM/SEC)	1.40C0E 01	2.299CE 01		
RADIUS RATE (KM/SEC)	-1.3480E 01	-1.411CE 01		
NADIR ANGLE RATE (DEG/HOUR)	2.56C0E 00	7.620CE 00		
SUN-PLANET-S/C ANGLE (DEG)	2.34C0E 01	7.8100E 01		
EARTH-PLANET-S/C ANGLE(DEG)	2.41C0E 01	7.870CE 01		
SOLAR ZENITH ANGLE (DEG)	2.34C0E 01	7.810CE 01		

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	1.C000E 00/ 7.0C00E-01	1.0000E 00/ 7.0000E-01	0.0 / 0.C	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	C.11/ 1	C.11/ 1	0.C / 0	0.0 / C
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	1.2C00E-01/ 4.0000E-01	1.2000E-01/ 4.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.13/ 1	0.13/ 1	0.0 / 0	0.0 / C
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL/MARGINAL VALUES	1.C000E-04/ 1.0C00E-03	1.0000E-04/ 1.0000E-03	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.13/ 14	C.13/ 14	0.0 / 0	0.0 / C
MEASUREMENT REQUIREMENT 14 ANGULAR RESOLUTION (DEGREE)				
OPTIMAL/MARGINAL VALUES	7.1C86E-02/ 5.7000E 01	4.7667E-01/ 5.7000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	C.99/ 1	C.99/ 1	0.C / 0	0.0 / C
MEASUREMENT REQUIREMENT 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	C.C / 0.0	0.C / 0.0	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.CC/ 6	1.CC/ 6	C.0 / 0	0.0 / C
MEASUREMENT REQUIREMENT 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	9.CC00E 01/ 9.0000E 01	9.0000E 01/ 9.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.0C/ 6	1.C0/ 6	0.0 / 0	0.0 / C

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 23

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 33 NORTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 8.0000E 01	9.0000E 01/ 8.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.13/ 4	0.13/ 4	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 34 SOUTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 8.0000E 01	9.0000E 01/ 8.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.13/ 4	0.13/ 4	0.0 / 0	0.0 / 0

	PT. 1	PT. 2
TOTAL OPTIMAL WORTH,	3.1103E-05	3.1103E-05

Table 3-10. SERA Computer Program Data Output (Cont)

*** MISSION MEASUREMENT REQUIREMENTS BY TECHNIQUE AND OBJECTIVE ***

MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)CASE 1

OBSERVATION TECHNIQUE 14. ULTRAVIOLET SPECTROMETRY
OBS. OBJECTIVE 12. ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.70 SD 70-24 PAGE 0097

FIXED MISSION AND EXPERIMENT PARAMETERS

1 PERIAPSIS ALTITUDE (KM)	6.0370E 04
2 INCLINATION (DEGREE)	1.2400E 01

SPECIAL CHARACTERISTICS OF SELECTED TRAJECTORY POINTS
POINT 1- MAXIMUM ALTITUDE FOR SENSOR USAGE
POINT 2- MINIMUM ALTITUDE FOR SENSOR USAGE

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 24

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.3900E 04	6.7400E 03		
TRUE ANOMALY (DEG)	-1.2000E 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.0600E 05	1.2020E 05		
LATITUDE (DEGREE)	5.5500E 00	-5.6300E 00		
LONGITUDE (DEGREE)	4.6410E 01	1.7000E-01		
GROUND SPEED (KM/SEC)	9.9900E 00	4.4400E 00		
SPACECRAFT VELOCITY(KM/SEC)	1.4000E 01	2.2990E 01		
RADIUS RATE (KM/SEC)	-1.3480E 01	-1.4110E 01		
NADIR ANGLE RATE (DEG/HOUR)	2.5600E 00	7.6200E 00		
SUN-PLANET-S/C ANGLE (DEG)	2.3400E 01	7.8100E 01		
EARTH-PLANET-S/C ANGLE(DEG)	2.4100E 01	7.8700E 01		
SOLAR ZENITH ANGLE (DEG)	2.3400E 01	7.8100E 01		

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	8.0000E-01/ 7.0000E-01	8.0000E-01/ 7.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.29/ 1	0.29/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	5.0000E-01/ 6.0000E-01	5.0000E-01/ 6.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.29/ 1	0.29/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E-04/ 2.0000E-03	1.0000E-04/ 2.0000E-03	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.29/ 1	0.29/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 14 ANGULAR RESOLUTION (DEGREE)				
OPTIMAL/MARGINAL VALUES	7.1087E-03/ 5.7000E 01	4.7667E-02/ 5.7000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 1	0.99/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 18 FRACTION OF SURFACE AREA OF PLANET IN ONE FIELD OF VIEW (PERCENT)				
OPTIMAL/MARGINAL VALUES	1.0000E 02/ 1.0000E 01	1.0000E 02/ 1.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.24/ 1	0.24/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 25

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 9.0000E 01	9.0000E 01/ 9.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 33 NORTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 0.0	9.0000E 01/ 0.0	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.14/ 2	0.14/ 2	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 34 SOUTHERNMOST LATITUDE OF AREA TO BE COVERED (DEGREES)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 0.0	9.0000E 01/ 0.0	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.14/ 2	0.14/ 2	0.0 / 0	0.0 / 0

TOTAL OPTIMAL WORTH,	1.1473E-04	1.1358E-04		

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 26

*** MISSION MEASUREMENT REQUIREMENTS BY TECHNIQUE AND OBJECTIVE ***

MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)CASE 1

OBSERVATION TECHNIQUE 14. ULTRAVIOLET SPECTROMETRY
OBS. OBJECTIVE 12. ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.30 SD 70-24 PAGE 0098

FIXED MISSION AND EXPERIMENT PARAMETERS

1	PERIAPSIS ALTITUDE (KM)	6.0370E 04
2	INCLINATION (DEGREE)	1.2400E 01

SPECIAL CHARACTERISTICS OF SELECTED TRAJECTORY POINTS
POINT 1- MAXIMUM ALTITUDE FOR SENSOR USAGE
POINT 2- MINIMUM ALTITUDE FOR SENSOR USAGE

NOT REPRODUCIBLE

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 26

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.3900E 04	6.7400E 03		
TRUE ANOMALY (DEG)	-1.2000E 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.0600E 05	1.2020E 05		
LATITUDE (DEGREE)	5.5500E 00	-5.8300E 00		
LONGITUDE (DEGREE)	4.6410E 01	1.7000E-01		
GROUND SPEED (KM/SEC)	9.9900E 00	4.4400E 00		
SPACECRAFT VELOCITY(KM/SEC)	1.4000E 01	2.2990E 01		
RADIUS RATE (KM/SEC)	-1.3480E 01	-1.4110E 01		
NADIR ANGLE RATE (DEG/HOUR)	2.5600E 00	7.6200E 00		
SUN-PLANET-S/C ANGLE (DEG)	2.3400E 01	7.8100E 01		
EARTH-PLANET-S/C ANGLE(DEG)	2.4100E 01	7.8700E 01		
SOLAR ZENITH ANGLE (DEG)	2.3400E 01	7.8100E 01		
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	8.0000E-01/ 5.0000E-01	8.0000E-01/ 5.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.04/ 1	0.04/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	9.0000E-02/ 1.2000E-01	9.0000E-02/ 1.2000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.04/ 1	0.04/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E-05/ 1.0000E-04	1.0000E-05/ 1.0000E-04	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.02/ 11	0.02/ 11	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 9.0000E 01	9.0000E 01/ 9.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0
TOTAL OPTIMAL WORTH,	3.2000E-05	3.2000E-05		

Table 3-10. SERA Computer Program Data Output (Cont)

*** MISSION MEASUREMENT REQUIREMENTS BY TECHNIQUE AND OBJECTIVE ***

MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)CASE 1

OBSERVATION TECHNIQUE 15. ULTRAVIOLET SPECTROMETRY
OBS. OBJECTIVE 12. ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.30 SD 70-24 PAGE C099

FIXED MISSION AND EXPERIMENT PARAMETERS

1	PERIAPSIS ALTITUDE (KM)	6.0370E 04
2	INCLINATION (DEGREE)	1.2400E 01

SPECIAL CHARACTERISTICS OF SELECTED TRAJECTORY POINTS
POINT 1- MAXIMUM ALTITUDE FOR SENSOR USAGE
POINT 2- MINIMUM ALTITUDE FOR SENSOR USAGE

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 27

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.3900E 04	6.7400E 03		
TRUE ANOMALY (DEG)	-1.2000E 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.0600E 05	1.2020E 05		
LATITUDE (DEGREE)	5.5500E 00	-5.8300E 00		
LONGITUDE (DEGREE)	4.6410E 01	1.7000E-01		
GROUND SPEED (KM/SEC)	9.9900E 00	4.4400E 00		
SPACECRAFT VELOCITY(KM/SEC)	1.4000E 01	2.2990E 01		
RADIUS RATE (KM/SEC)	-1.3480E 01	-1.4110E 01		
NADIR ANGLE RATE (DEG/HOUR)	2.5600E 00	7.6200E 00		
SUN-PLANET-S/C ANGLE (DEG)	2.3400E 01	7.8100E 01		
EARTH-PLANET-S/C ANGLE(DEG)	2.4100E 01	7.8700E 01		
SOLAR ZENITH ANGLE (DEG)	2.3400E 01	7.8100E 01		

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	8.0000E-01/ 5.0000E-01	8.0000E-01/ 5.0000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.06/ 1	0.06/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	9.0000E-02/ 1.2000E-01	9.0000E-02/ 1.2000E-01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.06/ 1	0.06/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL/MARGINAL VALUES	1.0000E-05/ 1.0000E-04	1.0000E-05/ 1.0000E-04	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	0.03/ 11	0.03/ 11	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 14 ANGULAR RESOLUTION (DEGREE)				
OPTIMAL/MARGINAL VALUES	7.1087E-03/ 5.7000E 01	4.7667E-02/ 5.7000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 1	0.99/ 1	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0
MEASUREMENT REQUIREMENT 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	9.0000E 01/ 9.0000E 01	9.0000E 01/ 9.0000E 01	0.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.00/ 6	1.00/ 6	0.0 / 0	0.0 / 0

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 28

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TOTAL OPTIMAL WORTH,	1.0800E-04	1.0692E-04		

Table 3-10. SERA Computer Program Data Output (Cont)

*** MISSION MEASUREMENT REQUIREMENTS BY TECHNIQUE AND OBJECTIVE ***

MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)CASE 1

OBSERVATION TECHNIQUE 15. ULTRAVIOLET SPECTROMETRY
OBS. OBJECTIVE 12. ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.60 SD 70-24 PAGE C104

FIXED MISSION AND EXPERIMENT PARAMETERS

1	PERIAPSIS ALTITUDE (KM)	6.0370E 04
2	INCLINATION (DEGREE)	1.2400E 01

SPECIAL CHARACTERISTICS OF SELECTED TRAJECTORY POINTS
POINT 1- MAXIMUM ALTITUDE FOR SENSOR USAGE
POINT 2- MINIMUM ALTITUDE FOR SENSOR USAGE

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 29

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.39CCE 04	6.7400E 03		
TRUE ANOMALY (DEG)	-1.2CCCE 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.06CCE 05	1.2020E 05		
LATITUDE (DEGREE)	5.55CCE 00	-5.8300E 00		
LONGITUDE (DEGREE)	4.641CE 01	1.700CE-01		
GROUND SPEED (KM/SEC)	9.99CCE CC	4.440CE 00		
SPACECRAFT VELOCITY(KM/SEC)	1.4CCCE C1	2.299CE 01		
RADIUS RATE (KM/SEC)	-1.348CE C1	-1.411CE 01		
NADIR ANGLE RATE (DEG/HOUR)	2.56CCE CC	7.6200E 00		
SUN-PLANET-S/C ANGLE (DEG)	2.34CCE C1	7.8100E 01		
EARTH-PLANET-S/C ANGLE(DEG)	2.41CCE C1	7.87C0E 01		
SOLAR ZENITH ANGLE (DEG)	2.34CCE C1	7.610CE 01		

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	3.CCCOE-01/ 2.5C0CE-01	3.0000E-01/ 2.5000E-01	C.C / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	C.35/ 2	0.35/ 2	0.C / 0	0.0 / C
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL/MARGINAL VALUES	1.5CCCE-01/ 2.0C0CE-01	1.50CCE-01/ 2.0000E-01	0.0 / 0.0	0.C / 0.0
OPTIMAL WORTH/WORTH FORM	C.35/ 2	C.35/ 2	0.0 / 0	0.0 / C
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL/MARGINAL VALUES	2.5CCCE-C3/ 2.C0C0E-02	2.5C00E-03/ 2.0C00E-02	C.C / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	C.35/ 2	C.35/ 2	C.C / 0	C.0 / 0
MEASUREMENT REQUIREMENT 14 ANGULAR RESOLUTION (DEGREE)				
OPTIMAL/MARGINAL VALUES	7.1086E-C2/ 5.7000E 01	4.7667E-C1/ 5.7C00E C1	0.0 / 0.C	C.0 / 0.0
OPTIMAL WORTH/WORTH FORM	C.99/ 1	C.99/ 1	0.0 / 0	0.0 / C
MEASUREMENT REQUIREMENT 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	C.C / C.0	0.C / 0.0	C.0 / 0.0	0.0 / 0.0
OPTIMAL WORTH/WORTH FORM	1.CC/ 6	1.0C/ 6	C.0 / 0	0.0 / C
MEASUREMENT REQUIREMENT 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL/MARGINAL VALUES	9.CCCCE C1/ 9.C00CE 01	9.00CCE 01/ 9.000CE 01	C.C / C.0	C.C / 0.0
OPTIMAL WORTH/WORTH FORM	1.CC/ 6	1.00/ 6	0.0 / 0	0.0 / C

Table 3-10. SERA Computer Program Data Output (Cont)

PAGE 30

CASE 1

** REQUIREMENTS AT SELECTED MISSION POINTS **

	PT. 1	PT. 2	PT. 3	PT. 4
TOTAL OPTIMAL WORTH,	4.2446E-02	4.2446E-02		

PAGE 31

*** SENSOR CAPABILITIES AND SUPPORT REQUIREMENTS ***

CASE 1

SENSOR TYPE 4. VISIBLE/UV SPECTROMETER

** MISSION DESCRIPTION **

MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76.

PLANET 6. SATURN(INCL. RINGS)

* CONSTANTS OF TRAJECTORY *

INCLINATION (DEGREE)	1.2400E 01
ORBITAL PERIOD (SEC)	0.0
PERIAPSIS ALTITUDE (KM)	6.0370E 04
APOAPSIS ALTITUDE (KM)	0.0
ARGUMENT OF PERIAPSIS (DEG)	0.0
LATITUDE OF PERIAPSIS (DEG)	-1.2400E 01
LONGITUDE ASCND. NODE (DEG)	-2.8300E 01
LAUNCH DATE (JULIAN DATE)	4.2990E 04
PERIAPSIS DATE(JULIAN DATE)	4.4700E 04
ORBIT ECCENTRICITY	1.3460E 00
EARTH-S/C DISTANCE (AU)	8.5600E 00
SUN-S/C DISTANCE (AU)	9.5500E 00

* TRAJECTORY POINTS SELECTED *

	PT. 1	PT. 2	PT. 3	PT. 4
TIME TO PERIAPSIS (SEC)	5.3900E 04	6.7400E 03		
TRUE ANOMALY (DEG)	-1.2000E 02	-6.5000E 01		
SURFACE ALTITUDE (KM)	8.0600E 05	1.2020E 05		
LATITUDE (DEGREE)	5.5500E 00	-5.8300E 00		
LONGITUDE (DEGREE)	4.6410E 01	1.7000E-01		

Table 3-10. SERA Computer Program Data Output (Cont)

GROUND SPEED (KM/SEC)	9.9900E 00	4.4400E 00
SPACECRAFT VELOCITY(KM/SEC)	1.4000E 01	2.2990E 01
RADIUS RATE (KM/SEC)	-1.3480E 01	-1.4110E 01
NADIR ANGLE RATE (DEG/HOUR)	2.5600E 00	7.6200E 00
SUN-PLANET-S/C ANGLE (DEG)	2.3400E 01	7.8100E 01
EARTH-PLANET-S/C ANGLE(DEG)	2.4100E 01	7.8700E 01
SOLAR ZENITH ANGLE (DEG)	2.3400E 01	7.8100E 01
SUN OCCULTED	F	F
EARTH OCCULTED	F	F

Table 3-10. SERA Computer Program Data Output (Cont)

*** SENSOR CAPABILITIES AND SUPPORT REQUIREMENTS ***

CASE 1

SENSOR TYPE 4. VISIBLE/UV SPECTROMETER
MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)

** INFORMATION REQUIREMENTS SUPPORTED **

OBS. OBJECTIVE 12.ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.50 SD 70-24 PAGE C092

OBS. OBJECTIVE 18.NON-THERMAL ELECTROMAGNETIC EMISSION CHARACTERISTICS AND SOURCE LOCATION.
OBS. WORTH 0.55 SD 70-24 PAGE C096

OBS. OBJECTIVE 12.ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.70 SD 70-24 PAGE C097

OBS. OBJECTIVE 12.ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.30 SD 70-24 PAGE C098

OBS. OBJECTIVE 12.ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.30 SD 70-24 PAGE C099

OBS. OBJECTIVE 12.ATOMIC, MOLECULAR, ISOTOPIC COMPOSITION OF ATMOSPHERE.
OBS. WORTH 0.60 SD 70-24 PAGE C104

* MEASUREMENT REQUIREMENTS *

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 1 MAXIMUM WAVELENGTH (MICRON)				
OPTIMAL VALUES(PTS. 1- 2)	1.0000E 00	1.0000E 00	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE)	1.0000E 00/	1.0000E 00. ORIGIN OF VALUES.	PT. 2/PT. 2, OBS. OBJ.	2/OBS. OBJ. 2
MEASUREMENT REQUIREMENT 2 MINIMUM WAVELENGTH (MICRON)				
OPTIMAL VALUES(PTS. 1- 2)	9.0000E-02	9.0000E-02	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE)	9.0000E-02/	9.0000E-02. ORIGIN OF VALUES.	PT. 2/PT. 2, OBS. OBJ.	5/OBS. OBJ. 5
MEASUREMENT REQUIREMENT 3 SPECTRAL RESOLUTION (MICRON)				
OPTIMAL VALUES(PTS. 1- 2)	1.0000E-05	1.0000E-05	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE)	1.0000E-05/	1.0000E-05. ORIGIN OF VALUES.	PT. 2/PT. 2, OBS. OBJ.	5/OBS. OBJ. 5

Table 3-10. SERA Computer Program Data Output (Cont)

*** SENSOR CAPABILITIES AND SUPPORT REQUIREMENTS ***

CASE 1

* MEASUREMENT REQUIREMENTS *

	PT. 1	PT. 2	PT. 3	PT. 4
MEASUREMENT REQUIREMENT 14 ANGULAR RESOLUTION (DEGREE)				
OPTIMAL VALUES(PTS. 1- 2)	7.1087E-03	4.7667E-02	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE) 7.1087E-03/ 4.7667E-02. ORIGIN OF VALUES. PT. 1/PT. 2, OBS. OBJ. 5/OBS. OBJ. 5				
MEASUREMENT REQUIREMENT 19 NUMBER OF SAMPLES OR MEASUREMENTS				
OPTIMAL VALUES(PTS. 1- 2)	1.0000E 02	1.0000E 02	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE) 1.0000E 02/ 1.0000E 02. ORIGIN OF VALUES. PT. 2/PT. 2, OBS. OBJ. 1/OBS. OBJ. 1				
MEASUREMENT REQUIREMENT 18 FRACTION OF SURFACE AREA OF PLANET IN ONE FIELD OF VIEW (PERCENT)				
OPTIMAL VALUES(PTS. 1- 2)	1.0000E 02	1.0000E 02	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE) 1.0000E 02/ 1.0000E 02. ORIGIN OF VALUES. PT. 2/PT. 2, OBS. OBJ. 3/OBS. OBJ. 3				
MEASUREMENT REQUIREMENT 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)				
OPTIMAL VALUES(PTS. 1- 2)	0.0	0.0	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE) 0.0 / 0.0 . ORIGIN OF VALUES. PT. 2/PT. 2, OBS. OBJ. 6/OBS. OBJ. 6				
MEASUREMENT REQUIREMENT 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)				
OPTIMAL VALUES(PTS. 1- 2)	9.0000E 01	9.0000E 01	0.0	0.0
OPTIMAL/MARGINAL VALUES(TO DATE) 9.0000E 01/ 9.0000E 01. ORIGIN OF VALUES. PT. 2/PT. 2, OBS. OBJ. 6/OBS. OBJ. 6				

Table 3-10. SERA Computer Program Data Output (Cont)

*** SENSOR CAPABILITIES AND SUPPORT REQUIREMENTS ***

CASE 1

SENSOR TYPE 4. VISIBLE/UV SPECTROMETER
MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)

** SENSOR CAPABILITIES **

	LIMIT	OPTIMAL	MARGINAL	PT. 1	PT. 2	PT. 3	PT. 4	MAX. WORTH
CAPABILITY PARAMETER 1 MAXIMUM WAVELENGTH (MICRON)	1.2000E 00	1.0000E 00	1.0000E 00	1.0000E 00	1.0000E 00	0.0	0.0	0.11
CAPABILITY PARAMETER 2 MINIMUM WAVELENGTH (MICRON)	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	0.0	0.0	0.04
CAPABILITY PARAMETER 3 SPECTRAL RESOLUTION (MICRON)	5.0000E-06	1.0000E-05	1.0000E-05	1.0000E-05	1.0000E-05	0.0	0.0	0.03
CAPABILITY PARAMETER 14 ANGULAR RESOLUTION (DEGREE)	5.7290E-04	1.6800E-02	1.6800E-02	1.6800E-02	1.6800E-02	0.0	0.0	1.00
CAPABILITY PARAMETER 19 NUMBER OF SAMPLES OR MEASUREMENTS	1.0000E 03	1.0000E 02	1.0000E 02	1.0000E 02	1.0000E 02	0.0	0.0	0.03
CAPABILITY PARAMETER 18 FRACTION OF SURFACE AREA OF PLANET IN ONE FIELD OF VIEW (PERCENT)	5.0000E 01	6.9468E-04	2.9165E-06	6.9468E-04	2.9165E-06	0.0	0.0	1.00
CAPABILITY PARAMETER 12 VIEWING AXIS ANGLE TO THE VERTICAL, AT THE SPACECRAFT (DEGREE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00
CAPABILITY PARAMETER 13 VIEWING AXIS ANGLE TO THE SURFACE TANGENT PLANE, AT SPACECRAFT (DEGREE)	9.0000E 01	9.0000E 01	9.0000E 01	9.0000E 01	9.0000E 01	0.0	0.0	1.00
TOTAL SENSOR WORTH		4.0382E-06	4.0382E-06	4.0382E-06	4.0382E-06			

Table 3-10. SERA Computer Program Data Output (Cont)

*** SENSOR CAPABILITIES AND SUPPORT REQUIREMENTS ***

CASE 1

* SUPPLEMENTARY CAPABILITY DATA *

	VALUE	WORTH
FRACTION OF SURFACE OF PLANET COVERED (PERCENT)	6.7100E 01	0.15
NORTHERNMOST LATITUDE OF AREA VIEWED (DEG)	8.5000E 01	0.14
SOUTHERNMOST LATITUDE OF AREA VIEWED (DEG)	7.5000E 01	0.13
(COARSEST) SPATIAL RESOLUTION AT FAR EDGE OF SWATH (M)	5.6400E 05	********

* FIXED EXPERIMENT PARAMETERS *

PARAMETER	LIMIT	VALUE
NUMBER OF DETECTORS	1.0000E 01	2.0000E 00
NUMBER OF MIRROR FACES	1.0000E 01	1.0000E 00
PHOTOMULTIPLIER RESPONSE TIME LIMIT (SEC)	1.0000E-08	1.0000E-08
PHOTOCONDUCTOR RESPONSE TIME LIMIT (SEC)	1.0000E-03	1.0000E-03
PHOTOMULTIPLIER SIGNAL/NOISE RATIO RQMT.	1.2000E 02	1.2000E 02
PHOTOCONDUCTOR SIGNAL/NOISE RATIO RQMT.	1.2000E 02	1.2000E 02
SPECTRAL ORDER	5.0000E 00	2.0000E 00
S-O-A GRATING DIAMETER LIMIT (M)	2.0000E-01	2.0000E-01
RECIPROCAL GRATING SPACING (LINE/M)	1.1800E 06	1.1800E 06
S-O-A COLLECTOR APERTURE F/NUMBER LOWER LIMIT	1.0000E 00	1.0000E 00
SCAN HALF-ANGLE (DEGREE)	9.0000E 01	4.4500E 00
SCANNING BEAM ANGULAR SIZE (DEGREE)	5.7300E-04	1.6800E-02

OTHER SENSOR TYPES MEETING SOME MEASUREMENT REQUIREMENTS
VISIBLE/UV PHOTOMETER WITH CASSEGRANIAN OPTICS
IR SPECTROMETER

Table 3-10. SERA Computer Program Data Output (Cont)

*** SENSOR CAPABILITIES AND SUPPORT REQUIREMENTS ***

CASE 1

SENSOR TYPE 4. VISIBLE/UV SPECTROMETER
MISSION 7. EARTH-JUPITER-SATURN FLYBY, LAUNCH 7/30/76. PLANET 6. SATURN(INCL. RINGS)

** SUPPORT REQUIREMENTS EVALUATION **

* SCALING LAW COEFFICIENTS AND OPTIONS *

		C1/	C2/	C3/	C4/	C5/
SUPPORT RQMT. 1.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
2.	COEFFICIENT/VALUE	1.00000E 00	2.20000E 00	0.0	0.0	0.0
3.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
4.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
5.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
6.	COEFFICIENT/VALUE	1.00000E 00	7.30000E-01	1.30000E 00	1.0000E-03	0.0
9.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
10.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
11.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
14.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0
15.	COEFFICIENT/VALUE	1.00000E 00	0.0	0.0	0.0	0.0

* SUPPORT REQUIREMENTS *

SUPPORT REQUIREMENT	MAXIMUM REQUIREMENT	MINIMUM REQUIREMENT	PT. 1	PT. 2	PT. 3	PT. 4
MASS (KG)	8.88667E 02	8.88667E 02	8.88667E 02	8.88667E 02		
AVERAGE POWER (WATT)	4.20000E 00	4.20000E 00	4.20000E 00	4.20000E 00		
LENGTH (M) (ORIENTED)	4.41046E 00	4.41046E 00	4.41046E 00	4.41046E 00		
WIDTH (M) (ORIENTED)	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00		
HEIGHT (M) (ORIENTED)	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00		
VOLUME (CUBIC M) (ORIENTED)	4.05548E 00	4.05548E 00	4.05548E 00	4.05548E 00		
DATA OUTPUT RATE (BIT/SEC)	1.61970E 04	5.43485E 03	5.43485E 03	1.61970E 04		
POINTING ACCURACY (DEG)	9.00936E 00	9.07922E 00	9.07922E 00	9.00936E 00		
ASPECT ANGLE RATE LIMIT (DEG/SEC)	3.80439E 00	1.13379E 01	3.80439E 00	1.13379E 01		
ROLL RATE LIMIT (DEG/SEC)	3.80439E 00	1.13379E 01	3.80439E 00	1.13379E 01		
SCAN RATE LIMIT (DEG/SEC)	7.82043E 03	7.82043E 03	7.82043E 03	7.82043E 03		

Table 3-10. SERA Computer Program Data Output (Cont)

1	2.00000000E 00	2	0.0	3	0.0	4	6.00000000E 00	5	0.0
6	0.0	7	0.0	8	0.0	9	0.0	10	0.0
11	0.0	12	0.0	13	0.0	14	0.0	15	0.0
16	0.0	17	0.0	18	0.0	19	0.0	20	0.0
21	0.0	22	0.0	23	0.0	24	0.0	25	0.0
26	0.0	27	0.0	28	0.0	29	0.0	30	0.0
31	2.30000000E 02	32	2.28107147E 02	33	0.0	34	0.0	35	0.0
36	5.00000000E-01	37	1.46607637E-01	38	0.0	39	0.0	40	0.0
41	1.50000000E 02	42	6.98326492E 00	43	0.0	44	0.0	45	0.0
46	9.99999642E-02	47	0.0	48	9.99999642E-02	49	0.0	50	0.0
51	1.50000000E 02	52	2.70000000E 03	53	1.92856888E 02	54	0.0	55	0.0
56	3.99999976E-01	57	0.0	58	3.99999976E-01	59	0.0	60	0.0
61	0.0	62	4.60000000E 02	63	5.00000000E 02	64	0.0	65	0.0
66	4.60000000E 02	67	0.0	68	0.0	69	0.0	70	0.0
71	1.99999988E-01	72	9.99999642E-02	73	2.19999850E-01	74	0.0	75	0.0
76	0.0	77	0.0	78	0.0	79	0.0	80	0.0
81	2.30000000E 02	82	0.0	83	1.74980960E-05	84	0.0	85	0.0
86	0.0	87	0.0	88	0.0	89	0.0	90	0.0
91	0.0	92	0.0	93	0.0	94	0.0	95	0.0
96	0.0	97	0.0	98	0.0	99	0.0	100	0.0
101	0.0	102	0.0	103	0.0	104	0.0	105	0.0
106	0.0	107	0.0	108	0.0	109	0.0	110	0.0
111	0.0	112	0.0	113	0.0	114	0.0	115	0.0
116	0.0	117	0.0	118	0.0	119	0.0	120	0.0
121	0.0	122	0.0	123	0.0	124	0.0	125	0.0
126	0.0	127	0.0	128	0.0	129	0.0	130	0.0
131	2.00000000E 00	132	1.00000000E 00	133	9.89999771E-02	134	0.0	135	0.0
136	9.99999931E-04	137	1.20000000E 02	138	1.99999983E-01	139	0.0	140	0.0
141	9.99999931E-04	142	1.20000000E 02	143	2.99999954E-07	144	4.00000000E 09	145	0.0
146	0.0	147	0.0	148	0.0	149	0.0	150	0.0
151	0.0	152	0.0	153	0.0	154	0.0	155	0.0
156	0.0	157	0.0	158	0.0	159	0.0	160	0.0
161	0.0	162	0.0	163	0.0	164	0.0	165	0.0
166	0.0	167	0.0	168	0.0	169	0.0	170	0.0
171	0.0	172	0.0	173	0.0	174	0.0	175	0.0
176	0.0	177	0.0	178	0.0	179	0.0	180	0.0
181	0.0	182	0.0	183	0.0	184	0.0	185	0.0
186	0.0	187	0.0	188	0.0	189	0.0	190	0.0
191	0.0	192	0.0	193	0.0	194	0.0	195	0.0
196	0.0	197	0.0	198	0.0	199	0.0	200	0.0
201	0.0	202	0.0	203	1.00000000E 00	204	8.99999976E-01	205	0.0
206	1.27720640E 08	207	1.89006240E 07	208	1.27720640E 08	209	1.89006240E 07	210	0.0

Table 3-10. SERA Computer Program Data Output (Cont)

211	0.0	212	9.07922268E 00	213	9.00936317E 00	214	9.07922268E 00	215	9.00936317E 00
216	0.0	217	0.0	218	0.0	219	0.0	220	0.0
221	0.0	222	9.99999642E-02	223	0.0	224	0.0	225	0.0
226	6.05782471E 01	227	8.96462250E 00	228	6.05782471E 01	229	8.96462250E 00	230	0.0
231	0.0	232	0.0	233	0.0	234	0.0	235	0.0
236	0.0	237	0.0	238	0.0	239	0.0	240	0.0
241	0.0	242	4.44999981E 00	243	0.0	244	0.0	245	0.0
246	4.44999981E 00	247	4.44999981E 00	248	4.44999981E 00	249	4.44999981E 00	250	0.0
251	0.0	252	0.0	253	0.0	254	0.0	255	0.0
256	0.0	257	0.0	258	0.0	259	0.0	260	0.0
261	0.0	262	1.67999975E-02	263	0.0	264	0.0	265	0.0
266	1.67999938E-02	267	1.67999938E-02	268	1.67999938E-02	269	1.67999938E-02	270	0.0
271	0.0	272	0.0	273	0.0	274	0.0	275	0.0
276	0.0	277	0.0	278	0.0	279	0.0	280	0.0
281	0.0	282	0.0	283	0.0	284	0.0	285	0.0
286	4.55463596E-05	287	4.55463596E-05	288	4.55463596E-05	289	4.55463596E-05	290	0.0
291	0.0	292	0.0	293	0.0	294	0.0	295	0.0
296	0.0	297	0.0	298	0.0	299	0.0	300	0.0
301	0.0	302	1.21999931E 00	303	0.0	304	0.0	305	0.0
306	4.16075438E-03	307	4.16075438E-03	308	4.16075438E-03	309	4.16075438E-03	310	0.0
311	0.0	312	0.0	313	0.0	314	0.0	315	0.0
316	0.0	317	0.0	318	0.0	319	0.0	320	0.0
321	1.27720640E 08	322	1.89006240E 07	323	1.27720640E 08	324	1.89006240E 07	325	0.0
326	0.0	327	4.72662598E 02	328	7.04889221E 01	329	4.72662598E 02	330	7.04889221E 01
331	0.0	332	0.0	333	4.73136139E 01	334	1.58759031E 01	335	4.73136139E 01
336	1.58759031E 01	337	0.0	338	0.0	339	0.0	340	0.0
341	0.0	342	1.00000000E 00	343	1.93000000E 02	344	0.0	345	0.0
346	7.60879230E 00	347	2.26758423E 01	348	7.60879230E 00	349	2.26758423E 01	350	0.0
351	0.0	352	0.0	353	0.0	354	0.0	355	0.0
356	0.0	357	0.0	358	0.0	359	0.0	360	0.0
361	9.99999727E-09	362	9.99999931E-04	363	0.0	364	0.0	365	0.0
366	1.10398559E-03	367	3.70437978E-04	368	1.10398559E-03	369	3.70437978E-04	370	0.0
371	0.0	372	0.0	373	0.0	374	0.0	375	0.0
376	0.0	377	0.0	378	0.0	379	0.0	380	0.0
381	0.0	382	1.70799923E 00	383	0.0	384	0.0	385	0.0
386	2.43942696E-03	387	5.61458990E-03	388	2.43942696E-03	389	5.61458990E-03	390	0.0
391	0.0	392	0.0	393	0.0	394	0.0	395	0.0
396	0.0	397	0.0	398	0.0	399	0.0	400	0.0
401	0.0	402	1.00000000E 00	403	0.0	404	0.0	405	0.0
406	9.17754591E-01	407	2.06204295E-01	408	9.17754591E-01	409	2.06204295E-01	410	0.0
411	0.0	412	0.0	413	0.0	414	0.0	415	0.0
416	0.0	417	0.0	418	0.0	419	0.0	420	0.0
421	2.00000000E 00	422	2.99999955E-12	423	3.32999992E 00	424	1.00000000E 00	425	0.0

Table 3-10. SERA Computer Program Data Output (Cont)

426	1.64770842E-01	427	6.00093305E-01	428	1.64770842E-01	429	6.00093305E-01	430	0.0
431	0.0	432	0.0	433	0.0	434	0.0	435	0.0
436	0.0	437	0.0	438	0.0	439	0.0	440	0.0
441	0.0	442	0.0	443	0.0	444	0.0	445	0.0
446	3.41046333E 00	447	3.41046333E 00	448	3.41046333E 00	449	3.41046333E 00	450	0.0
451	0.0	452	0.0	453	0.0	454	0.0	455	0.0
456	0.0	457	0.0	458	0.0	459	0.0	460	0.0
461	1.00000000E 00	462	5.70000000E 03	463	0.0	464	0.0	465	0.0
466	3.41046333E 00	467	3.41046333E 00	468	3.41046333E 00	469	3.41046333E 00	470	0.0
471	0.0	472	5.69999886E 00	473	5.69999886E 00	474	5.69999886E 00	475	5.69999886E 00
476	0.0	477	0.0	478	0.0	479	0.0	480	0.0
481	1.99999988E-01	482	2.00000000E 00	483	1.18000000E 06	484	0.0	485	4.23728675E-03
486	4.23728675E-03	487	4.23728675E-03	488	4.23728675E-03	489	0.0	490	0.0
491	1.41399956E 00	492	0.0	493	1.41399956E 00	494	1.41399956E 00	495	1.41399956E 00
496	1.41399956E 00	497	0.0	498	0.0	499	0.0	500	0.0
501	0.0	502	0.0	503	0.0	504	0.0	505	0.0
506	0.0	507	0.0	508	0.0	509	0.0	510	0.0
511	0.0	512	0.0	513	0.0	514	0.0	515	0.0
516	0.0	517	0.0	518	0.0	519	0.0	520	0.0
521	5.64331188E 05	522	3.65656484E 04	523	5.64331188E 05	524	3.65656484E 04	525	0.0
526	0.0	527	2.38788033E 00	528	1.03748608E 00	529	2.38788033E 00	530	1.03748608E 00
531	0.0	532	0.0	533	0.0	534	0.0	535	0.0
536	0.0	537	0.0	538	0.0	539	0.0	540	0.0
541	3.67495418E-03	542	1.33841336E-02	543	3.67495418E-03	544	1.33841336E-02	545	0.0
546	0.0	547	3.85479780E-06	548	3.85479780E-06	549	3.85479780E-06	550	3.85479780E-06
551	0.0	552	0.0	553	1.41661971E-08	554	5.15931156E-08	555	1.41661971E-08
556	5.15931156E-08	557	0.0	558	0.0	559	0.0	560	0.0
561	0.0	562	0.0	563	0.0	564	0.0	565	0.0
566	0.0	567	0.0	568	0.0	569	0.0	570	0.0
571	0.0	572	0.0	573	0.0	574	0.0	575	0.0
576	0.0	577	0.0	578	0.0	579	0.0	580	0.0
581	0.0	582	0.0	583	0.0	584	0.0	585	0.0
586	0.0	587	0.0	588	0.0	589	0.0	590	0.0
591	0.0	592	0.0	593	0.0	594	0.0	595	0.0
596	0.0	597	0.0	598	0.0	599	0.0	600	0.0
601	0.0	602	0.0	603	0.0	604	0.0	605	0.0
606	0.0	607	0.0	608	0.0	609	0.0	610	0.0
611	0.0	612	0.0	613	0.0	614	0.0	615	0.0
616	0.0	617	0.0	618	0.0	619	0.0	620	0.0
621	0.0	622	0.0	623	0.0	624	0.0	625	0.0
626	0.0	627	0.0	628	0.0	629	0.0	630	0.0
631	0.0	632	0.0	633	0.0	634	0.0	635	0.0
636	0.0	637	0.0	638	0.0	639	0.0	640	0.0

Table 3-11. Sensor Support Requirements
Summary

Sensor Type Visible/UV Spectrometer Mission No. 7 Planet Saturn

Observation Objectives: Total Observation Worth = 2.95

SD70-24	Page C - 92 Worth = 0.50	Page C - 99 Worth = 0.30
	Page C - 96 Worth = 0.55	Page C - 104 Worth = 0.60
	Page C - 97 Worth = 0.70	

Capability Level	Maximum
Observation Requirements Level	Optimal
Trajectory Points:*	
Point	1
Characteristics	Max. Alt.
Time to periapsis (s)	-5.39E04**
Latitude (deg)	5.55
Longitude (deg)	46.4
Sun angle (deg)	23.4
Support Requirements:	
Mass (kg)	888.7
Average power (w)	4.20
Length (m)	4.41
Width (m)	1.0
Height (m)	1.0
Volume (m^3)	4.05
Data rate (bit/s)	1.62E04
Pointing accuracy (deg)	9.0
Pointing stability (deg/s)	3.8
Roll Rate limit (deg/s)	3.8
Scan Rate limit (deg/s)	7.82E03
Scan amplitude (deg)	8.90
Collecting optics diameter	1.0

Table 3-11. Sensor Support Requirements Summary (Cont)

Capability Parameters:	
Max. wavelength (λ_M) (μ)	1.0
Min. wavelength (λ_m) (μ)	0.1
Spectral resolution ($\Delta\lambda$) (μ)	1.E-05
Spatial resolution (m)	2.34E+05
Angular resolution (deg)	0.0168
Exposure time (sec)	-
Field/view length (km)	-
Swath width (km)	-
Area/frame (%)	1.2E-04
Total area (%)	67.1
Total Sensor Worth	1.1E-08
Notes: Number of detectors	2
Number of mirror faces	1
Detector type	Photomultiplier

*Extrema of all requirements not necessarily incurred at point listed
**-5.39E04 = -5.39×10^{-4}

4.0 SENSOR GROUPING

4.1 GROUPING METHODOLOGY

A sensor family is defined as the set of remote sensors that can perform required observations when operated on a common mission trajectory. Two levels of families can be defined, corresponding to the levels of observation and measurement requirements:

1. Optimal: each sensor is designed to meet the optimal measurement requirements, subject to limitations imposed by the sensor SOA and the trajectory.

2. Marginal: each sensor is designed to meet only the marginal measurement requirements.

Obviously, if a sensor type cannot be represented in a marginal family due to SOA limitations or mission constraints, that type will not be represented in the optimal family for that mission. Normally, no sensor in a family will be overdesigned relative to its measurement requirements, but in a few instances (e.g., particle and field sensors), the designs presented are more than adequate for the observations defined in Reference 1.

Families are defined without reference to interference between sensors. Potential interference problems are indicated in Sections 4.2.3 and 4.3.4.

The grouping procedure depends to some extent on the kind of mission.

4.1.1 Single-Planet Flybys

The trajectory is adjustable to permit optimization of the worth of a sensor or a family of sensors, subject to the approach trajectory and the requirement that the planet not be impacted. The procedure adopted is to determine the trajectory that optimizes area coverage and spatial resolution by the visible-light imaging (TV) sensor, as discussed in Section 3.3. An attempt is then made to apply the scaling laws to design imaging sensors of other types to meet the remaining imaging observation requirements applicable to the planet encountered. The sensors that can be so designed, together with the TV sensor, constitute the imaging sensor family for this trajectory, even though some of the non-TV imaging sensors are not optimized as to worth or support requirements by this trajectory (i.e., some other trajectory exists on which one or more of the sensors would more nearly attain the optimal observation requirements).

However, if a sensor type cannot meet at least the marginal observation requirements on this trajectory, a different trajectory could be determined to optimize the worth of this type. Two or more families of imaging sensors could then be defined for this mission: (1) the TV sensor and other sensors compatible with its trajectory, (2) the sensors incompatible with that trajectory, but compatible with some other allowed trajectory. This procedure was not needed in the study.

The non-imaging sensors were then designed for the trajectory used for the TV sensor, and (if they meet at least the marginal observation requirements) form an integrated family (see Section 4.2.2) with the TV sensor and the imaging sensors compatible with the TV.

Missions in this category for which sensor families were designed are (2) 1984 Mercury flyby and (3) 1980 Venus flyby. Since these are inner-planet flyby missions, only non-imaging sensors are within the scope of the study. The part of the above procedure that applies to imaging sensors was not used for these missions.

4.1.2 Multi-Planet Flybys

At all but the terminal planet on a multi-planet flyby trajectory, the trajectory is fixed by gravity-assisted swingby requirements. Either a sensor type can meet or exceed the marginal observation requirements from this trajectory, or it cannot. Usually, one of the encounters leads to greater mass than the other encounters, to meet the given levels of observation requirements at the respective planets. The sensor designed for this encounter is usually compatible with the other encounters, i.e., it can meet at least the marginal observation requirements at all planets.

It is possible that a sensor design optimized for one planet is incompatible with other planets, but it is nevertheless included in the family. If a different sensor of this type can be designed to be compatible with the other encounters, the family for the mission contains both sensors of this type. One sensor would be used at one or two planets, the other at the remaining planets. This situation did not occur in the study.

In the tables of compatible sensor families for multi-planet missions, the key support requirements are given for sensors designed for each encounter. The sensors belonging to the family, i.e., the one to be used at all encounters, is the one with the greatest mass. However, the power, data rate, data quantity, and sensor worth were calculated for a sensor designed for individual encounters. Therefore, the sensor used at all encounters (but designed for one encounter) will have a different data rate, data quantity, and worth at the other encounters.

The terminal planet encounter is not constrained by gravity-assist, and is treated as a single-planet flyby.

Missions in this category for which sensor families were defined are (6) 1982 Venus-Mercury, (7) 1976 Jupiter-Saturn, (9) 1978 Jupiter-Uranus-Neptune, and (12) 1978 Jupiter-Saturn-Pluto. Imaging sensor support requirements were computed only for encounters at Saturn, Uranus, and Neptune, so only one imaging sensor of each type is considered for Missions (7) and (12), and none for Mission (6) (see Table 3-3). Single-planet procedures are employed for imaging and non-imaging sensor families for Saturn in Mission (7) and Neptune in Mission (9). Observations at Pluto are outside the scope of this study, but the requirement to fly past Pluto is a constraint on the Saturn encounter in Mission (12).

4.1.3 Orbiters

Imaging sensor families were defined for orbiter missions at Mercury, Venus, Mars, and Jupiter in Reference 3. Ten orbits were considered at each inner planet, and 11 at Jupiter. In this study, two orbits were selected at each inner planet, and three at Jupiter, for which the greatest number of imaging sensor designs were determined. Non-imaging sensors were designed for use in these orbits, and, if they met the observation requirements, were grouped into a non-imaging sensor family for the given orbit. Details of the orbit selection are presented in Section 3.2.2.

4.2 SENSOR FAMILIES FOR INNER PLANETS AND JUPITER

Families of compatible sensors for missions to the inner planets, Mercury and Venus, and to Jupiter are described in this section. The non-imaging sensors are those selected and described during this study, and the imaging sensors are derived from the results of Contract NAS2-4494 (Reference 3). Non-imaging sensor families are described in Section 4.2.1, imaging sensor families in Section 4.2.2, and integrated (imaging and non-imaging) families are described in Section 4.2.3.

The general scientific observational purpose, some descriptive characteristic (preferably quantitative), the most significant support requirements, and the total worth of each sensor in each family are given. The total data quantity is simply the mean data acquisition rate multiplied by the time interval from first to last operation of the sensor at the given encounter. The sensor may be operated intermittently, so the data quantity may be overestimated. The worth of sensors in a marginal-capability family is, by definition, zero unless the sensor design exceeds the marginal measurement requirements.

4.2.1 Non-Imaging Sensor Families

Compatible families of non-imaging sensors for missions to the inner planets and Jupiter are described in Tables 4.2-1.1 through 4.2-1.14. The sensors included in these families have been selected for these applications during the course of this study, and the support requirements are determined by the scaling law techniques previously discussed. Sensor families are developed for the missions noted below and are described in the tables as indicated.

Mission	Table
1984 Earth-Mercury	4.2-1.1
1980 Earth-Venus	4.2-1.2
1982 Earth-Venus-Mercury	4.2-1.3
1976 Earth-Jupiter-Saturn	4.2-1.4
1978 Earth-Jupiter-Saturn-Pluto*	4.2-1.5
1984 Mercury Orbit No. 1	4.2-1.6
1984 Mercury Orbit No. 10	4.2-1.7
1977 Venus Orbit No. 1	4.2-1.8
1977 Venus Orbit No. 9	4.2-1.9
1984 Mars Orbit No. 1	4.2-1.10
1984 Mars Orbit No. 8	4.2-1.11
1978 Jupiter Orbit No. 1	4.2-1.12
1978 Jupiter Orbit No. 9	4.2-1.13
1978 Jupiter Orbit No. 11	4.2-1.14

In Tables 4.2-1.1 to 4.2-2.9, the family and measurement requirement level are indicated. Each sensor is described by number, name, a key design characteristic, and the observational objective that led to the largest sensor mass. The planet at which the most massive sensor is required is indicated (this is relevant to multi-planet flyby missions). "Tabulation" refers to a one-page sensor requirements summary table in Appendix A. The sensor worth is a relative measure of the quantitative support of observation requirements by the sensor on the given mission, and of the importance of the observation objectives. At the marginal measurement requirements level, the sensor worth is zero. Sensor worth is defined further in Reference 2.

*Pluto not within scope of study

Table 4.2-1.1. Sensor Family for 1984 Earth-Mercury Mission (2)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number*	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation**		
							Sheet	Page	
4.	Microwave Radiometer-Measuring Antenna diameter 25.12 m Surface composition	Mercury	1900	75	50	1.84×10^{5}	4-1	A-25	7.22×10^{-6}
7.	Flux-Gate Magnetometer Triaxial Interior composition	Mercury	2.1	6.0	1500	2.52×10^{7}	7-1	A-54	1.22
8.	Helium Magnetometer Interior composition	Mercury	3.4	10.0	40	67.2×10^{4}	8-1	A-55	1.22
9.	Scintillation Spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	100	1.68×10^{6}	9-1	A-57	0.69
11.	Electrostatic or Faraday Cup Analyzer Diameter 10 cm Interior composition	Mercury	8.7	8.7	420	7.05×10^{6}	11-1	A-58	0.15

Notes: *See Table 3-1.
**Refers to Appendix A.

Space Division
North American Rockwell

Table 4.2-1.1. Sensor Family for 1984 Earth-Mercury Mission (2) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
12.	Geiger-Mueller Counter Array 2 counters Interior composition	Mercury	1.0	0.40	30	5.04×10^5	12-1	A-61	0.79
13.	Proportional Counter Array 2 counters Interior composition	Mercury	5.0	1.0	50	8.4×10^5	13-1	A-63	0.31
15.	Filter Radiometer Collector diameter: 0.01 m Surface temperature	Mercury	5.0	67.0	3.4	12.5×10^3	15-1	A-65	9.85×10^{-2}
22.	Laser Radar Nd YAG Surface topography	Mercury	315	331	11.67	7.66×10^4	22-1	A-110	2.14×10^{-14}
26.	Solid-State Telescope 3 Si wafers Interior composition	Mercury	0.53	1.0	100	1.68×10^6	26-1	A-138	0.79

Notes:

Table 4.2-1.1. Sensor Family for 1984 Earth-Mercury Mission (2) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
27.	Li^6 I Spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	50	8.4×10^5	27-1	A-140	0.34
28.	Curved Plate Plasma Spectrometer 1 slit Interior composition	Mercury	5.5	7.5	512	8.6×10^6	28-1	A-142	0.15

Notes:

Table 4.2-1.1. Sensor Family for 1984 Earth-Mercury Mission (2) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave Radiometer-Measuring Antenna diameter 1.25 m Surface composition	Mercury	3.3	5.0	.054	101	4-1	A-25	0.0
7.	Flux-Gate Magnetometer Triaxial Interior composition	Mercury	2.1	6.0	1.5	2.52×10^4	7-1	A-54	0.0
8.	Helium Magnetometer Interior composition	Mercury	3.4	10.0	40	67.2×10^4	8-1	A-55	0.0
9.	Scintillation Spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	100	1.68×10^6	9-1	A-57	0.69
11.	Electrostatic or Faraday Cup Analyzer Diameter 10 cm Interior composition	Mercury	1.5	1.5	70	1.17×10^6	11-1	A-58	0.0

Notes:

Table 4.2-1.1. Sensor Family for 1984 Earth-Mercury Mission (2) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
12.	Geiger-Mueller Counter Array 2 counters Interior composition	Mercury	1.0	0.40	30	5.04×10^{5}	12-1	A-61	0.79
13.	Proportional Counter Array 2 counters Interior composition	Mercury	5.0	1.0	50	8.4×10^{5}	13-1	A-63	0.31
15.	Filter Radiometer Collector diameter: 0.01 m Surface temperature	Mercury	2.0	25.5	1.8×10^{-2}	33.6	15-1	A-65	0.00
22.	Laser Radar Nd YAG Surface topography	Mercury	315	331	11.67	7.66×10^{4}	22-1	A-110	2.14×10^{-14}
26.	Solid-State Telescope 3 Si wafers Interior composition	Mercury	0.53	1.0	100	1.68×10^{6}	26-1	A-138	0.79

Notes:

Table 4.2-1.1. Sensor Family for 1984 Earth-Mercury Mission (2) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
27.	Li^6 I Spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	50	8.4×10^5	27-1	A-140	0.34
28.	Curved Plate Plasma Spectrometer 1 slit Interior composition	Mercury	5.5	7.5	512	8.6×10^6	28-1	A-142	0.0

Notes:

Table 4.2-1.2. Sensor Family for 1980 Earth-Venus Mission (3)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
4.	Microwave Radiometer-Measuring Antenna diameter: 5.05 m Cloud temperature	Venus	91.36	45.2	5.26	14.3×10^{4}	4-2	A-26	2.48×10^{-7}
15.	Filter Radiometer Collector diameter: .0242 m Atmospheric temperature	Venus	6.58	87.0	26.3	7.35×10^{4}	15-2	A-46	1.64×10^{-9}
22.	Laser Radar Nd YAG Aerosol size and distribution	Venus	316.2	333.3	11.67	15.5×10^{5}	22-2	A-111	4.52×10^{-18}
23.	Bi-Frequency Radio Occultation Antenna diameter: 33.22 m Ionosphere density; figure	Venus	1658	5.0	88	6×10^{3}	23-1	A-126	1.92×10^{-3}

Notes:

Table 4.2-1.2. Sensor Family for 1980 Earth-Venus Mission (3) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
4.	Microwave Radiometer-Measuring Antenna diameter .25 m Cloud temperature	Venus	1.094	5.0	2.57×10^{-5}	2.57×10^{-2}	4-2	A-26	0.0
15.	Filter Radiometer Collector diameter: .01 m Atmospheric temperature	Venus	4.99	66.5	.189	5.3×10^{2}	15-2	A-46	0.0
22.	Laser Radar Nd YAG Aerosol size and distribution	Venus	316.2	333.3	11.67	15.5×10^{5}	22-2	A-111	4.52×10^{-18}
23.	Bi-Frequency Radio Occultation Antenna diameter: 33.22 m Ionosphere density; figure	Venus	1658	5.0	.063	60	23-1	A-126	0.0

Notes:

Table 4.2-1.3. Sensor Family for 1982 Earth-Venus-Mercury Mission (6)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave Radiometer-Measuring								
	Antenna diameter: 12.63 m (Venus)								
	Antenna diameter: 25.1 m (Mercury)	Venus	507.7	75.2	4.03	27.4×10^{4}	4-3	A-27	1.69×10^{-5}
	Cloud temperature Surface composition	Mercury	1930	75.2	39.4	17.3×10^{4}	4-4	A-28	7.55×10^{-7}
7.	Flux-Gate Magnetometer		2.1	6.0	1500	3.2×10^{7}	7-2 (7-1)	A-56 (A-54)	1.22
	Triaxial Interior composition	Mercury							
8.	Helium Magnetometer		3.4	10.0	40	8.56×10^{5}	8-2 (8-1)	A-56 (A-55)	1.22
	Interior composition	Mercury							
9.	Scintillation Spectrometer		0.9	2.0	100	2.14×10^{6}	9-2 (9-1)	(A-57)	0.69
	5 cm photomultiplier Surface composition	Mercury							

Notes:

Table 4.2-1.3. Sensor Family for 1982 Earth-Venus-Mercury Mission (6) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
11.	Electrostatic or Faraday Cup Analyzer		8.7	8.7	420	8.95×10^{6}	11-2 (11-1)	A-60 (A-59)	0.15
	Diameter: 10 cm Interior composition	Mercury							
12.	Geiger-Mueller Counter Array		1.0	.40	30	6.42×10^{5}	12-2 (12-1)	A-62 (A-61)	0.79
	2 counters Interior composition	Mercury							
13.	Proportional Counter Array		5.0	1.0	50	10.7×10^{5}	13-2 (13-1)	A-64 (A-63)	0.31
	2 counters Interior composition	Mercury							
15.	Filter Radiometer								
	Collector diameter: 3.17 cm (Venus) Collector diameter: 3.17 cm (Mercury)	Venus	6.68	87	97	24.4×10^{4}	15-4	A-68	1.91×10^{-12}
	Atmosphere temperature Surface temperature	Mercury	6.68	87	43	21.8×10^{3}	15-3	A-67	9.85×10^{-2}

Notes:

Table 4.2-1.3. Sensor Family for 1982 Earth-Venus-Mercury Mission (6) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
22.	Laser Radar	Venus	316.2	333.3	11.67	11×10^{4}	22-3	A-112	7.91×10^{-17}
	Nd YAG Aerosol size and distribution Surface topography	Mercury	307.4	315.1	11.67	8.8×10^{4}	22-4	A-113	2.14×10^{-14}
23.	Bi-Frequency Radio Occultation		1658	5.0	59	6×10^{3}	23-2	A-127	1.92×10^{-3}
	Antenna diameter: 33.22 m Ionosphere density; figure	Venus							
26.	Solid-State Telescope		.53	1.0	100	2.14×10^{6}	26-2 (26-1)	A-139 (A-138)	0.79
	3 Si wafers Interior composition	Mercury							
27.	Li^{6} I Spectrometer		0.9	2.0	50	10.7×10^{5}	27-2 (27-1)	A-141 (A-140)	0.34
	5 cm photomultiplier Interior composition	Mercury							
28.	Curved Plate Plasma Spectrometer		5.5	7.5	512	11×10^{6}	28-2 (28-1)	A-143 (A-142)	0.15
	1 slit Interior composition	Mercury							

Notes:

Table 4.2-1.3. Sensor Family for 1982 Earth-Venus-Mercury Mission (6) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave Radiometer-Measuring								
	Antenna diameter: 1.25 m (Venus) Antenna diameter: 1.25 m (Mercury)	Venus	3.34	5.0	8.57×10^{-6}	8.57×10^{-3}	4-3	A-27	0.0
	Cloud temperature Surface composition	Mercury	3.34	5.0	.044	100	4-4	A-28	0.0
7.	Flux-Gate Magnetometer		2.1	6.0	1.5	3.2×10^{4}	7-2 (7-1)	A-56 (A-54)	0.0
	Triaxial Interior composition	Mercury							
8.	Helium Magnetometer		3.4	10.0	40	8.6×10^{5}	8-2 (8-1)	A-56 (A-55)	0.0
	Interior composition	Mercury							
9.	Scintillation Spectrometer		0.9	2.0	100	2.14×10^{6}	9-2 (9-1)	(A-57)	0.69
	5 cm photomultiplier Surface composition	Mercury							

Notes:

Table 4.2-1.3. Sensor Family for 1982 Earth-Venus-Mercury Mission (6) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
11.	Electrostatic or Faraday Cup Analyzer		1.5	1.5	70	15×10^5	11-2 (11-1)	A-60 (A-59)	0.0
	Diameter: 10 cm Interior composition	Mercury							
12.	Geiger-Mueller Counter Array		1.0	.40	30	6.42×10^5	12-2 (12-1)	A-62 (A-61)	0.79
	2 counters Interior composition	Mercury							
13.	Proportional Counter Array		5.0	1.0	50	10.7×10^5	13-2 (13-1)	A-64 (A-63)	0.31
	2 counters Interior composition	Mercury							
15.	Filter Radiometer								
	Collector diameter: .01 m (Venus) Collector diameter: .01 m (Mercury)	Venus	4.99	66.5	.112	2.82×10^2	15-4	A-68	0.0
	Atmospheric temperature Surface temperature	Mercury	4.99	66.5	.316	160	15-3	A-67	0.0

Notes:

Table 4.2-1.3. Sensor Family for 1982 Earth-Venus-Mercury Mission (6) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
22.	Laser Radar								
	Nd YAG	Venus	316.23	333.3	11.67	$11.\times10^{4}$	22-3	A-112	7.91×10^{-17}
	Aerosol size and distribution								
	Surface topography	Mercury	307.4	315.08	11.67	8.84×10^{4}	22-4	A-113	2.14×10^{-14}
23.	Bi-Frequency Radio Occultation		1658	5.0	.049	60	23-2	A-127	0.0
	Antenna diameter: 33.22 m								
	Ionosphere density; figure	Venus							
26.	Solid-State Telescope		.53	1.0	100	2.14×10^{6}	26-2 (26-1)	A-139 (A-138)	0.79
	3 Si wafers								
	Interior composition	Mercury							
27.	Li^{6} I Spectrometer		.9	2.0	50	1.07×10^{6}	27-2 (27-1)	A-141 (A-140)	0.34
	5 cm photomultiplier								
	Interior composition	Mercury							
28.	Curved Plate Plasma Spectrometer		5.5	7.5	512	11×10^{6}	28-2 (28-1)	A-143 (A-142)	0.0
	1 slit								
	Interior composition	Mercury							

Notes:

Table 4.2-1.4. Sensor Family for 1976 Earth-Jupiter-Saturn Mission (7)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave Radiometer-Measuring								
	Antenna diameter: 5.05 m	Jupiter	91.36	45.2	2.9	57.8×10^{3}	4-5	A-29	1.84×10^{-9}
	Cloud structure and temperature	Saturn	43.25	34.5	.404	31.2×10^{3}	4-6	A-30	1.49×10^{-8}
7.	Flux-Gate Magnetometer								
	Triaxial	Jupiter	2.1	6.0	1500	1.82×10^{10}	7-2 (7-1)	A-56 (A-54)	1.22
	Interior composition and motion	Saturn	2.1	6.0	1500	1.53×10^{10}	7-2		1.22
8.	Helium Magnetometer								
	Interior composition and motion	Jupiter	3.4	10.0	40	4.84×10^{8}	8-2 (8-1)	A-56 (A-55)	1.22
19.	Michelson Radiometer								
	Antenna diameter: .984 m Atmospheric composition and pressure	Jupiter	1260	87	7.66×10^{3}	18.1×10^{7}	19-1 (15-5)	A-69 (A-69)	1.46×10^{-6}
	Atmospheric composition and pressure; ring composition	Saturn	1260	87	1.07×10^{3}	3.4×10^{7}	19-2 (15-6)	A-70 (A-70)	9.35×10^{-7}

Notes:

Table 4.2-1.4. Sensor Family for 1976 Earth-Jupiter-Saturn Mission (7) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
21.	Visible/UV Spectrometer								
	Collector diameter: 1.0 m	Jupiter	888.7	4.2	1.19×10^{5}	9.05×10^{9}	21-1	A-100	5×10^{-9}
	Atmospheric composition	Saturn	888.7	4.2	1.62×10^{4}	17.5×10^{8}	21-2	A-101	1.1×10^{-8}
22.	Laser Radar								
	Nd YAG	Jupiter	100	83.3	11.67	11.6×10^{4}	22-5	A-104	1.13×10^{-17}
	Aerosol size and distribution	Saturn	100	83.3	11.67	20.5×10^{4}	22-6	A-105	2.26×10^{-17}
23.	Bi-Frequency Radio Occultation								
	Antenna diameter: 33.22 m	Jupiter	1658	5.0	247.6	20×10^{3}	23-3	A-128	1.92×10^{-3}
	Ionosphere density; figure	Saturn	1658	5.0	225.8	20×10^{3}	23-4	A-129	1.92×10^{-3}

Notes:

Table 4.2-1.4. Sensor Family for 1976 Earth-Jupiter-Saturn Mission (7) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave Radiometer-Measuring								
	Antenna diameter: .860 m	Jupiter	2.11	5.0	.01	566	4-5	A-29	0.0
	Cloud structure and temperature	Saturn	2.11	5.0	8.49×10^{-3}	655	4-6	A-30	0.0
7.	Flux-Gate Magnetometer								
	Triaxial	Jupiter	2.1	6.0	1.5	1.53×10^{7}	7-2 (7-1)	A-56 (A-54)	0.0
	Interior composition and motion	Saturn	2.1	6.0	1.5	1.82×10^{7}	7-2 (7-1)	A-56 (A-54)	0.0
8.	Helium Magnetometer								
	Interior composition	Jupiter	3.4	10.0	40	4.84×10^{8}	8-2 (8-1)	A-56 (A-55)	0.0
15.	Filter Radiometer								
	Collector diameter; 2.3 cm	Jupiter	5.07	66.5	1.22	2.88×10^{4}	15-5	A-69	0.0
	Atmospheric temperature	Saturn	3.03	66.5	.0856	2.74×10^{3}	15-6	A-70	0.0
21.	Visible/UV Spectrometer								
	Collector diameter; 10 cm	Jupiter	2.08	4.2	.494	494	21-1	A-100	0.0
	Atmospheric composition	Saturn	2.08	4.2	.404	404	21-2	A-101	0.0

Notes:

Table 4.2-1.4. Sensor Family for 1976 Earth-Jupiter-Saturn Mission (7) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
22.	Laser Radar								
	Nd YAG								
	Aerosol size and distribution	Jupiter	100	83.3	11.67	11.7×10^4	22-5	A-114	1.13×10^{-17}
		Saturn	100	83.3	11.67	20.5×10^4	22-6	A-115	2.26×10^{-17}
23.	Bi-Frequency Radio Occultation								
	Antenna diameter: 33.22 m	Jupiter	1658	5.0	.165	200	23-3	A-128	0.0
	Ionosphere density; figure	Saturn	1658	5.0	.137	200	23-4	A-129	0.0

Notes:

Table 4.2-1.5. Sensor Family for 1978 Earth-Jupiter-Saturn-Pluto* Mission (12)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave Radiometer-Measuring								
	Antenna diameter: 12.6 m	Jupiter	507.7	75.2	33.88	4.67×10^{6}	4-10	A-34	4.29×10^{-9}
	Cloud structure and temperature	Saturn	507.7	75.2	6.02	7.44×10^{5}	4-11	A-35	3.76×10^{-8}
7.	Flux-Gate Magnetometer								
	Triaxial	Jupiter	2.1	6.0	1500	8.72×10^{9}	7-2 (7-1)	A-56 (A-54)	1.22
	Interior composition and motion	Saturn	2.1	6.0	1500	8.48×10^{9}	7-2 (7-1)	A-56 (A-54)	1.22
8.	Helium Magnetometer								
	Interior composition and motion	Jupiter	3.4	10.0	40	23.2×10^{7}	8-2	A-56	1.22
		Saturn	3.4	10.0	40	22.6×10^{7}	8-2 (8-1)	A-56 (A-55)	1.22
19.	Michelson Interferometer								
	Collector diameter: 100 cm Atmospheric composition and pressure	Jupiter	1320	87	1.66×10^{3}	11.5×10^{8}	19-6 (15-10)	A-74 (A-74)	1.17×10^{-7}
	Atmospheric composition and pressure; ring composition	Saturn	1320	87	866	6.85×10^{7}	19-7	A-75	1.33×10^{-7}

Notes:
*Pluto not within scope of study.

Table 4.2-1.5. Sensor Family for 1978 Earth-Jupiter-Saturn-Pluto* Mission (12) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
21.	Visible/UV Spectrometer								
	Collector diameter: 100 cm	Jupiter	974.4	4.2	1.83×10^4	4.76×10^8	21-6	A-105	5.6×10^{-9}
	Atmospheric composition	Saturn	974.4	4.2	2.19×10^4	6.8×10^8	21-7	A-106	9.55×10^{-9}
22.	Laser Radar								
	Nd YAG								
	Aerosol size and distribution	Saturn	316.2	333.3	11.67	3.38×10^5	22-10	A-119	1.13×10^{-17}
23.	Bi-Frequency Radio Occultation								
	Antenna diameter: 33.22 m								
	Ionosphere density; figure	Jupiter	1658	5.0	92.75	20×10^3	23-8	A-133	1.92×10^{-3}

Notes:
* Pluto not within scope of study.

Table 4.2-1.5. Sensor Family for 1978 Earth-Jupiter-Saturn-Pluto* Mission (12) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
4.	Microwave Radiometer-Measuring								
	Antenna diameter: 1.19 m	Jupiter	3.124	5.0	9.76×10^{-3}	683	4-10	A-34	0.0
	1.19 m (Jupiter)								
	.86 m (Saturn)								
	Cloud structure and temperature	Saturn	2.1	5.0	.004	496	4-11	A-35	0.0
7.	Flux-Gate Magnetometer								
	Triaxial	Jupiter	2.1	6.0	1.5	8.72×10^{6}	7-2 (7-1)	A-56 (A-54)	0.0
	Interior composition and motion	Saturn	2.1	6.0	1.5	8.49×10^{6}	7-2 (7-1)	A-56 (A-54)	0.0
8.	Helium Magnetometer								
	Interior composition and motion	Jupiter	3.4	10.0	40	23.2×10^{7}	8-2	A-56	0.0
		Saturn	3.4	10.0	40	22.6×10^{7}	8-2 (8-1)	A-56 (A-55)	0.0
15.	Filter Radiometer								
	Collector diameter: 20 cm	Jupiter	5.05	66.5	.0546	38.2×10^{3}	15-10	A-74	0.0
	Atmospheric temperature	Saturn	3.0	66.5	.0320	25.4×10^{2}	15-11	A-75	0.0

Notes:

*Pluto not within scope of study.

Table 4.2-1.5. Sensor Family for 1978 Earth-Jupiter-Saturn-Pluto* Mission (12) (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
21.	Visible/UV Spectrometer								
	Collector diameter: 10 cm	Jupiter	2.08	4.2	.475	475	21-6	A-105	0.0
	Atmosphere composition	Saturn	2.08	4.2	.482	482	21-7	A-106	0.0
22.	Laser Radar								
	Nd YAG								
	Aerosol size and distribution	Saturn	316.2	333.3	11.67	3.39×10^{5}	22-10	A-119	1.13×10^{-17}
23.	Bi-Frequency Radio Occultation								
	Antenna diameter: 33.22 m								
	Ionosphere density; figure	Jupiter	1658	5.0	.084	200	23-8	A-133	0.0

Notes:

*Pluto not within scope of study.

Table 4.2-1.6. Sensor Family for 1984 Mercury Orbit No. 1

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 25.1 m Surface composition	Mercury	1930.0	75.0	122.0	8.5×10^5	4-12	A-36	6.52×10^{-2}
7.	Flux-gate magnetometer Triaxial Interior composition	Mercury	2.1	6.0	1500.0	1.04×10^7	7-1	A-54	1.22
8.	Helium magnetometer Interior composition	Mercury	3.4	10.0	40.0	2.78×10^5	8-1	A-55	1.22
9.	Scintillation spectrometer 5 cm. photomultiplier Surface composition	Mercury	0.9	2.0	100.0	6.96×10^7	9-1	A-57	0.69
11.	Electrostatic or Faraday Cup analyzer Diameter: 10 cm Interior composition	Mercury	8.7	8.7	420.0	2.92×10^6	11-1	A-58	0.15
12.	Geiger-Mueller counter array 2 counters Interior composition	Mercury	1.0	0.4	30.0	2.09×10^5	12-1	A-61	0.79

Notes:

Table 4.2-1.6. Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
13.	Proportional counter array 2 counters Interior composition	Mercury	5.0	1.0	50.0	3.48×10^5	13-1	A-63	0.31
15.	Filter radiometer Collector diameter: 0.01 m	Mercury	4.8	67.0	1.0	6.96×10^3	15-12	A-76	1.55×10^{-2}
22.	Laser radar Nd YAG Surface topography	Mercury	116.0	44.9	11.67	8.15×10^4	22-11	A-120	2.14×10^{-5}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Mercury	1681.0	5.0	15.2	2×10^3	23-9	A-134	1.87×10^{-3}

Notes:

Table 4.2-1.6. Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
26.	Solid-state telescope 3 Si wafers Interior composition	Mercury	0.53	1.0	100.0	6.96×10^5	26-1	A-138	0.79
27.	Li^6 I spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	50.0	3.48×10^5	27-1	A-140	0.34
28.	Curved-plate plasma spectrometer 1 slit Interior composition	Mercury	5.5	7.5	512.0	3.56×10^6	28-1	A-142	0.15

Notes:

Table 4.2-1.6. Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
4.	Microwave radiometer-measuring Antenna diameter: 0.05 m Surface composition	Mercury	1.0	5.0	0.11	780.0	4-12	A-36	0.0
7.	Flux-gate magnetometer Triaxial Interior composition	Mercury	2.1	6.0	1.5	1.04×10^4	7-1	A-54	0.0
8.	Helium magnetometer Interior composition	Mercury	3.4	10.0	40.0	2.78×10^5	8-1	A-55	0.0
9.	Scintillation spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	100.0	6.96×10^5	9-1	A-57	0.69
11.	Electrostatic or Faraday Cup analyzer Diameter: 10 cm Interior composition	Mercury	1.5	1.5	70.0	4.87×10^5	11-1	A-58	0.0
12.	Geiger-Mueller counter array 2 counters Interior composition	Mercury	1.0	0.4	30.0	2.09×10^5	12-1	A-61	0.79

Notes:

Table 4.2-1.6. Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
13.	Proportional counter array 2 counters Interior composition	Mercury	5.0	1.0	50.0	3.48×10^5	13-1	A-63	0.31
15.	Filter radiometer Collector diameter: .01 m Surface temperature	Mercury	2.0	26.0	0.19	133.0	15-13	A-77	0.0
22.	Laser radar Nd YAG Surface topography	Mercury	116.0	44.9	11.67	8.15×10^4	22-11	A-120	2.14×10^{-5}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Mercury	1681.0	5.0	0.015	2	23-9	A-134	0.0

Notes:

Table 4.2-1.6. Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
26.	Solid-state telescope 3 Si wafers Interior composition	Mercury	0.53	1.0	100.0	6.96×10^5	26-1	A-138	0.79
27.	Li^6 I spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	50.0	3.48×10^5	27-1	A-140	0.34
28.	Curved-plate plasma spectrometer 1 slit Interior composition	Mercury	5.5	7.5	512.0	3.56×10^6	28-1	A-142	0.0

Notes:

Table 4.2-1.7. Sensor Family for 1984 Mercury Orbit No. 10

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 25.1 m	Mercury	1930.0	75.0	1.2	3.6×10^5	4-13	A-37	8.85×10^{-4}
7.	Flux-gate magnetometer Triaxial Interior composition	Mercury	2.1	6.0	1500.0	3.29×10^8	7-1	A-54	1.22
8.	Helium magnetometer Interior composition	Mercury	3.4	10.0	40.0	8.79×10^6	8-1	A-55	1.22
9.	Scintillation spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	100.0	2.2×10^7	9-1	A-57	0.69
11.	Electrostatic or Faraday Cup analyzer Diameter: 10 cm Interior composition	Mercury	8.7	8.7	420.0	9.23×10^7	11-1	A-58	0.15
12.	Geiger-Mueller counter array 2 counters Interior composition	Mercury	1.0	0.4	30.0	6.6×10^6	12-1	A-61	0.79

Notes:

Table 4.2-1.7. Sensor Family for 1984 Mercury Orbit No. 10 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
13.	Proportional counter array 2 counters Interior composition	Mercury	5.0	1.0	50.0	1.10×10^{7}	13-1	A-63	0.31
15.	Filter radiometer Collector diameter: 0.01 m	Mercury	4.8	67.0	84.5	1.87×10^{7}	15-13	A-77	9.9×10^{-2}
22.	Laser radar Nd YAG Surface topography	Mercury	314.0	328.9	11.67	1.27×10^{5}	22-12	A-121	2.14×10^{-5}
26.	Solid-state telescope 3 Si wafers Interior composition	Mercury	0.53	1.0	100.0	2.20×10^{7}	26-1	A-138	0.79
27.	Li^6 I spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	50.0	1.10×10^{7}	27-1	A-140	0.34
28.	Curved-plate plasma spectrometer 1 slit Interior composition	Mercury	5.5	7.5	512.0	1.12×10^{8}	28-1	A-142	0.15

Notes:

Table 4.2-1.7. Sensor Family for 1984 Mercury Orbit No. 10 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 0.09 m	Mercury	1.0	5.0	4.2×10^{-5}	9.0	4-13	A-37	0.0
7.	Flux-gate magnetometer Triaxial Interior composition	Mercury	2.1	6.0	1.5	3.29×10^{5}	7-1	A-54	0.0
8.	Helium magnetometer Interior composition	Mercury	3.4	10.0	40.0	8.79×10^{6}	8-1	A-55	0.0
9.	Scintillation spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	100.0	2.2×10^{7}	9-1	A-57	0.69
11.	Electrostatic or Faraday Cup analyzer Diameter: 10 cm Interior composition	Mercury	1.5	1.5	70.0	1.54×10^{7}	11-1	A-58	0.0
12.	Geiger-Mueller counter array 2 counters Interior composition	Mercury	1.0	0.4	30.0	6.60×10^{6}	12-1	A-61	0.79

Notes:

Table 4.2-1.7. Sensor Family for 1984 Mercury Orbit No. 10 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
13.	Proportional counter array 2 counters Interior composition	Mercury	5.0	1.0	50.0	1.10×10^7	13-1	A-63	0.31
15.	Filter radiometer Collector diameter: 0.01 m	Mercury	1.9	26.0	2.4×10^{-3}	540	15-13	A-77	0.0
22.	Laser radar Nd YAG Surface topography	Mercury	314.0	328.9	11.67	1.27×10^5	22-12	A-121	2.14×10^{-5}
26.	Solid-state telescope 3 Si wafers Interior composition	Mercury	0.53	1.0	100.0	2.20×10^7	26-1	A-138	0.79
27.	Li^6 I spectrometer 5 cm photomultiplier Surface composition	Mercury	0.9	2.0	50.0	1.10×10^7	27-1	A-140	0.34
28.	Curved-plate plasma spectrometer 1 slit Interior composition	Mercury	5.5	7.5	512.0	1.02×10^8	28-1	A-142	0.0

Notes:

Table 4.2-1.8. Sensor Family for 1977 Venus Orbit No. 1

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
4.	Microwave radiometer-measuring Antenna diameter: 12.6 m	Venus	51.0	75.2	924.0	5.54×10^{6}	4-14	A-38	1.87×10^{-2}
15.	Filter radiometer Collector diameter: 0.01 m	Venus	4.8	67.0	139.0	8.3×10^{5}	15-14	A-78	1.65×10^{-6}
22.	Laser radar Nd YAG Surface topography	Venus	100.0	83.3	11.67	7.03×10^{4}	22-13	A-122	1.63×10^{-12}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Venus	1681.0	5.0	26.2	6×10^{3}	23-10	A-135	1.87×10^{-3}

Notes:

Table 4.2-1.8. Sensor Family for 1977 Venus Orbit No. 1 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 0.05 m	Venus	1.0	5.0	0.29	1730.0	4-14	A-38	0.0
15.	Filter radiometer Collector diameter: 0.01 m	Venus	4.8	67.0	0.09	540.0	15-14	A-78	0.0
22.	Laser radar Nd YAG Surface topography	Venus	100.0	83.3	11.67	7.03×10^4	22-13	A-122	1.63×10^{-12}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Venus	1681.0	5.0	0.024	6.0	23-10	A-135	0.0

Notes:

Table 4.2-1.9. Sensor Family for 1977 Venus Orbit No. 9

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave radiometer Antenna diameter: 12.6 m	Venus	508.0	75.0	3.2	1.88×10^5	4-15	A-39	1.18×10^{-2}
15.	Filter radiometer Collector diameter: 0.06 m	Venus	6.0	67.0	754.0	4.8×10^7	15-15	A-79	1.80×10^{-6}
22.	Laser radar Nd YAG Surface topography	Venus	100.0	83.3	11.67	2.95×10^4	22-14	A-123	1.13×10^{-12}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Venus	1681.0	5.0	68.6	6×10^3	23-11	A-136	1.87×10^{-3}

Notes:

Table 4.2-1.9. Sensor Family for 1977 Venus Orbit No. 9 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 0.074 m	Venus	1.0	5.0	2.6×10^{-4}	16.0	4-15	A-39	0.0
15.	Filter radiometer Collector diameter: 0.01 m	Venus	4.8	67.0	3.7×10^{-3}	232.0	15-15	A-79	0.0
22.	Laser radar Nd YAG Surface topography	Venus	100.0	83.3	11.67	2.95×10^{4}	22-14	A-123	1.13×10^{-12}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Venus	1681.0	5.0	0.023	6.0	23-11	A-136	0.0

Notes:

Table 4.2-1.10. Sensor Family for 1984 Mars Orbit No. 1

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
4.	Microwave radiometer-measuring Antenna diameter: 12.6 m	Mars	508.0	75.0	88.9	7.82×10^{5}	4-16	A-40	3.25×10^{-2}
9.	Scintillation spectrometer 5 cm photomultiplier	Mars	0.9	2.0	100.0	8.82×10^{5}	9-1	A-57	0.69
15.	Filter radiometer Collector diameter: 0.01 m	Mars	4.8	67.0	3.59	3.16×10^{4}	15-16	A-80	3.16×10^{4}
22.	Laser radar Nd YAG Surface topography	Mars	97.98	32.0	11.67	1.03×10^{4}	22-15	A-124	1.05×10^{-11}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Mars	1681.0	5.0	20.1	10^{4}	23-12	A-137	1.87×10^{-3}

Notes:

Table 4.2-1.10. Sensor Family for 1984 Mars Orbit No. 1 (Cont)

[ ] Imaging [X] Non-imaging [ ] Integrated sensor family
[ ] Optimal [X] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 0.05 m	Mars	1.0	5.0	0.06	531.0	4-16	A-40	0.0
9.	Scintillation spectrometer 5 cm photomultiplier Surface composition	Mars	0.9	2.0	100.0	8.82×10^5	9-1	A-57	0.69
15.	Filter radiometer Collector diameter: 0.01 m	Mars	4.8	67.0	0.022	20.0	15-16	A-80	0.0
22.	Laser radar Nd YAG Surface topography	Mars	97.98	32.0	11.67	1.03×10^4	22-15	A-124	1.05×10^{-11}
23.	Bi-frequency radio occultation Antenna diameter: 33.2 m; freq. No. 1 3.9 m; freq. No. 2	Mars	1681.0	5.0	0.02	10.0	23-12	A-137	0.0

Notes:

Table 4.2-1.11. Sensor Family for 1984 Mars Orbit No. 8

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 12.6 m	Mars	508.0	75.0	16.5	4.32×10^{5}	4-17	A-41	7.67×10^{-3}
9.	Scintillation spectrometer 5 cm photomultiplier Surface composition	Mars	0.9	2.0	100.0	2.96×10^{6}	9-1	A-57	0.69
15.	Filter radiometer Collector diameter: 0.01 m	Mars	4.8	67.0	28.6	8.46×10^{5}	15-17	A-81	1.81×10^{-6}
22.	Laser radar Nd YAG Surface topography	Mars	243.7	197.9	11.67	3.47×10^{5}	22-16	A-125	4.65×10^{-12}

Notes:

Table 4.2-1.11. Sensor Family for 1984 Mars Orbit No. 8 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
4.	Microwave radiometer-measuring Antenna diameter: 0.13 m	Mars	1.0	5.0	3.3×10^{-3}	93.0	4-17	A-41	0.0
9.	Scintillation spectrometer 5 cm photomultiplier Surface composition	Mars	0.9	2.0	100.0	2.96×10^{6}	9-1	A-57	0.69
15.	Filter interferometer Collector diameter: 0.01 m	Mars	4.8	67.0	2.6×10^{-3}	79.0	15-17	A-81	0.0
22.	Laser radar Nd YAG Surface topography	Mars	243.7	197.9	11.67	3.47×10^{5}	22-16	A-125	4.65×10^{-12}

Notes:

Table 4.2-1.12. Sensor Family for 1978 Jupiter Orbit No. 1

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 12.6 m	Jupiter	508.0	75.0	3.5	4.95×10^5	4-18	A-42	6.24×10^{-5}
7.	Flux-gate magnetometer Triaxial	Jupiter	2.1	6.0	1500.0	2.13×10^8	7-1	A-54	1.22
8.	Helium magnetometer Interior composition	Jupiter	3.4	10.0	40.0	5.68×10^7	8-1	A-55	1.22
19.	Michelson interferometer Collector diameter: 1.0 m	Jupiter	1960.0	67.0	4360.0	6.2×10^8	19-8 (15-18)	A-81 (A-81)	1.01×10^{-7}
21.	Visible/UV spectrometer Collector diameter: 0.5 m	Jupiter	166.9	4.2	1.76×10^4	1.55×10^{10}	21-8	A-107	6.84×10^{-10}

Notes:

Table 4.2-1.12. Sensor Family for 1978 Jupiter Orbit No. 1 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements				Tabulation		Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Sheet	Page	
4.	Microwave radiometer-measuring Antenna diameter: 0.69 m	Jupiter	1.7	5.0	8.8×10^{-4}	125.0	4-18	A-42	0.0
7.	Flux-gate magnetometer Triaxial Interior composition and motion	Jupiter	2.1	6.0	1.5	2.13×10^{5}	7-1	A-54	0.0
8.	Helium magnetometer Interior composition	Jupiter	3.4	10.0	40.0	5.68×10^{7}	8-1	A-55	0.0
15.	Filter radiometer Collector diameter:	Jupiter	5.0	67.0	0.049	6940.0	15-18	A-82	0.0
21.	Visible/UV spectrometer Collector diameter: 0.1 m	Jupiter	2.12	4.2	0.12	1.06×10^{4}	21-8	A-107	0.0

Notes:

Table 4.2-1.13. Sensor Family for 1978 Jupiter Orbit No. 9

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
4.	Microwave radiometer-measuring Antenna diameter: 12.6 m	Jupiter	508.0	75.0	0.90	1.68×10^5	4-19	A-43	6.02×10^{-5}
7.	Flux-gate magnetometer Triaxial Interior composition and motion	Jupiter	2.1	6.0	1500.0	3.36×10^8	7-1	A-54	1.22
8.	Helium magnetometer Interior composition	Jupiter	3.4	10.0	40.0	8.96×10^6	8-1	A-55	1.22
19.	Michelson interferometer Collector diameter: 1.0 m	Jupiter	2070.0	67.0	4450.0	9.97×10^8	19-9 (15-19)	A-83 (A-83)	1.01×10^{-7}
21.	Visible/UV spectrometer Collector diameter: 1.0 m	Jupiter	1215.0	4.2	1.6×10^4	6.75×10^9	21-9	A-108	6.84×10^{-10}

Notes:

Table 4.2-1.13. Sensor Family for 1978 Jupiter Orbit No. 9 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 1.9 m	Jupiter	6.5	5.0	1.5×10^{-4}	33.0	4-19	A-43	0.0
7.	Flux-gate magnetometer Triaxial Interior composition and motion	Jupiter	2.1	6.0	1.5	3.36×10^5	7-1	A-54	0.0
8.	Helium magnetometer Interior composition	Jupiter	3.4	10.0	40.0	8.96×10^6	8-1	A-55	0.0
15.	Filter radiometer Collector diameter: 0.17 m	Jupiter	24.0	67.0	0.014	3070.0	15-19	A-83	0.0
21.	Visible/UV spectrometer Collector diameter: 0.1 m	Jupiter	1.96	4.2	0.013	5.37×10^3	21-9	A-108	0.0

Notes:

Table 4.2-1.14. Sensor Family for 1978 Jupiter Orbit No. 11

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave radiometer-measuring Antenna diameter: 12.6 m	Jupiter	508.0	75.0	3.2	7.91×10^{5}	4-20	A-44	6.23×10^{-5}
7.	Flux-gate magnetometer Triaxial Interior composition and motion	Jupiter	2.1	6.0	1500.0	3.71×10^{8}	7-1	A-54	1.22
8.	Helium magnetometer Interior composition	Jupiter	3.4	10.0	40.0	9.92×10^{6}	8-1	A-55	1.22
19.	Michelson interferometer Collector diameter: 1.0 m	Jupiter	1990.0	67.0	1390.0	3.45×10^{8}	19-10 (15-20)	A-84 (A-84)	1.01×10^{-7}
21.	Visible/UV spectrometer Collector diameter: 0.5	Jupiter	193.0	4.2	9.65×10^{3}	1.29×10^{9}	21-10	A-109	1.37×10^{-9}

Notes:

Table 4.2-1.14. Sensor Family for 1978 Jupiter Orbit No. 11 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
4.	Microwave radiometer-measuring Antenna diameter: 0.95 m	Jupiter	2.4	5.0	6.2×10^{-4}	155.0	4-20	A-44	0.0
7.	Flux-gate magnetometer Triaxial Interior composition and motion	Jupiter	2.1	6.0	1.5	3.71×10^5	7-1	A-54	0.0
8.	Helium magnetometer Interior composition	Jupiter	3.4	10.0	40.0	9.92×10^6	8-1	A-55	0.0
15.	Filter radiometer Collector diameter: 0.028 m	Jupiter	5.0	67.0	0.03	7500.0	15-20	A-84	0.0
21.	Visible/UV spectrometer Collector diameter: 0.1 m	Jupiter	2.12	4.2	0.062	8.33×10^3	21-10	A-109	0.0

Notes:

4.2.2 Imaging Sensor Families

Families of imaging sensors for selected orbiter missions to the inner planets and Jupiter are described in Tables 4.2-2.1 through 4.2-2.9. The requirements for these sensors, their operational characteristics, and their support requirements are described in detail in Reference 3. The support requirements data have been extracted from Reference 3 and are presented in the Support Requirements Data Sheets (Appendix A) with conversion of units as necessary to provide uniformity in the summary tabulations. Imaging sensor designs were evaluated in Reference 3 only for the optimal observational requirements. Therefore, imaging sensor families for the orbiter missions are described here only for this level. These imaging sensor families are developed for the missions noted below.

Mission	Table
1984 Mercury Orbit No. 1	4.2-2.1
1984 Mercury Orbit No. 10	4.2-2.2
1977 Venus Orbit No. 1	4.2-2.3
1977 Venus Orbit No. 9	4.2-2.4
1984 Mars Orbit No. 1	4.2-2.5
1984 Mars Orbit No. 8	4.2-2.6
1978 Jupiter Orbit No. 1	4.2-2.7
1978 Jupiter Orbit No. 9	4.2-2.8
1978 Jupiter Orbit No. 11	4.2-2.9

In Reference 3, imaging sensor families were developed on the basis of orbital inclination as well as the periapsis altitude and eccentricity which correspond to orbit type numbers. In Tables 4.2-2.1 to 4.2-2.9, inclination was ignored, but the non-imaging sensors designed for these orbits (Tables 4.2-1.6 to 4.2-1.14) are based on the inclinations given in Table 3-5. It is possible to select an imaging sensor family for a single orbit size and inclination from Reference 3, and design non-imaging sensors for this inclination. However, the non-imaging sensor support requirements generally depend little on orbital inclination. Therefore, the procedure followed in this study results in nearly the same sensor designs as those based on matching of orbital inclinations.

Table 4.2-2.1 Sensor Family for 1984 Mercury Orbit No. 1

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
1.	Television System 11.43 cm RBV Topography; figure	Mercury	86.3	87.0	5.4×10^7		1-5	A-6	
2.	Camera System Film size: 24.13 cm. Topography; figure	Mercury	272.4	110	1.2×10^8		2-1	A-15	
3.	Passive Microwave Imaging System Antenna diameter: 6.4 m Surface composition	Mercury	217.5	100	2.1×10^3		3-5	A-22	
5.	Synthetic Aperture Radar Antenna shape: 4.8 m. x 10.1 m. Surface roughness	Mercury	290.6	3300	3.3×10^7		5-5	A-49	
6.	Non-coherent Radar System Antenna shape: 45.7 m. x 0.21 m. Surface roughness	Mercury	87.2	110	3.6×10^3		6-1	A-51	

Notes:

Table 4.2-2.1 Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family

[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
16.	Infrared Scanning System Collector diameter: 30 cm. Surface temperature	Mercury	34.96	4.0	1.1×10^6		16-5	A-89	
18.	Ultraviolet Scanning System Collector diameter: 26 cm. Atmospheric and surface composition	Mercury	23.15	1.0	1.3×10^6		18-1	A-95	

Notes:

Table 4.2-2.1 Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Support Requirements: Power (w)	Support Requirements: Data Rate (bit/sec)	Support Requirements: Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
1.	Television System 1.27 cm Vidicon Topography; figure	Mercury	3.6	8.0	3.9×10^3		1-5	A-6	
2.	Camera System Film size: 70 mm. Topography, figure	Mercury	28.6	36	2.5×10^6		2-1	A-15	
3.	Passive Microwave Imaging System Antenna size: 6.4 m. Surface composition	Mercury	217.5	100	2.1×10^3		3-5	A-22	
5.	Synthetic Aperture Radar System Antenna shape: 10.1 m. x 1.0 m. Surface roughness	Mercury	145.2	1300	9.6×10^5		5-5	A-49	
6.	Non-coherent Radar System Antenna shape: 6.86 m. x 0.21 m. Surface roughness	Mercury	70.4	120	760		6-1	A-51	

Notes:

Table 4.2-2.1 Sensor Family for 1984 Mercury Orbit No. 1 (Cont)

☒ Imaging ☐ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
16.	Infrared Scanning System Collector diameter: 1 cm. Surface temperature	Mercury	.91	4.0	1.1×10^4		16-5	A-89	
18.	Ultraviolet Scanning System Collector diameter: 0.24 m. Atmospheric and surface composition	Mercury	1.0	1.0	1.1×10^4		18-1	A-95	

Notes:

Table 4.2-2.2 Sensor Family for 1984 Mercury Orbit No. 10

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
1.	Television System 5.08 cm. RBV Topography; figure	Mercury	14.5	32	1.1×10^6		1-6	A-7	
16.	Infrared Scanning System Collector diameter: 4 cm. Surface temperature	Mercury	5.0	7.0	1.2×10^4		16-6	A-99	
18.	Ultraviolet Scanning System Collector diameter: 1.7 cm. Atmospheric and surface composition	Mercury	1.04	1.0	1.7×10^5		18-2	A-96	

Notes:

Table 4.2-2.3 Sensor Family for 1977 Venus Orbit No. 1

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
1.	Television System 3.81 cm. Vidicon Cloud structure	Venus	10.9	24.0	1.3×10^4		1-7	A-18	
3.	Passive Microwave Imaging System Antenna diameter: 0.61 m. Cloud temperature	Venus	16.8	72	440		3-6	A-23	
5.	Synthetic Aperture Radar System Antenna shape: 0.34 m. x 100.7 m Surface roughness	Venus	308.7	5.4×10^6	7.1×10^8		5-6	A-50	
6.	Non-coherent Radar System Antenna shape: 67.1 m. x 0.20 m. Surface roughness	Venus	136.2	540	6.3×10^4		6-2	A-52	
16.	Infrared Scanning System Collector diameter: 5.3 cm. Atmospheric temperature	Venus	3.18	3.0	1.4×10^4		16-7	A-91	
18.	Ultraviolet Scanning System Collector diameter: 0.3 cm. Atmospheric composition	Venus	1.0	1.0	3×10^4		18-3	A-97	

Notes:

Table 4.2-2.4 Sensor Family for 1977 Venus Orbit No. 9

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
1.	Television System 5.08 cm RBV Cloud structure	Venus	14.5	32	7.2×10^5		1-8	A-9	
16.	Infrared Scanning System Collector diameter: 2.8 cm. Atmospheric temperature	Venus	1.68	2.1	8.2×10^3		16-8	A-92	
18.	Ultraviolet Scanning System Collector diameter; 4.6 cm. Atmospheric composition	Venus	1.36	1.0	7.6×10^5		18-4	A-98	

Notes:

Table 4.2-2.5 Sensor Family for 1984 Mars Orbit No. 1

☒ Imaging ☐ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
1.	Television System 5.08 cm. RBV Topography; figure	Mars	14.5	32	3.8×10^5		1-9	A-10	
2.	Camera System Film size: 70mm Topography; figure	Mars	11.35	36	6.9×10^5		2-2	A-16	
3.	Passive Microwave Imaging System Antenna size: 10.1 m. Surface composition	Mars	547.1	110	1.4×10^3		3-7	A-24	
6.	Non-coherent Radar System Antenna shape: 58.0 m x 0.37 m. Surface roughness	Mars	172.5	140	2.2×10^4		6-3	A-53	

Notes:

Table 4.2-2.5 Sensor Family for 1984 Mars Orbit No. 1 (Cont)

☐ Imaging ☐ Non-imaging ☐ Integrated sensor family
☐ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
16.	Infrared Scanning System Collector diameter: 6.3 cm. Atmospheric and surface temperature	Mars	2.6	1.5	3250		16-9	A-93	
18.	Ultraviolet Scanning System Collector diameter: 0.07 cm. Atmospheric composition	Mars	1.0	1.0	430		18-5	A-99	

Notes:

Table 4.2-2.6 Sensor Family for 1984 Mars Orbit No. 8

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
1.	Television System 5.08 cm. RBV Topography; figure	Mars	163.4	47	2.4×10^8		1-10	A-11	
2.	Camera System Film size: 24.13 cm. Topography; figure	Mars	263.3	280	1.2×10^9		2-3	A-17	

Notes:

Table 4.2-2.7 Sensor Family for 1978 Jupiter Orbit No. 1

☒ Imaging ☐ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
1.	Television System 5.08 cm. RBV Cloud structure and motion; figure	Jupiter	127.1	32	3.8×10^5		1-11	A-12	

Notes:

Table 4.2-2.8 Sensor Family for 1978 Jupiter Orbit No. 9

☒ Imaging ☐ Non-imaging ☐ Integrated sensor family

☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
1.	Television System 5.08 cm. RBV Cloud structure and motion; figure	Jupiter	20.4	32	3.8×10^5		1-12	A-13	
16.	Infrared Scanning System Collector diameter: 82 cm Atmospheric temperature	Jupiter	726.4	28	1.2×10^6		16-10	A-94	

Notes:

Table 4.2-2.9 Sensor Family for Jupiter Orbit No. 11 (Cont)

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
1.	Television System 5.08 cm. RBV Cloud structure and motion; figure	Jupiter	25	32	3.8×10^5		1-13	A-14	

Notes:

4.2.3 Integrated Sensor Families

Integrated imaging and non-imaging sensor families for missions to the inner planets and Jupiter are described in Tables 4.2-3.1 through 4.2-3.14. The pertinent data for each non-imaging and each imaging sensor family are presented in paragraphs 4.2.1 and 4.2.2, and the pertinent tables are referenced in each instance. Integrated sensor families are developed for the families noted below.

Mission	Table
1984 Earth-Mercury	4.2-3.1
1980 Earth-Venus	4.2-3.2
1982 Earth-Venus-Mercury	4.2-3.3
1976 Earth-Jupiter-Saturn	4.2-3.4
1978 Earth-Jupiter-Saturn-Pluto*	4.2-3.5
1984 Mercury orbit No. 1	4.2-3.6
1984 Mercury orbit No. 10	4.2-3.7
1977 Venus orbit No. 1	4.2-3.8
1977 Venus orbit No. 9	4.2-3.9
1984 Mars orbit No. 1	4.2-3.10
1984 Mars orbit No. 8	4.2-3.11
1978 Jupiter orbit No. 1	4.2-3.12
1978 Jupiter orbit No. 9	4.2-3.13
1978 Jupiter orbit No. 11	4.2-3.14

*Pluto not within scope of study

For each of these missions, the sensor data for imaging and non-imaging sensors have been developed and tabulated previously. To avoid duplication, the summarized data are not repeated again; reference is given to the original summary table in each instance.

Table 4.2-3.1. Integrated Sensor Family for 1984
Earth-Mercury Mission No. 2

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
9.	Scintillation spectrometer
11.	Electrostatic or Faraday Cup analyzer
12.	Geiger-Mueller counter array
13.	Proportional counter array
15.	Filter radiometer
22.	Laser radar
26.	Solid-state telescope
27.	Li^6I spectrometer
28.	Curved plate plasma spectrometer
MARGINAL MEASUREMENT REQUIREMENTS	
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
9.	Scintillation spectrometer
11.	Electrostatic or Faraday Cup analyzer
12.	Geiger-Mueller counter array
13.	Proportional counter array
15.	Filter radiometer
22.	Laser radar
26.	Solid-state telescope
27.	Li^6I spectrometer
28.	Curved plate plasma spectrometer

Note: Sensor data for non-imaging sensors given in Table 4.2-1.1; imaging sensors for this mission not within scope of study.

Table 4.2-3.2. Integrated Sensor Family for 1980
Earth-Venus Mission No. 3

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
4.	Microwave radiometer - measuring
15.	Filter radiometer
21.	Visible/UV spectrometer
23.	Bi-frequency radio occultation
MARGINAL MEASUREMENT REQUIREMENTS	
4.	Microwave radiometer - measuring
15.	Filter radiometer
21.	Visible/UV spectrometer
23.	Bi-frequency radio occultation
Note: Sensor data for non-imaging sensors given in Table 4.2-1.2; imaging sensors for this mission not within scope of study.	

Table 4.2-3.3. Integrated Sensor Family for 1982
Earth-Venus-Mercury Mission No. 6

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
9.	Scintillation spectrometer
11.	Electrostatic or Faraday Cup analyzer
12.	Geiger-Mueller counter array
13.	Proportional counter array
15.	Filter radiometer
22.	Laser radar
23.	Bi-frequency radio occultation
26.	Solid state telescope
27.	Li^6I spectrometer
28.	Curved plate plasma spectrometer
MARGINAL MEASUREMENT REQUIREMENTS	
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
9.	Scintillation spectrometer
11.	Electrostatic or Faraday Cup analyzer
12.	Geiger-Mueller counter array
13.	Proportional counter array
15.	Filter radiometer
22.	Laser radar
23.	Bi-frequency radio occultation
26.	Solid state telescope
27.	Li^6I spectrometer
28.	Curved plate plasma spectrometer
Note: Sensor data for non-imaging sensors given in Table 4.2-1.3; imaging sensors for this mission not within scope of study.	

Table 4.2-3.4. Integrated Sensor Family for 1976
Earth-Jupiter-Saturn Mission No. 7

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
16.	Far IR radiometer
19.	Michelson interferometer (b)
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation
MARGINAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
15.	Filter radiometer (b)
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.4; imaging sensor data given in Table 4.3-1.1.

Table 4.2-3.5. Integrated Sensor Family for 1978
Earth-Jupiter-Saturn-Pluto* Mission No. 12

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
16.	Far IR radiometer
19.	Michelson interferometer (b)
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation
MARGINAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
15.	Filter radiometer
16.	Far IR radiometer (b)
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation

*Pluto not within scope of study.

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.5; data for imaging sensors in Table 4.3-1.3.

Table 4.2-3.6. Integrated Sensor Family for 1984
Mercury Orbit No. 1

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
2.	Camera system
3.	Passive microwave imaging system (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
6.	Non-coherent radar system (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
9.	Scintillation spectrometer
11.	Electrostatic or Faraday Cup analyzer
12.	Geiger-Mueller counter array
13.	Proportional counter array
15.	Filter radiometer (b)
16.	Infrared scanning system (b)
18.	Ultraviolet scanning system
22.	Laser radar (b*)
23.	Bi-frequency radio occultation
26.	Solid-state telescope
27.	Li^6 I spectrometer
28.	Curved-plate plasma spectrometer

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.6; data for imaging sensors given in Table 4.2-2.1.

Table 4.2-3.7. Integrated Sensor Family for 1984
Mercury Orbit No. 10

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
9.	Scintillation spectrometer
11.	Electrostatic or Faraday Cup analyzer
12.	Geiger-Mueller counter array
13.	Proportional counter array
15.	Filter radiometer (a)
16.	Infrared scanning system (a)
18.	Ultraviolet scanning system
22.	Laser radar (a*)
26.	Solid-state telescope
27.	Li^6 I spectrometer
28.	Curved-plate plasma spectrometer

(a) Operational incompatibility caused by (a*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.7; data for imaging sensors given in Table 4.2-2.2.

Table 4.2-3.8. Integrated Sensor Family for 1977
Venus Orbit No. 1

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
3.	Passive microwave imaging system (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar system (a*)
6.	Non-coherent radar system (a*)
15.	Filter radiometer (b)
16.	Infrared scanning system (b)
18.	Ultraviolet scanning system
22.	Laser radar (b*)
23.	Bi-frequency radio occultation

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.8; data for imaging sensors given in Table 4.2-2.3.

Table 4.2-3.9. Integrated Sensor Family for 1977
Venus Orbit No. 9

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
15.	Filter radiometer (a)
16.	Infrared scanning system (a)
18.	Ultraviolet scanning system
22.	Laser radar (a*)
23.	Bi-frequency radio occultation

(a) Operational incompatibility caused by (a*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.9; data for imaging sensors given in Table 4.2-2.4.

Table 4.2-3.10. Integrated Sensor Family for 1984
Mars Orbit No. 1

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
2.	Camera system
3.	Passive microwave imaging system (a)
4.	Microwave radiometer - measuring (a)
6.	Non-coherent radar system (a*)
9.	Scintillation spectrometer
15.	Filter radiometer (b)
16.	Infrared scanning system (b)
18.	Ultraviolet scanning system
22.	Laser radar (b*)
23.	Bi-frequency radio occultation

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.10; data for imaging sensors given in Table 4.2-2.5.

Table 4.2-3.11. Integrated Sensor Family for 1984
Mars Orbit No. 8

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
2.	Camera system
4.	Microwave radiometer - measuring
9.	Scintillation spectrometer
15.	Filter radiometer (a)
22.	Laser radar (a*)

(a) Operational incompatibility caused by (a*)

Note: Sensor data for non-imaging sensors given in Table 4.2-1.11; data for imaging sensors given in Table 4.2-2.6.

Table 4.2-3.12. Integrated Sensor Family for 1978
Jupiter Orbit No. 1

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
19.	Michelson interferometer
21.	Visible/UV spectrometer
Note: Sensor data for non-imaging sensors given in Table 4.2-1.12; data for imaging sensors given in Table 4.2-2.7.	

Table 4.2-3.13. Integrated Sensor Family for 1978
Jupiter Orbit No. 9

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
16.	Infrared scanning system
19.	Michelson interferometer
21.	Visible/UV spectrometer

Note: Sensor data for non-imaging sensors given in Table 4.2-1.13; data for imaging sensors given in Table 4.2-2.8.

Table 4.2-3.14. Integrated Sensor Family for 1978
Jupiter Orbit No. 11

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
19.	Michelson interferometer
21.	Visible/UV spectrometer
Note: Sensor data for non-imaging sensors given in Table 4.2-2.9.	

4.3 SENSOR FAMILIES FOR OUTER PLANETS

4.3.1 Imaging Sensor Families

Compatible families of imaging sensors for missions to the outer planets, including Jupiter, are described in Tables 4.3-1.1 through 4.3-1.3, and 4.2-2.7 through 4.2-2.9. The imaging sensors for the flyby missions are developed from the present effort; the imaging sensors for the Jupiter orbit missions are developed from Reference 3, and apply only to optimal measurement requirements. These imaging sensor families are developed for the missions noted below and are described in the tables as indicated.

Mission	Table
1976 Earth-Jupiter-Saturn	4.3-1.1
1978 Earth-Jupiter*-Uranus-Neptune	4.3-1.2
1978 Earth-Jupiter-Saturn-Pluto*	4.3-1.3
1978 Jupiter orbit No. 1	4.2-2.7
1978 Jupiter orbit No. 9	4.2-2.8
1978 Jupiter orbit No. 11	4.2-2.9

*Encounter not within scope of study

Note that the imaging sensor families for the orbit missions to Jupiter have been described previously in Section 4.2.2. The tables pertinent to these families are not repeated here but are referenced in the above listing.

Table 4.3-1.1. Sensor Family for 1976 Earth-Jupiter*-Saturn Mission No. 7

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
1.	Television Camera Vidicon; Tube diameter: 9.1 cm Cloud structure and motion; figure; ring structure	Saturn	193.5	57.3	1.07×10^{7}	2.43×10^{11}	1-1	A-2	7.95×10^{-5}
3.	Microwave Radiometer - Mapping Antenna diameter: 5.0 m. Cloud structure and temperature	Saturn	116.6	51.5	121.9	5.7×10^{6}	3-1	A-18	6.7×10^{-11}
5.	Synthetic Aperture Radar Antenna shape: 38.7 x 103.6 m. Cloud structure	Saturn	1.82×10^{4}	7.64×10^{4}	2.45×10^{6}	12×10^{9}	5-1	A-45	8.37×10^{-17}
16.	Far IR Radiometer Collector diameter: 1 cm Atmospheric temperature	Saturn	33.96	10.0	6.0	1.48×10^{5}	16-1	A-85	2.26×10^{-9}

Notes: *Imaging sensors for Jupiter encounter not within scope of study

Table 4.3-1.1. Sensor Family for 1976 Earth-Jupiter*-
Saturn Mission No. 7 (Cont)

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[ ] Optimal [X] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
1.	Television Camera Vidicon; Tube diameter: 0.91 cm Cloud structure and motion; figure; ring structure	Saturn	2.61	5.73	700	7×10^5	1-1	A-2	0.0
3.	Microwave Radiometer - Mapping Antenna diameter: 1.3×10^{-1} m. Cloud structure and temperature	Saturn	1.1	5.0	0.029	9.22	3-1	A-18	0.0
5.	Synthetic Aperture Radar Antenna shape: 2.12 x 8.68 m. Cloud structure	Saturn	97.14	205.9	1.27×10^{-5}	6.23×10^{-2}	5-1	A-45	0.0
16.	Far IR Radiometer Collector diameter: 1 cm Atmospheric temperature	Saturn	3.14	6.0	0.118	3.73×10^3	16-1	A-85	0.0

Notes: *Imaging sensors for Jupiter encounter not within scope of study

Table 4.3-1.2. Sensor Family for 1978 Earth-Jupiter*-Uranus-Neptune Mission No. 9

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family

[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
1.	Television Camera Vidicon; Tube diameter: 9.1 cm	Uranus	189	72.3	1.5×10^8	3.6×10^{12}	1-2	A-3	6.1×10^{-5}
	Cloud structure and motion; figure	Neptune	188.2	72.3	2.9×10^8	6.24×10^{12}	1-3	A-4	2.54×10^{-5}
3.	Microwave Radiometer - Mapping Antenna diameter: 5.0 m.	Uranus	114.2	50.9	188.7	5.65×10^6	3-2	A-19	4.68×10^{-11}
	Cloud structure and temperature	Neptune	129	54.5	213.7	2.26×10^6	3-3	A-20	1.9×10^{-11}
5.	Synthetic Aperture Radar Antenna shape: 105.5 x 96.34 m. Cloud structure	Uranus	4.5×10^4	5.8×10^3	5.05×10^6	23.2×10^9	5-2	A-46	1.51×10^{-15}
		Neptune	1.3×10^4	6.7×10^3	6.6×10^6	14.3×10^9	5-3	A-47	3.56×10^{-16}
16.	Far IR Radiometer Collector diameter: 1.0 cm	Uranus	33.96	10.0	6.07	2.37×10^5	16-2	A-86	1.92×10^{-7}
	Atmospheric temperature	Neptune	33.96	10.0	17.65	5.24×10^5	16-3	A-87	3.15×10^{-8}

Notes: *Jupiter encounter on this mission not within scope of study

Table 4.3-1.2. Sensor Family for 1978 Earth-Jupiter*-Uranus-Neptune Mission No. 9 (Cont)

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[ ] Optimal [X] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
1.	Television Camera Vidicon; Tube diameter: 0.91 cm Cloud structure and motion; figure	Uranus	2.61	5.73	700	7×10^5	1-2	A-3	0.0
		Neptune	2.61	5.73	700	7×10^5	1-3	A-4	0.0
3.	Microwave Radiometer - Mapping Antenna diameter: 0.026 m. Cloud structure and temperature	Uranus	1.0	5.0	4.34×10^{-3}	13.0	3-2	A-19	0.0
		Neptune	1.0	5.0	2.07×10^{-3}	23.6	3-3	A-20	0.0
5.	Synthetic Aperture Radar Antenna shape: 7.5 x 3.07 m. Cloud structure	Uranus	300	34.1	4.45×10^{-5}	20.5×10^{-2}	5-2	A-46	0.0
		Neptune	79.5	27.2	5.14×10^{-5}	11.1×10^{-2}	5-3	A-47	0.0
16.	Far IR Radiometer Collector diameter: 1.0 cm. Atmospheric temperature	Uranus	3.14	6.0	0.02	7.8×10^2	16-2	A-86	0.0
		Neptune	3.14	6.0	0.029	8.7×10^2	16-3	A-87	0.0

Notes: *Jupiter encounter on this mission not within scope of study

Table 4.3-1.3. Sensor Family for 1977 Earth-Jupiter*-Saturn-Pluto** Mission No. 12

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family

[X] Optimal [ ] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
1.	Television Camera Vidicon; Tube diameter: 9.1 cm Cloud structure and motion; figure; ring structure	Saturn	193.7	57.3	1.91×10^6	15.8×10^{10}	1-4	A-5	1.69×10^{-4}
3.	Microwave Radiometer - Mapping Antenna diameter: 12.5 m. Cloud structure and temperature	Saturn	543.2	79.6	80.6	13.4×10^6	3-4	A-21	9.66×10^{-11}
5.	Synthetic Aperture Radar Antenna shape: 72.61 x 95.36 m. Cloud structure	Saturn	6.8×10^4	5.75×10^5	2.2×10^6	14×10^9	5-4	A-48	2.39×10^{-17}
16.	Far IR Radiometer Collector diameter: 5.3 cm. Atmospheric temperature	Saturn	34.7	10.0	6.06	1.5×10^6	16-4	A-88	9×10^{-9}

Notes: *Imaging sensors for Jupiter on this mission not within scope of study
**Pluto encounter not within scope of study

Table 4.3-1.3. Sensor Family for 1977 Earth-Jupiter*-Saturn-Pluto** Mission No. 12 (Cont)

[X] Imaging [ ] Non-imaging [ ] Integrated sensor family
[ ] Optimal [X] Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation		
							Sheet	Page	
1.	Television Camera Vidicon; Tube diameter: 0.91 cm Cloud structure and motion; figure; ring structure	Saturn	2.61	5.73	700	7×10^5	1-4	A-5	0.0
3.	Microwave Radiometer - Mapping Antenna diameter: 0.64 m. Cloud structure and temperature	Saturn	3.46	5.0	0.046	5.7×10^3	3-4	A-21	0.0
5.	Synthetic Aperture Radar Antenna shape: 62.4 x 72.5 m. Cloud structure	Saturn	2.03×10^4	6.26	1.93×10^{-4}	1.22	5-4	A-48	0.0
16.	Far IR Radiometer Collector diameter: 1.0 cm. Atmospheric temperature	Saturn	3.14	6.0	0.071	3.86×10^3	16-4	A-88	0.0

Notes: *Imaging sensors for Jupiter on this mission not within scope of study
**Pluto encounter not within scope of study

4.3.2 Non-Imaging Sensor Families

Compatible families of non-imaging sensors for flyby and orbit missions to the outer planets, including Jupiter, are described for the missions listed below in the tables as indicated. As missions to and including Jupiter have been described previously, the descriptive tables are not repeated here but are referenced as pertinent.

Mission	Table
1976 Earth-Jupiter-Saturn	4.2-1.4
1978 Earth-Jupiter*-Uranus-Neptune	4.3-2.1
1978 Earth-Jupiter-Saturn-Pluto**	4.2-1.5
1978 Jupiter orbit No. 1	4.2-1.12
1978 Jupiter orbit No. 9	4.2-1.13
1978 Jupiter orbit No. 11	4.2-1.14

*Jupiter encounter on this mission not within scope of this study.
**Pluto not within scope of study.

Table 4.3-2.1. Sensor Family for 1978 Earth-Jupiter*-Uranus-Neptune Mission No. 9

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Tabulation: Page	Total Sensor Worth
4.	Microwave Radiometer - Measuring	Uranus	132.8	49.8	1.24	7.06×10^4	4-8	A-32	1.29×10^{-6}
	Antenna diameter: 6.2 m								
	Cloud structure and composition	Neptune	132.8	49.8	3.6	7.56×10^4	4-9	A-33	8.48×10^{-10}
7.	Flux-Gate Magnetometer	Uranus	2.1	6.0	1500	12.1×10^9	7-2 (8-1)	A-56 (A-56)	1.22
	Triaxial								
	Interior composition and motion	Neptune	2.1	6.0	1500	1.77×10^{10}	7-2 (8-1)	A-56 (A-56)	1.22
8.	Helium Magnetometer	Uranus	3.4	10.0	40	32.4×10^7	8-2 (8-1)	A-56 (A-56)	1.22
	Interior composition and motion								
		Neptune	3.4	10.0	40	4.72×10^8	8-2 (8-1)	A-56 (A-56)	1.22
19.	Michelson Interferometer								
	Collector diameter:	Uranus	2130	87	3.6×10^3	15.2×10^7	19-4 (15-8)	A-72 (A-72)	1.48×10^{-5}
	100 cm (Uranus)								
	103 cm (Neptune)	Neptune	2130	87	4.37×10^3	20×10^7	19-5 (15-9)	(A-73) (A-73)	7.65×10^{-4}
	Atmospheric composition, pressure								

Notes: *Jupiter encounter on this mission not within scope of study

Table 4.3-2.1. Sensor Family for 1978 Earth-Jupiter*-Uranus-Neptune Mission No. 9 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☒ Optimal ☐ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
21.	Visible/UV Spectrometer	Uranus	820.4	4.2	1.49×10^{4}	3.66×10^{8}	21-4	A-103	7.9×10^{-10}
	Collector diameter: 1.0 m								
	Atmospheric composition	Neptune	820.4	4.2	1.62×10^{4}	3.45×10^{8}	21-5	A-104	4.35×10^{-9}
22.	Laser Radar	Uranus	312.1	324.7	11.67	10.4×10^{5}	22-8	A-117	1.13×10^{-15}
	Nd YAG								
	Aerosol size, distribution	Neptune	310.1	320.5	11.67	12.1×10^{5}	22-9	A-118	2.26×10^{-15}
23.	Bi-Frequency Radio Occultation	Uranus	1658	5.0	74.76	14×10^{3}	23-6	A-131	1.92×10^{-3}
	Antenna diameter: 33.22 m								
	Ionosphere density; figure	Neptune	1658	5.0	156.5	14×10^{3}	23-7	A-132	1.92×10^{-3}

Notes: *Jupiter encounter on this mission not within scope of study

Table 4.3-2.1. Sensor Family for 1978 Earth-Jupiter*-Uranus-Neptune Mission No. 9 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family

☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements: Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation: Sheet	Page	Total Sensor Worth
4.	Microwave Radiometer - Measuring	Uranus	1.74	5.0	6.6×10^{-4}	58.8	4-8	A-32	0.0
	Antenna diameter: 0.7 m								
	Cloud structure, composition	Neptune	1.74	5.0	2×10^{-3}	93.4	4-9	A-33	0.0
7.	Flux-Gate Magnetometer	Uranus	2.1	6.0	1.5	12.1×10^{6}	7-2	A-56	0.0
	Triaxial						(8-1)	(A-56)	
	Interior composition and motion	Neptune	2.1	6.0	1.5	1.8×10^{7}	7-2	A-56	0.0
							(8-1)	(A-56)	
8.	Helium Magnetometer	Uranus	3.4	10.0	40	32.4×10^{7}	8-2	A-56	0.0
	Interior composition and motion						(8-1)	(A-56)	
		Neptune	3.4	10.0	40	4.8×10^{8}	8-2	A-56	0.0
							(8-1)	(A-56)	
15.	Filter Radiometer	Uranus	2.95	66.5	2.23×10^{-3}	93.6	15-8	A-72	0.0
	Collector diameter: 1.0 cm								
	Atmospheric composition, pressure	Neptune	2.95	66.5	4.69×10^{-3}	216	15-9	A-73	0.0
21.	Visible/UV Spectrometer	Uranus	2.12	4.2	0.0507	50.7	21-4	A-103	0.0
	Collector diameter: 10 cm								
	Atmospheric composition	Neptune	2.12	4.2	0.0245	24.5	21-5	A-104	0.0

Notes: *Jupiter encounter on this mission not within scope of study

Table 4.3-2.1. Sensor Family for 1978 Earth-Jupiter*-Uranus-Neptune Mission No. 9 (Cont)

☐ Imaging ☒ Non-imaging ☐ Integrated sensor family
☐ Optimal ☒ Marginal measurement requirements

Number	Sensor Type and Observational Purpose	Planet	Support Requirements						Total Sensor Worth
			Mass (kg)	Power (w)	Data Rate (bit/sec)	Data (bit)	Tabulation Sheet	Tabulation Page	
22.	Laser Radar Nd YAG Aerosol size, distribution	Uranus	312.1	324.7	11.67	10.4×10^5	22-8	A-117	1.13×10^{-15}
		Neptune	310.1	320.5	11.67	12.1×10^5	22-9	A-118	2.26×10^{-15}
23.	Bi-Frequency Radio Occultation Antenna diameter: 33.22 m Ionosphere density; figure	Uranus	1658	5.0	0.051	140	23-6	A-131	0.0
		Neptune	1658	5.0	0.075	140	23-7	A-132	0.0

Notes: *Jupiter encounter on this mission not within scope of study

4.3.3 Integrated Sensor Families

Integrated imaging and non-imaging sensor families for missions to the outer planets, including Jupiter, are described in Tables 4.3-3.1 through 4.3-3.6. The imaging sensors for orbit missions to Jupiter are derived from Reference 3, and apply only to optimal measurement require-quirements. Other imaging sensors and all non-imaging sensors are derived from the present study.

Mission	Table
1976 Earth-Jupiter-Saturn	4.3-3.1
1978 Earth-Jupiter*-Uranus-Neptune	4.3-3.2
1978 Earth-Jupiter-Saturn-Pluto*	4.3-3.3
1978 Jupiter orbit No. 1	4.3-3.4
1978 Jupiter orbit No. 9	4.3-3.5
1978 Jupiter orbit No. 11	4.3-3.6

*Encounter not within scope of study

For each of these missions, the sensor data for imaging and non-imaging sensors have been developed and tabulated previously. To avoid repetition, the summarized data are not repeated; reference is given to the original summary table in each instance.

Table 4.3-3.1. Integrated Sensor Family for 1976
Earth-Jupiter-Saturn Mission No. 7

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
16.	Far IR radiometer
19.	Michelson interferometer (b)
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation
MARGINAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
15.	Filter radiometer (b)
16.	Far IR radiometer
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for imaging sensors given in Table 4.3-1.1; data for non-imaging sensors given in Table 4.3-2.1

Table 4.3-3.2. Integrated Sensor Family for 1978
Earth-Jupiter*-Uranus-Neptune Mission No. 9

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
16.	Far IR radiometer
19.	Michelson interferometer (b)
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation
MARGINAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
15.	Filter radiometer (b)
16.	Far IR radiometer
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for imaging sensors given in Table 4.1-1.2; data for non-imaging sensors given in Table 4.2-2.2

Table 4.3-3.3. Integrated Sensor Family for 1978
Earth-Jupiter-Saturn-Pluto* Mission No. 12

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
16.	Far IR radiometer
19.	Michelson interferometer (b)
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation
MARGINAL MEASUREMENT REQUIREMENTS	
1.	Television camera
3.	Microwave radiometer - mapping (a)
4.	Microwave radiometer - measuring (a)
5.	Synthetic aperture radar (a*)
7.	Flux-gate magnetometer (a)
8.	Helium magnetometer (a)
15.	Filter radiometer (b)
16.	Far IR radiometer
21.	Visible/UV spectrometer
22.	Laser radar (b*)
23.	Bi-frequency radio occultation

*Pluto not within scope of study

(a) Operational incompatibility caused by (a*)
(b) Operational incompatibility caused by (b*)

Note: Sensor data for imaging sensors given in Table 4.3-1.3; data for non-imaging sensors given in Table 4.3-2.3

Table 4.3-3.4. Integrated Sensor Family for 1978 Jupiter Orbit No. 1

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
19.	Michelson interferometer
21.	Visible/UV spectrometer
Note: Sensor data for imaging sensors given in Table 4.2-2.7; data for non-imaging sensors given in Table 4.2-1.12	

Table 4.3-3.5. Integrated Sensor Family for 1978 Jupiter Orbit No. 9

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
16.	Infrared scanning system
19.	Michelson interferometer
21.	Visible/UV spectrometer
Note: Sensor data for imaging sensors given in Table 4.2-2.8; data for non-imaging sensors given in Table 4.2-1.13	

Table 4.3-3.6. Integrated Sensor Family for 1978 Jupiter Orbit No. 11

Number	Sensor Type
OPTIMAL MEASUREMENT REQUIREMENTS	
1.	Television system
4.	Microwave radiometer - measuring
7.	Flux-gate magnetometer
8.	Helium magnetometer
19.	Michelson interferometer
21.	Visible/UV spectrometer
Note: Sensor data for imaging sensors given in Table 4.2-2.9; data for non-imaging sensors given in Table 4.2-1.14	

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 SIGNIFICANCE OF STUDY RESULTS

The Remote Sensor Study has proved significant in both the methodology developed and in its specific results. The most important methods include the synthetic sensor design techniques embodied in the scaling laws, the calculation of trajectory segments on which sensors must be operated to satisfy area coverage and spatial resolution requirements, and the quantitative evaluation of sensor worth in terms of satisfaction of observation requirements. Computer programs were developed which not only perform numerical analyses but also document the top-down approach from planetary exploration goals to sensor support requirements.

Study methodology and results have certain limitations whose recognition is essential to proper understanding and use of the study products. The design procedure for any one sensor type is fixed: a new scaling law would be needed if the design began with specification, say, of the aperture rather than the detector sensitivity, but the support requirements would be nearly the same. Trade-off studies in which the trajectory is varied require repeated calculations.

Specific study results of greatest lasting value include a restatement by qualified scientists of planetary observation objectives, the flyby trajectory analyses, the sensor support requirements for a variety of missions and observations, and the compatible sensor families which guide the selection of candidate experiments and payloads.

The primary value of the methodology developed in this study is the planning of planetary and other space exploration missions. One area of application is the evaluation of the contribution of candidate missions and payloads to exploration objectives. Another application is to trade-off analyses. For example, sensor support requirements can be related parametrically to trajectory elements. The measurement capability of a given sensor design can be evaluated as a function of trajectory parameters by fixing sensor design parameters.

In multi-planet flyby missions, a sensor may be optimized for best performance at one planet, or for greatest total performance in the mission, provided that minimum requirements are met at all planets. The study methods can determine which approach is most effective in terms of mission objectives or minimizes sensor support requirements.

The study methodology is directly applicable to synthetic sensor design as a guide to designers of actual sensor hardware. Those state-of-art limits that restrict sensor performance are identified so that technology development can be concentrated on these aspects. Tradeoff analyses of sensor measurement capability versus support requirements can be made. Sensor designs can be used in tentative selection of sensors and evaluation of payload support requirements. Commonality of sensor component and support subsystems can be recognized and used in payload integration studies.

5.2 RECOMMENDATIONS FOR FURTHER STUDY

This study has covered a major portion of the field of sensor application to space investigations. Its usefulness would be enhanced by covering the remaining significant portions. These include other candidate missions such as the NASA-OSSA Grand Tour baseline*, and other solar system objects such as Pluto, the sun itself, satellites, asteroids, and comets. However, no mission study should be performed. Additional experiments worthy of study are imaging sensors on inner-planet flybys, particle and field sensors to measure magnetospheric and interplanetary environments, and atmospheric entry probe and surface lander experiments.

The utility of the results would also be increased if the results of Contract NAS2-4494 were entered into the SERA documentation file, and if more realistic limits were placed on some observation requirements and sensor technology developments. The limits used in this study were based on unrestricted scientific and technological considerations and did not reflect spacecraft, launch vehicle, schedule, or budgetary constraints.

*This consists of Jupiter-Saturn-Pluto flyby missions launched in 1976 and 1977, and two Jupiter-Uranus-Neptune flyby missions launched in 1979.

6.0 REFERENCES

1. Observation Requirements for Unmanned Planetary Missions, NR SD, SD 70-24 (11 March 1970), NASA CR 73458, 73459.

2. Remote Sensor Systems for Unmanned Planetary Missions, NR SD, SD 70-361 (September 1970).

3. Klopp, D. Orbital Imagery for Planetary Exploration, Illinois Institute of Technology Research Institute (September 1969), NASA CR 73453.

4. Swenson, B. L., and Manning, L. A., A Payload Capability and Operations Analysis - Mars Lander Mission, NASA TM (to be published).

5. Hellings, R. W., and Sergeyevsky, A. B., Precision Space Projectory Program, NR SD, SD 69-165 (April 1969).