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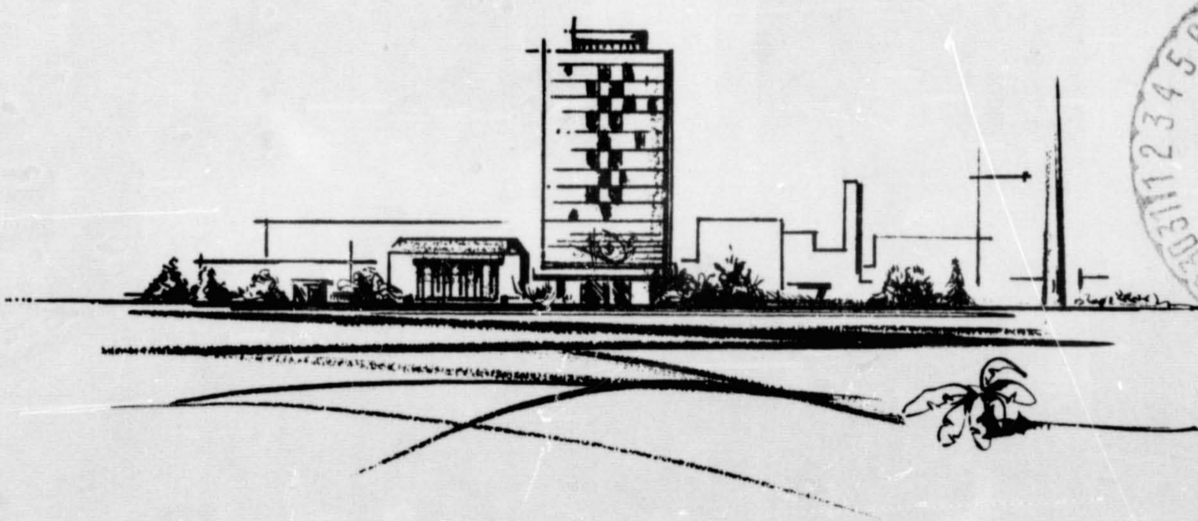

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SECOND INTERIM SCIENTIFIC REPORT

on

NAS 12-550

DEVELOPMENT OF AN EVALUATION TECHNIQUE
FOR STRAPDOWN GUIDANCE SYSTEMS

Submitted to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Electronics Research Center
Cambridge, Massachusetts

February 28, 1969

Contract No. NAS 12-550

DEVELOPMENT OF AN EVALUATION TECHNIQUE FOR STRAPDOWN GUIDANCE SYSTEMS

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February, 1969

Prepared under Contract No. NAS 12-550 by
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Electronics Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

This interim scientific report presents the results of a twelve-month study conducted by Battelle Memorial Institute, Columbus Laboratories, for the NASA Electronics Research Center in partial fulfillment of the work performed on Contract NAS 12-550.

The objective of this study was to extend the evaluation techniques developed for pure strapdown inertial guidance systems, in a previous phase of the contract, to aided inertial guidance systems.

This volume presents a summary of the study results, detailed technical discussion, recommendations, and conclusions.

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF MAJOR SYMBOLS AND DEFINITIONS

α	Exponent used in Weibull distribution
C_3	Hyperbolic excess velocity squared
D_T	Target miss degrees-of-freedom
D_V	Midcourse correction velocity degrees-of-freedom
Ig	Midcourse correction system specific impulse times gravity
ISU	Inertial Sensing Unit
K_{DC}	Midcourse correction system constant weight
K_{DV}	Midcourse correction system tankage factor
K_{P1}	Power source constant weight (lbs)
K_{P2}	Power source variable weight (lbs/watt)
K_1	Attitude control unit constant weight
K_2	Attitude control unit tankage factor
MTBF	Mean time between failures
MTTF	Mean time to failure
P_{FG}	Probability of mission failure attributable to the astrionics
P_{FR}	Probability of failure attributable to hardware reliability
P_{FT}	Probability of failure attributable to target miss
P_{FTR}	Probability of failure attributable to hardware reliability or target miss
P_{FV}	Probability of failure attributable to insufficient midcourse fuel
R_T	The square root of the trace of the target miss covariance matrix
R_V	The square root of the trace of the midcourse correction velocity covariance matrix
RTG	Radioisotope thermoelectric generator
W_{AC}	Attitude control unit weight

LIST OF MAJOR SYMBOLS AND DEFINITIONS (Continued)

W_{DV}	Midcourse correction system weight
W_F	Midcourse correction system fuel weight
W_{GS}	Combined astrionics system weight
W_{ICP}	Inertial measurement unit, communications, electro-optical sensors, computer, and electrical energy source weight
W_{NG}	Nonguidance spacecraft weight
W_P	Electrical energy source weight
W_T	Total spacecraft weight
V_∞	Hyperbolic excess velocity
X_{MISS}	Acceptable target miss
DR	Local vertical coordinate system down range component along velocity vector
CR	Local vertical coordinate system cross range component normal to DR and lying in the position-velocity plane
OP	Local vertical coordinate system out of plane component completing the orthogonal set
$\vec{e}$	Vector of state estimation errors
$\vec{d}$	Vector of state deviations
$\vec{d}_c$	Vector of state computed deviations
ΔV	Midcourse correction velocity
μ	Spacecraft midcourse correction mass ratio
ψ_T	Allowed target miss distance divided by the square root of the trace of the target miss covariance matrix
ψ_V	Spacecraft ΔV capability divided by the square root of the trace of the midcourse correction velocity covariance matrix

DEVELOPMENT OF AN EVALUATION TECHNIQUE
FOR STRAPDOWN GUIDANCE SYSTEMS

Interim Report for the Period of

February 1, 1968, to February 1, 1969

BATTELLE MEMORIAL INSTITUTE
Columbus Laboratories

INTRODUCTION

This report presents the results of the work on "Development of an Evaluation Technique for Strapdown Guidance Systems" for the time period starting February 1, 1968, and ending February 1, 1969. This work was performed in accordance with the statement of work which modified Contract No. NAS 12-550. The purpose of this modification was to extend the evaluation techniques developed for pure strapdown inertial guidance systems (Reference 1) to aided strapdown inertial guidance systems. This volume presents a summary of the study results, detailed technical discussion, recommendations, and conclusions. To further the reader's understanding of the organization of this report, the principal items of work for this reporting period are summarized below.

Summary of Added Study Elements

To accomplish the objective of extending the evaluation techniques developed for pure strapdown inertial guidance systems to aided strapdown inertial guidance systems, the work was carried out in the following steps:

(1) Techniques were developed to estimate the aided strapdown inertial guidance system parameters used in the penalty functions. These techniques are based upon analytical methods and available test data.

(2) Celestial sighting and midcourse correction strategies are incorporated in the computer programs by the specification of the mission schedule. The mission schedule also is considered in the determination of the amount of attitude control fuel required to sight selected observables. Guidance system power sequencing is determined by the mission event schedule.

(3) The penalty functions developed for evaluation of pure strapdown inertial guidance systems were expanded to include

all parameters and permit evaluation of aided strapdown inertial guidance systems and all other astrionics.

(4) Error models for horizon sensors, celestial trackers, and radio aids were incorporated in the computer programs. The error analysis of aided systems which utilize Kalman filtering for state estimation was included. This permits evaluation of integrated optical/inertial guidance systems, integrated radio/inertial guidance systems, or integrated radio/optical/inertial guidance systems.

(5) Digital computer programs were developed which:

(a) Calculate the penalty given the aided strapdown inertial guidance system parameters, or select, from candidate component lists, a quasi-optimum combination of subsystem components which minimize the penalty functions.

(b) Calculate estimates of the aided strapdown inertial guidance system parameters for use in the penalty functions.

(c) Evaluate celestial sighting and midcourse correcting strategies for a specific trajectory. Calculate the attitude control system fuel required for a specific sighting strategy.

(6) The digital computer programs developed were exercised on a Jupiter fly-by interplanetary mission with a specific aided strapdown inertial guidance system.

Guidelines

The factors which have to be considered in applying the evaluation method are primarily those associated with (1) the class of missions for which the evaluation technique has been specifically developed and (2) the astrionics design philosophy.

Interplanetary Missions

The evaluation technique, as presently structured, provides a measure or index of astrionics system performance for the class of interplanetary probe missions. These missions include flyby, orbiter, lander, and others such as multiple planet swingby. The specific mission being used for the present work is a Jupiter flyby mission. For this mission, the spacecraft passes close to the target planet at a nominal perijove. The acceptable uncertainty in perijove is also specified. No propulsion system is carried for orbit insertion about the target planet.

Astrionics Design Philosophy

Navigation and guidance of the launch vehicle which would be used for launching of interplanetary probe spacecraft were assumed to be under control of the astrionics subsystems contained above the final launch vehicle stage. It was assumed that the astrionics considered in the present work are an integral part of the spacecraft as shown in Figure 1. It would not be necessary for the astrionics to be an integral part of the spacecraft if only launch vehicle navigation and guidance were considered. In this case, certain subsystems such as the spacecraft attitude control would not be considered in the analyses. In addition, alternate electrical energy sources such as batteries would be used in the launch vehicle astrionics. Since the results presented in this report consider the astrionics to be part of the spacecraft, the spacecraft electrical energy source, midcourse propulsion system, and attitude control system are considered in the evaluation.

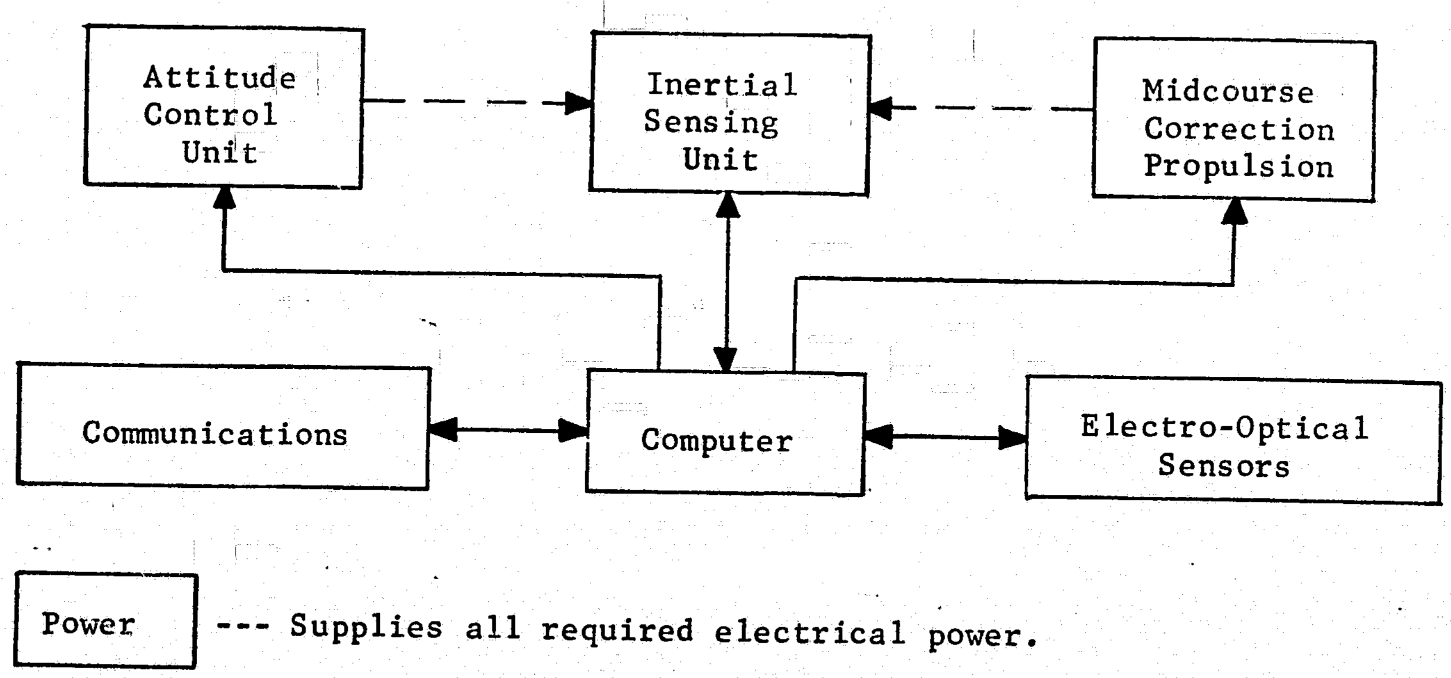

FIGURE 1. BLOCK DIAGRAM OF INTEGRATED ASTRIONICS

The attitude control unit provides the required torques for stabilizing and maneuvering the spacecraft. Various mechanizations are possible. The mechanization which led to the results reported herein is a set of six pairs of thruster nozzles driven with cold gas from a single tank. Other mechanizations such as reaction wheels plus gas jets or control moment gyroscopes could be considered.

The inertial sensing units can be either strapdown or gimballed. The results presented in this report consider both strapdown inertial sensing units and gimballed platforms.

A centralized general purpose digital computer is assumed to provide all data management. For example, this includes: (1) navigation, guidance, and control computations; (2) processing of data input and output to the communications subsystem; (3) control of all subsystem functions such as sequencing; and (4) data storage and processing.

Components of the communications subsystem include both onboard equipment and Earth-based tracking radars. The onboard equipment is assumed to consist of the necessary antennas, transponder, command decoder, and multiplexer.

Electro-optical sensors include horizon sensors, sun sensors, and gimballed or strapdown star trackers. All of these sensors were evaluated for the Jupiter flyby mission and sun sensors and strapdown star trackers were used in the determination of the results presented in a later section of this report.

The electrical power source and distribution network include the source of the electrical energy such as a radioisotope thermoelectric generator (RTG) or batteries, as well as power supplies and wiring.

SUMMARY

The evaluation techniques developed for pure strapdown inertial guidance systems have been extended to permit evaluation of astrionics systems which utilize aided inertial guidance systems. These techniques consider mission requirements, mission event schedules, and spacecraft design characteristics. The techniques provide a measure of astrionics system performance, aid in evaluation of competitive subsystems and in the preliminary design of conceptual subsystems, and are used in determination of the effectiveness of specific navigation updating and midcourse correction schedules.

Effectiveness evaluation is based on a cost effectiveness approach with cost defined to be the total astrionics system weight and effectiveness defined to be the probability that the astrionic system operates correctly. Using this cost or weight effectiveness model, several performance indices have been developed. These may be broken into two categories. The first category requires a specified effectiveness or probability of success and uses weight as the performance index, while the second category has a specified weight allowance for the astrionics and uses the ineffectiveness or probability of failure as the performance index.

Penalty Functions

Three different penalty functions were developed during the first phase of this contract and are discussed in detail in the Technical Discussion section of this report. The three penalty functions (modes) are defined as follows:

Mode 1. The probability of mission failure due to lack of astrionics reliability and accuracy, P_{FG}, is a specified constant. Another specified constant is all nonastrionics weight, W_{NG}. The penalty function is the astrionics system weight, W_{GS}, and is obtained by complete analysis of the astrionics, mission schedule, and spacecraft data. The total astrionics weight is defined to be the sum of the weights of (1) the astrionics hardware including the inertial sensing unit, (2) the electrical energy source and distribution network, (3) the attitude control unit, W_{AC}, and (4) the midcourse propulsion correction system, W_{DV}. An increase in the combined astrionics system weight necessary to assure a given influence, by the astrionics system, on probability of mission success is reflected in an increased launch weight, W_T.

Mode 2. The total launch weight, equal to the sum of the nonastrionics weight plus the combined astrionics system weight, is a specified constant. In addition, the nonastrionics weight is specified as is the combined astrionics system weight. Any decrease in astrionics system hardware or power source weight is offset with an increase in midcourse propulsion system weight or vice versa. The probability of mission failure due to lack of reliability or accuracy is the penalty function.

Mode 3. The third mode involves specified total launch weight and probability of mission failure due to lack of astrionics reliability and accuracy. The combined astrionics system weight is the penalty function. In this mode, the nonastrionics weight (useful payload) is the difference between the launch weight and combined astrionics system weight. Thus, for increasing W_{GS}, W_{NG} is reduced.

The three penalty functions are shown in Table I for comparison.

TABLE I. THREE PENALTY FUNCTIONS FOR EVALUATION OF ASTRIONICS SYSTEMS*

Mode	P_{FG}	W_{NG}	W_{GS}	W_T	Remarks
1	F	F	P	V	Fixed Nonastrionics Weight and Probability of Astrionics Failure
2	P	F	F	F	Fixed Total Weight and Astrionics Weight
3	F	V	P	F	Fixed Total Weight and Probability of Astrionics Failure

* V $\triangleq$ Variable with System, F $\triangleq$ Constant, P $\triangleq$ Penalty function.

For each of the modes, the minimum value of the penalty function defines the best system.

Evaluations discussed in this report were made using Mode 3. The probability that the astrionics system operates correctly, $1 - P_{FG}$, was specified as a mission constraint and the combined astrionics system weight, W_{GS}, is the penalty and is obtained by complete analysis of the astrionics, mission schedule, and spacecraft data.

Sensitivity of each penalty function with respect to specific system hardware parameters is expressed as the percent change in penalty per percent change in data. These sensitivities allow easy determination of the system parameters and components which affect the penalty function most directly (large sensitivity magnitude). The algebraic sign indicates which direction the penalty changes for an increase in the system parameter. Further explanation of the penalty functions and sensitivities is contained in the Technical Discussion section of this report.

System Parameters

The parameters used in the evaluation techniques are, in general: (1) weight, (2) power, (3) mean-time-to-failure (MTTF) and Weibull coefficient, and (4) performance which depends upon the functions of the particular subsystems. Of these parameters, the estimation of performance (accuracy) of aided inertial guidance systems which utilize aid measurements and Kalman filtering in the updating of system errors is the most difficult to achieve. Further description of the error analysis of aided inertial guidance systems is contained in the Technical Discussion section of this report.

Techniques to calculate the weight of the inertial sensing unit (ISU), midcourse correction propulsion subsystem, computer subsystem, and power subsystem were developed under Item 2 of the contract and are discussed in Reference 1. The total system weight is the summation of the weights of each of the subsystems. The weight of the attitude control system is estimated by the methods described in the Technical Discussion section of this report. The weight of the radio aid subsystem is estimated by summing the weights of the antenna and transponder/decoder. The weight of the electro-optical subsystem is the total weight of all electro-optical sensors used during the mission.

The power required by the astrionics system is estimated by summing the power required by each of the subsystems as a function of the system operating schedule for the mission of interest. The weight of the power sources is estimated from the resulting mission power load profile. The peak load determines the capacity of the RTG. The total weight of the power subsystem is the summation of the weights of the RTG, power conditioning and distribution equipment, and the wiring between subsystems.

The reliabilities of the ISU, midcourse correction propulsion subsystem, computer subsystem, and power subsystem are estimated as discussed in Reference 1. The reliability of the attitude control subsystem is estimated by the method described in the Technical Discussion section of this report. The Weibull distribution (Reference 1) with $\alpha = 1$ is used for the radio aid subsystem as well as the optical aid subsystem. The operating time for the various candidate aids depends upon the mission schedule.

Computer Programs

The calculation of the three penalty functions and the necessary estimation of the system parameters have been coded into a deck of FORTRAN subroutines. The subroutines, with a short, simple, main program calculate the necessary system parameters and evaluate them according to the specified penalty function.

Data needed to run the program are divided into four categories. The first three involve data describing the mission and spacecraft and include: (1) injection error sensitivities as computed by the Strapdown Error Analysis Program (SEAP) or Platform Error Analysis Program (PEAP); (2) state transition matrices generated by the n-body program; and (3) data describing mission values, ISU design values, and spacecraft subsystems. The fourth category is data describing candidate components (accelerometers, gyroscopes, electro-optical sensors, communication subsystem, and computers) and includes: component (1) weight, (2) dimensions, (3) excitation power, (4) reliability, and (5) error coefficients. Computer data required are similar to that for gyros and accelerometers except that the number of bits used to store each element of the attitude matrix, attitude update integration frequency, and integration scheme (rectangular, Runge-Kutta second order, or Runge-Kutta fourth order) are used in the error determination.

The program and its subroutines operate in one of two ways. A specific set of candidate components may be evaluated, or, by a searching technique (similar to steepest descent) a combination of the candidate components may be found which yields the minimum penalty. Energy source, attitude control, and midcourse correction subsystems, as well as the ISU block, base, and cover design are modelled internally. Options are provided to allow specification of the type of midcourse correction (zeroing all position or any one component of miss at the target), mechanical orientation (horizontal or vertical), mechanical configuration (one of the stored designs or the one yielding minimum weight), and an option which indicates if the gyros and accelerometers must be identical or may be non-identical along the three axes when the searching technique is selected. After selection of the desired options and a set of candidate components, either arbitrarily or by the searching technique, all other system characteristics are calculated and the penalty obtained. The program output consists of a four-page report listing the selected components and their data, mission and subsystem characteristics, and the penalty function value. In addition, normalized derivatives or sensitivities of the penalty to each piece of data are printed. This allows the designer to evaluate the relative importance of the data on the penalty function value. Furthermore, outputs in the form of tables or curves may be outlined to show the behavior of the penalty function as any piece of hardware or mission data is swept over a wide range of values.

Mission Characteristics

Launch Vehicle Characteristics

The conceptual 260(3.7)/SIVB/Centaur I/Kick launch vehicle was assumed to be suitable for the Jupiter flyby mission. A version of this vehicle has been studied extensively (References 2 and 3) by Battelle Memorial Institute, NASA Launch Vehicle Planning Project under Contract NASw-1146. Selected characteristics of this vehicle are given in Table II. The 260(3.7) first stage is a solid propellant, single engine stage and is described in detail in Reference 4 . The SIVB second stage is the same as the SIVB utilized by the Saturn IB and Saturn V launch vehicles. The Centaur I third stage is based on design evolution and concentrated development effort to employ hydrogen-flourine propellants (Reference 5). The "Kick" fourth stage is a small high energy stage originally proposed for use with the SLV3C and SLV3C/Centaur (Reference 5).

TABLE II. SELECTED CHARACTERISTICS OF 260(3.7)/SIVB/ CENTAUR I/KICK LAUNCH VEHICLE

Stage	260(3.7)	SIVB	Centaur I	Kick
Initial Total Gross Weight (lb)*	4,019,302	315,303***	54,202	12,410
Final Total Gross Weight (lb)*	720,302	85,303	17,602	6,460
Vacuum Thrust (lb)	6,430,000**	205,000	31,000	7,500
Propellant Weight Flow (lb/sec)	24,300**	482	68.20	16.47
Exit Area (ft^2)	376	35.8	16.58	4.14

* All weights include 5,410 lb payload

** Initial value only. For time history, see Appendix A, Figure A-2, Reference 1.

*** Includes 5,600 lb shroud which is ejected 26 seconds after SIVB ignition.

This launch vehicle was simulated using the Battelle three-degree-of-freedom computer program. The simulated boost trajectory was used in the guidance error analysis. Further discussion of the launch vehicle simulation and boost trajectory are contained in Appendix A of Reference 1.

Trajectory Characteristics

The boost trajectory was assumed to start with a vertical rise from Cape Kennedy until a relative velocity of 150 ft/sec was attained. The vehicle was subjected to an instantaneous deflection of the flight path through a selected kick angle of 1.83 degrees from the vertical along an initial azimuth of 100 degrees from true north. The vehicle then flew a gravity turn until first stage burnout. A linear time dependent pitch steering profile was used to steer the second stage into a nearly circular 100 nm parking orbit. It was assumed that the SIVB stage was restarted at the correct time to begin the final injection phase of the launch trajectory.

Characteristics of the interplanetary trajectory are tabulated in Table III. The Lewis Research Center n-body computer program was modified to calculate n-body state transition matrices. The state transition matrices used in exercising these computer programs were obtained by running the

Lewis n-body program for the trajectory summarized in Table III. Further discussion of the interplanetary trajectory and state transition matrices is contained in Reference 1.

TABLE III. CHARACTERISTICS OF 1972 JUPITER FLYBY MISSION INTERPLANETARY TRAJECTORY

Launch date	March 4, 1972
Arrival date	April 18, 1973
Time of flight	410 days
Departure asymptote (from Earth)	
V_∞	12.195 km/sec
C_3	147.718 km^2/sec^2
Declination	-25.3 deg
Angle to Sun-Earth line	93.0 deg
Approach asymptote (to Jupiter)	
V_∞	17.53 km/sec
Declination to plane of Jupiter	1.64 deg
Angle to Jupiter-Sun line	153.2 deg
Interplanetary Orbit	
True anomaly at launch	-6 deg
True anomaly at arrival	129.3 deg
Heliocentric central angle	135.3 deg
Inclination to ecliptic	-0.57 deg
Perihelion	0.989 AU
Aphelion*	650 AU
Eccentricity**	0.972 - 0.976
Earth-Jupiter distance at encounter	7.67989×10^{11} meters

* Does not pass aphelion on way to Jupiter.
** Varies due to n-body effects.

Nominal Spacecraft

Calculation of the attitude control subsystem weight requires certain nominal values for the spacecraft parameters. The injected weight on the nominal trajectory being used in this study is 5,410 lbs (Reference 1). Design of a spacecraft was beyond the scope of the contract. Therefore, existing spacecraft designs for this mission (References 6 and 7) were reviewed to determine if any of these could be used as the nominal spacecraft for this study. None of the spacecraft designs approached the weight the 260(3.7)/SIVB/CI/K conceptual launch vehicle would be capable of injecting for this mission. Design Concept D of the General Dynamics-Fort Worth study (Reference 6) does have certain characteristics which suggested the following approach.

Design Concept D is a three axis stabilized spacecraft to be launched by the Saturn IB/Centaur/HEKS (High Energy Kick Stage) on a 412-day flight to Jupiter (the reference trajectory being used has a 410-day flight time). The shroud used to enclose the spacecraft during launch is the Voyager shroud which is also used with an additional cylindrical section on the 260(3.7)/SIVB/CI/K (References 5 and 8). The weight of Design Concept D was estimated by General Dynamics to be 1581 pounds plus the weight of the booster to spacecraft adapter (Reference 6). General Dynamics notes that "A dual launch of the spacecraft by a Saturn V also allows 400-day missions in a year". A dual launch of the Voyager spacecraft has also been studied in the past.

A dual launch of the spacecraft similar to Design Concept D appears to be quite feasible using the 260(3.7)/SIVB/CI/K conceptual launch vehicle. For the purpose of this study, a dual launch of two spacecraft similar to the General Dynamics Design Concept D was assumed. Figure 2 depicts two views of this nominal spacecraft. Figure 3 depicts a sketch of the two spacecraft in the shroud used by Battelle in the trajectory simulations. In addition, the adapter mating the upper spacecraft to the launch vehicle is shown. This adapter is a suggested design based on standard aircraft structural design techniques. This adapter, shown from various viewing angles in Figure 4, was designed by a member of Battelle's NASA Launch Vehicle Planning (NLVP) Project. The weight of the adapter was estimated to be between 250 and 500 pounds by the designer. Another staff member used handbook formulas (for the probable materials and dimensions used in the adapter) and calculated the weight to be 360 pounds.

If it is assumed that the weight of each spacecraft could grow to 2000 pounds, a difference remains of 1410 pounds between the reference trajectory injected weight and the weight of the two spacecraft. Assuming that the adapter weight for mating the lower spacecraft to the launch vehicle is 6.5% of the weight of the spacecraft (this is the factor used by General Dynamics although the NLVP Project at Battelle and others sometimes use 5% as a standard), the total weight of both adapters can be determined. For the purpose of this report, it was assumed that the upper adapter weighs 360 pounds, the lower adapter weighs 130 pounds, and each spacecraft weighs 2000 pounds. This results in a total injected weight of 4,490 pounds which leaves a difference of 920 pounds between the reference weight and this weight. A portion of this 920 pound weight will undoubtedly be consumed by the ducting and associated equipment required to cool the RTG units on each spacecraft as discussed in Reference 6. In addition, electrical wiring between the adapter separation mechanism will reduce the weight difference even more.

Therefore, it was assumed that each spacecraft weigh 2000 pounds and the current reference trajectory be retained for the purposes of this study. Table IVa shows the weight breakdown used. The value of W_T in penalty modes 2 and 3 is 2000 pounds. Lever arms, moments of inertia, and other required spacecraft parameters were calculated based on data presented in Reference 6. General Dynamics was contacted, and they stated they had done the least analysis on Design Concept D and therefore did not have the moments of inertia. The lever arms were scaled from the drawing and the moments of inertia approximated

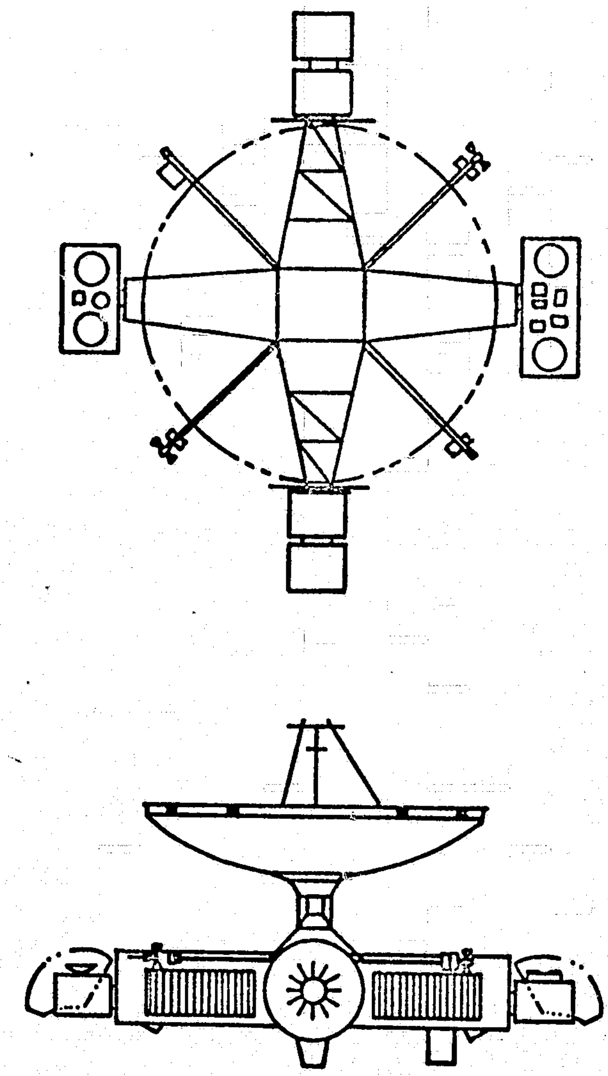

FIGURE 2. TWO VIEWS OF NOMINAL SPACECRAFT FOR JUPITER FLYBY MISSION

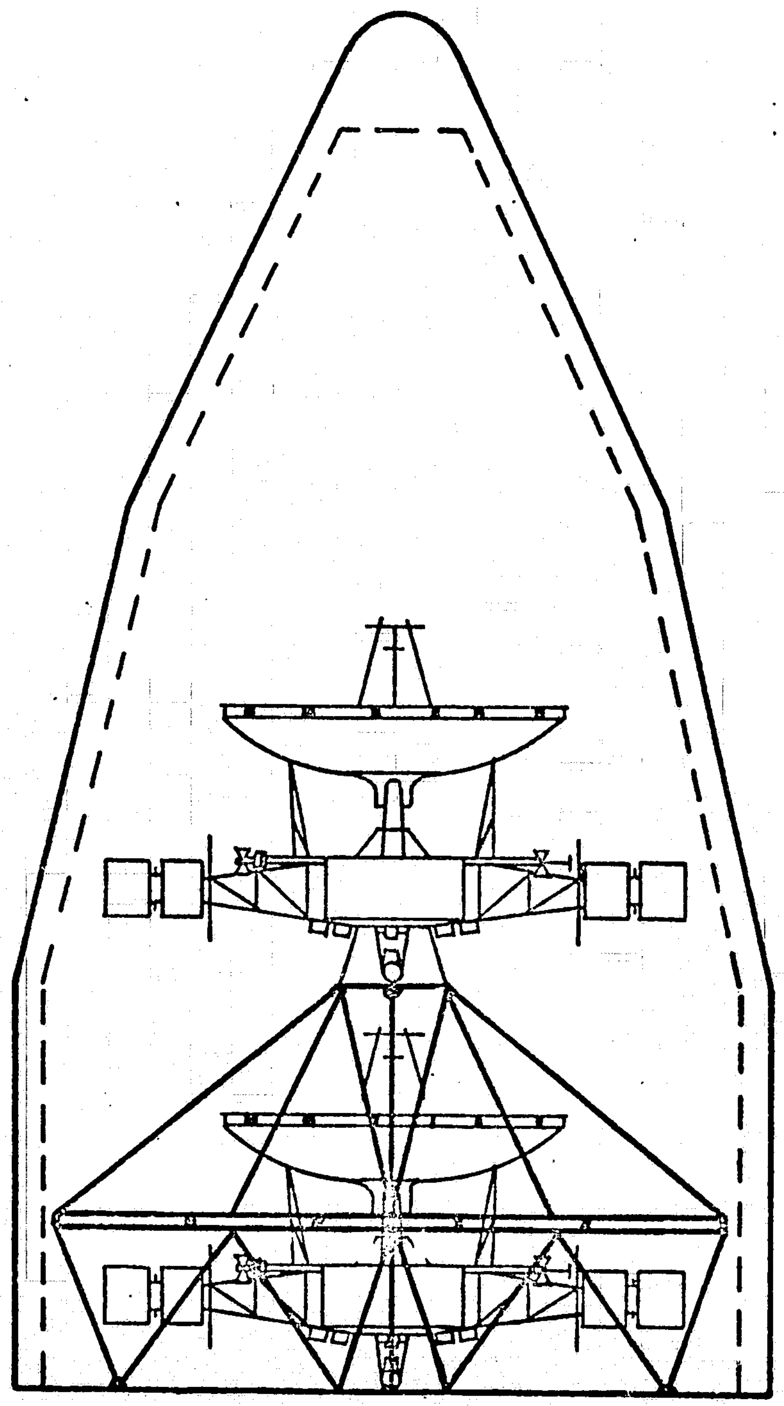

FIGURE 3. SKETCH OF TWO NOMINAL SPACECRAFT, ADAPTERS, AND SHROUD

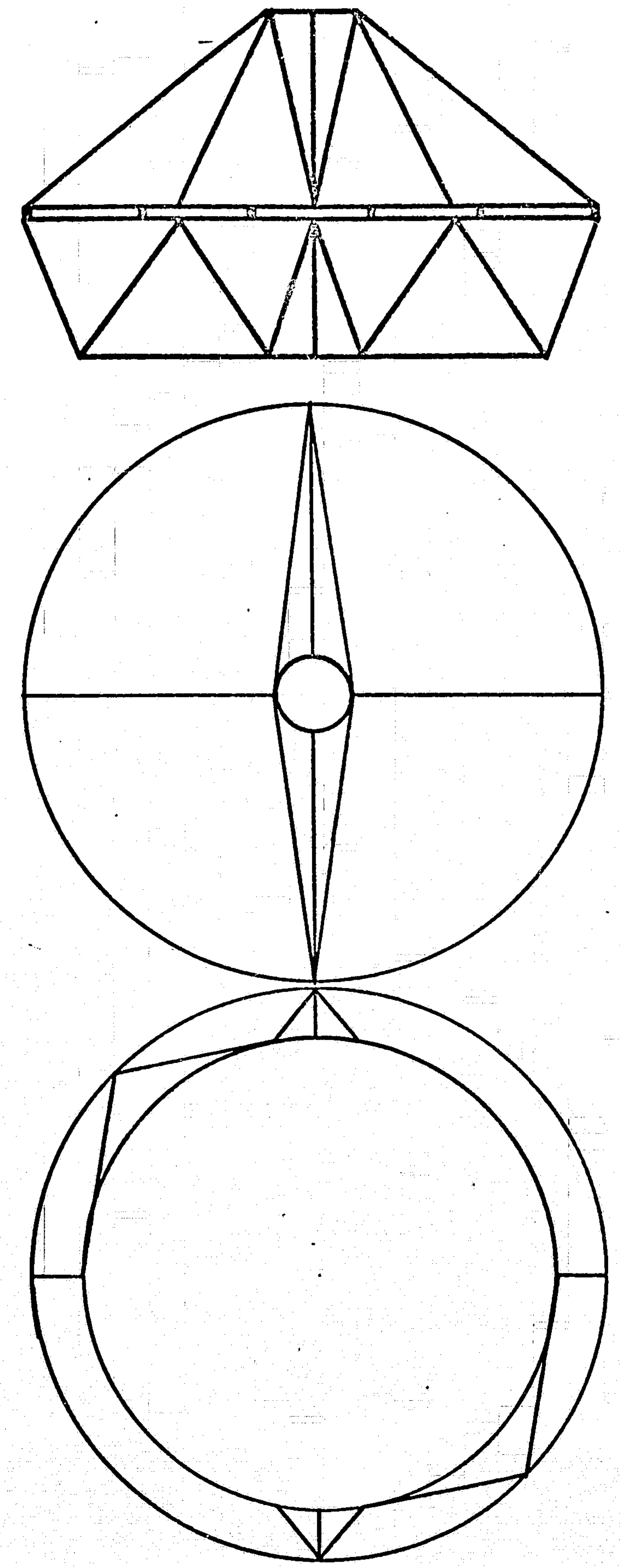

FIGURE 4. SIDE, TOP, AND BOTTOM VIEWS OF ADAPTER
FOR UPPERMOST SPACECRAFT

from the weights given in Reference 6 and the lever arms. The principal moments of inertia were calculated and are contained in Appendix A of this report.

TABLE IVa. INJECTED WEIGHT BREAKDOWN

Spacecraft (2 at 2000 lbs)	= 4,000
Adapters	= 490
Air Condition, Electrical, Etc.	= 920
Total	= 5,410 pounds

Mission Schedule

A detailed mission schedule, including all astrionics operation requirements, is needed before the effectiveness index may be obtained. The schedule must include the time and other parameters necessary to define the following operations:

(1) Turning on or turning off any astrionics subsystem

(2) Changes to the attitude control subsystem dead zone

(3) Beginning the attitude maneuver necessary to orient the electro-optical sensors toward the nominal location of the required celestial bodies

(4) The end of the acquisition maneuver and the beginning of the search operation

(5) The end of the search operation

(6) Ground based radar update with any specified radar

(7) Midcourse correction to minimize indicated component(s) of position or velocity at the target arrival.

Great care must be taken in specifying the mission schedule to insure that the schedule makes proper use of a selected suite of astrionics subsystems. An example of one mission schedule used for this study is shown in Figure 5.

SCHEDULE NO. 1

-0	00 0H 0M 0.00S	0.00	1	-0	-0	START THE LAUNCH	-0.
			6	7	1	TURN ON COM.RCVR.	-0.
-0	00 0H25M 0.00S	1500.00	3	1	2	UPDATE WITH ASCENSION TPQ RADAR	-0.
-0	00 0H42M 3.00S	2523.00	6	3	1	TURN ON ATTITUDE CONTROL	-0.
			8	0	-0	RAISE DEAD BAND	0.20000000E+02
			6	4	1	TURN ON STAR TRACKER	-0.
			6	5	1	TURN ON SUN SENSOR	-0.
			9	2	1	BEGIN MANEUVERING	-0.
2	00 0H57M 3.00S	3423.00	9	-0	2	BEGIN SEARCH	-0.
2	00 0H58M 3.00S	3483.00	9	-0	3	END SEARCH	-0.
			6	1	-0	TURN OFF COMPUTER	-0.
			6	2	-0	TURN OFF ISU	-0.
2	0010H 0M 0.00S	36000.00	6	1	1	TURN ON COMPUTER	-0.
			6	2	1	TURN ON ISU	-0.
-0+	0010H30M 0.00S	37800.00	8	-0	-0	DROP DEAD BAND	0.10000000E+00
			3	0	1	UPDATE WITH ANY USBS-30	-0.
-0+	0010H31M 0.00S	37860.00	5	2	-0	MAKE MIDCOURSE CORRECTION	-0.
			8	0	-0	RAISE DEAD BAND	0.20000000E+02
			6	1	-0	TURN OFF COMPUTER	-0.
			6	2	-0	TURN OFF ISU	-0.
			6	3	0	TURN OFF ATT. CONT.	-0.
			6	4	0	TURN OFF STAR TRACKER	-0.
			6	5	0	TURN OFF SUN SENSOR	-0.
2	4000 0H 0M 0.00S	34560000.00	6	1	1	TURN ON COMPUTER	-0.
			6	2	1	TURN ON ISU	-0.
			6	5	1	TURN ON SUN SENSOR	-0.
			6	4	1	TURN ON STAR TRACKER	-0.
			6	3	1	TURN ON ATT CONT.	-0.
			9	2	1	BEGIN MANEUVERING	-0.
2+	4000 0H30M 0.00S	34561800.00	9	2	2	BEGIN SEARCH	-0.
2+	4000 0H31M 0.00S	34561860.00	9	2	3	END SEARCH	-0.
-0+	4000 1H 1M 0.00S	34563660.00	8	-0	-0	DROP DEAD BAND	0.10000000E+00
			3	0	5	UPDATE WITH ANY DSIF	-0.
-0+	4000 1H 2M 0.00S	34563720.00	5	2	-0	MAKE MIDCOURSE CORRECTION	-0.
			6	3	-0		-0.
			6	1	-0		-0.
			6	2	-0		-0.
			6	4	-0		-0.
			6	5	-0		-0.
			6	7	-0		-0.
-0	4100 10H 4M 2.00S	35460242.00	99	2	-0	END OF THE SCHEDULE	-0.

OPT.=
0 FOR ALL SYSTEMS
1 FOR NON OPTICAL
2 FOR OPTICAL

FIGURE 5. MISSION SCHEDULE 1.

A second mission schedule, which was used in obtaining the results presented in this report, is contained in the Technical Discussion section of this report.

Reference Aided Strapdown Inertial System

The strapdown inertial sensing unit assembled in breadboard form at ERC was used in the exercising of the computer programs developed under this contract. This system is made up of the Honeywell GG 334A gyroscope (three units orthogonally mounted) and the Arma D4E accelerometer (three units orthogonally mounted). The evaluation techniques estimate the weight of a conceptual ISU utilizing these components. In addition, estimates of the characteristics of a conceptual computer, referred to as SRT, were made (Reference 1) for purposes of exercising the computer programs.

The onboard aids are an ITT-Lunar Orbiter strapdown star tracker, an Adcole-1402 strapdown sun sensor, and a Motorola MCR-503 communications receiver.

The reference system is made up from the foregoing components.

Mission Results Using the Reference System

The computer programs developed as part of this study were exercised on the Jupiter flyby mission for the Reference System described in the foregoing section. Figure 6 presents a summary of the evaluation of this system for the mode being evaluated (mode 3 penalty is weight) when operated as shown in Mission Schedule No. 1, Figure 5. The ISU components are listed, followed by the information that ISU Horizontal Design Number 4 (Reference 1) is optimum, and the results of the computed design of the ISU for this mission and schedule. These results include the results of the mechanical design, the total exciting energy in watt hours, the exciting power in watts, the total probability of failure due to unreliability, and the total weight of the ISU. The next block of information shows the thermal analysis and calculations using the variable thermal impedance techniques discussed later in this report. When heater power is considered, the total energy and power requirements are 176.7 watt hours and 141.4 peak watts. The next block of information shows the time, energy, power, probability of failure due to lack of reliability, and weight of the remaining subsystems of the astrionics system. These subsystems are the computer, the star tracker, the sun sensor, the ISU/computer power supply, the communication system, and the horizon sensor. Indicated under each heading is the name given the component selected for that subsystem. None indicates no components and hence no subsystem. The attitude control system analysis is listed next. Thrust sizing is determined by analysis of the torques needed to: (1) counter solar pressure; (2) remove meteorite impact induced disturbances; (3) maneuver the spacecraft through (a) a given angle in a given time, or (b) change the angular rotation rate by a given increment

```
                                   PENALTY (MODE 3)

ERROR ANALYSIS (SCHEDULE NO. 1)

ISU COMPONENTS

        ACCELEROM.=  ARMA D-4E   ARMA D-4E   ARMA D-4E     GYROSCOPES=  GG 334-A    GG 334-A    GG 334-A

ISU DATA(HORIZONTAL DESIGN NUMBER  4  OPTIMUM)                        ON TIME (HR)=      2.517

        OUTSIDE DIMENSIONS        WEIGHT                  WEIGHT                                  EXCIT.ENERGY=     109.511
        LENGTH=      9.350       BLOCK=       8.703    INSULATION=       1.345                      EXCIT.POWER =      43.500
         WIDTH=     10.450        BASE=       4.549   ELECTRONICS=      10.000                      TOTAL P.FAIL=      .00063
        HEIGHT=      5.450       COVER=       2.867    COMPONENTS=       6.000                      TOTAL WEIGHT=      33.463

ISU THERMAL ANALYSIS
                       MAX.HEATER POWER=      97.875        MAX.THERMAL COND.=      2.1750          TOTAL ENERGY=     176.711
                       MIN.HEATER POWER=      -.000         MIN.THERMAL COND.=      1.0875          TOTAL POWER =     141.375

SUBSYSTEM PARAMETERS
                COMPUTERS    STAR TRCKR  SUN SENSOR  ISU/C.P.S.   COM. SYST.   HORIZ.SEN.
                SRT RUK-2    ITT-LUN.OB  ADCL-1402     NONE       MCR-503        NONE
       TIME=      2.517        10.849      10.849      0.000      9601.033       0.000        0.000
     ENERGY=    226.575        86.793      54.246      0.000     33603.617       0.000        0.000    TOTAL ENERGY= 33971.231
      POWER=     90.000         8.000       5.000      0.000         3.500       0.000        0.000    TOTAL POWER =   106.500
     P.FAIL=     .00042        .00012      .00011    0.00000        .09155     0.00000      0.00000    TOTAL P.FAIL=     .09213
     WEIGHT=     36.000         7.000       2.000      0.000         3.100       0.000        0.000    TOTAL WEIGHT=     48.100

ATTITUDE CONTROL SYSTEM ANALYSIS                                     ON TIME (HR)=     10.849

    THRUST SIZING (LB)                                          FUEL CONSUMPTION (LB-SEC)
               ROLL.        YAW       PITCH                        ROLL         YAW        PITCH
SOLAR PRES=    .0000       .0000      .0000
MET.IMPACT=    .0000       .0000      .0001        SEARCHING=    4.0585       2.3060       .0031
MANEUVERS =    .0099       .0099      .0099        DEAD BAND=     .0001        .4445       .2560
MIDCOURSE =   0.0000       .3778      .3778        MANEUVERS=     .2793        .1547       .1917    TOTAL ENERGY=     108.492
MAX.THRUST=    .0099       .3778      .3778        TOTAL IMP=    4.3379       2.9052       .4508    TOTAL POWER =      10.000
                                                                                                 TOTAL P.FAIL=      .00278
NO. OF FIRINGS=     22440      TOTAL IMPULSE=      7.6940        FUEL WEIGHT=    .137393            TOTAL WEIGHT=      21.215

ENERGY SOURCE DATA
                    TOTAL POWER=    257.875    TOTAL ENERGY= 34256.434                           TOTAL WEIGHT=     102.167

WIRING                                                                                           TOTAL WEIGHT=     110.000

MIDCOURSE ENGINE
        EXPECTED DELTA-V=     14.985 DOF=1.000 CAPABILITY=     28.147                            TOTAL WEIGHT=      28.515

PENALTY SUMMATION               PROBABILITIES                             WEIGHT
                   INSUF.MIDCOURSE FUEL=     .06053          ASTRIONICS=    343.460
                   EXCESSIVE TGT. MISS =    0.00000          SPACECRAFT=   1656.540
                   UNRELIABILITY       =     .09523              TOTAL=   2000.000
                   ASTRIONICS TOTAL    =     .15000
                                                                     PENALTY(MODE 3)=              343.45989
EXECUTION TIMES, START= 19.87, END= 33.19, ELAPSED=13.322(SEC.)

                                                                           02/18/69    143806    PAGE 1
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FIGURE 6. SUMMARY OF EVALUATION OF REFERENCE SYSTEM ON MISSION SCHEDULE 1

within a specified time or within a specified change in angle; and (4) counter disturbance torques produced by midcourse correction thrusts. The maximum thrust to meet these various requirements is listed for each axis. Within the attitude control system analysis section is listed the fuel consumption required for (1) searching, (2) dead band operation, and (3) maneuvers. The total impulse per axis is summarized. From the operating time, number of firings, and total impulse, the attitude control subsystem parameters of weight, power, energy, and probability of failure are calculated. The energy and wiring weight is added. The midcourse engine is sized to insure sufficient probability of having enough fuel. The engine weight includes fuel, tankage, and nozzle. The sum of the weights of the astrionics subsystems described above is the penalty.

Optimum Aided Strapdown Inertial System

A search for an optimum system operating on mission schedule 1 was conducted. The list of candidate components included four gyroscopes, four accelerometers, three computers, a strapdown or a gimballed star tracker, and a strapdown sun sensor. Only one communication receiver was in the list, so no optimization of this subsystem was performed. The evaluation considered the possibilities of not using electro-optical sensors. The optimum system and its effectiveness evaluation are shown in Figure 7. The optimum system consists of GG177 accelerometers, 18 IRIG-B gyroscopes, a SIGN III computer, and the strapdown star tracker and sun sensor used in the reference system. The penalty for the optimum system is 331.45 pounds compared to 343.46 pounds for the reference system.

The reference and the optimum system found on mission schedule 1 were then evaluated using mission schedule 2. These results are shown in summary form in Table IVb. As can be seen in Table IVb, the expected target miss distance for the optimum system is considerably larger than the expected miss distance of the reference system. However, since both distances are much less than the target miss requirement for the mission (7.8×10^7 ft), this has negligible impact on the effectiveness index. The dominant factor is the actual physical hardware weight of the subsystem components.

An additional entry in Table IVb shows the results for the reference system evaluated on schedule 1 with the ground based radar used for the range rate measurement prior to the first midcourse degraded in accuracy. Increased update accuracies increase the required midcourse fuel and decrease target miss. If the target miss is already well below the mission requirement, P_{FT} remains essentially zero and hence only the increased penalty due to W_{DV} increase is noted. For fixed launch weight, this reduces scientific payload.

In actual operation, partial midcourse corrections rather than deliberate degradation of update accuracy would remove this effect. Partial corrections would add ΔV to bring the expected miss just to the edge of the allowed miss area rather than correcting to the nominal aim point.

```
ISU COMPONENTS

            ACCELEROM.=  GG-177      GG-177      GG-177        GYROSCOPES=  18-IRIG-B   18-IRIG-B   18-IRIG-B

ISU DATA(HORIZONTAL DESIGN NUMBER  5  OPTIMUM)                          ON TIME (HR)=     2.517

            OUTSIDE DIMENSIONS           WEIGHT                         WEIGHT                                 EXCIT.ENERGY=   108.001
            LENGTH=      10.200         BLOCK=       5.407     INSULATION=      1.019                          EXCIT.POWER =    42.900
             WIDTH=       7.500          BASE=       3.540    ELECTRONICS=     10.000                          TOTAL P.FAIL=    .00062
            HEIGHT=       4.610         COVER=       2.171     COMPONENTS=      4.500                          TOTAL WEIGHT=    26.637

ISU THERMAL ANALYSIS
                     MAX.HEATER POWER=     96.525          MAX.THERMAL COND.=     2.1450               TOTAL ENERGY=   174.274
                     MIN.HEATER POWER=     -.000           MIN.THERMAL COND.=     1.0725               TOTAL POWER =   139.425

SUBSYSTEM PARAMETERS
              COMPUTERS   STAR TRCKR   SUN SENSOR  ISU/C.P.S.  COM. SYST.   HORIZ.SEN.
              SIGN III    ITT-LUN.08   ADCL-1402      NONE     MCR-503        NONE
       TIME=     2.517      10.849       10.849       0.000     9601.033      0.000        0.000
     ENERGY=   289.512      86.793       54.246       0.000    33603.617      0.000        0.000   TOTAL ENERGY= 34034.168
      POWER=   115.000       8.000        5.000       0.000        3.500      0.000        0.000   TOTAL POWER =   131.500
     P.FAIL=    .00045      .00012       .00011     0.00000       .09155    0.00000      0.00000   TOTAL P.FAIL=    .09216
     WEIGHT=    27.000       7.000        2.000       0.000        3.100      0.000        0.000   TOTAL WEIGHT=    39.100

ATTITUDE CONTROL SYSTEM ANALYSIS                                        ON TIME (HR)=    10.849

        THRUST SIZING (LB)                                  FUEL CONSUMPTION (LB-SEC)
                    ROLL        YAW       PITCH                            ROLL        YAW       PITCH
   SOLAR PRES=      .0000      .0000      .0000
   MET.IMPACT=      .0000      .0000      .0001        SEARCHING=       4.0598     2.3060      .0007
   MANEUVERS =      .0099      .0099      .0099        DEAD BAND=        .0001      .4445      .2560
   MIDCOURSE =     0.0000      .3778      .3778        MANEUVERS=        .2793      .1547      .1917      TOTAL ENERGY=   108.492
   MAX.THRUST=      .0099      .3778      .3778        TOTAL IMP=       4.3392     2.9052      .4484      TOTAL POWER =    10.000
                                                                                                       TOTAL P.FAIL=    .00278
   NO. OF FIRINGS=     22446    TOTAL IMPULSE=    7.6928        FUEL WEIGHT=   .137372                 TOTAL WEIGHT=    21.215

ENERGY SOURCE DATA
                     TOTAL POWER=    280.925     TOTAL ENERGY= 34316.934                               TOTAL WEIGHT=   110.119

WIRING                                                                                                 TOTAL WEIGHT=   110.000

MIDCOURSE ENGINE
            EXPECTED DELTA-V=      7.430 DOF=1.000 CAPABILITY=    13.957                               TOTAL WEIGHT=    24.377

PENALTY SUMMATION                PROBABILITIES                        WEIGHT
                     INSUF.MIDCOURSE FUEL=     .06051          ASTRIONICS=   331.448
                     EXCESSIVE TGT. MISS =    0.00000         SPACECRAFT=   1668.552
                     UNRELIABILITY       =     .09525              TOTAL=   2000.000
                     ASTRIONICS TOTAL    =     .15000
                                                                                   PENALTY(MODE 3)=            331.44832

EXECUTION TIMES, START=808.04, END=836.33, ELAPSED=28.288(SEC.)
```

FIGURE 7. SUMMARY OF EVALUATION OF OPTIMUM SYSTEM ON MISSION SCHEDULE 1.

TABLE IVb. SUMMARY OF RESULTS

System	Schedule	R_T (ft)	R_V (ft/sec)	W_{DV} (lb)	W_{AC} (lb)	Penalty (Mode 3) W_{GS} (lb)
Reference 1*	1	1.54×10^6	14.985	28.515	21.21	343.460
Reference 1	2	0.153×10^6	14.94	28.571	21.40	343.700
Optimum**	1	1.90×10^6	7.43	24.377	21.21	331.448
Optimum	2	0.255×10^6	7.39	24.392	21.40	331.645
Reference 2 ‡	1	5.49×10^6	14.984	28.514	21.21	343.459

	Gyros	Acceler-ometers	Computer	Sun Sensor	Star Tracker	Receiver
* Reference 1 System	GG 344-A	D-4E	SRT	Adcole 1402	ITT Lunar Orbiter	503
‡ Same as Reference with Degraded Radar	GG 334-A	D-4E	SRT	Adcole 1402	ITT Lunar Orbiter	503
**Optimum For Schedule 1	18-IRIG	GG-177	SIGN III	Adcole 1402	ITT Lunar Orbiter	503

TECHNICAL DISCUSSION

Review of Evaluation Criteria Formulation

Evaluation criteria were formulated in the phase of work which preceded the phase this Interim Scientific Report covers. These criteria will be reviewed in the following section. It should be noted that the definitions of some of the parameters used in the original criteria (Reference 1) have been expanded to include the additional astrionics subsystems which were considered during this phase of the work.

Penalty Function Analysis

The effectiveness of an astrionics system on a specific spacecraft mission is evaluated by one of three penalty functions. The astrionics system is described by the six system parameters shown in Table V.

TABLE V
ASTRIONICS SYSTEM PARAMETERS

Symbol	Definition
P_{FR}	Probability of mission failure due to inadequate hardware reliability.
R_V	Square root of the trace of the midcourse delta-V (ΔV) covariance matrix.
D_V	Degrees-of-freedom of the midcourse ΔV covariance.
R_T	Square root of the trace of the target miss covariance matrix.
D_T	Degrees-of-freedom of the target miss covariance.
W_{ICP}	Weight of onboard inertial measurement unit, computer, electrical energy source, electro-optical sensors, tracking and command subsystem, attitude control, and wiring.

The penalty functions are calculated from the above system parameters and the mission and spacecraft parameters shown in Table VI.

TABLE VI
MISSION AND SPACECRAFT PARAMETERS

Symbol	Definition
P_{FG}	Probability of mission failure attributable to the astrionics system.
W_{NG}	Nonastrionics spacecraft weight.
W_T	Total spacecraft weight.
X_{MISS}	Allowed miss distance at target.
K_{DV}	Midcourse correction system tankage factor (system weight/fuel weight).
K_{DC}	Midcourse correction system constant weight.
Ig	Specific impulse of the midcourse correction system times gravity.

The three penalty functions are defined in Table VII.

TABLE VII
PENALTY FUNCTION DEFINITION

Penalty Mode	P_{FG}	W_{NG}	W_{GS}	W_T
1	F	F	P	V
2	P	F	F	F
3	F	V	P	F

F $\triangleq$ Fixed
P $\triangleq$ Penalty
V $\triangleq$ Variable with System

Penalty function, mode 1, assumes that a certain probability of mission failure attributable to astrionics (P_{FG}) is reasonable and that non-astrionics spacecraft weight (W_{NG}) is fixed. The astrionics system weight is calculated and used as the penalty function.

Penalty function, mode 2, assumes nonastrionics, astrionics system, and total spacecraft weights are constants with the probability of mission failure attributable to astrionics (P_{FG}) variable and used as the penalty function.

Penalty function, mode 3, assumes that a certain probability of mission failure attributable to astrionics (P_{FG}) is reasonable and that total spacecraft weight (W_T) is fixed. The astrionics system weight (W_{GS}) is variable and used as the penalty function.

Calculation of the penalty function under any of the three modes will involve calculating the intermediate quantities defined in Table VIII.

TABLE VIII
INTERMEDIATE QUANTITIES USED IN
CALCULATING THE PENALTY FUNCTIONS

Symbol	Definition
P_{FV}	Probability of having insufficient midcourse fuel.
P_{FT}	Probability of exceeding target miss criteria.
P_{FTR}	Probability of failure due to inadequate reliability or target miss
W_F	Weight of midcourse fuel
W_{DV}	Total weight of midcourse propulsion system
ΔV	Midcourse velocity correction
μ	Spacecraft mass ratio
ψ_V	$\Delta V/R_V$
ψ_T	X_{MISS}/R_T

A detailed discussion of the steps used to calculate each penalty mode is given below.

Penalty Mode 1. Probability of missing the target (P_{FT}) is calculated from the system parameters describing accuracy at the target as follows:

$$P_{FT} = \mathrm{Prob}(\psi_T, D_T)$$

where

$$\psi_T = X_{MISS}/R_T \quad .$$

The function Prob(ψ, D) is the probability distribution of the magnitude of a vector with normal, zero-mean, components as discussed in Reference 9 . A table of this distribution is shown in Figure 8.

The combined probability of missing the target or failing due to inadequate reliability is obtained from

$$P_{FTR} = P_{FR} + P_{FT} - P_{FR}P_{FT} \quad .$$

With the probability of failure due to target miss or inadequate reliability known, the probability of failure due to insufficient fuel which results from the specified P_{FG} is calculated as follows:

$$P_{FV} = \frac{P_{FG} - P_{FTR}}{1 - P_{FTR}} \quad .$$

Note that if P_{FTR} exceeds P_{FG}, P_{FV} does not exist. In other words, if the probability of failure due to inadequate reliability or target miss is greater than P_{FG}, even a perfect system (zero probability of insufficient fuel) will exceed P_{FG}.

The ΔV capability needed to achieve the required P_{FG} is calculated from

$$\psi_V = \psi(P_{FV}, D_V)$$

PROB.	D= 1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.4	2.6	2.8	3.0
1.00E+00	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X	0 0000X
9.00E-01	.2072	.2162	.2257	.2358	.2464	.2577	.2696	.2822	.2955	.3097	.3237	.3522	.3770	.4004	.4218	.4398
8.00E-01	.3016	.3146	.3285	.3431	.3645	.3872	.4072	.4252	.4418	.4575	.4608	.4989	.5228	.5431	.5617	.5786
7.00E-01	.3866	.4220	.4506	.4748	.4967	.5182	.5371	.5539	.5695	.5840	.5972	.6209	.6411	.6591	.6746	.6887
6.00E-01	.5251	.5572	.5841	.6067	.6281	.6466	.6629	.6779	.6914	.7036	.7147	.7343	.7511	.7655	.7781	.7892
5.00E-01	.6753	.7028	.7255	.7459	.7631	.7783	.7918	.8036	.8143	.8239	.8326	.8476	.8602	.8708	.8800	.8880
4.00E-01	.8416	.8637	.8812	.8965	.9091	.9202	.9296	.9379	.9451	.9515	.9572	.9669	.9746	.9809	.9863	.9910
3.00E-01	1.0367	1.0500	1.0606	1.0690	1.0756	1.0814	1.0860	1.0897	1.0927	1.0952	1.0973	1.1004	1.1025	1.1039	1.1048	1.1053
2.00E-01	1.2819	1.2836	1.2841	1.2835	1.2822	1.2804	1.2784	1.2761	1.2737	1.2712	1.2686	1.2634	1.2583	1.2532	1.2483	1.2436
1.00E-01	1.6452	1.6284	1.6128	1.5982	1.5845	1.5716	1.5594	1.5480	1.5372	1.5270	1.5174	1.4997	1.4836	1.4689	1.4555	1.4433
9.00E-02	1.6955	1.6764	1.6586	1.6419	1.6263	1.6118	1.5982	1.5855	1.5736	1.5624	1.5518	1.5322	1.5146	1.4986	1.4841	1.4709
8.00E-02	1.7510	1.7288	1.7083	1.6894	1.6721	1.6559	1.6408	1.6267	1.6134	1.6010	1.5893	1.5678	1.5485	1.5312	1.5154	1.5009
7.00E-02	1.8120	1.7868	1.7637	1.7424	1.7228	1.7046	1.6878	1.6721	1.6574	1.6436	1.6307	1.6071	1.5860	1.5670	1.5497	1.5340
6.00E-02	1.8812	1.8522	1.8258	1.8017	1.7796	1.7593	1.7405	1.7230	1.7068	1.6916	1.6773	1.6513	1.6281	1.6073	1.5885	1.5712
5.00E-02	1.9600	1.9269	1.8970	1.8699	1.8450	1.8222	1.8011	1.7816	1.7635	1.7466	1.7308	1.7020	1.6764	1.6534	1.6326	1.6138
4.00E-02	2.0538	2.0157	1.9815	1.9506	1.9225	1.8967	1.8730	1.8511	1.8307	1.8118	1.7941	1.7620	1.7335	1.7081	1.6851	1.6643
3.00E-02	2.1704	2.1261	2.0865	2.0508	2.0185	1.9890	1.9619	1.9370	1.9139	1.8925	1.8726	1.8364	1.8044	1.7758	1.7501	1.7268
2.00E-02	2.3266	2.2740	2.2272	2.1852	2.1474	2.1129	2.0814	2.0525	2.0257	2.0009	1.9779	1.9362	1.8995	1.8668	1.8374	1.8108
1.00E-02	2.5760	2.5101	2.4518	2.3999	2.3531	2.3107	2.2721	2.2367	2.2041	2.1740	2.1460	2.0955	2.0511	2.0117	1.9764	1.9446
9.00E-03	2.6122	2.5444	2.4845	2.4311	2.3830	2.3395	2.2998	2.2635	2.2300	2.1991	2.1704	2.1186	2.0731	2.0327	1.9966	1.9640
8.00E-03	2.6521	2.5822	2.5205	2.4655	2.4160	2.3712	2.3304	2.2931	2.2587	2.2269	2.1973	2.1442	2.0975	2.0560	2.0189	1.9854
7.00E-03	2.6971	2.6247	2.5609	2.5040	2.4529	2.4067	2.3646	2.3261	2.2907	2.2579	2.2275	2.1728	2.1247	2.0821	2.0439	2.0095
6.00E-03	2.7482	2.6731	2.6069	2.5480	2.4951	2.4472	2.4037	2.3636	2.3272	2.2933	2.2619	2.2053	2.1557	2.1116	2.0723	2.0368
5.00E-03	2.8075	2.7293	2.6604	2.5991	2.5441	2.4943	2.4491	2.4077	2.3696	2.3344	2.3018	2.2431	2.1916	2.1460	2.1052	2.0685
4.00E-03	2.8784	2.7965	2.7244	2.6603	2.6027	2.5508	2.5035	2.4603	2.4205	2.3838	2.3498	2.2886	2.2349	2.1874	2.1449	2.1066
3.00E-03	2.9680	2.8812	2.8050	2.7372	2.6765	2.6217	2.5720	2.5264	2.4846	2.4460	2.4102	2.3459	2.2895	2.2395	2.1949	2.1547
2.00E-03	3.0905	2.9973	2.9155	2.8429	2.7778	2.7191	2.6658	2.6171	2.5724	2.5311	2.4929	2.4242	2.3641	2.3110	2.2635	2.2207
1.00E-03	3.2907	3.1671	3.0961	3.0154	2.9433	2.8783	2.8192	2.7654	2.7160	2.6704	2.6283	2.5525	2.4863	2.4277	2.3754	2.3284
9.00E-04	3.3202	3.2156	3.1227	3.0409	2.9677	2.9018	2.8419	2.7873	2.7372	2.6910	2.6482	2.5715	2.5043	2.4450	2.3920	2.3443
8.00E-04	3.3528	3.2460	3.1522	3.0691	2.9948	2.9278	2.8670	2.8116	2.7607	2.7138	2.6704	2.5925	2.5243	2.4641	2.4103	2.3620
7.00E-04	3.3897	3.2807	3.1854	3.1008	3.0252	2.9571	2.8953	2.8389	2.7871	2.7394	2.6953	2.6160	2.5468	2.4856	2.4310	2.3819
6.00E-04	3.4318	3.3206	3.2232	3.1370	3.0599	2.9905	2.9275	2.8700	2.8173	2.7687	2.7237	2.6430	2.5724	2.5101	2.4545	2.4045
5.00E-04	3.4809	3.3673	3.2677	3.1794	3.1006	3.0296	2.9652	2.9065	2.8526	2.8029	2.7570	2.6745	2.6025	2.5388	2.4820	2.4309
4.00E-04	3.5401	3.4235	3.3212	3.2306	3.1497	3.0768	3.0107	2.9505	2.8952	2.8442	2.7972	2.7126	2.6387	2.5734	2.5153	2.4629
3.00E-04	3.6154	3.4946	3.3890	3.2955	3.2120	3.1367	3.0685	3.0063	2.9493	2.8967	2.8481	2.7609	2.6846	2.6175	2.5575	2.5035
2.00E-04	3.7191	3.5931	3.4827	3.3850	3.2978	3.2192	3.1482	3.0833	3.0239	2.9691	2.9184	2.8276	2.7483	2.6782	2.6158	2.5597
1.00E-04	3.8907	3.7558	3.6375	3.5331	3.4399	3.3561	3.2801	3.2108	3.1473	3.0889	3.0348	2.9380	2.8535	2.7787	2.7122	2.6524
9.00E-05	3.9162	3.7800	3.6607	3.5551	3.4610	3.3765	3.2997	3.2298	3.1657	3.1067	3.0522	2.9544	2.8691	2.7936	2.7265	2.6662
8.00E-05	3.9445	3.8068	3.6863	3.5796	3.4845	3.3990	3.3215	3.2508	3.1861	3.1266	3.0714	2.9727	2.8865	2.8102	2.7425	2.6816
7.00E-05	3.9764	3.8370	3.7150	3.6072	3.5109	3.4245	3.3460	3.2745	3.2090	3.1489	3.0931	2.9932	2.9061	2.8290	2.7604	2.6989
6.00E-05	4.0130	3.8717	3.7480	3.6387	3.5412	3.4537	3.3742	3.3017	3.2353	3.1744	3.1179	3.0168	2.9285	2.8504	2.7810	2.7187
5.00E-05	4.0559	3.9123	3.7866	3.6757	3.5767	3.4878	3.4072	3.3336	3.2662	3.2044	3.1470	3.0444	2.9548	2.8756	2.8051	2.7419
4.00E-05	4.1077	3.9615	3.8334	3.7206	3.6196	3.5292	3.4471	3.3722	3.3037	3.2406	3.1822	3.0778	2.9867	2.9061	2.8343	2.7700
3.00E-05	4.1739	4.0240	3.8930	3.7778	3.6745	3.5818	3.4979	3.4213	3.3514	3.2867	3.2271	3.1203	3.0273	2.9449	2.8715	2.8058
2.00E-05	4.2655	4.1106	3.9756	3.8570	3.7505	3.6546	3.5680	3.4894	3.4176	3.3506	3.2893	3.1793	3.0832	2.9987	2.9231	2.8556
1.00E-05	4.4177X	4.2546X	4.1136X	3.9877	3.8763	3.7758	3.6848	3.6028	3.5276	3.4573	3.3925	3.2779	3.1766	3.0884	3.0091	2.9378
9.00E-06	4.4404X	4.2760X	4.1342X	4.0072	3.8950	3.7939	3.7024	3.6197	3.5440	3.4732	3.4079	3.2927	3.1906	3.1018	3.0220	2.9501
8.00E-06	4.4656X	4.2999X	4.1570X	4.0288X	3.9158	3.8140	3.7219	3.6385	3.5623	3.4909	3.4250	3.3091	3.2062	3.1165	3.0363	2.9638
7.00E-06	4.4944X	4.3268X	4.1828X	4.0533X	3.9393	3.8368	3.7440	3.6597	3.5829	3.5110	3.4443	3.3277	3.2237	3.1330	3.0525	2.9792
6.00E-06	4.5266X	4.3577X	4.2124X	4.0813X	3.9662X	3.8628	3.7692	3.6840	3.6067	3.5342	3.4665	3.3490	3.2439	3.1520	3.0711	2.9969
5.00E-06	4.5648X	4.3939X	4.2471X	4.1142X	3.9978X	3.8934X	3.7989	3.7125	3.6345	3.5614	3.4934	3.3741	3.2675	3.1743	3.0930	3.0184
4.00E-06	4.6112X	4.4376X	4.2892X	4.1541X	4.0362X	3.9305X	3.8349X	3.7471	3.6683	3.5945	3.5260	3.4036	3.2963	3.2014	3.1196	3.0446
3.00E-06	4.6705X	4.4937X	4.3429X	4.2049X	4.0851X	3.9779X	3.8809X	3.7913X	3.7114X	3.6367	3.5676	3.4408	3.3326	3.2359	3.1536	3.0779
2.00E-06	4.7524X	4.5715X	4.4174X	4.2756X	4.1530X	4.0436X	3.9447X	3.8527X	3.7713X	3.6954X	3.6254X	3.4925	3.3827	3.2840	3.2002	3.1243

X indicates extrapolation from Gamma Function Table

FIGURE 8. CUMULATIVE PROBABILITY DISTRIBUTION FUNCTION [Pr($|X| > \psi \sqrt{TRACE}$)] OF A VECTOR WITH NORMAL, ZERO MEAN, COMPONENTS

Magnitude/ $\sqrt{Trace} = \psi$

and

$$\Delta V = R_V \psi_V$$

where $\psi(P, D)$ is obtained from function $Prob(\psi, D)$ by solving for ψ knowing P and D.

The familiar rocket equation,

$$\Delta V = Ig \log_e(\mu) \quad ,$$

is used to obtain the spacecraft mass ratio,

$$\mu = e^{\Delta V/Ig} \quad .$$

The spacecraft mass ratio is the initial spacecraft weight divided by the final spacecraft weight and is calculated as follows:

$$\mu = \frac{W_T}{W_T - W_F} \quad .$$

The weight of the required midcourse fuel is

$$W_F = W_T \frac{(\mu - 1)}{\mu} \quad .$$

The midcourse propulsion system weight is estimated using the equation

$$W_{DV} = W_F K_{DV} + K_{DC} \quad .$$

Defining

$$W_T = W_{ICP} + W_{NG} + W_{DV} \quad ,$$

substitution into the equation for W_F in terms of W_T and μ yields

$$W_F = \frac{(\mu - 1)(W_{ICP} + W_{NG} + K_{DC})}{\mu - [\mu - 1] K_{DV}} \quad .$$

The effective weight of the complete astrionics system is then

$$W_{GS} = W_{ICP} + W_F K_{DV} + K_{DC} \quad .$$

This is the desired penalty function. The above equations are shown in flow chart form in Figure 9.

Penalty Mode 2. The probability of failing due to inadequate reliability or miss at the target (P_{FTR}) is calculated as in penalty mode 1. The combined astrionics system probability of failure (P_{FG}), the penalty of mode 2, is calculated by including the probability of insufficient midcourse correction fuel (P_{FV}).

The total spacecraft weight (W_T) and nonastrionics spacecraft weight (W_{NG}) define the total astrionics system weight to be

$$W_{GS} = W_T - W_{NG} \quad .$$

The midcourse system weight is assumed to be

$$W_{DV} = W_{GS} - W_{ICP} \quad .$$

Thus, the fuel weight is determined from the equation,

$$W_F = \frac{W_{DV} - K_{DC}}{K_{DV}}$$

and the spacecraft mass ratio is

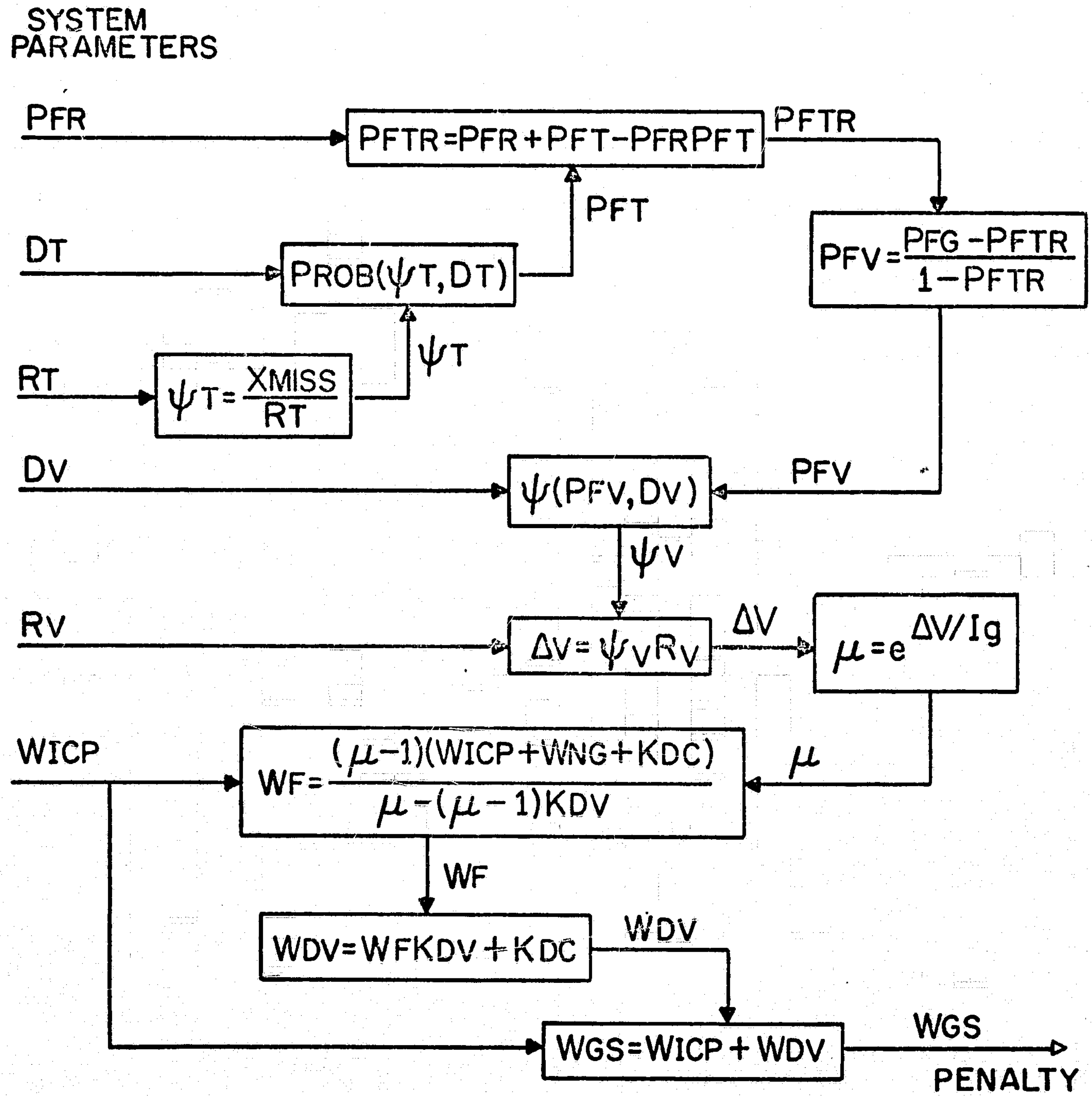


FIGURE 9. CALCULATION OF PENALTY, MODE 1

$$\mu = \frac{W_T}{W_T - W_F} \quad .$$

The ΔV capability is found from the rocket equation,

$$\Delta V = Ig \log(\mu)$$

and the probability of insufficient fuel is

$$P_{FV} = \text{Prob}(\psi_V, D_V)$$

where

$$\psi_V = \frac{\Delta V}{R_V} \quad .$$

The combined probability of mission failure attributable to the astrionics is

$$P_{FG} = P_{FTR} + P_{FV} - P_{FTR} P_{FV}$$

and is the desired penalty, mode 2. The above equations are shown in flow chart form in Figure 10.

Penalty Mode 3. Penalty mode 3 is similar to penalty mode 1 in that the penalty is the effective weight of the astrionics system (W_{GS}). However, the total spacecraft weight (W_T) is held constant under mode 3 unlike mode 1 where the nonastrionics weight was held constant.

The probability of failing due to reliability or miss at the target (P_{FTR}) is calculated as under mode 1. The probability of insufficient fuel is obtained from the equation

$$P_{FV} = \frac{P_{FG} - P_{FTR}}{1 - P_{FTR}} \quad .$$

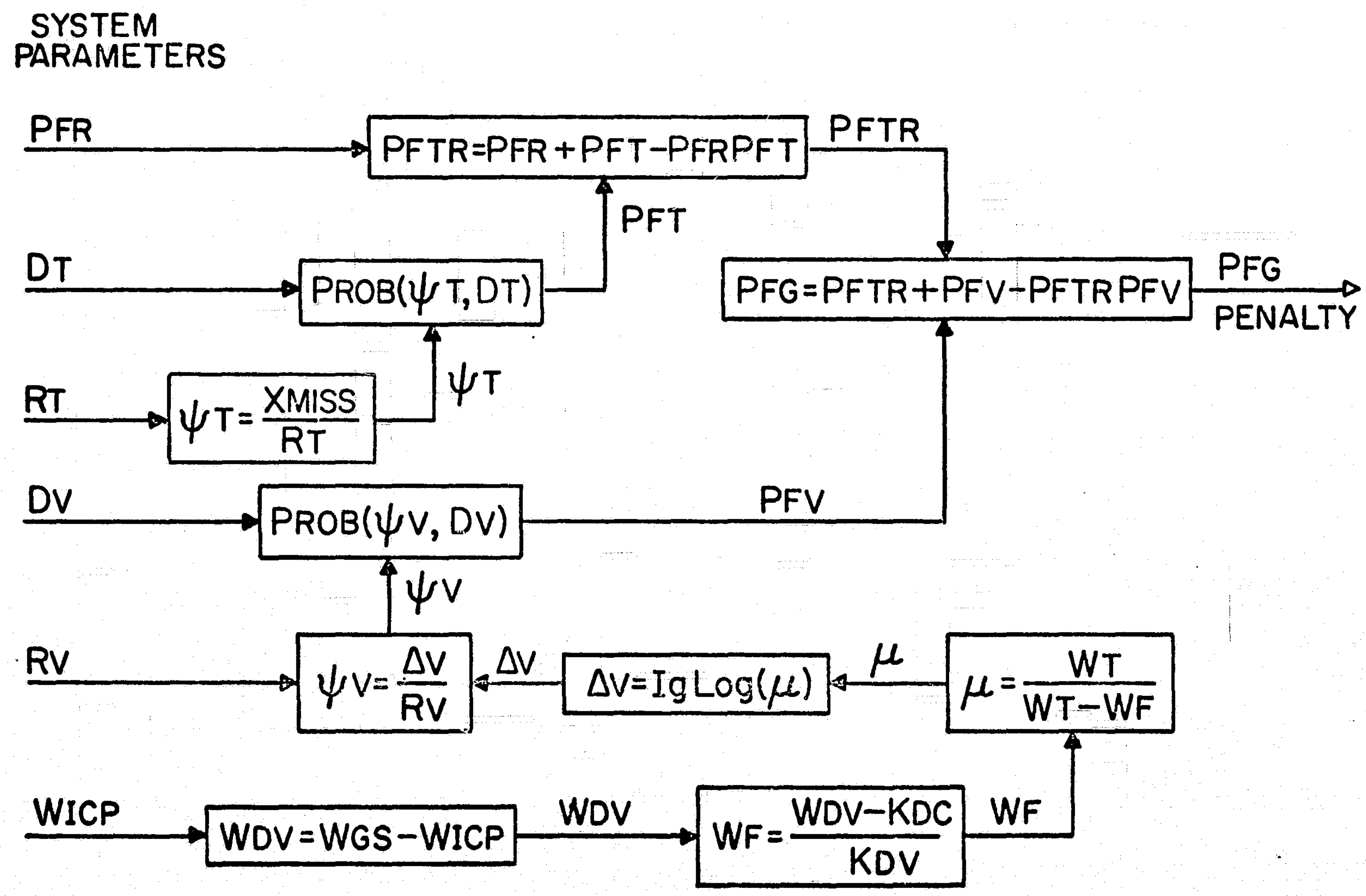


FIGURE 10. CALCULATION OF PENALTY, MODE 2

The result is used to compute the required midcourse ΔV capability from the equation

$$\Delta V = R_V \psi_V$$

where the number of traces (ψ_V) is obtained from the statistical distribution

$$\psi_V = \psi(P_{FV}, D_V) \quad .$$

With the ΔV requirement known, the mass ratio is

$$\mu = e^{\Delta V/Ig} \quad .$$

Since the total spacecraft weight is known, the required fuel weight may be obtained directly from

$$W_F = W_T \frac{(\mu - 1)}{\mu} \quad .$$

The total effective astrionics system weight is obtained by adding the midcourse system weight to the weight of the other astrionics subsystems as shown below,

$$W_{GS} = W_{ICP} + W_F K_{DV} + K_{DC} \quad .$$

The equations for penalty mode 3 are shown in Figure 11.

Development of System Parameter Estimation Techniques

The system parameters which must be estimated for conceptual astrionics systems are those used in the system performance indices (penalty functions). These parameters were discussed in the preceding section and are listed in Table V. This section describes the techniques developed to:

(1) Perform the error analysis of aided inertial systems which utilize Kalman filtering in the updating of system errors using aid measurements

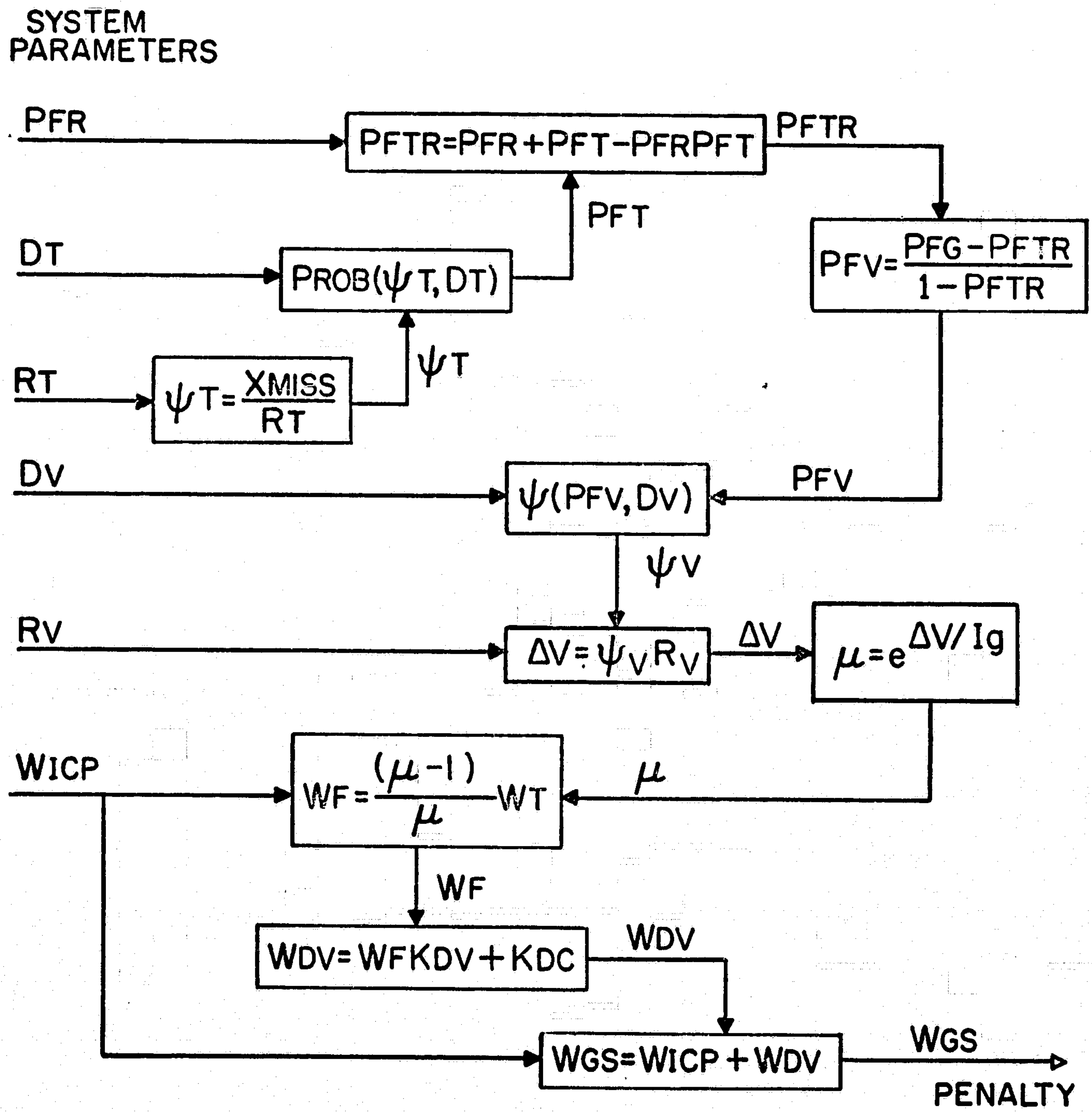


FIGURE 11. CALCULATION OF PENALTY, MODE 3

(2) Estimate the needed parameters for

(a) Electro-optical sensors

(b) Radio aids

(3) Permit evaluation of

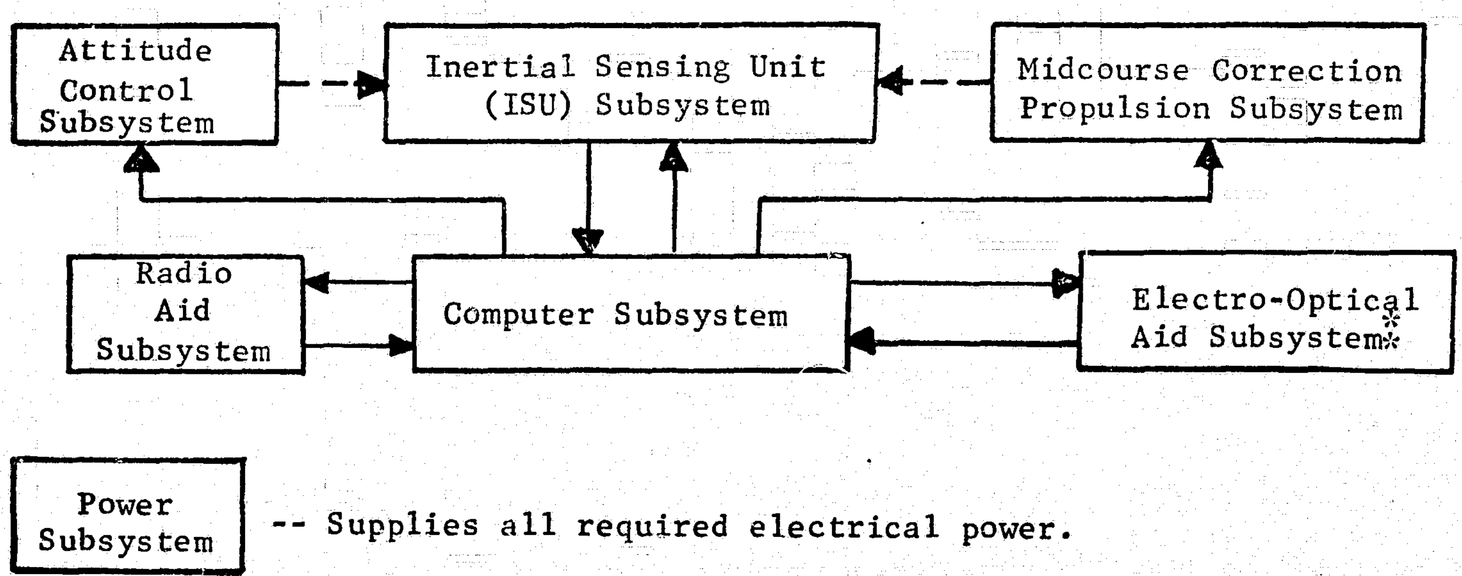
(a) Alternate inertial sensing unit configurations (gimballed or strapdown)

(b) Power supply options

(4) Estimate the parameters of a three axes mass expulsion attitude control system.

A modular guidance system philosophy (References 10 and 11) is considered applicable to this study. Using this philosophy, the system parameters used in the penalty functions (Reference 1) were modified to reflect the increased on-board weight, power requirements, and reliability of the candidate aids. These parameters and data describing the errors contributed by the various candidate aids are used in the penalty calculations.

The aided inertial guidance system (integrated astrionics) is depicted in block diagram form in Figure 12 with the attitude control, midcourse correction propulsion, and power subsystems shown since these subsystems are included in the guidance system effectiveness evaluation.



* Horizon Sensor -- Parking Orbit
Star Tracker/Sun Sensor -- Injection to Midcourse

FIGURE 12. BLOCK DIAGRAM OF INTEGRATED ASTRIONICS SUBSYSTEMS CONTRIBUTION TO PENALTY

The error analysis of this aided inertial system is discussed first. Later sections discuss estimation of the other parameters for the subsystems depicted in Figure 12.

Error Analysis Formulation

A nine element state vector is used to describe the error and deviation states of the spacecraft and its guidance system. The nine elements of a state vector $\tilde{X}$ are defined to be:

X_1 down range (DR) position

X_2 cross range (CR) position

X_3 out of plane (OP) position

X_4 DR velocity

X_5 CR velocity

X_6 OP velocity

X_7 small angles about the DR axis

X_8 small angles about the CR axis

X_9 small angles about the OP axis

where, in a right handed orthogonal set

DR = the direction of the velocity vector

CR = normal to DR in the position-velocity (P-V) plane

OP = normal to the P-V plane.

Nominal attitude is assumed to be

DR roll

CR = -yaw

OP = -pitch

except when the vehicle is commanded to a specific attitude for optical measurements or corrective maneuvers.

Errors and deviations are defined by differences between the nominal (X_o), actual (X_a), and computed (X_c) state of the vehicle. That is,

$$\vec{e} = \vec{X}_c - \vec{X}_a$$

$$\vec{d} = \vec{X}_a - \vec{X}_o$$

and

$$\vec{d}_c = \vec{X}_c - \vec{X}_o = \vec{e} + \vec{d}$$

where $\vec{e}$ is the error or difference between the computed state and the actual state, $\vec{d}$ is the deviation or difference between the actual and nominal states, and $\vec{d}_c$ is the computed deviation or difference between the computed and nominal states. Thus, $\vec{d}_c$ represents the state of the navigation system and $\vec{d}$ the state of the physical spacecraft.

Statistical Treatment of Errors and Deviations

The covariance of the errors or deviations are found by adding the covariances of two contributions. The first contribution is the covariance due to hardware error sources which are treated as statistical biases. Statistical biases are numbers which remain constant throughout the mission but are random with Gaussian distributions. The covariance due to statistical biases is found at any point, i, in the mission by

$$[Cb_i] = [G_i][\delta b \; \delta b^T][G_i]^T$$

where $[Cb_i]$ = 9 x 9 covariance due to bias sources

$[G_i]$ = 9 x N sensitivity to each of N bias sources

$[\delta b \; \delta b^T]$ = N x N covariance of bias sources (assumed diagonal).

The sensitivity matrix G_i at any point in the mission is found by

$$[G_i] = [\Phi_i][G_{i-1}] + [S_i]$$

where $[\Phi_i]$ = 9 x 9 state transition matrix from i-1 to i

$[S_i]$ = 9 x N sensitivity to each of N bias sources for flight from i-1 to i.

The covariance due to noise sources is found at any point in the mission by

$$[Cn_i] = [\Phi_i][Cn_{i-1}][\Phi_i]^T + [N_i]$$

where $[Cn_i]$ = 9 x 9 covariance at i due to noise sources

$[N_i]$ = 9 x 9 covariance due to noise sources from i-1 to i.

Noise sources are those contributions to the errors which are assumed uncorrelated in time and include all optical and radio update measurement errors, and initial position, velocity and attitude uncertainties. The above relationships hold for errors and deviations so the notation is expanded to include the suffix e or d to indicate errors or deviations.

Computed Deviation Statistical Treatment

Deterministically the computed deviation at any point in the mission is equal to the errors plus the deviations. The computed deviations due to bias sources may then be found by

$$[Cdcb_i] = [Geb_i + Gdb_i][\delta b\ \delta b^T][Geb_i + Gdb_i]^T$$

where $[Cdcb_i]$ = 9 x 9 covariance of computed deviations due to bias sources.

The noise contribution to computed deviations is found by

$$[Cdcn_i] = [Cen_i] + [Cdn_i] + [Cedn_i] + [Cedn_i]^T$$

where $[Cdcn_i]$ = the 9 x 9 covariance of computed deviations due to noise sources

and

$$[Cedn_i] = [\Phi e_i][Cedn_{i-1}][\Phi d_i]^T$$

which is necessary to account for the correlation between errors and deviations.

Generalized Mission Operation

Any mission operation such as coasting flight, midcourse correction, or aid update may be defined by its state transition matrices and sensitivity matrices and the noise contributions to errors and deviations. These matrices for the various mission operations are developed as follows.

Powered Flight. The sensitivity and state transition matrices for powered flight are generated separately by the strapdown error analysis program (SEAP) and the platform error analysis program (PEAP) which operate on trajectories developed under Battelle's three degree of freedom program. During powered flight perfect closed loop control is assumed. The steering devices are controlled by the guidance system so that at cutoff the computed state is equal to the nominal state. Or, after powered flight

$$\vec{e} = -\vec{d}$$

and

$$\vec{d}_c = 0.$$

Thus,

$$[\Phi e] = [\Phi d] = \text{output of SEAP or PEAP}$$

$$[Sd] = [-Se] = \text{output of SEAP or PEAP}$$

$$[Nd] = [Ne] = [0] \text{ (zero)}.$$

The sensitivity matrix for deviations is equal to the negative of the sensitivity matrix for errors. The state transition matrices are equal.

Coasting Flight. Coasting flight is open loop for position and velocity. Since disturbing forces are neglected and the ISU accelerometers are assumed to be disconnected, there are no sensitivites of position or velocity errors or deviations to bias sources. The ISU gyros or optical aids may be operating with or without the attitude control subsystem operating. This allows the following alternatives to bias or noise attitude errors or deviations.

(1) ISU and attitude control operating. In this case the error sensitivities to D_{FR} (gyro fixed drift) increase with time. Since the attitude loop is closed, the deviation D_{FR} sensitivities are equal in magnitude and opposite in sign to the error sensitivities. The attitude computed deviations are equal to the dead band width. These drifts cause the errors and deviations to grow with time. However, an attitude error that is greater than $\pm 180°$ has no meaning. Thus, an upper bound of 180° is placed on the attitude errors and deviations.

(2) Electro-optical sensors and attitude control operating. This is similar to case 1. However, there is no sensitivity to bias sources. The electro-optical sensors errors are contributions to the noise covariances Nd and Ne. The attitude computed deviations are equal to the deadbands.

(3) Sensors and attitude control turned off. Turning off all sensors and the attitude control subsystem zeroes the sensitivity arrays Ge and Gd. The noise covariances Nd and Ne are set to the diagonal form with π^2 on the diagonal to indicate complete uncertainty of attitude errors and deviations.

Other combinations such as running the attitude control with no sensors operating are not reasonable and therefore have not been modeled.

Kalman Updating

A general Kalman update of the state errors (Reference 12) is performed by

$$\vec{X}^{+} = \vec{X}^{-} - K\,[M\vec{X} - \vec{Y}]$$

where

$\vec{X}^{+}$ = the 9 element state estimate vector immediately after the measurement

$\vec{X}^{-}$ = the 9 element state estimate vector immediately prior to the measurement

$\vec{Y}$ = the m element measurement vector

$\vec{K}$ = 9 x m weighting matrix

M = m x 9 measurement matrix.

K is obtained by (Reference 12)

$$K = P^{-}M^{T}[MP^{-}M^{T} + W]^{-1}$$

where

P^{-} = covariance matrix of the state error just prior to update

W = covariance matrix of measurement noise.

The use of P^{-} in computing K necessitates computation of the covariance matrix in the on-board computer. The covariance must also be updated to reflect the inclusion of the measurement, and References 12 and 13 give an expression for the updated covariance P^{+}.

In this study the updated covariance alone is of little value. Simple propagation of the updated covariance would not permit proper inclusion of a later powered flight segment. The correlation of hardware errors between the powered flight segments would be lost. Instead, updating of the error state will be used. This will now be shown to be equivalent to the Kalman update of the covariance matrix.

A measurement produces an output $\vec{d}_m$ defined to be the difference between the measurement result and that obtained if the spacecraft were in its nominal state. Then

$$\vec{d}_m = M\vec{d} + \vec{e}_m$$

where $\vec{e}_m$ is the error in making the measurement.

The update of the computed deviation is made by

$$\vec{d}_c^{\,+} = \vec{d}_c^{\,-} - K\,(M\vec{d}_c - \vec{d}_m) \quad .$$

Substituting the actual deviation and measurement error gives

$$\vec{d}_c^{\,+} = \vec{d}_c^{\,-} - K\,(M\vec{d}_c^{\,-} - M\vec{d} - \vec{e}_m) \quad .$$

Substituting errors and deviations for computed deviations yields

$$\vec{e}^{\,+} + \vec{d}^{\,+} = \vec{e}^{\,-} + \vec{d}^{\,-} - K\,(M\vec{e} - \vec{e}_m) \quad .$$

Note that the deviation is unchanged and the errors are updated by

$$\vec{e}^{\,+} = \vec{e}^{\,-} - K\,(M\vec{e}^{\,-} - \vec{e}_m)$$

or

$$\vec{e}^{\,+} = (I - KM)\vec{e}^{\,-} + K\vec{e}_m \quad .$$

The covariance of the error after the update is found by taking the expected value

$$P^+ = E\,(\vec{e}^{\,+}\,\vec{e}^{\,+\,T})$$

or

$$P^+ = (I - KM)\,E(e^-\,e^{-T})(I - KM)^T + (I - KM)\,E(e^-\,e_m^{\;T})\,K^T +$$

$$KE\,(e_m\,e^{-T})(I - KM)^T + KE\,(e_m\,e_m^{\;T})\,K^T \quad .$$

Let

$E\,(e^-\,e^{-T}) = P^-$, the covariance matrix of the state error prior to the update

$E\,(e_m\,e_m^{\;T}) = W$, the covariance matrix of the measurement noise

$E\,(e_m\,e^{-T}) = E(e^-\,e_m^{\;T}) = 0$, assuming no correlations between the measurement and system errors.

Thus,

$$P^+ = (I - KM)\,P^-(I - KM)^T + KWK^T$$

which expands to

$$P^+ = P^- - KMP^- - P^-M^TK^T + KMP^-M^TK^T + KWK^T$$

and combining the last two terms gives

$$P^+ = P^- - KMP^- - P^-M^TK^T + K(MP^-M^T + W)K^T \quad .$$

The Kalman update matrix K is given by

$$K = PM^{-T}(MP^-M^T + W)^{-1}$$

which when substituted into the first K factor of the last term gives

$$P^+ = P^- - KMP^- - P^-M^TK^T + P^-M^T(M^{P-}M^T + W)^{-1}(MP^-M^T + W)K^T \quad .$$

Cancelling the inverses, the last two terms give

$$P^+ = P^- - KMP^-$$

which is the well known expression for the update of the system covariance with a Kalman filter.

Thus, expressing the Kalman update entirely by

$$\vec{e}^{\,+} = (I - KM)\vec{e}^{\,-} + K\vec{e}_m$$

is valid. This approach fits the state transition matrix and error generation formulation when (I - KM) is considered a state transition matrix and K a sensitivity to measurement error, $\vec{e}_m$.

Thus,

$$[\Phi e] = (I - KM)$$

$$[Se] = 0$$

$$[\Phi d] = I$$

$$[Sd] = 0$$

$$[Ne] = [K][e_m \, e_m^T][K]^T$$

$$[Nd] = 0$$

<u>Midcourse Corrections</u>. Midcourse corrections may be made to zero any component (DR, CR, or OP) or all three components of the deviations at the target. The midcourse correction ΔV is computed by

$$\Delta\vec{V} = [D]\,\vec{d}_c = [D][\vec{e} + \vec{d}]$$

where D = a 3 x 9 correction matrix.

D is obtained from the state transition matrix from the point of the correction to the target as discussed in Reference 1. The net state transition matrix for errors is identity since the midcourse correction is a change in the physical state of the system. Thus,

$$[\Phi e] = I$$

and since

$$\begin{Bmatrix} \vec{r} \\ \vec{v} \\ \vec{0} \end{Bmatrix}^+ = \begin{Bmatrix} \vec{r} \\ \vec{v} \\ \vec{0} \end{Bmatrix} + \begin{Bmatrix} 0 \\ D\vec{d} \\ 0 \end{Bmatrix} + \begin{Bmatrix} 0 \\ D\vec{e} \\ 0 \end{Bmatrix}$$

$$[\Phi d] = [I] + \begin{bmatrix} 0 \\ D \\ 0 \end{bmatrix}$$

and

$$[Sd] = \begin{bmatrix} 0 \\ D \\ 0 \end{bmatrix} [G_e] \quad .$$

Errors Generated Making A Correction

Errors are generated in making the correction. Thus, there are error sensitivity terms for roll accelerometer error sources K_0, K_1, and K_2. These sensitivities are computed by assuming the correction is made by a deterministic engine burn at the specified thrust for a ΔV of

$$RMV = \sqrt{\text{Trace}\ ([D][Cdc][D]^T)}\ .$$

Errors are also generated because of attitude uncertainties at the time of the correction. This contribution to velocity error is

$$\vec{e}_{v_\theta} = \Delta\vec{V} \times \vec{\theta}$$

where $\vec{e}_{v_\theta}$ = the velocity error due to attitude error

$\Delta\vec{V}$ = the ΔV correction

$\vec{\theta}$ = the vector of small angle attitude errors.

The result of this vector cross product poses some problems when treated in a statistical fashion. If the vectors $\Delta\vec{V}$ and $\vec{\theta}$ are assumed to be zero mean gaussian, the product has a mean and is not normally distributed. The following approximation is used to maintain compatability with the zero mean normal formulation of the error analysis.

$$\vec{e}_{v_\theta} \approx \vec{SD}_v \times \vec{\theta} + \Delta\vec{V} \times \vec{SD}_\theta$$

where the vectors $\vec{SD}_v$ and $\vec{SD}_\theta$ are treated as coefficients equal to the standard deviations of the $\Delta\vec{V}$ and $\vec{\theta}$ covariances. This contribution to error is treated as uncorrelated with the other sources. Thus,

$$[Ne_v] = [S(\vec{SD}_v)][Ce_a][S(\vec{SD}_v)]^T + [S(\vec{SD}_\theta)][C_{\Delta\vec{V}}][S(\vec{SD}_\theta)]^T$$

where

$[Ne_v]$ = 3 x 3 velocity noise covariance

$[S(\vec{x})]$ = 3 x 3 skew symmetric matrix of the form

$$[S(\vec{x})] = \begin{bmatrix} 0 & X_3 & -X_2 \\ -X_3 & 0 & X_1 \\ X_2 & -X_1 & 0 \end{bmatrix}$$

$[Ce_\theta]$ = 3 x 3 covariance of attitude sensors

$[Ce_{\Delta V}]$ = 3 x 3 covariance of delta-V.

Then,

$$[Ne] = \begin{bmatrix} 0 & 0 & 0 \\ 0 & Ne_v & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Since the midcourse correction is made under closed loop conditions, the contributions to deviations are equal and opposite to the error contributions. Thus,

$$[Sd] = -[Se]$$

and

$$[Nd] = [Ne] \quad .$$

Inertial Sensing Unit

The estimation of the weight and reliability of the designed strapdown inertial sensing unit (ISU) is unchanged from the methods previously reported (Reference 1). The estimation of the power required has been modified from the previously reported method (Reference 1) to include provision for variable thermal conductance. A data section entitled "Thermal Control Data" has been added to permit specifying or calculating maximum and minimum thermal conductance.

The thermal model is described by

$$P_{EX} + P_H = (T_{OP} - T_A) \text{ COND}$$

where P_{EX} = ISU exciting power (gyros, accelerometers, and electronics) in watts

P_H = ISU heater power in watts

T_{OP} = ISU operating temperature in degrees Farenheit (F)

T_A = Ambient temperature in degrees F

COND = Thermal conductance in watts/degree F.

Temperature control is provided by varying either P_H or COND. Thermal conductance, COND, is constrained to lie between a maximum value, $COND_{MAX}$, and a minimum value, $COND_{MIN}$. $COND_{MAX}$ is either specified or calculated by the program to give zero heater power, P_H, with T_A at its maximum value. COND is then assumed to decrease with T_A until it reaches its minimum value, $COND_{MIN}$. If additional thermal control is required, heater power is assumed to overcome the additional heat loss.

In the program, the minimum value of the ratio

$$\frac{COND_{MIN}}{COND_{MAX}} = CONR$$

is used to define the variable conductance range. If CONR is set to 1.0, the maximum and minimum conductance are the same and all control is provided by heater power. If CONR is set to 0.0 all control will be provided by the thermal conductance and no heater power is required. Intermediate values of CONR use both variable conductance and heater power as required.

To properly evaluate the thermal model, profiles of ambient temperature versus time elapsed in the mission should be known. However, an approximate evaluation can be made from values of the maximum, average, and minimum ambient temperatures. Table IX summarizes outputs from the modified program for the reference system ISU and computer with CONR set to 1.0, 0.5, and 0.0 respectively. The results are intended to demonstrate the potential reduction in system power source weight by including a variable thermal conductance in the estimation techniques. Further work toward the loading or calculation of temperature profiles is required before conclusive results may be obtained.

TABLE IX. SUMMARY OF MODE 3 POWER SOURCE WEIGHT AND THERMAL ANALYSIS FOR THREE VALUES OF VARIABLE THERMAL CONDUCTANCE RATIO, REFERENCE SYSTEM ISU AND COMPUTER

CONR = $\frac{\text{Minimum Conductance*}}{\text{Maximum Conductance}}$	1.0	0.5	0.0
Average Watts	198.7	160.2	133.5
Peak Watts	372.7	231.4	133.5
Minimum Heater Watts	0.0	0.0	0.0
Maximum Heater Watts	239.2	97.9	0.0
Minimum Conductance Used	2.17	1.09	0.33
Maximum Conductance Used	2.17	2.17	2.17
Power Source Weight (lbs)	141.80	93.02	59.26
Penalty Sensitivity to CONR	0.39889	0.24913	0.00000

* CONR sets the minimum permissable conductance ratio. The full range may not be needed.

The capability to evaluate a specified strapdown inertial sensing unit or a specified gimballed inertial measurement unit has been added to the computer programs. Examples of these evaluations are shown later in this report. The required input data includes the inertial unit weight, power, MTTF, error coefficients of the inertial sensors carried by the unit being evaluated, and the appropriate error sensitivity matrix (strapdown or gimballed).

Electro-Optical Aids

The weight of the electro-optical aid subsystem is considered to be the total weight of the horizon sensor subsystem (if used), the sun sensor subsystem, and the star tracker subsystem. These subsystems consist of specified components and are not designed by the computer programs which were written on this contract. Later discussion presents possible approaches toward estimating the weight and accuracy of these subsystems and points out some of the reasons these approaches were not coded into computer subroutines at this time.

Star Tracker. The weight of the star tracker subsystem is estimated by summing the weights of the various candidate components making up that system in a manner similar to the ISU weight estimation technique. A recent survey (Reference 10) indicates a number of different star tracker configurations are available. These are divided into subsystems using mechanical

2

scanning and electronic scanning. Furthermore, the same electro-optical sensor has been used as a strapdown tracker and as the tracker head of a gimballed tracker. The electronics subassembly weight includes the tracker head electronics, power supply electronics, and electronics associated with the type of scanning. The electronics may be a separate package, but a noted trend, due to microelectronics development, is toward electronics design which allows packaging of modular units in the same housing containing the optical subassembly. Depending upon the system configuration, the items making up the system's weight can be selected from the breakdown in Table X. The weight of these items is summed and is the input data for the weight of the star tracker subsystem.

TABLE X. STAR TRACKER SUBSYSTEM COMPONENTS

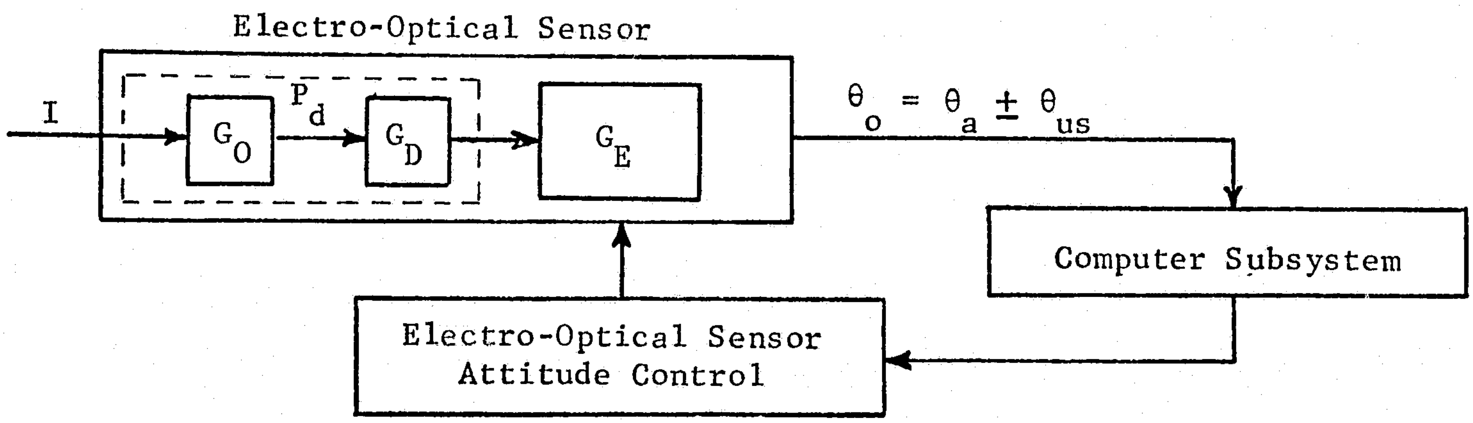
Optics	Gimbals (if any)
Telescope	Gimbal Angle Pick-offs
Mirrors	Gimbal Torquers
Electronics	Housing
Sensor/Detector	
Servo Interface	
Power Supply	

The power required by the star tracker subsystem is dependent on the electro-optical sensor used, the method employed for controlling its attitude (gimballed or strapdown), and the power dissipated in the associated electronics. The power input data is in the sum of the power required for the sensor, electronics, and gimballed servo system (if used).

Reliability is estimated by assuming that a Weibull distribution with $\alpha = 1$ applies for each component of the electro-optical aid subsystem. This assumption, when used with the operating time of each component, permits determination of the probability of failure of the subsystem. The operating time for the various components is dependent upon the system operating schedule which is an input parameter of the computer program. The input parameter for the electro-optical aids is the mean-time-to-failure (MTTF).

The pointing errors due to the electro-optical aid subsystem are complex since they are functions of the complete closed loop system. The pointing errors due to a strapdown electro-optical sensor used as a star tracker are discussed first and are followed by a discussion of the errors due to using the sensor as a gimballed tracker. Later paragraphs treat horizon sensor error models and sun sensor error models.

Consider the celestial tracker subsystem to consist of an electro-optical sensor operating in a closed loop through the integrated astrionics subsystems shown below in Figure 13.



Note: G - symbol for transfer function

Subscripts: O - optics
D - detector
E - electronics

FIGURE 13. CELESTIAL TRACKER SUBSYSTEM (CLOSED LOOP)

The output signal from the electro-optical sensor is the star position signal and consists of the actual position signal, θ_a, plus the signal due to the position uncertainty, θ_{us}. The flux density received from a star of visual magnitude m_v is given by (Reference 14)

$$I = I_o \, 2.51^{-m_v}$$

where I_o = luminous flux density of a star of zero visual magnitude (m_v = 0). Reference 14 gives the following values for I_o:

$$I_o = 2.1 \times 10^{-10} \frac{\text{lumens}}{\text{cm}^2}$$

or

$$I_o = 3.1 \times 10^{-13} \frac{\text{watts}}{\text{cm}^2} \quad .$$

The transfer function of the optics is G_o and can be written as

$$G_o = A_o T_o = \frac{\pi}{4} D_o^2 T_o$$

where D_o is the diameter of the optics aperture and T_o is the optics transmission factor ($T_o < 1$). The power input to the detector P_d, is given by the expression

$$P_d = IG_o = \frac{\pi I_o D_o^2 T_o}{4[2.51^{m_v}]}$$

if the electronic scanning of the photo-cathode is used. If mechanical scanning of the photocathode is employed, the power input to the detector is a function of the scanning technique and the expression for P_d must be modified to account for the mechanical scanning. References 10, 15, and 16 propose use of the electronically scanned image dissector for interplanetary missions. Mechanically scanned sensors will not be discussed in this report, although they can be evaluated by the computer program.

The signal to noise ratio, $(S/N)_d$, at the output of the detector is dependent upon the detector being used. Signal to noise ratio is defined as the ratio of the power output of the detector when a reference star is focused on the detector to the power output of the detector when the reference star is not present. This is the ratio of peak signal and root-mean-square noise power. The image dissector error models (References 10, 16, and 17) are most commonly discussed in the literature and therefore will be examined in this report.

The uncertainty in the pointing error, θ_{us}, due to the electro-optical sensor can be expressed as a function of the total system noise bandwidth (including that due to the electronics, G_E, used for processing the detector output), signal to noise ratio, $(S/N)_d$, instantaneous field of view, total field of view encompassed by the photocathode, and time required to scan the total field of view. Among other things, the time required to scan the total field of view depends upon the scanning technique being used.

A suggested model for the pointing error uncertainty has been developed and is based upon the fundamental relationship for the signal-to-noise ratio $(S/N)_d$ in a photomultiplier tube. An approximate expression for $(S/N)_d$ is (Reference 18, page 258)

$$(S/N)_d = \frac{i_s}{\sqrt{2ei_o\ (f_2-f_1)(\frac{G}{G-1})}}$$

where i_s = current from the photocathode due to photoemission (amperes)

i_o = current from the photocathode due to both photoemission and thermionic emission (dark current) (amperes)

e = charge on the electron = 1.60×10^{-19} coulombs

$f_2 - f_1 = B_E$ = bandwidth of the electronic signal amplifier (Hertz)

G = gain per dynode stage within the photomultiplier.

Now

$$i_o = i_s + i_d + i_b$$

where i_d = dark current

i_b = current due to background radiation.

Laverty states that i_d is approximately zero for photomultiplier tubes and image dissector tubes (Reference 16). Therefore, it is planned to omit this term for the present. The current from the photocathode due to photoemission can be approximated as:

$$i_s = P_d S_d k_1 T_a = I \frac{\pi}{4} D_o^2 T_o S_d k_1 T_a$$

where

$$P_d = IG_o = \frac{I\pi D_o^2 T_o}{4}$$

I = flux density received from a star of visual magnitude m_v

D_o = diameter of the optics aperture

T_o = optics transmission factor

S_d = photosurface sensitivity to radiation of 2870° K color temperature (amps/watt) or (amps/lumen)

k_1 = the ratio of detector sensitivity using incident radiation of the color temperature of the star to the sensitivity to radiation of 2870° K color temperature

T_a = aperture dwell time.

Assuming that the illumination due to background radiation (if present) is I_B, the current, i_b, is approximately

$$i_b = \frac{\pi I_B D_o^2 T_o S_d k_2 T_a}{4}$$

where k_2 = the ratio of detector sensitivity using incident radiation of the color temperature of the background to the sensitivity to radiation of 2870° K color temperature.

The signal-to-noise ratio, $(S/N)_d$, can be written as

$$(S/N)_d = \frac{i_s}{\sqrt{2e\ (i_s + i_b)\ B_E\ (\frac{G}{G-1})}} \quad .$$

Squaring both sides, substituting for i_s and i_b, and cancelling exponents gives:

$$(S/N)_d^2 = \frac{\frac{\pi}{4} D_o^2 T_o I\ S_d k_1 T_a}{2e\ (1 + \frac{I_B k_2}{I k_1})\ B_E\ (\frac{G}{G-1})} \quad .$$

Define f_B as

$$f_B = \frac{I_B k_2}{I k_1} \quad .$$

Substituting f_B and taking the square root, $(S/N)_d$ can be expressed as

$$(S/N)_d = \frac{\frac{\sqrt{\pi}}{2} D_o \sqrt{T_o I\ S_d k_1 T_a}}{\sqrt{2e\ (1 + f_B)\ B_E\ (\frac{G}{G-1})}} \quad .$$

Notice that the method of scanning which determines the aperture dwell time, T_a, has been accounted for, but the uncertainty in the time of passage of the star image through the instantaneous solid angle field of view, α^2, has not. McCanless (Reference 15) gives the uncertainty in time of passage through α^2 as

$$\epsilon_{\tau_p} = \frac{\tau_p}{(S/N)_d}$$

where τ_p is the electrical rise time of the photosensor and electronics.

Laverty (Reference 16) includes a term, $1-e^{-\delta/RC}$ (δ = signal pulse width and RC = time constant of integration in the signal processing amplifier), in the numerator of the expression for $(S/N)_d$ to approximately account for the same effect. He notes "this quantity may be replaced by the numerical value of 0.70 assuming a δ to RC ratio of 1.25, for optimum detection". To account for this time uncertainty, a constant, C_R, times the expression for $(S/N)_d$ will be used. This constant will be a piece of data for each photosensor. Therefore, the expression for $(S/N)_d$ can be written as

$$(S/N)_d = \frac{C_R\sqrt{\frac{\pi}{4}}\, D_o \sqrt{T_o I\, S_d k_1 T_a}}{\sqrt{2e\ (1 + f_B)\ B_E\left(\frac{G}{G-1}\right)}} .$$

The scanned photocathode diameter, D_{pc}, is given by

$$D_{pc} = 2f \tan\left(\theta/2\right)$$

where f = focal length of the lens system

θ = system angular field of view (degrees).

Similarly, the relationship between the diameter of the scanning aperture, D_{sa}, and the instantaneous field of view, α, is

$$D_{sa} = 2f \tan\frac{\alpha}{2} .$$

The F number is given by

$$F = \frac{f}{D_o} .$$

The aperture dwell time, T_a, is given approximately by

$$T_a = \frac{D_{sa}}{V}$$

where V = the aperture velocity (scan speed).

Birnbaum and Salomon (Reference 17) give the uncertainty location of the star on the photocathode as

$$d_{pc} = K_s \frac{\pi D_{sa}}{(S/N)_d}$$

where K_s = constant dependent upon the scanning technique

πD_{sa} = scan distance for one complete scan = D_{scan}.

The pointing angle uncertainty is then given by

$$\theta_{us} = 2 \tan^{-1} \left(\frac{d_{pc}}{2f}\right) \cong \frac{d_{pc}}{f}$$

using small angle approximations. Substituting for d_{pc}

$$\theta_{us} = \frac{K_s \pi D_{sa}}{(S/N)_d f} = \frac{K_s D_{scan}}{(S/N)_d f} .$$

Laverty (Reference 16) states that in application of a photosensor to interplanetary navigation, the background radiation may be considered to be essentially nonexistent. Therefore, f_B shall be set equal to zero for the present. The expression for $(S/N)_d$ becomes

$$(S/N)_d = \frac{C_R \sqrt{\frac{\pi}{4}} D_o \sqrt{T_o I S_d k_1 T_a}}{\sqrt{2e B_E \left(\frac{G}{G-1}\right)}} .$$

Recall that $B_E = \frac{1}{2T_{scan}}$. Substituting for B_E, $(S/N)_d$ can be written as

$$(S/N)_d = \frac{C_R\sqrt{\frac{\pi}{4}}\ D_o\sqrt{T_oI\ S_dk_1T_aT_{scan}}}{\sqrt{e\ (\frac{G}{G-1})}} = K_dD_o\sqrt{\frac{T_oI\ S_dk_1T_aT_{scan}}{\frac{G}{G-1}}}$$

where $K_d = \frac{C_R}{2}\sqrt{\frac{\pi}{e}}$.

Substituting $(S/N)_d$ into the equation for θ_{us} gives

$$\theta_{us} = \frac{K_sD_{scan}}{fK_dD_o\sqrt{\frac{T_oI\ S_dk_1T_aT_{scan}}{(\frac{G}{G-1})}}} = K\frac{D_{scan}}{fD_o\sqrt{\frac{T_oI\ S_dk_1T_aT_{scan}}{(\frac{G}{G-1})}}}$$

where $K = \frac{K_s}{K_d}$.

If the appropriate values are substituted, θ_{us} can then be determined for a given star.

The pointing error due to the electro-optical sensor is one component of the total celestial tracker subsystem pointing error. The other principal component of error is due to the method used in controlling the attitude of the electro-optical sensor. Before continuing the discussion of the electro-optical sensor attitude control, some words of explanation regarding the use of the celestial tracker might clarify the entire topic.

Celestial tracker subsystems are used for scanning that portion of the celestial sphere within a field of view in order to detect and identify a particular star and then for tracking the star of interest. The output of the celestial tracker subsystem can be used for vehicle navigation and guidance or attitude control.

In the celestial sphere mode, the system scans a comparatively large field of view on the basis of a preprogrammed or radio command. High accuracy in the indicated angular position of the star being searched for is generally sacrificed for rapid scan times, high signal to noise ratios, and high probability of detection.

In the tracking mode, high angular resolution and tracking accuracy are desired since the system is now operating in a closed loop feedback mode.

The error signal in the tracking mode is nulled by repositioning the electro-optical sensor or some portion of the optics used in the sensor.

The manner in which the sensor is repositioned for either scanning of the celestial sphere or tracking of a particular star depends upon the electro-optical sensor attitude control mechanization. The two alternatives are mounting the electro-optical sensor on a set of gimbals and driven from an associated servo system, or fixing the electro-optical sensor to the vehicle (strapdown) and reorienting the vehicle to reorient the sensor. The computer programs written are capable of evaluating the tradeoffs between these two concepts in terms of the system parameters used in the penalty functions. Weight, reliability, and power considerations are rather straightforward and were discussed previously. The performance (pointing accuracy) is the proper statistical combination of the pointing error due to the electro-optical sensor and the pointing error due to the method used in controlling the attitude of the sensor.

If the sensor is gimballed, the following errors due to the gimballed system (Reference 19) must be considered. These are:

(1) Inaccuracy of the gimbal angle readout

(2) Misalignment of the gimbal baseplate with respect to the body axes

(3) Runout of gimbal bearings

(4) Nonorthogonality of gimbal axes

(5) Misalignment of the line of sight of the sensor with respect to the gimbal pointing direction

(6) Servo system errors (static and dynamic).

Except for servo dynamic errors (which depend upon the type of transient inputs the servo system must follow) and the quality of the servos, the sources of pointing error due to the gimballed system are mechanical and electrical inaccuracies which can be described in a statistical manner (Reference 19). The statistical description of the errors due to the gimballed system and the combination of these errors with those due to the electro-optical sensor must, at this time, be done prior to inputting as data the total pointing angle uncertainty. The effort required to program the equations (Reference 19) which permit more precise calculation of the pointing angle uncertainty as a function of gimbal angles required to sight selected observables was not consistent with the available funds and the overall objectives of the project.

Should the electro-optical sensor be strapped down, initial study indicates that the pointing errors are principally the combination of the error in alignment of the sensor axes with respect to the body axes and the pointing error inherent to the sensor. This assumes the vehicle attitude control system mechanization can maintain an accuracy sufficient to keep the star being observed within the sensor optical field of view. At present, the statistical combination of the pointing error inherent to the sensor, θ_{us}, and the errors in alignment of the sensor to the body axes must be done prior to loading into the computer program the total pointing angle uncertainty as an item of data for a specific star tracker. The many parameters which make up θ_{us} are quite interdependent and cannot be chosen arbitrarily. For this reason, and also since the objective of this project was not to design electro-optical sensors, the equation previously given for θ_{us} was not programmed.

If it is desired to estimate various parameters of a star tracker which consists of certain baseline components, or determine how variations in these components might affect the overall parameters of the star tracker subsystem, the preliminary approaches discussed in succeeding paragraphs should be useful. These approaches have not been made part of the computer program since the objective of the contract was not the computer aided design of star trackers.

The weight of the optics subassembly can be estimated as

$$W_{(opt)} \triangleq W_{(det)} + W_{(tel)} + W_{(housing)}$$

where $W_{(opt)} \triangleq$ weight of optics subassembly

$W_{(det)} \triangleq$ weight of detector element subassembly

$W_{(tel)} \triangleq$ weight of the telescope (barrel, mirrors, plates, etc.).

If the variation in weight of the different detector subassemblies (sensor element + housing) is insignificant, $W_{(det)}$ could be treated as a constant. (The photomultiplier tube housing has the form of a glass envelope.) Otherwise, material densities and thicknesses plus dimensions must be known to estimate $W_{(det)}$. The major portion of the telescope's weight is in the barrel, but mirrors and corrector plates (if used) should be accounted for. The telescope weight is approximately

$$W_{(tel)} = (\pi D_o)(\text{Thickness})(\text{Length})(\text{Density}) + W_{(mirrors)} \quad .$$

Weight of the housing for the telescope and detector (and possibly the electronics as well) may be estimated in a manner similar to estimating the barrel weight.

If the optical subassembly is gimballed, estimates of weight may be made on the basis of ring mounting, including weight of drive motors, $W_{(dm)}$, pickoffs, $W_{(po)}$, and housing structure, $W_{(h)}$. Letting D_1 and D_2 equal the outer and inner diameters of the gimbals, then

$$W_{(gim)} = \frac{\pi}{4}(D_1^2 - D_2^2)(\text{Thickness})(\text{Density}) + W_{(dm)} + W_{(po)} + W_{(h)} \quad .$$

An example of the weight and accuracy estimation technique is given in the following paragraphs. There are three options in the use of star trackers. These are: (1) use an unmodified off-the-shelf subsystem; (2) operate a given electro-optical sensor in a strapdown mode or estimate the total subsystem weight, power, reliability, and performance when gimballed; or (3) design the electro-optical sensor using the relationships described in succeeding paragraphs and estimate the total subsystem parameters when operated in either strapdown or gimballed modes. Since design of electro-optical sensors is not within the scope of the work statement, the third option is ruled out.

For a given electro-optical sensor used under option 1 or 2, θ_{us} must be considered a function of I and k_1. The other parameters used in determining θ_{us} remain invariant when sighting on different stars.

For specified sensors, the following data will be needed:

(1) θ = total system angular field of view

(2) θ_{us} (I,k_1) = pointing angle uncertainty as a function of the star illumination, I, and the temperature sensitivity ratio, k_1

(3) Weight

(4) Power

(5) Mean time to failure (MTTF).

If θ_{us} is known for a reference star with visual magnitude, m_{vref}, the value of θ_{us} for a star with a different visual magnitude, m_{vx}, and star temperature can be determined by using

$$\theta_{usx} = \theta_{usref} \sqrt{2.51^{(m_{vx} - m_{vref})} \left(\frac{k_{1ref}}{k_{1x}}\right)}$$

where k_{1ref} = the ratio of detector sensitivity using incident radiation of the color temperature of the reference star to the sensitivity to radiation of 2870° K color temperature

K_{1x} = the ratio of detector sensitivity using incident radiation of the color temperature of the x star to the sensitivity to radiation of 2870° K color temperature

θ_{usref} = uncertainty in pointing angle for reference star.

Alternatively, θ_{us} for each star to be observed can be used if it is known.

An example illustrates the approach to estimating the total pointing error uncertainty, subsystem weight, power, and MTTF. The data used in this example was not gathered by Battelle and should not be considered as conclusive, but it suffices to illustrate the procedure.

For the ITT Type FW 143 photomultiplier used as the Lunar Orbiter Canopus sensor, Reference 10 gives the following values:

$$\theta_o = 8.2^\circ$$

$$\alpha = 1^\circ$$

$$D_o = 2\text{cm}$$

$$S_d = 80\ \mu\ \text{amps/lumen}$$

$$G = 2.5$$

$$\Delta f = 15.7\ \text{HZ}$$

$$k_1 = 1.35$$

$$T_o = 0.75$$

For Canopus, $m_v = -0.72$ (Reference 10) and therefore

$$I = \frac{I_o}{2.51^{m_v}} = 2.65 \times 10^{-10} \frac{\text{lumens}}{\text{cm}^2} \times (2.51)^{0.72} = 5.2 \times 10^{-10} \frac{\text{lumens}}{\text{cm}^2} .$$

Since the data listed from Reference 10 are incomplete as required for the generalized model previously discussed, values given in Reference 10 for the signal to noise ratio, $(S/N)_d = 224$, and $\theta_{us} = 48$ sec $= 0.01333^\circ$ will be used. The data required for the generalized model discussed previously will be incomplete for most sensors and will not permit direct calculation of θ_{us}. The generalized model does permit determination of the variation in θ_{us} with a selected parameter and therefore can be used as illustrated below.

Assume the diameter of the optics, D_o, was changed with all other parameters involved in $(S/N)_d$ held constant. θ_{us} would then change according to the equation

$$\theta_{usx} = \theta_{usref} \frac{D_{oref}}{D_{ox}} .$$

If D_o is doubled to 4 cm, then

$$\theta_{usx} = 48\ (\frac{2}{4}) = 24 \text{ sec} = 0.00667^\circ \quad .$$

The weight of the lens assembly will change according to

$$W_{L_X} = W_{L_{Ref}} \frac{D^2_{o_x}}{D^2_o}$$

where $W_{L_{Ref}}$ = weight of lens assembly of reference optics

W_{L_X} = weight of lens assembly of new optics

$D_{o_{ref}}$ = diameter of lens of reference optics

D_{o_x} = diameter of lens of new optics.

Before estimating the weight of the telescope, it is necessary to discuss the relationship of D_o and f.

A sketch illustrating two angles, θ and u, the diameter of the optics, D_o, the diameter of the detector, D_{pc}, and the focal length, f, is shown in Figure 14.

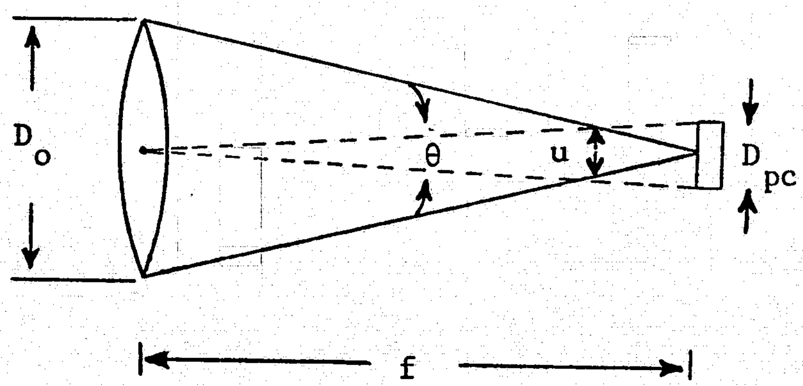


FIGURE 14. OBJECTIVE LENS FORMING IMAGE OF STAR ON DETECTOR

It is seen that

$$D_{pc} = 2f \tan\frac{\theta}{2} \approx f\theta \qquad \text{(using small angles)}$$

where θ = system angular field of view.

Smith (Reference 20) notes that the relationship between D_o and f is a limited one and states that for the optical system to be free of spherical aberration and coma, the second principal surface must be spherical. For this reason, the effective diameter D_o cannot exceed the focal length f, and the slope of the marginal ray at the image cannot exceed 90°. This limits the numerical aperture of the system to N.A. = $N' \sin 90^\circ = N'$. Smith introduces the effective f/# of the objective which is

$$f/\# = \frac{f}{D_o} = \frac{D_{pc}}{D_o\theta}$$

for systems in air.

For systems with the final image in a medium of refractive index N', Reference 20 gives

$$\text{N.A.} = N' \sin\frac{u}{2} = \frac{D_o\theta}{2D_{pc}} \quad .$$

This was determined by setting the optical invariant, I* (a constant for a given optical system) at the objective ($I^* = D_o\theta/4$) equal to the invariant at the image ($I^* = 1/2\, D_{pc} N' u/2$) and substituting u/2 for sin u/2.

Since $D_o = 2f \tan u/2$, it can be seen that changing D_o does not necessitate changing f unless one desires to maintain f/# constant. Therefore, if we hold f constant, the length of the telescope will not change.

The thin lens law (Reference 21, p 46)

$$\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where n = index of refraction

R_1 and R_2 = lens radii of curvature indicates that f does not change unless R_1, R_2, or both R_1 and R_2 change. Therefore, one might be led to believe that D_o could be changed merely by increasing the thickness of the lens without changing f. However, this is not the case as shown by the thick lens law (Reference 21, p 58)

$$\frac{1}{f} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n - 1)t}{nR_1 R_2}\right) .$$

where t = lens thickness. The last term is a second order effect which illustrates that care must be used before making radical changes in parameters such as D_o.

Continuing with the weight estimation, the weight of the telescope would change according to

$$W_{Tel_x} = W_{Tel_{Ref}} \frac{D_{ox}}{D_{o_{Ref}}}$$

where $W_{Tel_{Ref}}$ = weight of the telescope barrel.

If it is assumed that f and D_{pc} remain the same, then it can be assumed that the weight of the detector is the same even though the diameter of the optics has changed.

The total weight of the electro-optical sensor with a change from $D_{o_{Ref}}$ to D_{o_x} would be approximately

$$W_{sensor_x} = W_{L_{Ref}} \frac{D^2_{ox}}{D^2_{o_{Ref}}} + W_{Tel_{Ref}} \frac{D_{o_x}}{D_{o_{Ref}}} + W_{Det} + W_{Elect}$$

where W_{Det} = weight of detector

W_{Elect} = weight of electronics and any other constant weight not included in W_{Det}.

For the purpose of illustration, assume the following for the ITT Type FW 143 photomultiplier

$$
\begin{aligned}
W_L &= 1.0 \text{ lb} \\
W_{Tel} &= 3.5 \\
W_{Det} &= 0.25 \\
W_{Elect} &= 2.25 \\
\hline
W_{sensor} &= 7.00
\end{aligned}
$$

If $D_{ox} = 4$ cm and $D_{o_{Ref}} = 2$ cm, then

$$W_{sensor_x} \cong 1.0 \left(\frac{4}{2}\right)^2 + 3.5 \left(\frac{4}{2}\right) + 0.25 + 2.25 = 13.50 \text{ lb} \quad .$$

Assume the sensor is operated in the strapdown mode. Then the total pointing angular uncertainty, θ_{uT}, is the root sum square of the uncertainty inherent to the sensor θ_{us} and the uncertainty in alignment of the sensor axes with respect to the body axes, θ_{uB}. Assume $\theta_{uB} = 60 \ \widehat{\text{sec}}$. For the reference sensor

$$\theta_{uT_{Ref}} = \sqrt{(48)^2 + (60)^2} \approx 76.9 \text{ sec} \qquad (1\sigma) \quad ,$$

For the new sensor

$$\theta_{uT_x} = \sqrt{(24)^2 + (60)^2} \cong 64.6 \text{ sec} \qquad (1\sigma) \quad .$$

The tradeoff between the reference sensor

$$(W_{sensor_{Ref}} = 7 \text{ lb}, \quad \theta_{uT_{Ref}} \approx 76.9 \text{ sec})$$

and the new sensor

$$(W_{sensor_x} \cong 13.50 \text{ lb}, \quad \theta_{uT_x} \approx 64.6 \text{ sec})$$

can be made by using the computer program to evaluate a system using the reference sensor and then the new sensor. This example was meant to illustrate the approach used in development of the estimation techniques and should not be used conclusively since the data are only estimates.

System power and MTBF would be unchanged with a change in D_o only.

Horizon Sensor Error Models. Many reports and papers (References 10, 13, and 22-32) have been reviewed in an attempt to determine if a common horizon sensor error model is in general use. A model, widely accepted by industry does not appear to exist.

It was observed that the errors inherent in the navigation solution when using horizon sensors as state measurement instruments are dependent on four effects. These are: (1) the uncorrelated errors intrinsic to the horizon sensor, (2) correlated errors independent of intrinsic horizon sensor accuracy which are usually classed as Earth phenomenology errors, (3) the use of statistical filtering to process the sensor output and hence reduce the errors from those directly due to the sensor and Earth phenomenology errors, and (4) the measurement schedule employed.

The majority of the works reviewed indicated some form of the Kalman filter is used to process the horizon sensor output. Also, measurement schedules varied widely.

Earth phenomenology effects include the random fluctuations in atmospheric density and in the altitude of the apparent horizon as seen by the spacecraft horizon sensor. Statistical variations in apparent-horizon altitude were related to temperature fluctuations by McArthur (Reference 28) and described by the autocorrelation function

$$\phi(\tau,d) = (0.88)^2 \; e^{-\tau/10} \; e^{-d/2500} \; (\mathrm{km})^2$$

where (0.88) = the standard deviation in the horizon (km)

10 = correlation time (days)

2500 = correlation distance (nautical miles)

d = distance separating two places on the earth where the horizon height is being measured

τ = time between measurements of horizon height.

Fitzgerald states, "In any case, the correlation times of interest represent such a large number of orbits that it is probably safe, in satellite navigation problems, to neglect the time dependence of these processes entirely" (Reference 24). This would appear to be true for the Jupiter flyby mission. Values other than 0.88 km for the standard deviation in the horizon altitude have been estimated (Reference 27).

Finding a correlation function of the density variations appears to be quite complex (References 23 and 24).

References 10 and 27 assumed systematic effects such as earth oblateness are compensated for in the onboard digital computer.

Errors intrinsic to the horizon sensor (References 10, 25, 27, and 30) can be generally listed as:

(1) Bias and bias instability

(2) Misalignment

(3) Random errors due to detector and preamplifier noise.

These random errors will be classed as sensor noise errors. It is assumed that deterministic bias, as determined in prelaunch calibration, is compensated for in the data processing. Therefore, the errors inherent in the sensor are considered to be bias instability, misalignment, and sensor noise. If it is assumed that horizon sensors of the type studied in Reference 10 are used, then the sensor noise induced error near null can be represented as (Reference 10)

$$\Delta\theta_n = \frac{\pi\gamma}{2(S/N)} \quad (1\ \sigma \text{ value})$$

where γ = scan amplitude (degrees)

S/N = horizon sensor signal to noise ratio.

According to Reference 10, if all four horizon measurements are combined, the system sensor noise is $2\Delta\theta_n$. It is suggested that, for the purpose of this study, S/N be calculated as shown below.

$$S/N = \frac{C\, A_T\, \Omega_T\, D^*}{\sqrt{A_a\, B_\eta}}$$

where C = constant = $\dfrac{N_{\Delta_\lambda}\eta}{k}$

A_T = telescope clear aperature area (cm^2)

Ω_T = telescope field of view (FOV) (steradians)

D^* = detector detectivity $\left(\dfrac{cm\text{-}(Hz)^{1/2}}{watts}\right)$

A_a = detector area (cm^2)

B_η = noise bandwidth (H_z)

N_{Δ_λ} = minimum earth radiance = 365 $\dfrac{watts}{cm^2 \text{ steradian}}$

η = telescope transmission factor

k = preamplifier noise figure (TRW used $k = 2$ in Reference 10)

Reference 10 calculated the bias instability as the root sum square (RSS) of the Earth phenomenology errors previously discussed, the telescope angle transducer nonlinearity, and the uncertainty drift in the alignment of the horizon sensor subsystem to the spacecraft. The Earth phenomenology errors dominate the other two errors due to hardware bias instability. Therefore, it is suggested that the hardware bias instability should either be removed from the combination with the other bias instabilities due to Earth phenomenological errors or might be ignored for this analysis.

Misalignment is actually a bias effect caused by the inability to perfectly align the horizon sensor subsystem to the spacecraft.

Results presented later in this report illustrate that for this mission, use of horizon sensors is not warranted. Therefore, a general horizon sensor model is not contained in the computer program at this time.

Sun Sensor. The error model assumed for the sun sensor has three principal contributors. The first contributor is assumed to be due to instability of the measured bias of the sensor. The second term is assumed to be an uncorrelated noise inherent in the sensor. The final term is assumed to be due to the uncertainty in the alignment of the sensor to the body axes. These terms are combined statistically by taking the root sum square (RSS) of the values for the terms. This value is used in the computer program. The time constant associated with the bias instability is assumed to be large.

Radio Aids

The inertial system can be updated by using radio command guidance which consists of various Earth based radar tracking networks and onboard radio equipment. The onboard radio equipment is assumed to consist of the necessary antennas, a transponder, command decoder, and multiplexer. The input parameters for the onboard equipment include weight, power, MTTF, and Weibull coefficient. These parameters must be specified for the present version of the program. It is assumed that the errors of the tracking radar are combined with the inertial sensing unit errors using a Kalman filter as previously discussed. Various error models were examined for the candidate tracking radars. These are discussed in the following paragraphs.

An error model for interferometer tracking systems is contained in Reference 33. This model considers three types of radar noise and bias for each radar data output. These include:

(1) Known bias

(2) Unknown bias

(3) Random noise

The noise error equations are:

$$\Delta R = (a_R \times E + c_R)\, W_R + b_R V_R$$

$$\Delta \dot{R} = a_{\dot{R}D} W_{\dot{R}D} + b_{\dot{R}D} V_{\dot{R}D}$$

$$\Delta p = (a_p \times \csc^2 E + c_p)\, W_p + b_p V_p$$

$$\Delta q = (a_q \times \csc^2 E + c_q)(\rho_{pq} W_p + \sqrt{1 - \rho_{pq}^2}\, W_q) + b_q V_q$$

$$\Delta \dot{p} = (a_{\dot{p}} \times \csc^2 E + c_{\dot{p}})\, W_{\dot{p}} + b_{\dot{p}} V_{\dot{p}}$$

$$\Delta \dot{q} = (a_{\dot{q}} \times \csc^2 E + c_{\dot{q}})(\rho_{\dot{p}\dot{q}} W_{\dot{p}} + \sqrt{1 - \rho_{\dot{p}\dot{q}}^2}\, W_{\dot{q}}) + b_{\dot{q}} V_{\dot{q}}$$

where ΔR = random error in the range measurement

$\Delta \dot{R}$ = random error in range rate

Δp	=	random error in the range difference measurement between the central station and the second doppler station (L configuration) or between the first and second doppler stations (X configuration)
Δq	=	random error in the range difference measurement between the central station and the third doppler station (L configuration) or between the third and fourth doppler stations (X configuration)
$\Delta\dot{p}$	=	rate of change of Δp
$\Delta\dot{q}$	=	rate of change of Δq
E	=	elevation angle measured from the horizontal
a_R, b_R, c_R	=	coefficients for range rate error - ft/sec
$a_{\dot{R}}$, $b_{\dot{R}}$	=	coefficients for range rate error - ft/sec
a_p, b_p, c_p	=	coefficients for Δp error - ft
a_q, b_q, c_q	=	coefficients for Δq error - ft
ρ_{pq}	=	correlation coefficient relating Δp and Δq
$a_{\dot{p}}$, $b_{\dot{p}}$, $c_{\dot{p}}$	=	coefficients for $\Delta\dot{p}$ error - ft/sec
$a_{\dot{q}}$, $b_{\dot{q}}$, $c_{\dot{q}}$	=	coefficients for $\Delta\dot{q}$ error - ft/sec
$\rho_{\dot{p}\dot{q}}$	=	correlation coefficient relating $\Delta\dot{p}$ and $\Delta\dot{q}$
W_R, $W_{\dot{R}D}$, W_p, W_q, $W_{\dot{p}}$, $W_{\dot{q}}$	=	outputs of random number generator with zero mean and unit variance. New numbers are generated for each tracking data point in a simulation
V_R, $V_{\dot{R}D}$, V_p, V_q, $V_{\dot{p}}$, $V_{\dot{q}}$	=	outputs of random number generator with zero mean and unit variance. New numbers are generated for each new computer run, but the numbers are constant for each tracking data point within a run.

Reference 33 states that the random noise error (associated with W_R, $W_{\dot{R}D}$, etc.) might be due to thermal noise, noise due to propagation effects, quantization noise, or multipath. The error described as unknown bias (associated with V_R, $V_{\dot{R}D}$, etc.) represents errors that are constant for a given mission but change in a random manner from mission to mission. This error includes the very low frequency components of noise, drifts due to equipment warm up, limits in the accuracy to which the equipment can be calibrated, and errors in the propagation correction.

Use of the appropriate numerical values for the error coefficients in the foregoing equations will allow use of the following tracking systems:

Azusa II (interferometer)

Mistram I (interferometer)

Mistram II (interferometer)

Glotrac (not an interferometer)

UDOP (not an interferometer)

ODOP (not an interferometer)

GE MK II Guidance System

GE MK III Guidance System.

Data for the two GE systems are classified confidential. Reference 33 states that examination of the data upon which the foregoing equations are based indicates that the coefficients a_R, c_p, c_q, $c_{\dot{p}}$, and $c_{\dot{q}}$ are zero. Coefficients for a system with average accuracy are listed in Reference 33. A rating factor R (listed in Reference 33) is used to calculate coefficients for a "good" system or a "poor" system. The coefficients for an "average" system are multiplied by 1/R to obtain the coefficients for a "good" system and by R to obtain the coefficients for a "poor" system.

Since the vehicle will be "over the horizon" as viewed by the Azusa II and Mistran I and II systems at the time of the possible parking orbit updates, and past the maximum range of these systems at the times of possible updates prior to midcourse, this interferometer model was not used.

C-band radar tracking accuracies are given in Reference 34. The values used in the program were obtained by taking the RSS of the noise and bias.

An error model which could be used for the Unified S Band System (USBS) is given in Reference 35. The model assumes that three uncoupled error sources contribute to each of the two measurements (range and range rate) for each station. These three error sources are:

(1) "White" noise (i.e., measurement errors uncorrelated from one sample to the next)

(2) Correlated noise with a short correlation time and termed "colored" noise

(3) Correlated noise with a long correlation time and termed "bias".

The values for range errors are given in Table XI.

TABLE XI. RANGE ERRORS

White	$\sigma = 5.25$ meters	
Colored	$\sigma = 7.67 \times 10^{-5}$ R meters,	$\tau = 7.5$ sec
Bias	$\sigma = 10$ meters,	$\tau = 4 \times 10^{4}$ sec

The values for range-rate errors are given in Table XII.

TABLE XII. RANGE-RATE ERRORS

White	$\sigma^2 = 2 \times 10^{-13} (1 + 0.03 \dot{R})^2 R^2 + 6.5 \times 10^{-8} (1 + 0.03 \dot{R})^2 R + 2 \times 10^{-4} (1 + 0.03 \dot{R})^4$	
Colored	$\sigma = 0.05$ meter/sec,	$\tau = 0.2$ sec
Bias	$\sigma = 0.05$ meter/sec,	$\tau = 4 \times 10^{4}$ sec

The values of the parameters in this model can be changed to represent an actual radar system such as the USBS.

Values for the USBS and alternate error models are given in Reference 34. These models and values are being used. All of the USBS radar sites being used in the program are land based. Therefore, the land based tracking accuracy of the USBS 30 foot antennas was examined for the cases of: two-way Doppler, nondestructive T count; two-way Doppler, destructive N count;

and three-way Doppler, nondestructive T count. It was arbitrarily decided to use the two-way Doppler, nondestructive T count at a sampling rate of 1 per second for the purpose of exercising the computer program. The 1σ values used for range, range-rate, and angles were found by taking the RSS of the total noise and the bias.

The error model assumed for the DSIF is the two-way Doppler, nondestructive T count, discussed in Reference 10. The range-rate error used in the program is the RSS of the range-rate bias and uncorrelated noise on the Doppler rate.

Ground tracking station data are loaded as shown at the top of Figure 15. For each ground station a label, latitude, longitude, and the names of the radars available at that station are given. For each radar used by ground tracking stations, the maximum range in feet, range error in feet, elevation and azimuth errors in radians, and range-rate error in feet per second are loaded. It should be noted that the maximum range specified for the DSIF radar is 1×10^{50} feet, a number chosen to represent an arbitrarily large maximum range. It should also be noted that zero range-rate error has been specified for the C-band radars. This could be interpreted as perfect measurement of range-rate. However, the program is designed to assume a zero error as an unmeasured parameter.

A check of spacecraft visibility by various radars from the specified tracking stations may be requested. Examples of such output are shown in Figures 16, 17 , and 18. This check is performed by specifying a starting time, a stopping time, and a time increment. For example, the run of Figure 16 specified a check from zero seconds to 7200 seconds (2 hours) in steps of 30 seconds. The results indicate the spacecraft is first visible from Antigua Island during the launch portion (first burn) by radars number 1 and 4. The spacecraft is considered visible when it has an elevation of greater than 5° above the horizon and a range less than the maximum range of one of the radars available at the station. Because the program only checks at the specified step intervals, the initial elevation printed will always be the first elevation greater than 5°, and the last elevation printed will always be the first elevation below 5°; thus, the printing of 6.03° for the first visibility from Antigua Island. The output then shows the spacecraft to be lost by Antigua Island 12 minutes (720 seconds) into the mission with the elevation of 4.13°, and a total time in view of 210 seconds. The spacecraft is then viewed by Ascension Island, radars number 1 and 2, 22 minutes into the mission while in the parking orbit, and lost by Ascension Island 26 minutes into the mission, for a total time in view of 240 seconds. Finally, Carnarvon picks up the spacecraft 44 minutes and 30 seconds into the mission with radars number 1 and 4 at a range of 3.04×10^7 feet. Carnarvon loses contact with the spacecraft beyond the 7200 seconds specified for the check. Therefore, the time in view was not printed. Figure 17 shows a similar check of tracking stations from zero seconds to 2 days and 2 hours into the mission with checking occurring every hour. Figure 17 also shows the visibility of the spacecraft in the early heliocentric portion of the mission. Figure 18 is a check of tracking stations from 379 days into the mission to 410 days, 10 hours,

TRACKING NET DATA

STA. NO.		LAT.	LONG.	RADARS	
1	ASCENSION	-7.966	-14.400	USBS-30	TPQ-18
2	PRETORIA	-25.950	-28.670	MPS-25	
3	CARNARVON	-24.900	113.710	USBS-30	FPQ-6
4	ANTIGUA	17.150	-61.800	USBS-30	FPQ-6
5	GOLDSTONE	35.384	-116.850	DSIF	
6	MADRID	40.416	-3.667	DSIF	
7	CANBERRA	-35.316	149.132	DSIF	

RAD. NO.		MAX. RANGE	RANGE ERROR	ELEV. ERROR	AZIM. ERROR	RANGE DOT ERROR
1	USBS-30	3.500000E+09	6.700000E+01	1.780000E-03	1.780000E-03	1.240000E-01
2	TPQ-18	1.920000E+08	6.700000E+01	4.500000E-04	4.500000E-04	-0.
3	MPS-25	6.076000E+06	1.340000E+02	2.240000E-03	2.240000E-03	-0.
4	FPQ-6	1.920000E+08	4.500000E+01	3.350000E-04	3.350000E-04	-0.
5	DSIF	1.000000E+50	-0.	-0.	-0.	4.100000E-02

FIGURE 15. RADAR TRACKING NET DATA

```
                    CHECK OF TRACKING STATIONS

      FROM           0.00      TO        7200.00 STEPS          30.00
             0D 0H 0M 0.00S         0D 2H 0M 0.00S        0D 0H 0M30.00S

             TIME                    STATION                    RANGE     ELE.          TIME IN VIEW
  0D 0H 8M30.00S
             510.00     LAUNCH       ANTIGUA     ON     3.271429E+06   6.03                0.00
                          RADAR NO.    1      USBS-30
                          RADAR NO.    4      FPQ-6
  0D 0H12M 0.00S
             720.00     PARK         ANTIGUA     OFF    3.789864E+06   4.13              210.00
                          RADAR NO.    1      USBS-30
                          RADAR NO.    4      FPQ-6
  0D 0H22M 0.00S
            1320.00     PARK         ASCENSION   ON     3.297192E+06   6.21                0.00
                          RADAR NO.    1      USBS-30
                          RADAR NO.    2      TPQ-18
  0D 0H26M 0.00S
            1560.00     PARK         ASCENSION   OFF    3.945508E+06   3.55              240.00
                          RADAR NO.    1      USBS-30
                          RADAR NO.    2      TPQ-18
  0D 0H44M30.00S
            2670.00     ESCAPE       CARNARVON   ON     3.045361E+07   6.51                0.00
                          RADAR NO.    1      USBS-30
                          RADAR NO.    4      FPQ-6

        EXECUTION TIME     3.30
```

FIGURE 16. SPACECRAFT VISIBILITY, 2 HOURS INTO MISSION

```
                              CHECK OF TRACKING STATIONS

          FROM           0.00       TO        180000.00 STEPS          3600.00
                  0D 0H 0M 0.00S          2D 2H 0M 0.00S          0D 1H 0M 0.00S

                   TIME                      STATION                      RANGE    ELE.          TIME IN VIEW

     0D 1H 0M 0.00S
               3600.00      ESCAPE           CARNARVON  ON      6.028323E+07 45.25                 0.00
                                  RADAR NO.    1     USBS-30
                                  RADAR NO.    4     FPQ-6
     0D 3H 0M 0.00S
              10800.00      ESCAPE           ASCENSION  ON      3.687074E+08 10.20                 0.00
                                  RADAR NO.    1     USBS-30
     0D 7H 0M 0.00S
              25200.00      ESCAPE           CARNARVON  OFF     9.561837E+08 -3.82             21600.00
                                  RADAR NO.    1     USBS-30
     0D 7H 0M 0.00S
              25200.00      ESCAPE           ANTIGUA    ON      9.515641E+08  8.89                 0.00
                                  RADAR NO.    1     USBS-30
     0D15H 0M 0.00S
              54000.00      ESCAPE           ASCENSION  OFF     2.111944E+09 -3.48             43200.00
                                  RADAR NO.    1     USBS-30
     0D17H 0M 0.00S
              61200.00      ESCAPE           ANTIGUA    OFF     2.398626E+09  1.12             36000.00
                                  RADAR NO.    1     USBS-30
     0D18H 0M 0.00S
              64800.00      ESCAPE           CARNARVON  ON      2.539522E+09 10.06                 0.00
                                  RADAR NO.    1     USBS-30
     1D 3H 0M 0.00S
              97200.00      HELIOCENT.       ASCENSION  ON      3.849404E+09  7.27                 0.00
                                  RADAR NO.    1     USBS-30
     1D 7H 0M 0.00S
             111600.00      HELIOCENT.       CARNARVON  OFF     4.440029E+09   .25             46800.00
                                  RADAR NO.    1     USBS-30
     1D 7H 0M 0.00S
             111600.00      HELIOCENT.       ANTIGUA    ON      4.437743E+09  6.53                 0.00
                                  RADAR NO.    1     USBS-30
     1D15H 0M 0.00S
             140400.00      HELIOCENT.       ASCENSION  OFF     5.616536E+09  1.25             43200.00
                                  RADAR NO.    1     USBS-30
     1D18H 0M 0.00S
             151200.00      HELIOCENT.       CARNARVON  ON      6.056076E+09  5.23                 0.00
                                  RADAR NO.    1     USBS-30
     1D18H 0M 0.00S
             151200.00      HELIOCENT.       ANTIGUA    OFF     6.060298E+09 -6.37             39600.00
                                  RADAR NO.    1     USBS-30

          EXECUTION TIME      1.17
```

FIGURE 17. SPACECRAFT VISIBILITY, 2 DAYS, 2 HOURS INTO MISSION

CHECK OF TRACKING STATIONS.

FROM	32760242.00	TO	35460242.00 STEPS	10000.00
	3790 4H 4M 2.00S		410010H 4M 2.00S	0D 2H46M40.00S

TIME	STATION			RANGE	ELE.	TIME IN VIEW
3790 4H 4M 2.00S						
32760242.00	HELIOCENT.	CARNARVON	ON	2.650438E+12	63.30	0.00
	RADAR NO.	1	USBS-30			
3790 6H50M42.00S						
32770242.00	HELIOCENT.	ASCENSION	ON	2.650289E+12	25.64	0.00
	RADAR NO.	1	USBS-30			
3790 9H37M22.00S						
32780242.00	TARGET CT.	CARNARVON	OFF	2.649625E+12	-9.90	20000.00
	RADAR NO.	1	USBS-30			
3790 9H37M22.00S						
32780242.00	TARGET CT.	ANTIGUA	ON	2.649616E+12	15.78	0.00
	RADAR NO.	1	USBS-30			
379017H57M22.00S						
32810242.00	TARGET CT.	ASCENSION	OFF	2.649114E+12	-10.26	40000.00
	RADAR NO.	1	USBS-30			
379020H44M 2.00S						
32820242.00	TARGET CT.	ANTIGUA	OFF	2.648941E+12	-7.78	40000.00
	RADAR NO.	1	USBS-30			
379023H30M42.00S						
32830242.00	TARGET CT.	CARNARVON	ON	2.648750E+12	41.99	0.00
	RADAR NO.	1	USBS-30			
3800 7H50M42.00S						
32860242.00	TARGET CT.	ASCENSION	ON	2.648224E+12	40.31	0.00
	RADAR NO.	1	USBS-30			
380010H37M22.00S						
32870242.00	TARGET CT.	CARNARVON	OFF	2.648068E+12	-22.81	40000.00
	RADAR NO.	1	USBS-30			
380010H37M22.00S						
32870242.00	TARGET CT.	ANTIGUA	ON	2.648050E+12	29.42	0.00
	RADAR NO.	1	USBS-30			
380018H57M22.00S						
32900242.00	TARGET CT.	ASCENSION	OFF	2.647530E+12	-24.73	40000.00
	RADAR NO.	1	USBS-30			
380021H44M 2.00S						
32910242.00	TARGET CT.	CARNARVON	ON	2.647333E+12	17.84	0.00
	RADAR NO.	1	USBS-30			
380021H44M 2.00S						
32910242.00	TARGET CT.	ANTIGUA	OFF	2.647347E+12	-21.93	40000.00
	RADAR NO.	1	USBS-30			
3810 6H 4M 2.00S						
32940242.00	TARGET CT.	ASCENSION	ON	2.646782E+12	13.86	0.00
	RADAR NO.	1	USBS-30			
3810 8H50M42.00S						
32950242.00	TARGET CT.	CARNARVON	OFF	2.646601E+12	.58	40000.00
	RADAR NO.	1	USBS-30			
381011H37M22.00S						
32960242.00	TARGET CT.	ANTIGUA	ON	2.646400E+12	42.47	0.00

FIGURE 18a. SPACECRAFT VISIBILITY, 379 DAYS TO ENCOUNTER

		RADAR NO. 1 USBS-30					
409017H24M 2.00S							
35400242.00	TARGET CT.	ASCENSION	OFF	2.577869E+12	.72	40000.00
		RADAR NO. 1 USBS-30					
409020H10M42.00S							
35410242.00	TARGET CT.	ANTIGUA	OFF	2.577543E+12	3.52	40000.00
		RADAR NO. 1 USBS-30					
409022H57M22.00S							
35420242.00	TARGET CT.	CARNARVON	ON	2.577208E+12	31.12	0.00
		RADAR NO. 1 USBS-30					
4100 7H17M22.00S							
35450242.00	TARGET CT.	ASCENSION	ON	2.576618E+12	28.92	0.00
		RADAR NO. 1 USBS-30					
410010H 4M 2.00S							
35460242.00	TARGET CT.	CARNARVON	OFF	2.576465E+12	-13.72	40000.00
		RADAR NO. 1 USBS-30					
410010H 4M 2.00S							
35460242.00	TARGET CT.	ANTIGUA	ON	2.576453E+12	19.60	0.00
		RADAR NO. 1 USBS-30					

EXECUTION TIME 10.03

FIGURE 18b. SPACECRAFT VISIBILITY, 379 DAYS TO ENCOUNTER (Continued)

4 minutes, and 2 seconds (the time of nominal perijove) with checking of the spacecraft occurring every 10,000 seconds. This run resulted in a lengthy output, so only the first portion (Figure 18a) and last portion (Figure 18b) of the run are shown. These checks of tracking station visibility are necessary to make reasonable mission schedules so that impossible updates will not be specified.

Attitude Control Subsystem

The attitude control system consists of twelve thruster nozzles (a pair for control about each positive and negative axis). The thrusters are driven with cold gas from a single tank. All nozzles are not necessarily identical and their moment arms about the spacecraft center of gravity may differ.

The control system of each axis is assumed to operate in a bang-bang fashion. Each pair of nozzles delivers a thrust F for a brief duration t, with each nozzle in a pair being separated by a distance 2R. The impulses from a pair of nozzles form an impulsive couple which makes step changes in spacecraft angular rate given by

$$\Delta\omega = \frac{2RFt}{I} = \frac{2R\Delta M}{I}$$

where I is the appropriate moment of inertia and ΔM is the linear impulse Ft. It is assumed that the durations of the impulses are equal. However, because of differing radii and moments of inertia, the $\Delta\omega$ about each axis may be different.

Proper sizing of the thrust level of mass expulsion attitude control systems, such as the cold gas reaction jet system being used as the reference system for this study, requires consideration of the requirements imposed upon the system during operation. Basically, the requirements which determine the reaction jet thrust can be listed as follows:

(1) A specified change in angular rate, $\Delta\dot{\theta}$, must occur within a specified increment of time

(2) A specified change in angular rate, $\Delta\dot{\theta}$, must occur within a specified angular increment, $\Delta\theta$

(3) A specified increment in angle, $\Delta\theta$, must occur within a specified time increment.

During these possible maneuvers, both control and disturbing torques may be continuously or intermittently present. The variety of possibilities which must be considered in sizing the attitude control system, and hence permit determination of its weight, will be discussed before developing the equations needed for sizing of the system. The requirements to be met include:

(1) Sufficient control torque must be available to remove the rates imparted at separation of the spacecraft from the launch vehicle

(2) Sufficient control torque must be available to perform required reorientation maneuvers

(3) Sufficient control torque must be available to maintain the required pointing accuracy of the vehicle while subject to disturbing torques.

The disturbing torques during interplanetary mission may be imparted due to (1) misalignment of the midcourse propulsion system thrust chamber during midcourse correction maneuvers, (2) solar radiation pressure, and (3) meteorite impact.

A general mathematical model, which will be useful in many of the cases, is developed in the following paragraphs. Assume that at some point on the limit cycle ($\dot{\theta}_0$, θ_0) a disturbance torque, M_d, introduces a disturbance angular acceleration, α_d. Sufficient control acceleration, α_c, must be available to assure that the vehicle remains within the tolerance band, $\pm\delta$, i.e., the pointing accuracy requirement. The phase plane plot in Figure 19 depicts the case being considered.

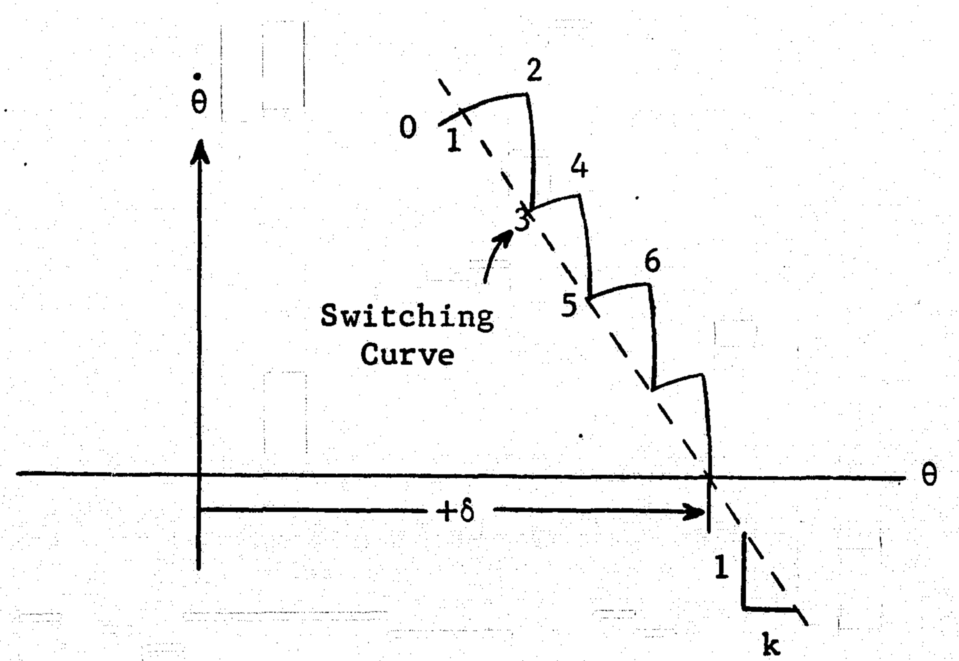


FIGURE 19. PHASE PLANE PLOT DEPICTING DISTURBING AND CONTROLLING ACCELERATIONS

Referring to the numbers on the plot, it can be shown that

$$\theta_1 = \theta_0 + \frac{\dot{\theta}_1^2 - \dot{\theta}_0^2}{2\alpha_d} \quad . \tag{1}$$

At point 1, the plot intersects the switching line of slope k. Therefore,

$$\delta = k\dot{\theta}_1 + \theta_1 \quad . \tag{2}$$

Solving Equation (2) for θ_1 and substituting the result for θ_1 into Equation (1) gives

$$\delta - k\dot{\theta}_1 = \theta_0 + \frac{\dot{\theta}_1^2 - \dot{\theta}_0^2}{2\alpha_d} \quad . \tag{3}$$

This can be written as

$$\dot{\theta}_1^2 + 2\alpha_d \, k\dot{\theta}_1 - 2\alpha_d \, (\delta - \theta_0) - \dot{\theta}_0^2 = 0 \quad . \tag{4}$$

Therefore,

$$\dot{\theta}_1 = -\alpha_d \, k + \sqrt{\alpha_d^2 \, k^2 + 2\alpha_d \, (\delta - \theta_0) + \dot{\theta}_0^2} \quad . \tag{5}$$

Due to the control reaction time, t_r seconds pass after intersecting the switching line before the control acceleration is actually applied at point 2. Then

$$\dot{\theta}_2 = \dot{\theta}_1 + \alpha_d t_r \tag{6}$$

and

$$\theta_2 = \theta_1 + \frac{(\dot{\theta}_2^2 - \dot{\theta}_1^2)}{2\alpha_d} \quad . \tag{7}$$

Substuting $\dot{\theta}_1$ from Equation (5) into Equation (6) gives

$$\dot{\theta}_2 = -\alpha_d k + \sqrt{\alpha_d^2 k^2 + 2\alpha_d (\delta - \theta_0) + \dot{\theta}_0^2} + \alpha_d t_r$$

$$= \alpha_d (t_r - k) + \sqrt{\alpha_d^2 k^2 + 2\alpha_d (\delta - \theta_0) + \dot{\theta}_0^2} \qquad (8)$$

Squaring Equation (6) gives

$$\dot{\theta}_2^2 = \dot{\theta}_1^2 + 2\alpha_d t_r \dot{\theta}_1 + (\alpha_d t_r)^2 \quad . \qquad (9)$$

Therefore,

$$\theta_2 = \theta_1 + \frac{\dot{\theta}_1^2 + 2\alpha_d t_r \dot{\theta}_1 + (\alpha_d t_r)^2 - \dot{\theta}_1^2}{2\alpha_d} = \theta_1 + t_r \dot{\theta}_1 + \alpha_d \frac{t_r^2}{2} \qquad (10)$$

Recalling that $\theta_1 = \delta - k\dot{\theta}_1$ permits Equation (10) to be written as

$$\theta_2 = \delta - k\dot{\theta}_1 + t_r \dot{\theta}_1 + \alpha_d \frac{t_r^2}{2} = \delta + \dot{\theta}_1 (t_r - k) + \alpha_d \frac{t_r^2}{2} \qquad (11)$$

Substituting for $\dot{\theta}_1$ from Equation (5) gives

$$\theta_2 = \delta + (k - t_r) \alpha_d k + (t_r - k) \sqrt{\alpha_d^2 k^2 + 2\alpha_d (\delta - \theta_0) + \dot{\theta}_0^2} + \alpha_d \frac{t_r^2}{2} \quad . \qquad (12)$$

The initial conditions at the moment in time the control acceleration is applied are $\dot{\theta}_2 = \dot{\theta}_{IC}$ and $\theta_2 = \theta_{IC}$. At the end of the first on period, t_{01},

$$\dot{\theta}_{t_{01}} = \dot{\theta}_{IC} + \ddot{\theta}_0 t_{01} \qquad (13)$$

and

$$\theta_{t_{01}} = \theta_{IC} + \dot{\theta}_{IC}\, t_{01} + \ddot{\theta}_0 \frac{t_{01}^2}{2} \tag{14}$$

where

$$\ddot{\theta}_0 = -(\alpha_c - \alpha_d) \quad . \tag{15}$$

At the end of the first recharge period, t_{rc1},

$$\dot{\theta}_{t_{r1}} = \dot{\theta}_{t_{01}} + \ddot{\theta}_r\, t_{rc1} \tag{16}$$

and

$$\theta_{t_{r1}} = \theta_{t_{01}} + \dot{\theta}_{t_{01}}\, t_{rc1} + \ddot{\theta}_r \frac{t_{rc1}^2}{2} \tag{17}$$

where

$$\ddot{\theta}_r = \alpha_d \quad . \tag{18}$$

Substituting for $\dot{\theta}_{t_{01}}$ in Equation (16) gives

$$\dot{\theta}_{t_{r1}} = \dot{\theta}_{IC} + \ddot{\theta}_0\, t_{01} + \ddot{\theta}_r\, t_{rc1} \tag{19}$$

Similarly,

$$\begin{aligned} \theta_{t_{r1}} &= \theta_{IC} + \dot{\theta}_{IC}\, t_{01} + \ddot{\theta}_0 \frac{t_{01}^2}{2} + (\dot{\theta}_{IC} + \ddot{\theta}_0\, t_{01})\, t_{rc1} + \ddot{\theta}_r \frac{t_{rc1}^2}{2} \\ &= \theta_{IC} + \dot{\theta}_{IC}\, t_{CY} + \ddot{\theta}_0 \left[\frac{t_{01}^2}{2} + t_{01}\, t_{rc1}\right] + \ddot{\theta}_r \frac{t_{rc1}^2}{2} \end{aligned} \tag{20}$$

where

$$t_{cy} = t_{01} + t_{rc1} \quad . \tag{21}$$

At the end of the second period, t_{02},

$$\dot{\theta}_{t_{02}} = \dot{\theta}_{t_{rc1}} + \ddot{\theta}_0 \, t_{02} = \dot{\theta}_{IC} + \ddot{\theta}_0 \, (t_{01} + t_{02}) + \ddot{\theta}_r \, t_{rc1} \tag{22}$$

and

$$\theta_{t_{02}} = \theta_{t_{r1}} + \dot{\theta}_{t_{rc1}} \, t_{02} + \ddot{\theta}_0 \, \frac{t_{02}^2}{2} \quad . \tag{23}$$

At the end of the second recharge period, t_{rc2},

$$\dot{\theta}_{t_{r2}} = \dot{\theta}_{t_{02}} + \ddot{\theta}_r \, t_{rc2} = \dot{\theta}_0 + \ddot{\theta}_0 \, (t_{01} + t_{02}) + \ddot{\theta}_r \, (t_{rc1} + t_{rc2}) \tag{24}$$

and

$$\theta_{t_{r2}} = \theta_{t_{02}} + \dot{\theta}_{t_{02}} \, t_{rc2} + \ddot{\theta}_r \, \frac{t_{rc2}^2}{2} = \theta_{IC} + \dot{\theta}_{IC} \, t_{cy} + \dot{\theta}_{IC} \left[t_{02} + t_{rc2}\right]$$

$$+ \ddot{\theta}_0 \left[\frac{t_{01}^2}{2} + t_{01} \, t_{rc1} + t_{01} \, t_{02} + \frac{t_{02}^2}{2} + (t_{01} + t_{02}) \, t_{rc2}\right]$$

$$+ \ddot{\theta}_r \left[\frac{t_{rc1}^2}{2} + t_{rc1} \, t_{02} + t_{rc1} \, t_{rc2} + \frac{t_{rc2}^2}{2}\right] \quad . \tag{25}$$

Now $t_{cy_1} = t_{cy_2} = t_{cy}$, $t_{01} = t_{02} = t_0$, and $t_{rc1} = t_{rc2} = t_{rc}$. Therefore,

$$\theta_{t_{r2}} = \theta_{IC} + 2\dot{\theta}_{IC}\, t_{cy} + \ddot{\theta}_0 \left[2t_0^2 + 3t_0\, t_{rc}\right] + \ddot{\theta}_r \left[3t_{rc}^2 + t_{rc}\, t_0\right] \qquad (26)$$

For N cycles,

$$\dot{\theta}_N = \dot{\theta}_{IC} + Nt_0\, \ddot{\theta}_0 + Nt_{rc}\, \ddot{\theta}_r = \dot{\theta}_{IC} + N\,(\ddot{\theta}_0\, t_0 + \ddot{\theta}_r\, t_{rc}) \qquad (27)$$

and

$$\theta_N = \theta_{IC} + N\dot{\theta}_{IC}\, t_{cy} + \ddot{\theta}_0 \left[N^2 \frac{t_0^2}{2} + \frac{N\,(N+1)}{2}\, t_0\, t_{rc}\right] + \ddot{\theta}_r \left[N^2 \frac{t_{rc}^2}{2} + \frac{N\,(N-1)}{2}\, t_{rc}\, t_0\right] \qquad (28)$$

Solving Equation (27) for N gives

$$N = \frac{\dot{\theta}_N - \dot{\theta}_{IC}}{\ddot{\theta}_0\, t_0 + \ddot{\theta}_r\, t_{rc}} = \frac{\Delta\dot{\theta}}{\ddot{\theta}_0\, t_0 + \ddot{\theta}_r\, t_{rc}} \qquad (29)$$

where

$$\Delta\dot{\theta} = \dot{\theta}_N - \dot{\theta}_{IC} \quad .$$

Recall that $\ddot{\theta}_0 = \alpha_d - \alpha_c$ and $\ddot{\theta}_r = \alpha_d$. Substituting these relationships for $\ddot{\theta}_0$ and $\ddot{\theta}_r$ in Equations (28) and (29) gives

$$\theta_N = \theta_{IC} + N\dot{\theta}_{IC}\, t_{cy} + \frac{\alpha_d}{2} N^2\, t_{cy}^2 - \frac{\alpha_c}{2} \left[N^2\, t_0^2 + N(N+1)\, t_0\, t_{rc}\right] \qquad (30)$$

and

$$N = \frac{\Delta\dot{\theta}}{\alpha_d\, t_{cy} - \alpha_c\, t_0} \quad . \qquad (31)$$

Substituting N from Equation (31) into Equation (30), and setting up to solve for α_c, gives, after much manipulation, an equation which can be written as

$$a\alpha_c^2 + b\alpha_c + c = 0 \tag{32}$$

where $$a = t_0^2 \left(\Delta\theta - \frac{\Delta\dot{\theta}\, t_{rc}}{2}\right) \tag{33}$$

$$b = \Delta\dot{\theta}\, \dot{\theta}_{IC}\, t_{cy}\, t_0 - 2\alpha_d\, t_{cy}\, t_0\, \Delta\theta + \frac{\Delta\dot{\theta}^2}{2}\left(t_0\, t_{rc} + t_0^2\right)$$
$$+ \frac{\Delta\dot{\theta}}{2}\, \alpha_d\, t_{cy}\, t_0\, t_{rc} \tag{34}$$

$$c = \alpha_d^2\, t_{cy}^2\, \Delta\theta - \Delta\dot{\theta}\, \dot{\theta}_{IC}\, t_{cy}^2\, \alpha_d - \frac{\alpha_d}{2}\, \Delta\dot{\theta}^2\, t_{cy}^2 \quad . \tag{35}$$

Therefore,

$$\alpha_c = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad . \tag{36}$$

It is known that $$\alpha_c = \frac{2RF}{I_i} \tag{37}$$

where R = distance from each reaction jet to the vehicle's center of gravity

F = reaction jet thrust level

I_i = moment of inertia about the i^{th} vehicle axis.

Therefore,

$$F = \frac{I_i}{2R}\, \alpha_c = \frac{I_i}{2R}\left[\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\right] \quad . \tag{38}$$

If it is assumed that the vehicle is not undergoing a disturbing acceleration, i.e., $\alpha_d = 0$, then

$$a = t_0^2 \left(\Delta\theta - \frac{\Delta\dot{\theta}}{2} t_{rc}\right) \tag{39}$$

$$b = \Delta\dot{\theta}\, \dot{\theta}_{IC}\, t_{cy}\, t_0 + \frac{\Delta\dot{\theta}_1^2}{2} (t_0\, t_{rc} + t_0)^2 \tag{40}$$

$$c = 0. \tag{41}$$

In this case,

$$\alpha_c = -\frac{b}{a} = -\left[\frac{2\Delta\dot{\theta}\, \dot{\theta}_{IC} + \Delta\dot{\theta}^2}{\Delta\dot{\theta}\, t_{rc} - 2\Delta\theta}\right] \frac{t_{cy}}{t_0} = \left[\frac{2\Delta\dot{\theta}\, \dot{\theta}_{IC} + \Delta\dot{\theta}^2}{2\Delta\theta - \Delta\dot{\theta}\, t_{rc}}\right] \frac{t_{cy}}{t_0} \quad . \tag{42}$$

This equation applies to the case in which a specified change in angular rate, $\Delta\dot{\theta}$ (such as that which must be removed after separating from the launch vehicle with a higher than desired angular rate), must occur within a specified angular increment, $\Delta\theta$.

Therefore,

$$F = \frac{I_i}{2R} \left[\frac{\Delta\dot{\theta}^2 + 2\Delta\dot{\theta}\, \dot{\theta}_{IC}}{2\Delta\theta - \Delta\dot{\theta}\, t_{rc}}\right] \frac{t_{cy}}{t_0} \quad . \tag{43}$$

If $t_{rc} = 0$, then $t_{cy} = t_0$ and the minimum F results. That is,

$$F = \frac{I_i}{2R} \left[\frac{\dot{\theta}_N^2 - \dot{\theta}_{IC}^2}{2\Delta\theta}\right] = \frac{I_i}{4R} \left[\frac{\dot{\theta}_N^2 - \dot{\theta}_{IC}^2}{\Delta\theta}\right] \quad . \tag{44}$$

Recall from Equation (27) that for each cycle the change in $\dot{\theta}$, $\Delta\dot{\theta}$, is equal to the $\Delta\dot{\theta}$ of every other cycle provided the $\ddot{\theta}_0$ and $\ddot{\theta}_r$ remain constant from cycle to cycle. Therefore, if the requirement is to change $\dot{\theta}$ by the amount $\Delta\dot{\theta}$ within a specific time increment, Equation (27) can be used to find the value of α_c required. Substituting from Equation (15) for $\ddot{\theta}_0$ and Equation (18) for $\ddot{\theta}_r$ gives

$$\dot{\theta}_N = \dot{\theta}_{IC} + N(\alpha_d - \alpha_c)\, t_0 + N\alpha_d\, t_{rc}$$

$$= \dot{\theta}_{IC} + N\alpha_d\,(t_0 + t_{rc}) - N\alpha_c\, t_0$$

$$= \dot{\theta}_{IC} + N\alpha_d\, t_{cy} - N\alpha_c\, t_0 \quad . \tag{45}$$

As before, it is assumed that t_0, t_{rc}, and t_{cy} are constants. If the time increment is specified as t_N, then the number of cycles, to the nearest integer, is obtained from

$$N = \frac{t_N}{t_{cy}} \tag{46}$$

Substituting this into Equation (45) gives

$$\dot{\theta}_N = \dot{\theta}_{IC} + \alpha_d \frac{t_N}{t_{cy}}\, t_{cy} - \frac{t_N}{t_{cy}}\, \alpha_c\, t_0$$

$$= \dot{\theta}_{IC} + \alpha_d\, t_N - \alpha_c \frac{t_N}{t_{cy}}\, t_0 \quad . \tag{47}$$

Solving for α_c gives

$$\alpha_c = \frac{(\dot{\theta}_{IC} - \dot{\theta}_N + \alpha_d\, t_N)\, t_{cy}}{t_N\, t_0}$$

$$= \frac{(\Delta\dot{\theta} + \alpha_d\, t_N)\, t_{cy}}{t_N\, t_0} \quad . \tag{48}$$

The required value of F is

$$F = I_i \frac{\alpha_c}{2R} = \frac{I_i \, (\Delta\dot{\theta} + \alpha_d \, t_N) \, t_{cy}}{2R \, t_N \, t_0} \quad . \tag{49}$$

If α_d is zero, Equation (49) reduces to

$$F = \frac{I_i \, \Delta\dot{\theta} \, t_{cy}}{2R \, t_N \, t_0} \quad . \tag{50}$$

The minimum thrust level would occur when continuous thrust is available, i.e., $t_{rc} = 0$. In this case $t_0 = t_{cy}$ and

$$F = \frac{I_i \, \Delta\dot{\theta}}{2R \, t_N} \quad . \tag{51}$$

The final requirement to be analyzed is the maneuver through a known angle, $\Delta\theta$, in a given time, t_T. It is possible to determine the control acceleration from Equation (28), and the relationships $\ddot{\theta}_0 = \alpha_d - \alpha_c$ and $\ddot{\theta}_r = \alpha_d$. That is,

$$(\alpha_c - \alpha_d) \left[N^2 \frac{t_0^2}{2} + \frac{N(N+1)}{2} \, t_0 \, t_{rc} \right] = \theta_{IC} - \theta_N + N\dot{\theta}_{IC} \, t_{cy}$$

$$+ \alpha_d \left[N^2 \frac{t_{rc}^2}{2} + \frac{N(N+1)}{2} \, t_{rc} \, t_0 \right]$$

which yields

$$\alpha_c = \frac{\theta_{IC} - \theta_N + N\theta_{IC} \, t_{cy} + \alpha_d \left[N^2 \frac{t_{rc}^2}{2} + \frac{N(N-1) \, t_{rc} \, t_0}{2} + N^2 \frac{t_0^2}{2} + \frac{N(N+1)}{2} t_{rc} \, t_0 \right]}{N^2 \frac{t_0^2}{2} + \frac{N(N+1)}{2} \, t_0 \, t_{rc}}$$

or

$$\alpha_c = \frac{\theta_{IC} - \theta_N + N\dot{\theta}_{IC}\, t_{cy} + \alpha_d \left[N^2 \frac{t_{cy}^2}{2} + N^2\, t_{rc}\, t_0\right]}{N^2 \frac{t_0^2}{2} + \frac{N(N+1)}{2}\, t_0\, t_{rc}} \quad . \tag{52}$$

Now $N = \frac{t_T}{t_{cy}}$. Also, $F = \frac{I_i \alpha}{2R}$. Therefore,

$$F = \frac{I_i}{R} \left[\frac{\theta_{IC} - \theta_N + N\dot{\theta}_{IC}\, t_{cy} + \alpha_d \left[N^2 \frac{t_{cy}^2}{2} + N^2\, t_{rc}\, t_0\right]}{N^2\, t_0^2 + N(N+1)\, t_0\, t_{rc}}\right] \quad . \tag{53}$$

If no disturbing acceleration is present, then

$$F = \frac{I_i}{R} \left[\frac{\theta_{IC} - \theta_N + N\dot{\theta}_{IC}\, t_{cy}}{N^2\, t_0^2 + N(N+1)\, t_0\, t_{rc}}\right] \quad . \tag{54}$$

It must be remembered that if the final conditions require $\dot{\theta} = 0$, then the given time and angle entered in the above equations are one-half the total maneuver time and angle.

The minimum value of F results when $t_{rc} = 0$. Figure 20 depicts three different levels of thrust for the bang-bang type of control system. The line marked F_3 corresponds to the minimum thrust case. $\dot{\theta}$ equals zero at the start and end of the manuever for all three cases.

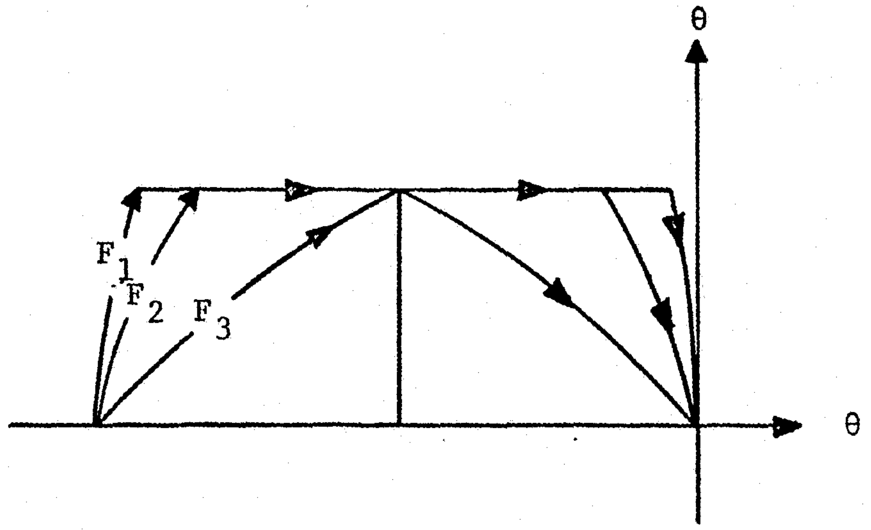


FIGURE 20. REORIENTATION MANEUVER PHASE PLANE PLOT FOR CONSTANT IMPULSE AND DIFFERENT THRUST LEVELS

Notice the linear impulse, $Ft = \Delta M$, is constant and that $F_1 > F_2 > F_3 = F_{Minimum}$.

After determining the maximum thrust level required to perform the various maneuvers described by the above equations, the weight of the propellant for each maneuver can be determined from the relationship

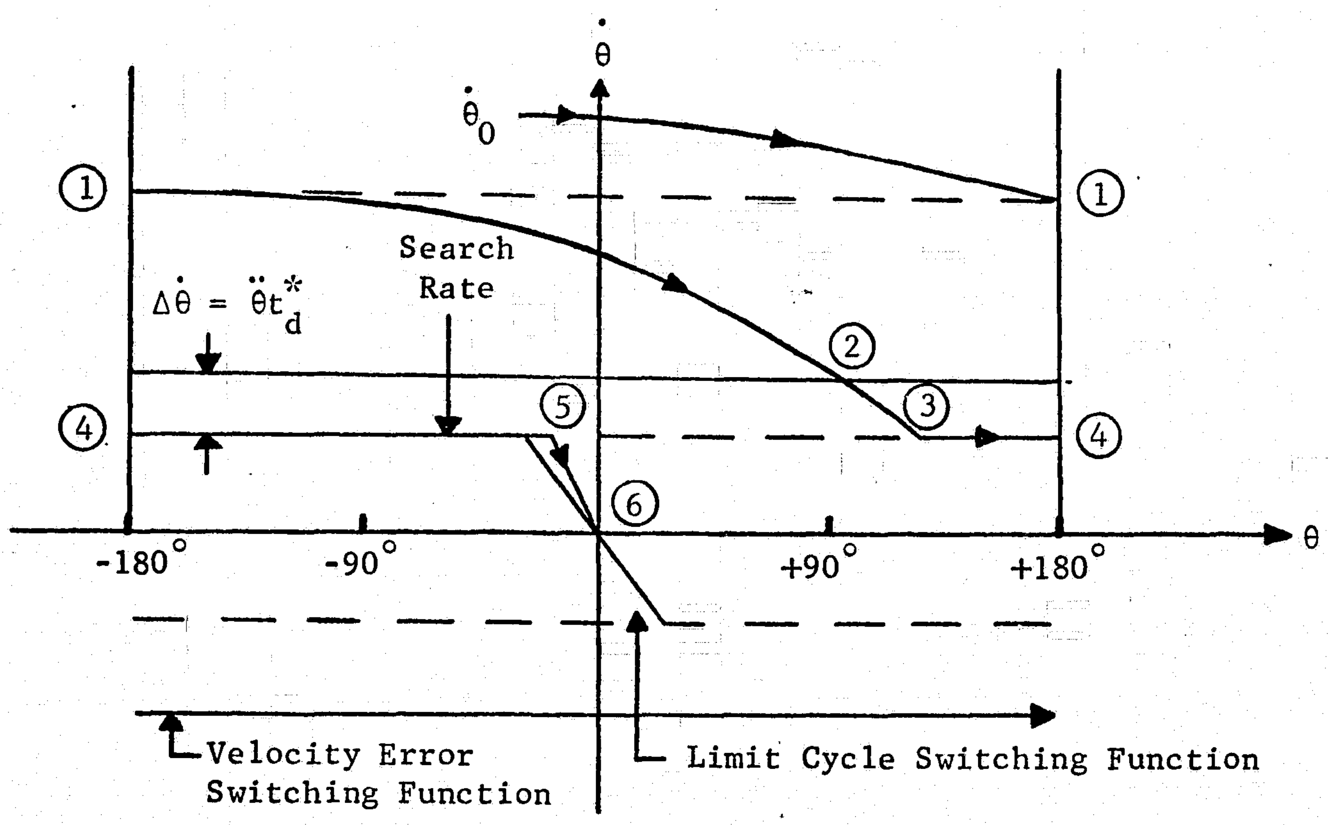
$$W = 2\int_{o}^{t_T} \frac{F}{I_{sp}}\, dt$$

where I_{sp} = specific impulse of the propellant. The factor of 2 is due to the fact that two thrusters are required for performing a maneuver.

The needed equations for determining the weight of the attitude control system propellant have now been developed. The application of these equations can be best illustrated by reexamining the principal functions which the attitude control system must satisfy. Three principal functions must be performed by the attitude control system. These are: (1) establishment of the initial orientation of the vehicle after separation from the launch vehicle; (2) occasional reorientation maneuvers; and (3) attitude stabilization during coasting phases of the mission.

The initial orientation function consists of eliminating initial angular velocity errors and establishing the necessary orientation for acquisition of predetermined observables by the electro-optical sensors. Reference 36 suggests a logic for this phase which is described in the following paragraph.

Control is actuated on angular velocity error, $\dot{\theta}$, and keeps operating until a predetermined $\dot{\theta}$ is attained. The vehicle continues at this low $\dot{\theta}$, termed "search rate", until the electro-optical sensors respond and indicate "lock" on the desired observable. As the vehicle approaches the zero attitude error point, the limit cycle switching function is energized and arrests the motion, reducing all deviations to steady-state limit cycle values. Figure 21 illustrates the phase plane plot of this maneuver.



*Legend: t_d = cutoff time lag (from off signal to zero thrust), sec

FIGURE 21 . INITIAL ORIENTATION MANEUVER PHASE PLANE PLOT

The advantages of this mode of operation are: (1) no excess impulse is supplied by the control, and (2) the limit-cycle switching function is given a slope such that it reduces the search rate to limit cycle rate with one impulse (Reference 36).

The magnitude of the search rate can be set at a level which will permit acquisition of the reference observables before the vehicle completes one revolution. All systems will be considered stable and if given sufficient time, the maneuver can be accomplished. However, if the requirements specify that the maneuver must be accomplished within a definite time or that the angular displacement, $\Delta\theta$, during the maneuver may not exceed a definite value, then the thrust requirements are unique as shown by Equations (38), (43), (44), (49), (50), and (52). For the systems sizing calculations, the most severe maneuver on the mission schedule is taken as the determining factor.

Performing a reorientation maneuver to sight another observable involves rotating the vehicle about one or more axes. If the rotation through a specified angle, $\Delta\theta$, is to be performed within a specified time limit, t_T, several levels of thrust could be used. As previously stated, it is assumed that $\dot{\theta}(0) = \dot{\theta}(t_T) = 0$. The start command signal is given on an attitude error, $\Delta\theta$, and the cutoff command is given on an angular velocity, $\dot{\theta}_c$. The vehicle then coasts at this constant rate until it approaches the desired attitude, at which time an equal and opposite control impulse is applied, bringing it to rest or within the limit-cycle region. Figure 22 depicts a phase plane plot of this maneuver.

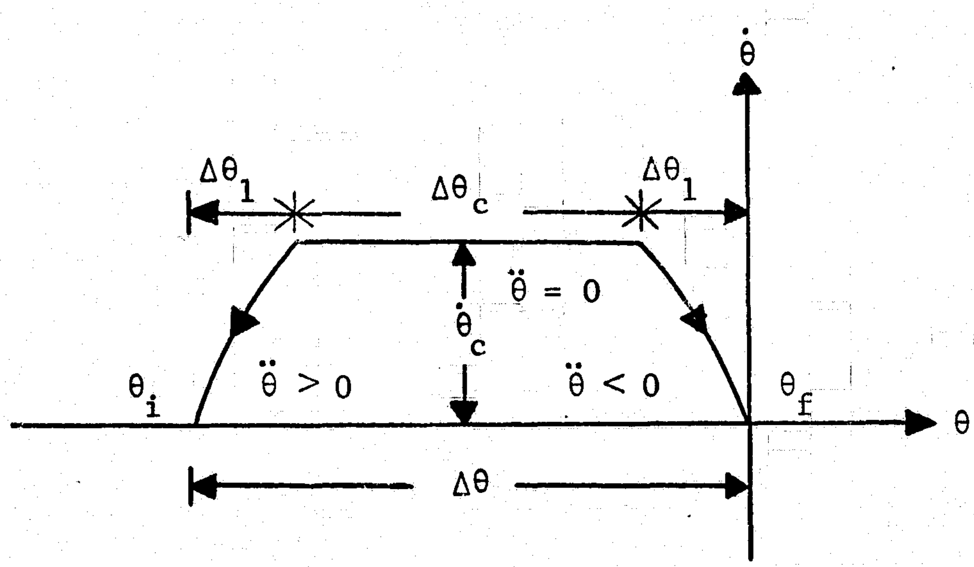


FIGURE 22. ROTATION MANEUVER PHASE PLANE PLOT

Notice that no limitation has been specified on the thrust F except that it be of constant magnitude. Recall that $2RF = I_i\ddot{\theta}$. This implies that any value of F would allow solution for $\ddot{\theta}$. In reality, an additional constraint must be applied. Strapdown inertial guidance system components and torquing loops are generally designed to operate at or below a specified angular rate, $\dot{\theta}$. Therefore, constraining $\dot{\theta}$ to some mean or maximum value results in constraint of the thrust to a corresponding mean or maximum value. This implies that the vehicle must have a definite velocity increment imparted to it within a specified time period. Theoretically, the propellant weight is not influenced by thrust variation, because thrust level, F, and impulse duration, t, are assumed to vary inversely such that their product, $Ft = \Delta M$, is a constant.

For attitude stabilization, consideration must be given to undisturbed and disturbed limit cycle operation. In undisturbed operation, the thrust level should be as low as possible, since increasing thrust increases the limit cycle frequency and decreases the amplitude of operation. The impulse requirements for disturbed limit cycle operation are invariant with control thrust, since they are determined by the magnitude of the disturbance. Because of time delays between sensing of the disturbance and actuation of the control system, the control torque must be higher than the disturbance torque.

The principal difficulty arises in determining the magnitude of the disturbance which may be due to various sources. Examples of these disturbance sources include: (1) meteorite impacts; (2) torques due to solar pressure acting on the area of the spacecraft normal to the spacecraft-sun line; (3) midcourse correction maneuver roll axis control; and (4) excessive (unplanned) launch vehicle/spacecraft separation rates.

As discussed in Reference 6, meteorite impact is potentially a serious source of attitude disturbances. The average thrust capability must be set to permit cancellation of meteorite induced angular rotation before the spacecraft has drifted out of the attitude tolerance band (2δ) which is determined by the necessity to maintain the optical sensor lock on the observable being used. This band is directly related to the optical sensor field of view (FOV).

A meteorite of linear momentum M_m striking the spacecraft at a distance L from the center of gravity imparts an increase in angular rate

$$\omega_m = \frac{L\,M_m}{I} \quad .$$

The average torque required to cancel ω_m before drifting through the angle 2δ is

$$T_a = \frac{L^2 M_m^2}{2\delta I} \quad .$$

The required thrust is then

$$F = \frac{L^2 M_m^2 \, t_{rc}}{4\delta IR \, t_0} \quad .$$

However, the L, I, and R may be different on each axis. The thrust must be set for the worst case. Thus,

$$F = \frac{M_m^2 \, t_{cy}}{4\delta \, t_0} \left[\text{Maximum of} \left(\frac{L_i^2}{I_i R_i} \right) \right] \qquad i = \text{yaw, pitch, roll.}$$

It should be noted that the meteorite impact data used for determining the required thrust do not agree with that in Reference 37, a NASA Contractor Report. The source of the data used was Reference 6 (also a NASA Contractor Report).

Disturbance torques to solar radiation pressure can be estimated starting with the expression for solar radiation force derived in Reference 38. This same equation is listed in Reference 39. The equation is

$$\overline{F} = \left[\frac{2}{3} \rho \, (1 - S) \cos\theta + (1 + s\rho) \cos^2\theta \right] P_f A \, \overline{u}_n + (1 - S\rho) \, P_f A \cos\theta \sin\theta \, \overline{u}_t$$

where $\overline{F}$ = the force developed as a result of momentum transfer of the photons at the satellite surface

ρ = reflectivity, where $\rho = 1$ means complete reflection and $\rho = 0$ means complete absorption

S = specularity, where $S = 1$ means that all photons reflected are reflected specularly and $S = 0$ means that all photons reflected are reflected diffusely

A = area of spacecraft intercepting the radiation

θ = angle between the spacecraft normal and the radiation field

P_f = radiation pressure = 0.47×10^{-5} newton/m^2 near earth (Reference 38) radiation pressure = 9.8×10^{-8} lb/ft^2 near earth (Reference 39)

$\overline{u}_n$ = unit normal vector as shown in Figure 23

$\overline{u}_t$ = unit vector formed by intersection of the surface with a plane containing $\overline{u}_i$ and $\overline{u}_n$ as shown in Figure 23.

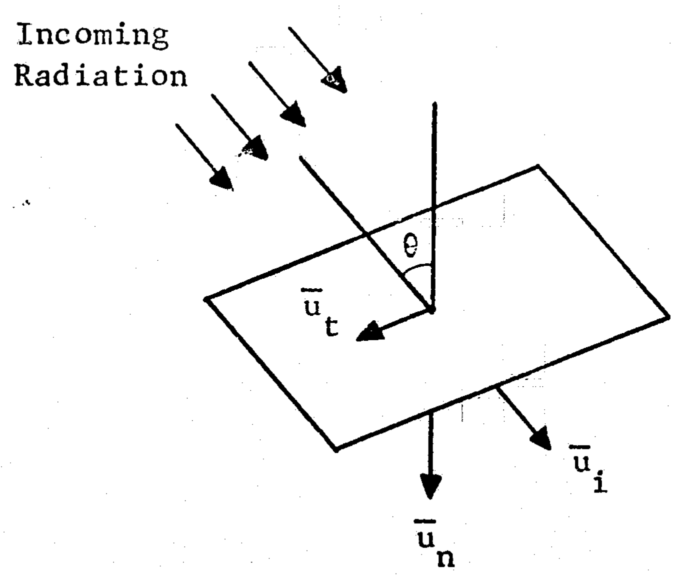


FIGURE 23. SOLAR RADIATION ACTING ON A SPACECRAFT

The solar torque can be calculated from the equation

$$T = |F| \, \ell \sin \lambda$$

where λ = angle between the force vector and a line joining the spacecraft center of mass and center of solar radiation pressure

ℓ = distance between the vehicle center of mass and center of solar radiation pressure

T = torque due to solar radiation.

The maximum force due to solar radiation will occur when $\theta = 0$ and $\rho = S = 1$. Then

$$\bar{F} = 2P_f A \, \bar{u}n$$

and

$$T = 2P_f A \, \ell \sin \lambda \quad .$$

The maximum torque occurs when $\lambda = 90^{\circ}$. The maximum disturbance torque due to solar radiation is

$$T_{max} = 2P_f A \ell \quad .$$

The reaction jet thrust level required to balance the disturbing torque due to solar radiation can be found from the equation

$$F = \frac{2P_f A \ell}{2R} = \frac{P_f A \ell}{R} \quad .$$

As the spacecraft proceeds away from the Sun, the intensity of the radiation decreases as shown in Figure 24(Reference 39). Therefore, the maximum disturbance torque caused by solar radiation occurs in the earliest phase of the reference mission.

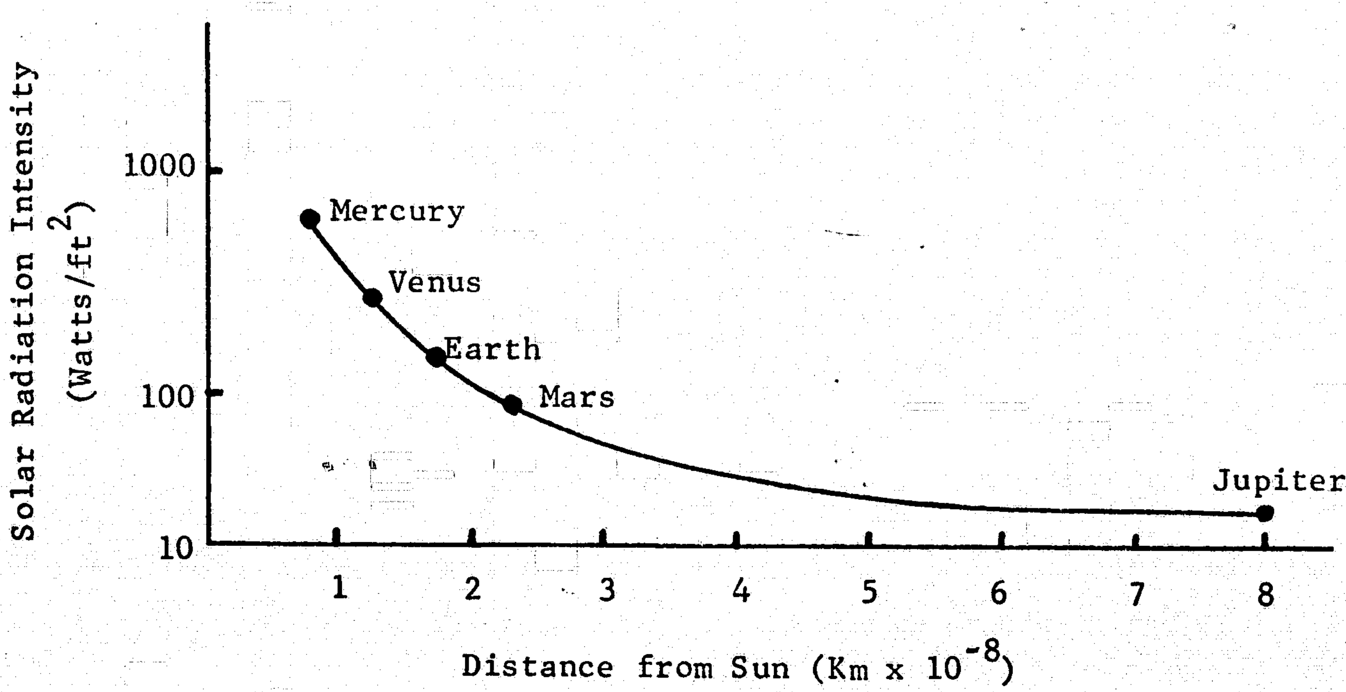


FIGURE 24. SUN'S RADIATION VERSUS DISTANCE FROM THE SUN (Ref. 39)

Misalignment of the midcourse propulsion system thrust chamber with respect to the center of mass of the vehicle creates a disturbing torque when midcourse corrections are made.

The torque on the spacecraft is given by

$$\vec{\tau} = \vec{\ell}_{MC} \times \vec{F}_{MC}$$

where $\vec{\ell}_{MC}$ = the engine location with respect to the center of mass

$\vec{F}_{MC}$ = the engine thrust.

If errors in location and thrust are included, then

$$\vec{\tau} = (\vec{\ell}_o + \Delta\vec{\ell}) \times (\vec{F}_o + \Delta\vec{F})$$

where the subscript o indicates nominal and Δ indicates errors. Expanding and dropping second order terms gives

$$\vec{\tau} = \vec{\ell}_o \times \vec{F}_o + \vec{\ell}_o \times \Delta\vec{F} + \Delta\vec{\ell} \times \vec{F}_o \quad .$$

The nominal location and thrust are both assumed to be collinear with the roll axis so any disturbing torque is due only to errors. That is,

$$\vec{\tau} = \vec{\ell}_o \times \Delta\vec{F} - \vec{F}_o \times \Delta\vec{\ell} \quad .$$

Expanding in roll (R), pitch (P), and yaw (Y) coordinates gives

$$\tau_R = 0 \quad ,$$

$$\tau_P = -\ell_R \, \Delta F_Y + F_R \, \Delta\ell_Y \quad , \text{ and}$$

$$\tau_Y = \ell_R \, \Delta F_P - F_R \, \Delta\ell_P \quad .$$

The errors in force, ΔF_Y and ΔF_P are

$$\Delta F_P = F_R \zeta_P \qquad \text{and} \qquad \Delta F_Y = F_R \zeta_Y$$

where ζ_P and ζ_Y are the small angles (radians) describing the misalignment about the pitch and yaw axes.

Thus, dropping algebraic signs for worst case analysis yields

$$\tau_P = F_{MC} (\ell_R \zeta_P + \Delta\ell_Y)$$

and

$$\tau_Y = F_{MC} (\ell_R \zeta_Y + \Delta\ell_P)$$

where F_{MC} = the nominal magnitude of the midcourse engine thrust. Assuming the errors are equal about pitch and yaw gives

$$\tau_d = F_{MC} (\ell_R \zeta + \Delta\ell) \quad .$$

The reaction jet thrust level required to counter the disturbing torque is given by

$$F = \frac{F_{MC} (\ell_R \zeta + \Delta\ell)}{2R} \quad .$$

Excessive (unplanned) launch vehicle/spacecraft separation rates will affect principally the time sequence of events during the mission. If the attitude control system is sized on the basis of a change in rate in (1) specified time, or (2) angular increment, the excessive (unplanned) rate will essentially cause the rate to be higher than desired at the end of the time or angular increment.

Since thrust levels are established by evaluating all sizing requirements and using the maximum, it is possible that maneuvering through a given angle in a given time may involve coasting as shown in Figure 22. Using the thrust levels established by the sizing, the total impulse required for performing the maneuvers must be calculated. For maneuvers involving rotation about more than a single axis, the total time allowed is proportioned between the axes. With the requirement of traversing through a given angle in a given time thus established, the total on time is calculated for each axis. The on time is calculated assuming that the total angle, $\Delta\theta = 2\Delta\theta_1 + \Delta\theta_c$, and that impulses are supplied until the angular velocity $\dot{\theta}_c$ is reached at which time the vehicle coasts at the constant rate $\dot{\theta}_c$ until the remaining time equals the total time of the first series of impulses. At this time, a series of equal and opposite impulses are applied to bring the vehicle to rest.

The equations of motion are

$$\dot{\theta}_c = \omega_c = \ddot{\theta}\Delta t$$

where Δt = on time of the first series of impulses. Also,

$$\Delta\theta_1 = \frac{\ddot{\theta}\,(\Delta t)^2}{2}$$

and therefore,

$$\Delta\theta = 2\Delta\theta_1 + \Delta\theta_c = \ddot{\theta}\,(\Delta t)^2 + \dot{\theta}_c t_c = \ddot{\theta}\,(\Delta t)^2 + \ddot{\theta} t_c \Delta t$$

where t_c = time of coast.

Using $t_T = 2\Delta t + t_c$ with the above equation, there are two equations with two unknowns when $\Delta\theta$ and t_T are specified.

$$\Delta\theta = \ddot{\theta}\,[(\Delta t)^2 + t_c \Delta t]$$

$$t_T = 2\Delta t + t_c$$

Substituting for t_c, the equation for $\Delta\theta$ becomes

$$\begin{aligned}\Delta\theta &= \ddot{\theta}\,[(\Delta t)^2 + (t_T - 2\Delta t)\,\Delta t] \\ &= \ddot{\theta}\,[(\Delta t)^2 + t_T\Delta t - 2(\Delta t)^2] \\ &= \ddot{\theta}\,[t_T\Delta t - (\Delta t)^2] \quad .\end{aligned}$$

Solving for Δt gives

$$\Delta t = \frac{t_T}{2} \pm \sqrt{\frac{t_T^2}{4} - \frac{\Delta\theta}{\ddot{\theta}}} \quad .$$

The total on time for the maneuver is $2\Delta t$.

The total impulse for the maneuver is the summation on the three axes, or

$$M_{TOT} = \sum_{i=1}^{3} \frac{t_0}{t_0 + t_{rc}} F_i \left[t_{T_i} - \sqrt{t_{T_i}^2 - \frac{2\Delta\theta_i \, I_i}{R_i \, F_i}} \right]$$

where

F_i = thrust of i^{th} axis

R_i = thrust arm of i^{th} axis

I_i = moment of inertia of i^{th} axis

$\Delta\theta_i$ = angle to be traversed by i^{th} axis

t_{T_i} = time allowed for maneuver about i^{th} axis.

The fuel weight is then

$$W_{MANEUVER} = 2 \frac{M_{TOT}}{I_{sp}}$$

as previously discussed.

Each factor that influences the attitude control system thruster sizing is evaluated based upon the data input to describe the spacecraft, mission schedule, and the attitude control parameters. The maximum value of thruster magnitude required to meet the data specified can be the same for all three axes, if that option in the program is elected or different for all three axes of the spacecraft. The data used to describe the attitude control requirements should be realistic to permit evaluation of the tradeoffs between maneuvering the spacecraft with strapdown electro-optical sensors and gimballing the electro-optical sensors (EOS). It must be remembered that the gimballed EOS still requires some level of attitude stabilization of the spacecraft.

Since the objective of this effort was not the investigation of the many means of attitude control, further examination of tradeoffs between single level and dual level thrusters and other mechanizations was not conducted. It would be possible to use the techniques developed to further examine attitude control if this were a specified objective.

Although the system must be sized to meet the requirements which have been discussed, these requirements usually exist for relatively short periods of time. The limit cycle operation, typical of all bang-bang control systems, is the principal factor in determining the amount of fuel that must be carried if the attitude control system operates for the duration of the mission. The limit cycle operation, as shown in Figure 25, is maintained for the entire time of attitude control system operation. Fuel consumption is determined by the total angular momentum change on each of the three axes. Each thruster, after delivering its impulse, must be recharged from the primary fuel tank. This results in a maximum duty cycle given by

$$D = \frac{t_o}{t_{rc} + t_o} = \frac{t_o}{t_{cy}}$$

where t_{rc} is the recharge time. A thruster delivering its impulse with thrust F, has a maximum average thrust

$$F_a = DF \quad .$$

The limit cycle dead zone, θ_D, must be set to the attitude tolerance band, 2δ, less the overshoot, or angle by which attitude exceeds the dead zone while reversing at each side.

$$\theta_D = 2\delta - 2\theta_{OS}$$

where

$$\theta_{OS} = \frac{RFt^2}{2I} \quad .$$

Each time the edge of the dead zone ($\pm\theta_D/2$) is reached, the thrusters fire and the direction of rotation is reversed. The thrusters then fire with a period determined by the time it takes to move through the dead zone. The frequency of firing for one axis is then

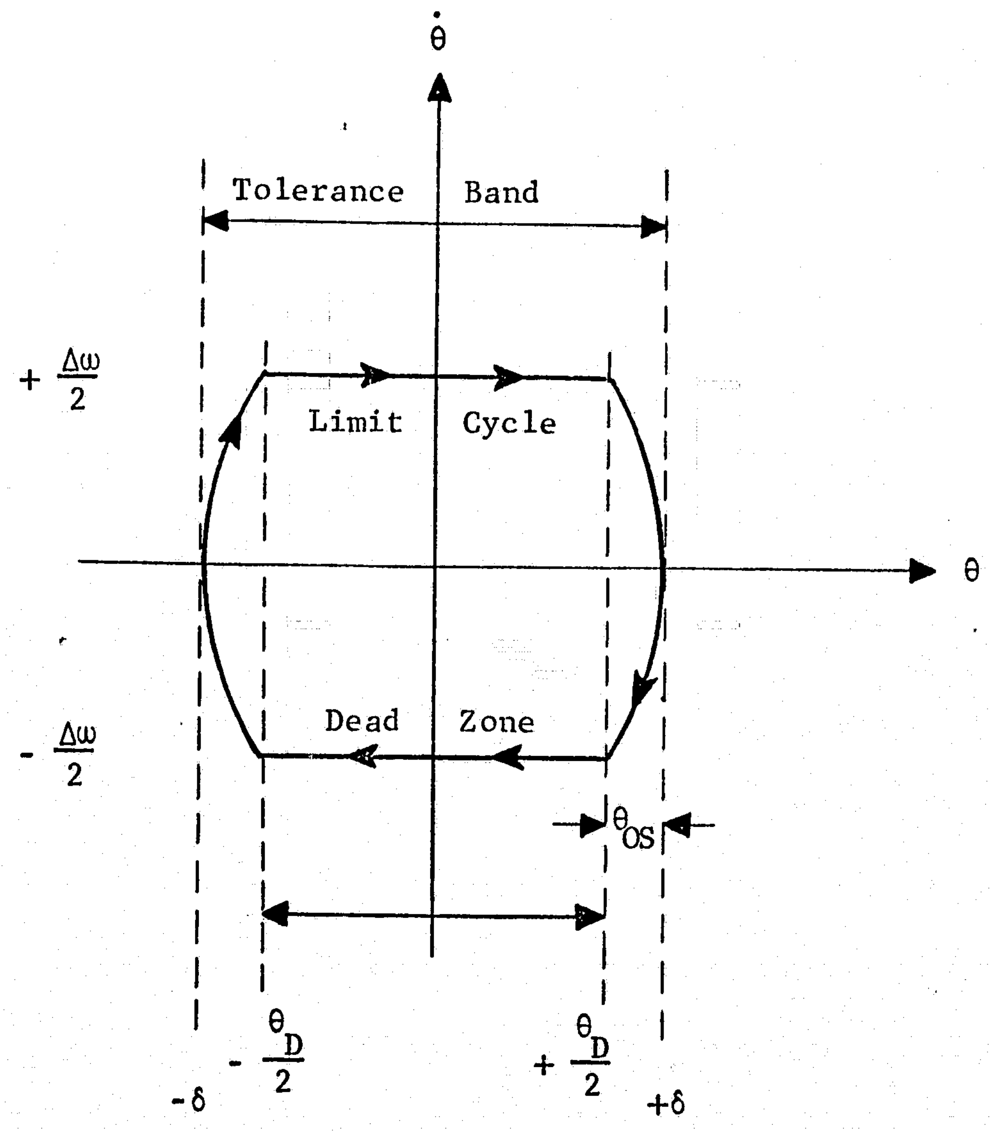


FIGURE 25. ATTITUDE CONTROL LIMIT CYCLE

$$f = \frac{\Delta\omega}{2\theta_D} = \frac{2RFt}{2\theta_D I} = \frac{R\Delta M}{\theta_D I} .$$

The total frequency of firings is the sum of the frequencies of firing for all three axes

$$f_t = \frac{\Delta M}{\theta_D} \Sigma \frac{R_i}{I_i} .$$

The total number of firings is found by multiplying the total frequency by the operating time, T.

The total impulse for the limit cycling during the mission is then found by multiplying the total number of firings by $2\Delta M$. Then,

$$M_t = 2\Delta M\ f_t\ T = \frac{2\Delta M^2 T}{\theta_D} \Sigma \frac{R_i}{I_i} .$$

The weight of attitude control fuel, W_F, is

$$W_F = \frac{M_t}{I_{sp}}$$

where I_{sp} is the specific impulse of the fuel. The attitude control system weight W_{ac}, is

$$W_{ac} = K_1 + K_2\ W_F$$

where K_1 and K_2 are, respectively, a constant and coefficient that may be obtained as discussed in Appendix E of Reference 6.

Attitude control system probability of failure is assumed to be due to thruster subsystem and electronics failure. With p_n equal to the probability of nozzle failure per impulse, the thruster subsystem probability of failure may be found by

$$P_{f_{Th}} = 1.0 - e^{-(f_t T p_n)} \quad .$$

The attitude control system parameter estimation discussed above requires the data shown in Table XIII in addition to the data already used in other subsystem calculations. It should be noted that moments of inertia and physical dimensions must be known in addition to the spacecraft parameters considered in other subsystems. For this reason a reasonably detailed spacecraft physical design is needed.

Power Supplies

Evaluation of specified systems requires consideration of all system parameters used in the evaluation technique. Many specified systems are packaged with the inertial sensing unit and/or computer power supplies being separate rather than integral items. A subsystem was added to permit evaluation of systems utilizing this packaging technique. The required input data for the power supply subsystem include the weight, power, MTTF, and Weibull coefficient. An example which includes a specified power supply is shown with the H-429 evaluation later in this report.

Mission Operation Schedule

To properly analyze an astrionics system, a detailed schedule of the astrionics system operation must be known. This schedule must specify the time of each of the updates and midcourse corrections. In addition, details such as the time each subsystem is turned on or off and the time attitude maneuvers are to be made to orient the electro-optical sensors toward the desired celestial bodies are part of the schedule. The time allowed for searching for the celestial bodies must also be stipulated. The complete schedule represents a large volume of data and many details may have a great effect on the penalty evaluation. This will be discussed further in the results section of this report.

Maneuver Sequences

In order to perform the necessary reorientations during the updating maneuvers, as well as other portions of the flight, Euler angles are obtained for the reorientation from the initial and final direction cosine matrices.

TABLE XIII. ATTITUDE CONTROL SYSTEM DATA

Data	Description	Units
I_y, I_p, I_r	Spacecraft moments of inertia	Lb-ft^2
R_y, R_p, R_r	Thruster arm radii	Ft
l_y, l_p, l_r	Distance from solar center of pressure to center of gravity	Ft
L_y, L_p, L_r	Maximum meteorite impact radii	Ft
A_y, A_p, A_r	Solar pressure area	Ft^2
K_1	Attitude system constant weight	Lb
K_2	Attitude system weight coefficient	Lb system/Lb fuel
I_{sp}	Attitude control specific impulse	Seconds
t_o	Thruster impulse time	Seconds
t_{rc}	Thurster recharge time	Seconds
2δ	Attitude tolerance	Radians
l_R	Midcourse engine lever arm	Ft
Δl	Midcourse engine lever arm uncertainty	Ft
P_n	Probability of thruster failure per impulse	---
MTTF	Attitude control electronics mean time to failure	Hours
M_m	Meteorite impact impulse	Lb-sec
P	Power required by electronics	Watts
ζ	Misalignment of midcourse engine	Radians

A very general technique was first developed to calculate the proper sequence of maneuvers for each reorientation, given the transformation matrix C. This matrix was obtained as shown in Figure 26.

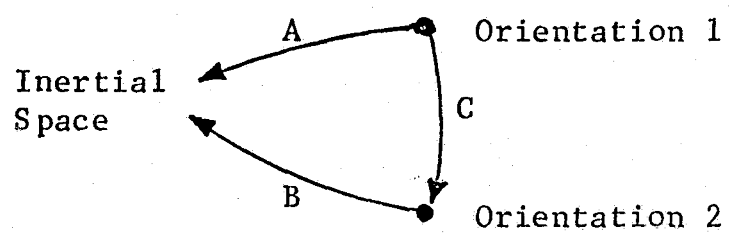


FIGURE 26. DEFINITION OF C

Matrix A maps the local body coordinates of orientation 1 to inertial coordinates. Likewise, matrix B does the same for orientation 2. To go from orientation 1 to orientation 2, it is evident from the figure that

$$C = B^T A \quad .$$

The significance of each element of matrix C as a trigonometric function of the Eulerian angles is well known. The angles themselves were determined by solving these trigonometric equations. Several solutions were made, using different rotation sequences. It was found that, provided that the first angle was not exactly 90°, the solution could be obtained very quickly and efficiently utilizing a sequence of rotation of pitch axis - yaw axis - pitch axis.

A much shorter derivation was thus obtained, with the optimization features left out, which, given matrix C, provides the values of the three Euler angles. It seems very unlikely that an angle of exactly 90° will ever appear in the simulation of a real mission.

Sun and Star Searching

In order to perform an attitude update on a spacecraft, it is often desired to acquire optically two celestial bodies by means of optical sensors, and then orient the craft according to a predetermined scheme, using the two celestial bodies as references. Such optical acquisition systems may be either sun-star or star-star combinations.

For the sun-star problem, a search is performed after the spacecraft is nominally pointed at the star and sun. "Nominally" is here defined to mean that if the inertial attitude errors are equal to zero, no search would be necessary. Therefore, the purpose of the search is to calculate the maneuvering required to move the sensor's field of view over the angular area of the attitude errors. The search is performed twice, once for each celestial body. The search is performed by sweeping the sensor field of view across the area of angular uncertainty as shown in Figure 27.

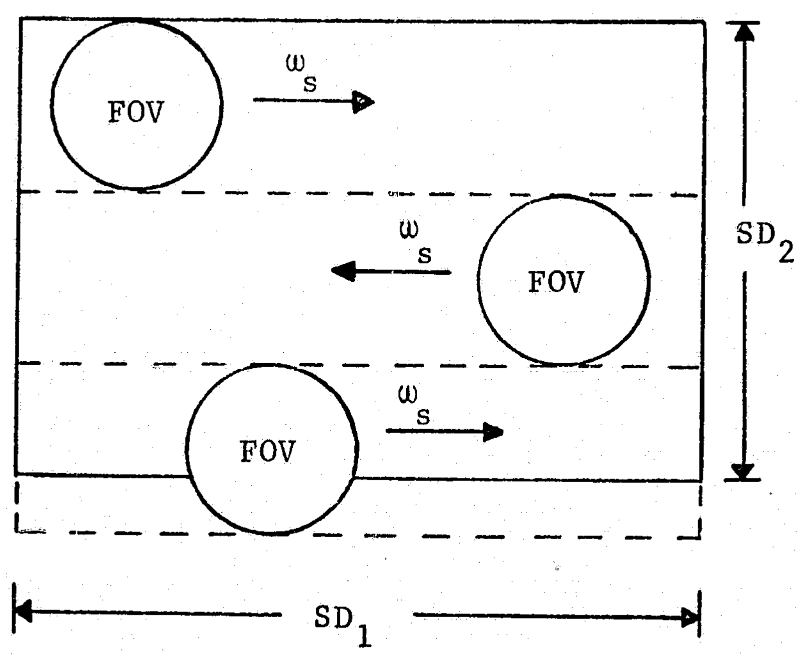


FIGURE 27. SEARCH OF ANGULAR UNCERTAINTY

The length of the search in radians is

$$L = SD_1\ SD_2/FOV$$

where SD_1 and SD_2 are the standard deviations of attitude errors about axes normal to the sensor line of sight and FOV = the sensor angular field of view. If the search is to be made in t_s seconds, the angular rate is found by the equation,

$$\omega_s = L/t_s \quad .$$

At the end of each pass the direction of rotation must be reversed and hence requires an angular rate change of $2\omega_s$. The total angular rate change is

$$\Delta\omega_s = 2\omega_s N_p$$

where N_p is the number of passes and is found by

$$N_p = SD_2/FOV \quad .$$

Combining the above equations yields

$$\Delta\omega_s = \frac{2\ SD_1\ SD_2^2}{t_s\ (FOV)^2} \quad .$$

From the above expression it can be seen that the direction of the search should be chosen such that SD_2 is less than SD_1 to minimize $\Delta\omega_s$. This will yield optimum fuel usage if the moments of inertia and thrust levels are identical on the two axes. With the total change in angular rate known, attitude control fuel consumption can be calculated as discussed earlier in this report.

It should be noted that the problem has been simplified by assuming the one sigma error area must be searched. In any one search it is possible to have to search a larger area 62 percent of the time. However, since many such searches are required in any one mission, the one sigma case represents an expected value and is suitable for estimation purposes.

Star Identification

Searching for the star as described in the previous section is not in itself sufficient for acquisition. There must also be available a method by which the correct star can be distinguished from any others that may cross the detector's field of view.

In practice, there are at least three properties of a star which can be used to identify it by automated methods. These are: (1) its spatial relationship with other stars on the celestial sphere; (2) its intensity; and (3) its spectral radiance. Table XIV, taken from Reference 40, shows the location, in ecliptic coordinates on the celestial sphere, of the six brightest

TABLE XIV. CHARACTERISTICS OF THE SIX BRIGHTEST (S-4) STARS
(Reference 40)

Star Name	Position: Right Ascension Hrs.	Position: Right Ascension Min.	Position: Declination Deg.	Position: Declination Min.	Spectrum: Class	Spectrum: Color	Intensity Magnitude: Visual (1)	Intensity Magnitude: S-4(2)
Sirius	6	41	-16	35	A1 V	Bluish-white	-1.46	-1.46
Canopus	6	22	-52	38	F0 Ib	Yellow-white	-0.71	-0.56
Rigel	5	10	- 8	19	B8 Ia	Bluish	+0.15	-0.03
Vega	18	34	+38	41	A0 V	Bluish-white	+0.02	+0.02
Agena	13	57	-59	53	B1 II	Bluish	+0.61	+0.13
Achernar	1	34	-57	45	B5 IV	Bluish	+0.49	+0.17

(1) H. L. Johnson, Comm. of the Lunar and Planetary Lab. No. 63, University of Arizona.

(2) Aerobee and OAO Projects, NASA Goddard.

stars (excluding the sun), and Figure 28 shows Canopus' geometry with respect to Rigel and Vega, the two stars most difficult to distinguish from Canopus. Location of a star, such as Canopus, with respect to other stars on the celestial sphere will generally require (1) several star trackers, (2) star map correlation techniques, or (3) sequential sighting on a number of stars using one star tracker. Methods (1) and (3) can involve a large amount of equipment, and in the case of (3) is unnecessarily complex in operating requirements. Method (2) greatly increases computer memory storage requirements if a star map is stored onboard the spacecraft, and is relatively complicated if a star map output from a star sensor is telemetered back to ground stations for comparison and correlation with maps on the ground. Comparison of sensor output versus roll angle with ground based star maps has the advantage of having been shown to be feasible, as this method was used by the Jet Propulsion Laboratory in the flight of Mariner IV to Mars in 1964.

Spectral radiance of a star can be used to distinguish it from other stars, but is not generally considered reliable as a sole method of identification. The reason for this is that a number of stars on the celestial sphere have similar color characteristics and unique separation of stars by this method is virtually impossible. This similarity of spectral outputs is not obvious from Table XIV, where mainly bluish stars are tabulated. However, there are many other stars with a spectrum similar to that of Canopus.

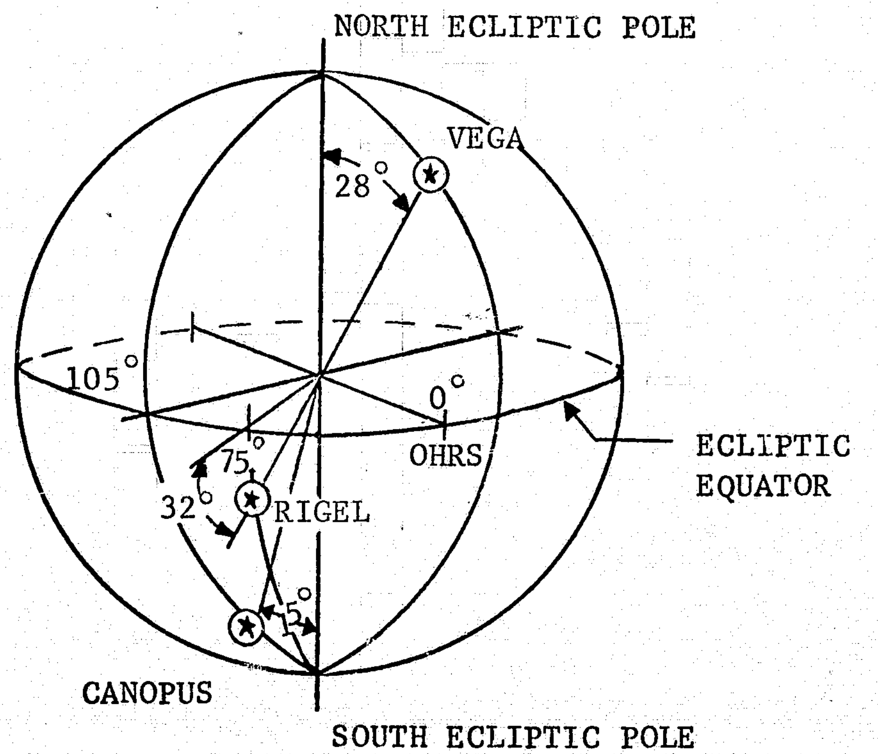


FIGURE 28. CELESTIAL GEOMETRY OF CANOPUS, RIGEL, AND VEGA

Probably the simplest method of identifying a navigation star is the intensity method. The advantage of this method lies in the fact that very few stars have an apparent high brightness. From Table XV it can be seen that Sirius and Canopus have relatively large magnitudes, Sirius being the brightest star in the sky with the exception of the sun, which has a magnitude of -23. The vast majority of stars have visual magnitudes smaller than fifth magnitude. Hence, by designing a system, which can "see" only the brighter stars, the problems of identification and discrimination are greatly simplified. In essence, the problem is reduced to that of distinguishing the brighter stars, the most important of which are shown in Tables XIV and XV.

The intensity method of identification amounts to setting upper and lower gate levels about the intensity level of a star such as Canopus. From Table XIV, it can be seen that Rigel's and Vega's intensities are closest to Canopus, being approximately 60 percent of Canopus intensity. Therefore, the lower gate setting is probably the most critical. If we normalize Canopus intensity to unity, then Rigel's and Vega's intensities would be 0.6. The likely choice of lower gate setting would be approximately 0.8 of Canopus' intensity to maximize the probability of accepting Canopus and at the same time reject Vega and Rigel. Hence, the gate level variation must be maintained within ± 20 percent, since a variation of +20 percent would reject Canopus, and a variation of -20 percent would accept Vega or Rigel.

This problem has not yet been incorporated into the evaluation technique. Instead, at its present status, the evaluation technique assumes that only the star of interest exists in the area to be searched, or, from another point of view, that sufficient safeguards already exist to reject any but the correct star.

Equatorial Celestial Coordinate System

Celestial bodies to be sighted are positioned on the celestial sphere with respect to the equatorial plane. A standard reference direction in the equatorial plane (from celestial mechanics) is defined by a line from the origin of coordinates toward an imaginary point on the celestial sphere known as the first point of Aries (symbolized by the sign of the ram, ♈, as in Figure 29). The angle in the equatorial plane from this reference side (measured eastward) to the great circle (sometimes called "hour circle or celestial meridian") passing through both celestial poles and the celestial body being sighted is defined as right ascension (RA) or longitude. This angle is generated in a counterclockwise manner from zero through 360° and is usually expressed in units of time on a 24 hour circle. Longitude is expressed in angular units. The position of the celestial body (along the great circle) above or below (i.e., toward the north celestial pole or south celestial pole) the celestial equator is called the declination angle, A_D, or latitude. Plus values indicate north declination. It should be noted that latitude and longitude are used to emphasize that the angles are measured in degrees, arc minutes, and arc seconds, not hours, minutes, and seconds of time.

TABLE XV.** STAR MAGNITUDES FROM SEVERAL REFERENCES

Star Name	Allen V	Air Almanac m_v	Yale m_v	Becvar m_v	Spectral Class	Approx. Color Temp - °K (Visual)
Sirius	-1.44	-1.6	-1.6	-1.37	A1-V	14000*
Canopus	-0.72	-0.9	-0.9	-0.86	FO - I, II	9000*
Vega	0.03	0.1	0.14	0.14	AO - V	15400
Capella+	0.09	0.2	0.21	0.21	GO	6300
Pollux	1.15	1.2	1.21	1.21	Ko III	4400
Alnair	1.75	2.2	--	2.16	B5 V	23000
Polaris+	2.02	2.1	Var.	2.12	F-8 III	6200*
Kochab	2.04	2.2	2.24	2.24	K4 - III	4000*
Mirach	2.07	--	2.37	2.37	MO - III	3400
Pheoda (Pheeda)	2.44	--	2.54	2.54	AO - V	15400

* Interpolated
\+ Variable; spectroscopic binary
** Source: Reference 41.

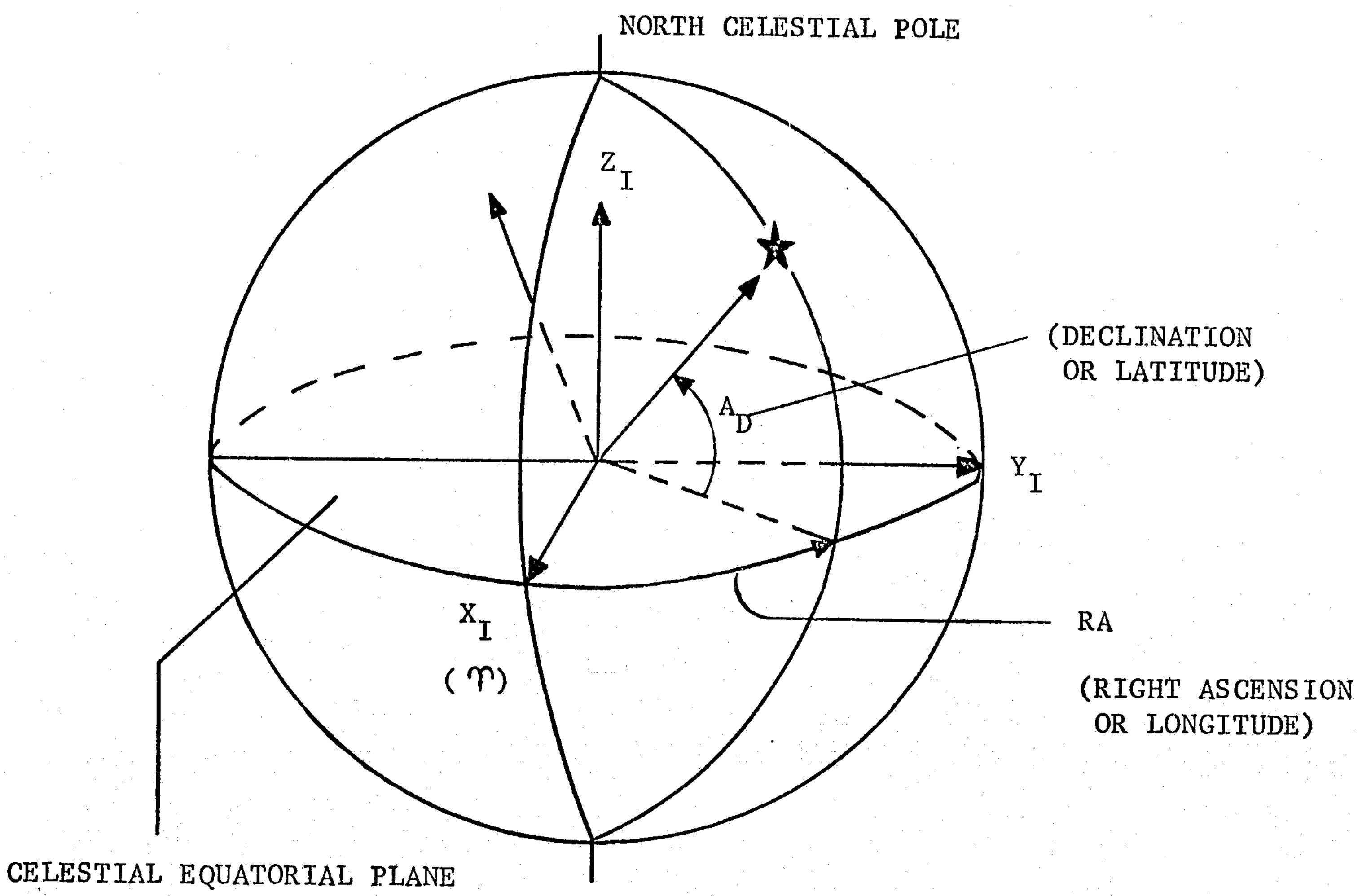


FIGURE 29. EQUATORIAL CELESTIAL COORDINATES

With inertial coordinates in an equatorial plane (X_I along the line from the origin to the first point of Aries, Z_I normal to the equatorial plane, and Y_I completing the right-handed set), RA may be viewed as a rotation about Z_I and the declination angle, A_D, as a rotation in the great circle plane containing the star. The corresponding equations in rectangular coordinates and distance are as follows:

$$X_I = (R_{os} \cos A_D) \cos RA$$

$$Y_I = (R_{os} \cos A_D) \sin RA$$

$$Z_I = (R_{os} \sin A_D)$$

where R_{OS} is the distance from the coordinate origin to the celestial body (the "b_I" - vector then, is seen to be the sine and cosine functions [direction cosine coefficients] which diminsh R_{OS}).

Probability of Detection

It is possible for a star to transit the detector and remain undetected. It is necessary to determine the probability of detecting the star as a function of the computed search rates and the physical and electrical properties of the electro-optical sensor (EOS). The star must be on the detector for a sufficient length of time to permit detection. The detection time required is a function of the method used to scan the detector. If the commanded rate is such that the probability of detection is less than a specified value, a warning is printed that the search rate determined by the schedule and error analysis is excessive and the schedule should be adjusted to allow a lower rate. Two methods of scanning, namely rectangular and circular scanning, were examined. The rectangular method of scanning is analogous to that used by many electrically scanned sensors such as the image dissector and vidicon. Circular scanning is analogous to the method used in mechanically scanned sensors such as the photomultiplier.

Rectangular Scanning of Detector. Consider a scan pattern as shown in Figure 30 and a detector as shown in Figure 31, with width a, height b, and scan width c:

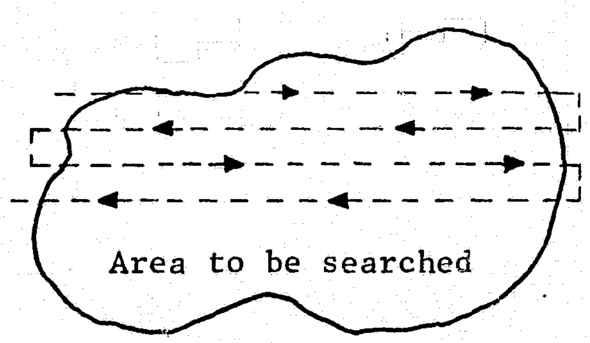


FIGURE 30. SEARCH PATTERN

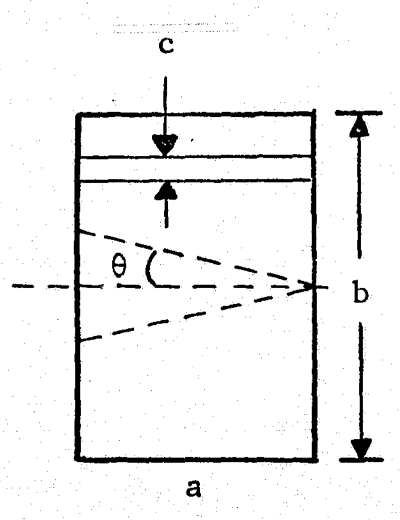


FIGURE 31. RECTANGULAR DETECTOR

The angle θ, measured with respect to the horizontal, of the star trace as it passes across the detector is shown in Figure 31. θ has some distribution centered about 0, as shown in Figure 32.

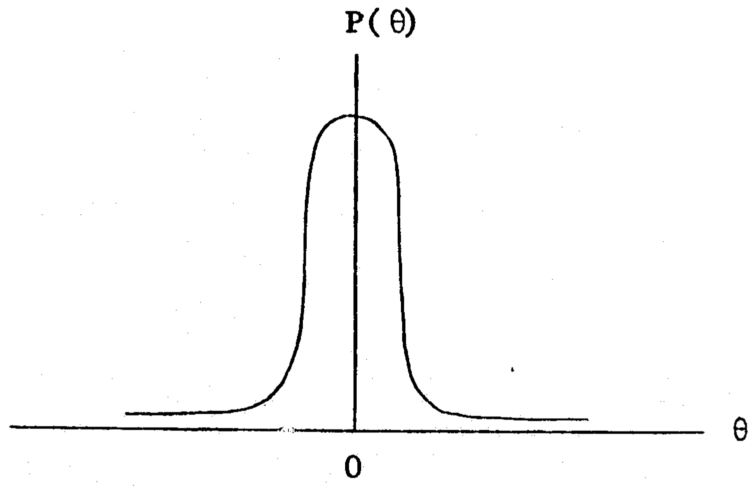


FIGURE 32. DISTRIBUTION OF θ

A logical expression would be $P(\theta) = k\,e^{-\theta^2}$, where k would be determined from

$$\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} k\,e^{-\theta^2}\,d\theta = 1 \quad .$$

With a distribution as above, it can be assumed that the star will almost always enter and leave through the vertical sides of the detector. In this way, for every $\theta \neq 0$, the path becomes longer and the probability of detection increases, since the star stays in view for a longer time. The worst case occurs when $\theta = 0$, which permits elimination of the probability density function from the computation.

For a scanner such as shown in Figure 31, with $\theta = 0$, and a scanning frequency of f_s scans per second,

$$\text{Number of complete scans per second} = \frac{f_s c}{b} \quad .$$

If the star's relative velocity is v, then it will stay in view for $\frac{a}{v}$ seconds. During this time, at least one complete scan of the detector's face must take place. So, in order to acquire the star, it is necessary that

$$\frac{a}{v} + t_{rise} \geq \frac{b}{f_s c} \quad ,$$

where $t_{rise} = t_r$ = rise time. This yields a probability of detection of unity, in the $\theta = 0$ case. For greater velocities

$$P_{det} = \frac{\frac{a}{v} + t_r}{\frac{b}{f_s c}} = \frac{(t_r v + a)\ f_s c}{bv}$$

For $\theta \neq 0$, the values of P_{det} will be conservative. Since the variation of θ is expected to be small, however, the results should be consistently within the accuracy limits of the rest of the calculations. If large values of θ are allowed, the above equation should be adjusted, since more than one scan may be needed to insure detection.

Circular Scanning of Detector. Consider the circular detector with a radar-type scan as shown in Figure 33.

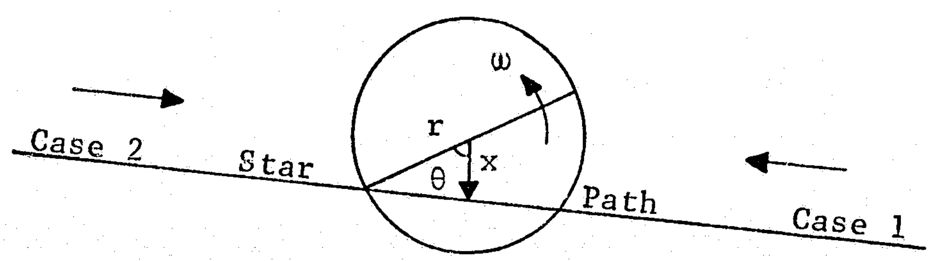


FIGURE 33. CIRCULARLY SCANNED DETECTOR

The scanning line revolves with an angular velocity ω. The radius of the sensor is r.

Again, the star path across the sensor is associated with a probability distribution. This distribution is dependent on the position of the sensor in the search plane, and the past search history. Once defined, this distribution will assign a probability value to each path crossing the sensor, dependent on the distance x from the center of the sensor to the path in question.

The length of the star path is

$$l = 2\sqrt{r^2 - x^2} \quad .$$

Now, if the relative velocity of the star with respect to the sensor is v, the time the star is in view will be

$$t_v = \frac{l}{v} \quad .$$

There are two distinct cases to be examined, depending on the direction of the star's velocity with respect to the scanning direction. In Case 1, as shown in Figure 33, the star is traveling in the same direction as the scanning pattern and it must stay in view long enough for the sensor to scan an angle of $2\pi - 2\theta$, for a detection probability of unity.

Since

$$r \sin \theta = \frac{1}{2}, \qquad \theta = \sin^{-1} \frac{1}{2r}$$

and the angle needed is $2\pi - 2 \sin^{-1} \frac{1}{2r}$. Since the scan proceeds at ω rad/sec, the time required is

$$t = \frac{2\pi - 2 \sin^{-1} \frac{1}{2r}}{\omega}$$

to which must be added the rise time, t_r, so that the total time the star must be in view becomes

$$t = t_r + \frac{2\pi - 2 \sin^{-1} \left[\frac{\sqrt{r^2 - x^2}}{r} \right]}{\omega} .$$

So, if $t_v \geq t$, the probability of detection is unity

$$\frac{1}{v} \geq t_r + \frac{2\pi - 2 \sin^{-1} \left[\frac{\sqrt{r^2 - x^2}}{r} \right]}{\omega} .$$

If the inequality does not hold, the probability is less than one, and, in fact, in such a case,

$$P_{det} = \frac{\frac{1}{v}}{\frac{t_r\omega + 2\pi - 2\sin^{-1}\left[\frac{\sqrt{r^2 - x^2}}{r}\right]}{\omega}}$$

$$= \frac{1\omega}{v\left[t_r\omega + 2\pi - 2\sin^{-1}\left(\frac{\sqrt{r^2 - x^2}}{r}\right)\right]} .$$

In Case 2, as shown in Figure 33, the star should stay in view long enough for the sensor to complete one complete revolution plus 2θ, in order for detection to be a certainty. Otherwise, the discussion is identical with Case 1, and we have

$$P_{det} = 1 \quad ,$$

if

$$\frac{2\sqrt{r^2 - x^2}}{v} \geq t_r + \frac{2\pi + 2\sin^{-1}\left[\frac{\sqrt{r^2 - x^2}}{r}\right]}{\omega}$$

and, for $P < 1$,

$$P_{det} = \frac{2\sqrt{r^2 - x^2}\ \omega}{v\left[t_r\omega + 2\pi + 2\sin^{-1}\left(\frac{\sqrt{r^2 - x^2}}{r}\right)\right]} .$$

This last formula can always be used, with the provision that if $P_{det} > 1$, then $P_{det} = 1$, and will encompass all of the previous discussion. This makes it a worst case analysis, however, and unnecessarily harsh in Case 1.

Now, consider the probability density function P(x) to be as shown in Figure 34.

3

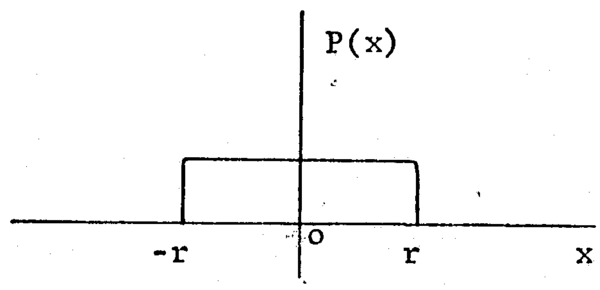


FIGURE 34. PROBABILITY DENSITY FUNCTION

The integral, $\int_{-r}^{r} P(x)\,dx = 1$. From this it is obvious that $P(x) = d$ for $-r < x < r$, or

$$\int_{-r}^{r} P(x)\,dx = \int_{-r}^{r} d \cdot dx = d \cdot x \Big|_{-r}^{r} = 2rd = 1$$

which yields $d = \frac{1}{2r}$. So, the general expression becomes

$$P_{det} = \int_{-r}^{r} \frac{2\sqrt{r^2 - x^2}\,\omega}{v\left[t_r\omega + 2\pi \pm 2\sin^{-1}\left(\frac{\sqrt{r^2 - x^2}}{r}\right)\right]} \cdot \frac{1}{2r} \cdot dx$$

where the minus sign in the denominator of the above equation applies to Case 1, and the plus sign to Case 2.

This is the defining equation for the circular radar-type scanner.

Computer Programs

The effectiveness evaluation techniques discussed above have been coded into a FORTRAN IV computer program for running on a Control Data 6400 computer. The data necessary for running the program is discussed in the applications section of this report. The following types of output are available from the program:

(1) Level 1 Evaluation. A level 1 evaluation produces a 1-page report summarizing the astrionics subsystem parameters and the effectiveness evaluation calculations. An example of a level 1 evaluation is shown in Figure 6.

(2) Leval 2 Evaluation. Level 2 evaluation includes a detailed printing of all mission operations and error analysis quantities as a function of time from the beginning of the mission to arrival at the target point. A level 2 evaluation generates 5 to 10 pages of computer printout and is shown in Appendix B.

(3) Sensitivity Analysis. Sensitivity is defined to be the percent change in effectiveness per percent change in any data value. Sensitivity reports may be generated for all mission, spacecraft, and astrionics data or selected subsets of data. These reports aid in identifying the subsystem parameters and mission values with the greatest impact on astrionics effectiveness.

(4) Optimum System Selection. The optimum suite of astrionics is found by successive substitution of candidate subsystems for evaluation. The substitution algorithm is similar to a steepest descent technique with the possibility of finding only local minima. Multiple starting points are used to minimize the probability that the system found is a local rather than a global optimum.

The program requires 45,056 ($130{,}000_8$) memory words and uses no magnetic tapes. Execution times depend on mission schedule complexity. The following examples are for a two midcourse schedule:

Level 1 evaluation = 18 seconds (0.2 seconds if the error analysis data has not been changed since the last evaluation).

Level 2 evaluation = 18 seconds.

Plots and tables = 0.2 seconds per point (18 seconds per point if the parameter being swept affects the error analysis).

Sensitivities = 15 seconds plus 18 seconds for each component error parameter evaluated

Optimization = 18 seconds per evaluation. A typical search requires 40 evaluations (720 seconds).

Applications of Study Techniques to a Jupiter Flyby Mission

The techniques developed in this study were applied to a Jupiter flyby mission similar to the one discussed in Reference 6. The launch vehicle trajectory and injected weight are identical to those discussed in Reference 1. Reference 1, however, assumed a perfect update in the parking orbit and was limited to a strapdown ISU.

Data Required

The data required for exercising the computer programs implementing these techniques were compiled or derived in a cooperative effort with NASA/ERC, personnel of the NASA Launch Vehicle Planning (NLVP) Project at Battelle, and those Battelle staff members assigned to this study. Much of the hardware data, particularly the reliability and error coefficient data, is assumed based on manufacturers' data and is not to be used conclusively.

Error Analysis Sensitivity. The Battelle Three-Degree-of-Freedom Program, the Strapdown Error Analysis Program (SEAP), and the Platform Error Analysis Program (PEAP) were used to generate the necessary inertial navigation error sensitivity coefficients for injections into the parking orbit and escape hyperbola.

Radar. Other data required for the Jupiter flyby mission are shown in Figure 35. Ground based radar tracking net data (Reference 34) are shown at the top of Figure 35a. Seven station locations were considered with the indicated radars available at these sites. The radar accuracy data (Reference 34) are shown immediately below the station descriptions.

Star. Data are shown for five stars. However, the studies conducted used only Canopus. The star locations are specified in the celestial equatorial latitude and longitude coordinate frame discussed previously in this report. In addition to the star locations, visual magnitude and color temperature are needed to permit ratioing of the star tracker accuracy for the reference star to estimate the accuracy for alternate stars. This ratioing technique is discussed more fully in a preceding section of this report.

Interplanetary Trajectory. The interplanetary trajectory obtained from the Lewis n-body code, Reference 42, is summarized at the bottom of Figure 35a and the top of Figure 35b. The interplanetary trajectory is divided into three sections, each with a different dominant gravity center. The summary shows the conditions as the trajectory moves from one dominant

TRACKING NET DATA

STA.NO.		LAT.	LONG.	RADARS	
1	ASCENSION	-7.966	-14.400	USBS-30	TPQ-18
2	PRETORIA	-25.950	-28.670	MPS-25	
3	CARNARVON	-24.900	113.710	USBS-30	FPQ-6
4	ANTIGUA	17.150	-61.800	USBS-30	FPQ-6
5	GOLDSTONE	35.384	-116.850	DSIF	
6	MADRID	40.416	-3.667	DSIF	
7	CANBERRA	-35.316	149.132	DSIF	

RAD.NO.		MAX.RANGE	RANGE ERROR	ELEV. ERROR	AZIM. ERROR	RANGE DOT ERROR
1	USBS-30	3.500000E+09	6.700000E+01	1.780000E-03	1.780000E-03	1.240000E-01
2	TPQ-18	1.920000E+08	6.700000E+01	4.500000E-04	4.500000E-04	-0.
3	MPS-25	6.076000E+06	1.340000E+02	2.240000E-03	2.240000E-03	-0.
4	FPQ-6	1.920000E+08	4.500000E+01	3.350000E-04	3.350000E-04	-0.
5	DSIF	1.000000E+50	-0.	-0.	-0.	4.100000E-02

STAR DATA

NAME	LAT.	LONG.	VIS.MAG.	COLR,TEMP.	REL. ACC.
SIRIUS	-16D 40M 15S	100D 56M -0S	-1.60	14000	1.00000
CANOPUS	-52D 40M 40S	95D 48M -0S	-.90	9000	1.38002
VEGA	38D 45M 10S	278D 58M -0S	.10	15400	2.18636
CAPELLA	45D 58M 5S	78D 35M -0S	.20	6300	2.28932
POLLUX	28D 6M 18S	115D 50M -0S	1.20	4400	3.62696

SUMMARY OF LEWIS N-BODY TRAJECTORY (FT-SEC)

		POSITION			MAG.	VELOCITY			MAG.	ANG.
TIME= 0.		POSITION			MAG.	VELOCITY			MAG.	ANG.
NO. 1	0.	-1.9989E+07	7.2696E+06	3.3133E+06	2.1527E+07	-2.0565E+04	-4.4774E+04	-2.1728E+04	5.3849E+04	89.33
CROSS 0.75102315E+05		POSITION			MAG.	VELOCITY			MAG.	ANG.
NO. 40	7.5102E+04	-3.3122E+08	-2.7173E+09	-1.3102E+09	3.0348E+09	-3.9854E+03	-3.5862E+04	-1.7288E+04	4.0010E+04	.55
NO. 0	7.5102E+04	-4.6830E+11	1.2044E+11	5.2102E+10	4.8634E+11	-3.2532E+04	-1.2236E+05	-5.4803E+04	1.3797E+05	92.01
NO. 0	7.5102E+04	-4.6797E+11	1.2316E+11	5.3413E+10	4.8684E+11	-2.8547E+04	-8.6502E+04	-3.7515E+04	9.8513E+04	89.16
TIME= 0.76000001E+05		POSITION			MAG.	VELOCITY			MAG.	ANG.
NO. 1	7.6000E+04	-4.6833E+11	1.2033E+11	5.2053E+10	4.8633E+11	-3.2515E+04	-1.2237E+05	-5.4804E+04	1.3796E+05	92.01
CROSS 0.32775357E+08		POSITION			MAG.	VELOCITY			MAG.	ANG.
NO. 40	3.2775E+07	-1.0462E+12	-1.9429E+12	-8.6431E+11	2.3699E+12	4.9194E+04	-3.3066E+04	-1.4580E+04	6.1040E+04	27.50
NO. 0	3.2775E+07	-2.9401E+10	1.4404E+11	5.7369E+10	1.5781E+11	1.0867E+04	-5.2093E+04	-2.1805E+04	5.7508E+04	179.01
NO. 0	3.2775E+07	1.0756E+12	-2.0869E+12	-9.2168E+11	2.5222E+12	3.8326E+04	1.9027E+04	7.2254E+03	4.3395E+04	92.69
TIME= 0.32832000E+08		POSITION			MAG.	VELOCITY			MAG.	ANG.

FIGURE 35a. PROGRAM DATA

NO. 1 3.2832E+07 -2.8786E+10 1.4109E+11 5.6134E+10 1.5455E+11 1.0866E+04 -5.2098E+04 -2.1807E+04 5.7514E+04 178.99

SEGMENTS 0. 39 0.75102315E+05 39 0.32775357E+08 8 0.10000000E+21

MATCH WITH N-BODY AT 543 SECONDS, 0.33600000E+08 FT.

	SEAP	N-BODY	ERROR
VELOCITY MATCH	49155	49359	-204
ANGLE MATCH	45.06	44.65	.40

TARGET CONDITIONS
TIME 0.35460242E+08 SECONDS
RADIUS 0.16798375E+10 FEET
VELOCITY 0.92543781E+05 FT/SEC
ANGLE 90.00 DEG.

	RANGE ANG.	CUM. TOTAL	TIME	CUM. TOTAL
LAUNCH	20.000	20.000	565.000	565.000
PARK	69.250	89.250	1016.296	1581.296
BURN	54.198	143.448	941.500	2522.796
ESCAPE	48.940	192.388	74559.271	77082.067

LAUNCH

LAT.= 28.500 LONG.= -80.500 AZ.= 100.000

FIGURE 35b. PROGRAM DATA (Continued)

gravity center to another. There are a total of 40 points loaded in each section. It should be emphasized that the Lewis n-body code contains an ephemeris and generates a true n-body trajectory, not a patched conic trajectory. However, the coordinate system in which the integration is performed is transferred from one dominant gravity center to another as the spheres of influence are crossed. The coordinates are oriented with the X-Y plane parallel to the Earth's equatorial plane with the X axis in the direction of the first point of Aries, January 1, 1950. At each crossing, three rows of data are printed. Each row shows the position vector, its magnitude, the velocity vector, its magnitude, and the angle between the position and velocity vectors. The first row shows the end of the previous section. The second row shows the same information at the first point on the new section. The third row of information shows the position, velocity, and angle information relating the second dominant gravity center to the first.

Since the launch vehicle trajectory and the Lewis n-body trajectory are generated independently, it is necessary to find a point on the two trajectories where a suitable match occurs. The match is found by looking for a point on the Lewis trajectory with the same radius from the center of the Earth as the cutoff point on the launch vehicle trajectory. The magnitude of the velocities and the angles between the position and velocity vectors for the two trajectories are then compared. At the matched radii, (543 seconds into the Lewis trajectory) the velocities differ by 204 feet per second and the angles by 0.4 degrees.

The target point is specified by indicating a time on the Lewis n-body trajectory. This time is shown in Figure 35b. Additional information is then printed showing the position and velocity magnitudes at the target time and the angle between the vectors. The angle of 90.00 degrees indicates perijove.

The range angles, measured in degrees from the center of the Earth are input for: (1) launch burn, (2) park, (3) escape burn, and (4) the escape hyperbola. From these, the cumulative range angles, the time of each operation, and the cumulative time are calculated. Finally, the launch site latitude and longitude and launch azimuth must be specified. The launch latitude and longitude shown at the bottom of Figure 35b represent Cape Kennedy. The launch azimuth of 100 degrees was chosen to insure the parking orbit passing over several ground based radar stations for parking orbit update.

Additional data describing the spacecraft, mission, and astrionic subsystems are shown in Figure 36. These data are divided into sections as shown.

Spacecraft/Mission Data (Section 1). The first four items of Section 1, Figure 36, are important parameters in the penalty evaluation. The total weight is the total spacecraft plus astrionics weight and is used by penalty modes 2 and 3. Penalty mode 1, not considered in this report, computes the total weight of the spacecraft plus astrionics. The non-astrionics weight represents the spacecraft plus scientific payload and is used by penalty modes 1 and 2. In penalty mode 3, the non-astrionics weight is calculated by

DATA

SPACECRAFT/MISSION DATA (SECTION 1)

1	TOTAL WEIGHT (LB)=	2000.00000	2	NONASTRIONICS WEIGHT (LB)=	1500.00000
3	PROBABILITY OF ASTRIONICS FAIL=	.15000	4	TARGET MISS DISTANCE (FT)=	78087800.00000
5	VIBRATION(MILLIRAD/SEC)**2/CPS=	.30457	6	VIBRATION UPPER FREQ. (CPS)=	100.00000
7	WIRING WEIGHT (LB)=	110.00000	8	ROLL MOM. OF INER.(SLUG-FT**2)=	1100.00000
9	YAW MOM. OF INERT.(SLUG-FT**2)=	625.00000	10	PIT MOM. OF INERT.(SLUG-FT**2)=	563.00000
11	ROLL MOMENT ARM (FT)=	7.00000	12	YAW MOMENT ARM (FT)=	7.00000
13	PITCH MOMENT ARM (FT)=	7.00000	14	ROLL MAX. ARM (FT)=	3.50000
15	YAW MAX. ARM (FT)=	3.50000	16	PITCH MAX. ARM (FT)=	3.50000

MIDCOURSE ENG./ENERGY SOURCE (SECTION 2)

1	SPECIFIC IMPULSE (SEC.)=	233.00000	2	MIDCOURSE THRUST (LB)=	50.00000
3	MIDCOURSE SYSTEM COEF.(LB/LB)=	1.09600	4	MIDCOURSE SYSTEM CON. (LB)=	20.30000
5	ENERGY SOURCE CONSTANT (LB)=	13.20000	6	ENERGY SOURCE COEF. (LB/W)=	.34500
7	ENERGY SOURCE COEF. (LB/W-HR)=	0.00000	8	MIDCOURSE ENGINE ARM (FT)=	3.50000
9	MIDCOURSE ENG. OFFSET UNC.(FT)=	.02000	10	MIDCOURSE ENG. ANG. UNC. (RAD)=	.00436

I. S. UNIT DESIGN DATA (SECTION 3)

1	BLOCK DENSITY (LB/IN**3)=	.09700	2	BASE DENSITY (LB/IN**3)=	.09700
3	COVER DENSITY (LB/IN**3)=	.09700	4	INSULATION DENSITY (LB/IN**3)=	.09100
5	ISU COMPONENT SEPARATION (IN)=	.25000	6	BASE OFFSET (IN)=	1.50000
7	COVER CLEARANCE (IN)=	.25000	8	BASE THICKNESS (IN)=	.50000
9	COVER THICKNESS (IN)=	.10000	10	INSULATION THICKNESS (IN)=	.05000
11	ELECTRONICS WEIGHT (LB)=	10.00000	12	ELECTRONICS MTBF (HR)=	10000.00000
13	ELECTRONICS POWER (WATTS)=	30.00000	14	DESIGN NO. (0=OPTIMUM) =	0.00000
15	1=HORIZONTAL, 2=VERTICAL =	1.00000			

THERMAL CONTROL DATA (SECTION 4)

1	OPERATING TEMPERATURE(DEG-F)=	160.00000	2	MAX.AMBIENT TEMPERATURE(DEG-F)=	140.00000
3	AVE.AMBIENT TEMPERATURE(DEG-F)=	60.00000	4	MIN.AMBIENT TEMPERATURE(DEG-F)=	30.00000
5	THERMAL CONDUCTANCE (W/DEG-F)=	0.00000	6	MIN. THERMAL CONDUCTANCE RATIO=	.50000

ATTITUDE CONTROL DATA (SECTION 5)

1	ROLL SOLAR PRESS. AREA(FT**2)=	113.00000	2	YAW SOLAR PRESS. AREA(FT**2)=	32.00000
3	PITCH SOLAR PRESS. AREA(FT**2)=	32.00000	4	ROLL CG-CP ARM (FT)=	.25000
5	YAW CG-CP ARM (FT)=	1.00000	6	PITCH CG-CP ARM (FT)=	1.00000
7	SIZING OPTION (1 SETS=THRUSTS)=	0.00000	8	A/C SPECIFIC IMPULSE (SEC.)=	56.00000
9	EMPTY DATA SPACE =	0.00000	10	IMPULSE TIME (SEC)=	.02000
11	RECHARGE TIME (SEC)=	.04000	12	METEORITE IMPACT IMP. (LB-SEC)=	.01400
13	AT.CONT.RELIB. (FAIL/1000IMP.)=	.00010	14	A.C. ELECTRONICS MTBF (HR)=	20000.00000
15	A.C. ELECTRONICS POWER (WATTS)=	10.00000	16	ATT. CONT. WEIGHT CONS. (LB)=	21.00000
17	ATT. CONT. COEF. (LB/LB)=	1.56300	18	ATTITUDE TOLERANCE (DEG)=	1.00000

FIGURE 36. SPACECRAFT, MISSION, AND SUBSYSTEM ESTIMATION DATA

subtracting the astrionics weight, the penalty itself, from the total weight. The probability of astrionics failure is used by penalty modes 1 and 3. Penalty mode 2 computes the probability of astrionics failure. The target miss distance, used in obtaining the probability of missing the target, is the maximum distance by which the spacecraft may miss the target and still be considered a successful mission. The remaining items of data in section 1 describe the vibration environment during booster burn, the weight of the wiring connecting the various astrionics subsystems, and the spacecraft moments of inertia, maximum moment arms for meteorite impact, and attitude control thruster arms.

Midcourse Engine/Energy Source (Section 2). The midcourse propulsion system data required for exercising the computer programs, the fixed weight, specific impulse, thrust, and tankage constant were extracted from Reference 6. This system is a constant gas-pressure-regulated monopropellant hydrazine unit using a Shell 405-type catalyst. It was selected because this type of system is applicable to accelerometer and burn timer shutoff mechanisms.

Bipropellant midcourse propulsion systems are competitive with monopropellant systems when the total impulse requirement is 50,000 lb-sec or greater (Reference 7). Assuming the maximum delta velocity required is 20 ft/sec for example, the total impulse requirement for the 2000 lb spacecraft is approximately

$$I_t = \frac{2000}{32.2} \times 20 = 1242 \text{ lb-sec} \quad .$$

Since in none of the exercise runs was the ΔV required as great as 20 ft/sec, a monopropellant system should be used for the midcourse propulsion system for the payload and mission considered.

The choice between the pressure regulated and blowdown monopropellant systems (References 6 and 7) was not considered to be of major importance for the purpose of exercising the computer programs. Therefore, the midcourse propulsion system data used in the exercising were based upon the pressure regulated system. These data are shown in Section 2 of Figure 36.

The guidance system power source was assumed to be a radioisotope thermoelectric generator (RTG) for the purpose of exercising the computer programs. Mission durations restrict power source consideration to solar, nuclear reactors, or an RTG. Due to the extreme distance from the sun, solar power sources were ruled out due to size and weight considerations. Solar thermal energy intensity at Jupiter's orbit is approximately 4 percent of that at a near Earth orbit according to Reference 6 . This low level prohibits use of any currently envisioned solar energy collection system. Nuclear reactors have a minimum critical size and weight required to maintain a controlled nuclear reaction (Reference 6). The minimum weight is currently approximately 250 pounds, and therefore the only practical choice of power at this time is the RTG.

The major components of an RTG are: (1) an isotope heat source, (2) thermoelectric converters, and (3) a heat rejection system (Reference 7). A power conditioning and distribution system is also required. These components weights can be estimated by assuming the weight to be made up of a fixed weight plus a specific power factor expressed in lb/watt required. Section 2 of Figure 36 lists the values assumed for the RTG data used in the exercising. These values are quite optimistic but suffice for exercising of the program.

It was assumed throughout the power source weight estimation that the power source required at the target planet for the experiments could be used in the earlier phases of the mission for the guidance system. Should one assume guidance only through the first midcourse, a lower power source weight might result if a different source was selected. Since the power needed for experiments on a Jupiter flyby mission will require use of an RTG (References 6 and 7), it was decided to make use of the same power source to keep the total scientific experiment payload as large as possible.

I.S.Unit Design Data (Section 3). Section 3 of Figure 36 contains the data necessary to design a strapdown ISU as discussed in Reference 1.

Thermal Control Data (Section 4). This section contains the data necessary to design the variable thermal impedance environmental control subsystem.

Attitude Control Data (Section 5). This section contains the data necessary to perform the attitude control subsystem design as discussed earlier in this report.

Candidate Components. Candidate components and subsystems data for system evaluation and optimization are shown in Figures 37a, 37b, 37c, and 37d.

Four accelerometers, shown at the top of Figure 37a, and seven gyroscopes, shown at the bottom of Figure 37b and at the top of Figure 37c, were used in this study. However, it should be noted that gyroscopes 6 and 7 differ from gyroscope 1 only by the value used for their fixed drift, R.

The four on-board computers considered are shown at the bottom of Figure 37b and the top of Figure 37c. The first computer is a conceptual computer using a second order Runge-Kutta updating algorithm for the direction cosine matrix. The other computers are currently available.

ACCELEROM.

No.	Component	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
1	ARMA D-4E	.35000	1.50000	100000.00000	1.00000	1.30000	2.70000	-0.00000
2	GG-177	.30000	1.00000	50000.00000	1.00000	1.80000	1.50000	-0.00000
3	2401-005	.20000	8.00000	188217.00000	1.00000	2.00000	1.00000	1.13000
4	BELL-7	.40000	3.50000	40000.00000	1.00000	1.15000	1.75000	-0.00000

No.	K0	K1	K2	K3	M0	N0	M1	N1	IP	IN
1	6.700E-06 G	1.000E-05 G/G	9.000E-07 G/G**2	1.000E-07 G/G**3	-0. G/G	-0. G/G	5.600E-06 G/G**2	5.600E-06 G/G**2	2.000E+01 ARC SEC	2.000E+01 ARC SEC
2	4.200E-05 G	5.100E-05 G/G	9.400E-06 G/G**2	1.040E-06 G/G**3	-0. G/G	-0. G/G	5.000E-06 G/G**2	5.000E-06 G/G**2	2.000E+01 ARC SEC	2.000E+01 ARC SEC
3	2.000E-05 G	1.000E-05 G/G	1.000E-06 G/G**2	2.000E-07 G/G**3	1.000E-07 G/G	1.000E-05 G/G	-0. G/G**2	-0. G/G**2	5.000E+00 ARC SEC	5.000E+00 ARC SEC
4	4.000E-06 G	8.000E-05 G/G	2.000E-06 G/G**2	1.600E-07 G/G**3	1.000E-05 G/G	1.000E-05 G/G	2.000E-06 G/G**2	2.000E-06 G/G**2	1.500E+01 ARC SEC	1.500E+01 ARC SEC

GYROSCOPES

No.	Component	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
1	GG 334-A	1.65000	3.00000	25000.00000	1.00000	4.70000	2.50000	-0.00000
2	RI-1139	1.45000	3.32000	18000.00000	1.00000	2.60000	3.50000	-0.00000
3	18-IRIG-B							

No.	R	UI	US	S	IS	IO	T			
1	5.000E-02 DEG/HOUR	6.000E-02 DEG/HR/G	1.000E-01 DEG/HR/G	4.000E-02 DEG/H/G**2	6.000E+00 ARC-SEC	7.000E+00 ARC-SEC	1.000E-04 UNITY	-0.	-0.	-0.
2	1.500E-01 DEG/HOUR	5.000E-02 DEG/HR/G	7.000E-02 DEG/HR/G	1.400E-02 DEG/H/G**2	1.500E+01 ARC-SEC	1.500E+01 ARC-SEC	8.500E-05 UNITY	-0.	-0.	-0.

FIGURE 37a. CANDIDATE COMPONENT DATA

1.20000	3.30000	35000.00000	1.00000	3.86000	2.00000	-0.00000

R	UI	US	S	IS	IO	T			
1.500E-02	3.000E-02	3.000E-02	3.000E-02	5.000E+00	1.000E+00	3.000E-05	-0.	-0.	-0.
DEG/HOUR	DEG/HR/G	DEG/HR/G	DEG/H/G**2	ARC-SEC	ARC-SEC	UNITY			

		WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
4	SYG-1440	1.40000	4.00000	50000.00000	1.00000	3.86000	2.00000	-0.00000

R	UI	US	S	IS	IO	T			
5.000E-02	1.000E-01	1.000E-01	2.000E-02	5.000E+00	5.000E+00	5.000E-05	-0.	-0.	-0.
DEG/HOUR	DEG/HR/G	DEG/HR/G	DEG/H/G**2	ARC-SEC	ARC-SEC	UNITY			

		WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
5	GG-49	-0.00000	-0.00000	-0.00000	-0.00000	-0.00000	-0.00000	-0.00000

R	UI	US	S	IS	IO	T			
9.400E-02	1.100E-01	1.900E-01	9.000E-03	1.100E+01	1.100E+01	-0.	-0.	-0.	-0.
DEG/HOUR	DEG/HR/G	DEG/HR/G	DEG/H/G**2	ARC-SEC	ARC-SEC	UNITY			

		WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
6	GG 334-AX1	1.65000	3.00000	25000.00000	1.00000	4.70000	2.50000	-0.00000

R	UI	US	S	IS	IO	T			
5.050E-02	6.000E-02	1.000E-01	4.000E-02	6.000E+00	7.000E+00	1.000E-04	-0.	-0.	-0.
DEG/HOUR	DEG/HR/G	DEG/HR/G	DEG/H/G**2	ARC-SEC	ARC-SEC	UNITY			

		WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
7	GG334-AX10	1.65000	3.00000	25000.00000	1.00000	4.70000	2.50000	-0.00000

R	UI	US	S	IS	IO	T			
5.500E-02	6.000E-02	1.000E-01	4.000E-02	6.000E+00	7.000E+00	1.000E-04	-0.	-0.	-0.
DEG/HOUR	DEG/HR/G	DEG/HR/G	DEG/H/G**2	ARC-SEC	ARC-SEC	UNITY			

COMPUTERS

		WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
1	SRT RUK-2	36.00000	90.00000	6000.00000	1.00000	-0.00000	-0.00000	-0.00000

BITS	COMP.FREQ.	INT.SCHEME							
3.200E+01	1.280E+02	2.000E+00	-0.	-0.	-0.	-0.	-0.	-0.	-0.

		WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
2	SIGN III	27.00000	115.00000	5582.00000	1.00000	-0.00000	-0.00000	-0.00000

BITS	COMP.FREQ.	INT.SCHEME							
4.000E+01	5.000E+01	1.000E+00	-0.	-0.	-0.	-0.	-0.	-0.	-0.

FIGURE 37b. CANDIDATE COMPONENT DATA (Continued)

3	1824	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		34.14000	92.90000	2949.00000	1.00000	-0.00000	-0.00000	-0.00000

BITS	COMP.FREQ.	INT.SCHEME							
2.400E+01	5.000E+01	1.000E+00	-0.	-0.	-0.	-0.	-0.	-0.	-0.

4	TELEDYNE	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		30.00000	70.00000	5000.00000	1.00000	-0.00000	-0.00000	-0.00000

BITS	COMP.FREQ.	INT.SCHEME							
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.

PLATFORMS

1	H-429	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		30.00000	100.00000	2000.00000	1.00000	-0.00000	-0.00000	-0.00000

1=SD,2=GIM									
1.000E+00	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.

2	CENT.IMG	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		80.00000	225.00000	1350.00000	1.00000	-0.00000	-0.00000	-0.00000

1=SD,2=GIM									
2.000E+00	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.

STAR TRCKR

1	ITT-LUN.08	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		7.00000	8.00000	90000.00000	1.00000	-0.00000	-0.00000	-0.00000

ERROR(DEG)	FOV (DEG)	DIRCOS(1)	DIRCOS(2)	DIRCOS(3)	REF.STAR				
1.400E-02	8.000E+00	1.000E+00	0.	0.	2.000E+00	-0.	-0.	-0.	-0.

2	GIMB.ST	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		26.50000	14.00000	45000.00000	1.00000	-0.00000	-0.00000	-0.00000

ERROR(DEG)	FOV (DEG)	DIRCOS(1)	DIRCOS(2)	DIRCOS(3)	REF.STAR				
7.000E-03	1.200E+02	1.000E+00	-0.	-0.	2.000E+00	-0.	-0.	-0.	-0.

SUN SENSOR

1	ADCL-1402	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		2.00000	5.00000	100000.00000	1.00000	-0.00000	-0.00000	-0.00000

ERROR(DEG)	FOV (DEG)	DIRCOS(1)	DIRCOS(2)	DIRCOS(3)					
4.000E-02	6.400E+01	0.	1.000E+00	0.	-0.	-0.	-0.	-0.	-0.

FIGURE 37c. CANDIDATE COMPONENT DATA (Continued)

2	ADCL-1402X	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		2.00000	5.00000	100000.00000	1.00000	-0.00000	-0.00000	-0.00000

ERROR(DEG)	FOV (DEG)	DIRCOS(1)	DIRCOS(2)	DIRCOS(3)					
8.618E-03	6.400E+01	0.	1.000E+00	0.	-0.	-0.	-0.	-0.	-0.

3	ADCL-1402Y	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		2.00000	5.00000	100000.00000	1.00000	-0.00000	-0.00000	-0.00000

ERROR(DEG)	FOV (DEG)	DIRCOS(1)	DIRCOS(2)	DIRCOS(3)					
4.000E+00	6.400E+01	0.	1.000E+00	0.	-0.	-0.	-0.	-0.	-0.

ISU/C.P.S.

1	H-429 SYS	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		14.25000	85.00000	10000.00000	1.00000	-0.00000	-0.00000	-0.00000

-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.

COM. SYST.

1	MCR-503	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		3.10000	3.50000	100000.00000	1.00000	5.25000	3.37500	4.56300

-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.

HORIZ.SEN.

1	A-OGO	WEIGHT	POWER	MTTF	ALPHA	LENGTH	DIAMETER	WIDTH
		16.80000	12.00000	1700.00000	1.00000	-0.00000	-0.00000	-0.00000

RMS ERROR	FOV (DEG)								
2.000E-01	4.500E+01	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.

FIGURE 37d. CANDIDATE COMPONENT DATA (Continued)

A specified ISU may be either gimballed or strapdown. Two such subsystems were loaded as shown in the center of Figure 37c. ISU 1, the H-429, is strapdown. ISU 2, the Centaur IMG, is gimballed. If no ISU is specified, the program designs a strapdown ISU as discussed in Reference 1. Star tracker and sun sensor data are shown at the bottom of Figure 37c and the top of Figure 37d. A strapdown and a gimballed star tracker were considered. The predominant differences between the strapdown and gimballed star tracker are the weight, power, and fields of view. It should be noted that star tracker and sun sensor data include direction cosines describing the line-of-sight (center of the field of view) in the spacecraft body coordinates. In addition, the star tracker data indicate the index of the reference star. The reference star is the star for which the accuracy is given. Accuracies on other stars are computed by the ratioing technique. It should be noted that sun sensors 2 and 3 are identical to sun sensor 1 with perturbed accuracy for sensitivity studies.

It was found that some specified ISU's required an additional hardware package for power processing for the ISU and computer. For this reason, the ISU/CPS section was created. The data shown at the center of Figure 37d describes the ISU/CPS for the H-429 system.

Only one communications receiver was used in this study. Its data are shown in the center of Figure 37d.

The horizon sensor shown at the bottom of Figure 37d was used in this study.

<u>Mission Schedules</u>. Two mission schedules are discussed in this report. The first schedule, Schedule 1, is shown in Figure 38. Each line in the schedule contains the following information: a system index with the value 0, 1, or 2. All systems will execute all instructions in the schedule with the index 0. Instructions with the index 1 are executed only by those systems not containing electro-optical sensors. Instructions with index 2 are executed by those systems which contain electro-optical sensors. Thus, a system with no electro-optical sensors would skip over all operations with an index 2. The next entry shows the time of the operation in days, hours, minutes, and seconds from launch. If this information is blank, the time is assumed to be very nearly equal to the time indicated above. The next entry shows the same time in total seconds from launch. Schedule data are entered by giving the time in total seconds. Three operation codes are then shown, followed by a comment describing the operation specified by the codes. Some operations require an additional floating point variable. For example, raising or lowering the dead band requires a floating point number to describe the new dead band value in degrees. Schedule 2 is shown in Figure 39.

SCHEDULE NO. 1

-0	0D 0H 0M 0.00S	0.00	1	-0	-0	START THE LAUNCH	-0.
			6	7	1	TURN ON COM.RCVR.	-0.
-0	0D 0H25M 0.00S	1500.00	3	1	2	UPDATE WITH ASCENSION TPQ RADAR	-0.
-0	0D 0H42M 3.00S	2523.00	6	3	1	TURN ON ATTITUDE CONTROL	-0.
			8	0	-0	RAISE DEAD BAND	0.20000000E+02
			6	4	1	TURN ON STAR TRACKER	-0.
			6	5	1	TURN ON SUN SENSOR	-0.
			9	2	1	BEGIN MANEUVERING	-0.
2	0D 0H57M 3.00S	3423.00	9	-0	2	BEGIN SEARCH	-0.
2	0D 0H58M 3.00S	3483.00	9	-0	3	END SEARCH	-0.
			6	1	-0	TURN OFF COMPUTER	-0.
			6	2	-0	TURN OFF ISU	-0.
2	0D10H 0M 0.00S	36000.00	6	1	1	TURN ON COMPUTER	-0.
			6	2	1	TURN ON ISU	-0.
-0+	0D10H30M 0.00S	37800.00	8	-0	-0	DROP DEAD BAND	0.10000000E+00
			3	0	1	UPDATE WITH ANY USBS-30	-0.
-0+	0D10H31M 0.00S	37860.00	5	2	-0	MAKE MIDCOURSE CORRECTION	-0.
			8	0	-0	RAISE DEAD BAND	0.20000000E+02
			6	1	-0	TURN OFF COMPUTER	-0.
			6	2	-0	TURN OFF ISU	-0.
			6	3	0	TURN OFF ATT. CONT.	-0.
			6	4	0	TURN OFF STAR TRACKER	-0.
			6	5	0	TURN OFF SUN SENSOR	-0.
2	400D 0H 0M 0.00S	34560000.00	6	1	1	TURN ON COMPUTER	-0.
			6	2	1	TURN ON ISU	-0.
			6	5	1	TURN ON SUN SENSOR	-0.
			6	4	1	TURN ON STAR TRACKER	-0.
			6	3	1	TURN ON ATT CONT.	-0.
			9	2	1	BEGIN MANEUVERING	-0.
2+	400D 0H30M 0.00S	34561800.00	9	2	2	BEGIN SEARCH	-0.
2+	400D 0H31M 0.00S	34561860.00	9	2	3	END SEARCH	-0.
-0+	400D 1H 1M 0.00S	34563660.00	8	-0	-0	DROP DEAD BAND	0.10000000E+00
			3	0	5	UPDATE WITH ANY DSIF	-0.
-0+	400D 1H 2M 0.00S	34563720.00	5	2	-0	MAKE MIDCOURSE CORRECTION	-0.
			6	3	-0		-0.
			6	1	-0		-0.
			6	2	-0		-0.
			6	4	-0		-0.
			6	5	-0		-0.
			6	7	-0		-0.
-0	410D10H 4M 2.00S	35460242.00	99	2	-0	END OF THE SCHEDULE	-0.

OPT.=
0 FOR ALL SYSTEMS
1 FOR NON OPTICAL
2 FOR OPTICAL

FIGURE 38. MISSION SCHEDULE 1

SCHEDULE NO. 2

-0	0D 0H 0M 0.00S	0.00	1	-0	-0	START THE LAUNCH	-0.
			6	7	1	TURN ON COM.RCVR.	-0.
-0	0D 0H25M 0.00S	1500.00	3	1	2	UPDATE WITH ASCENSION TPQ RADAR	-0.
-0	0D 0H42M 3.00S	2523.00	6	3	1	TURN ON ATTITUDE CONTROL	-0.
			8	0	-0	RAISE DEAD BAND	0.20000000E+02
			6	4	1	TURN ON STAR TRACKER	-0.
			6	5	1	TURN ON SUN SENSOR	-0.
			9	2	1	BEGIN MANEUVERING	-0.
2	0D 0H57M 3.00S	3423.00	9	-0	2	BEGIN SEARCH	-0.
2	0D 0H58M 3.00S	3483.00	9	-0	3	END SEARCH	-0.
			6	1	-0	TURN OFF COMPUTER	-0.
			6	2	-0	TURN OFF ISU	-0.
2	0D10H 0M 0.00S	36000.00	6	1	1	TURN ON COMPUTER	-0.
			6	2	1	TURN ON ISU	-0.
-0+	0D10H30M 0.00S	37800.00	8	-0	-0	DROP DEAD BAND	0.10000000E+00
			3	0	1	UPDATE WITH ANY USBS-30	-0.
-0+	0D10H31M 0.00S	37860.00	5	2	-0	MAKE MIDCOURSE CORRECTION	-0.
			8	0	-0	RAISE DEAD BAND	0.20000000E+02
			6	1	-0	TURN OFF COMPUTER	-0.
			6	2	-0	TURN OFF ISU	-0.
			6	3	0	TURN OFF ATT. CONT.	-0.
			6	4	0	TURN OFF STAR TRACKER	-0.
			6	5	0	TURN OFF SUN SENSOR	-0.
2	200D 0H 0M 0.00S	17280000.00	6	1	1	TURN ON COMPUTER	-0.
			6	2	1	TURN ON ISU	-0.
			6	5	1	TURN ON SUN SENSOR	-0.
			6	4	1	TURN ON STAR TRACKER	-0.
			6	3	1	TURN ON ATT CONT.	-0.
			9	2	1	BEGIN MANEUVERING	-0.
2+	200D 0H30M 0.00S	17281800.00	9	2	2	BEGIN SEARCH	-0.
2+	200D 0H31M 0.00S	17281860.00	9	2	3	END SEARCH	-0.
-0+	200D 1H 1M 0.00S	17283660.00	8	-0	-0	DROP DEAD BAND	0.10000000E+00
			3	0	5	UPDATE WITH ANY DSIF	-0.
-0+	200D 1H 2M 0.00S	17283720.00	5	2	-0	MAKE MIDCOURSE CORRECTION	-0.
			8	0	-0	RAISE DEAD BAND	0.20000000E+02
			6	1	-0	TURN OFF COMPUTER	-0.
			6	2	-0	TURN OFF ISU	-0.
			6	3	0	TURN OFF ATT. CONT.	-0.
			6	4	0	TURN OFF STAR TRACKER	-0.
			6	5	0	TURN OFF SUN SENSOR	-0.
2	400D 0H 0M 0.00S	34560000.00	6	1	1	TURN ON COMPUTER	-0.
			6	2	1	TURN ON ISU	-0.
			6	5	1	TURN ON SUN SENSOR	-0.
			6	4	1	TURN ON STAR TRACKER	-0.
			6	3	1	TURN ON ATT CONT.	-0.
			9	2	1	BEGIN MANEUVERING	-0.
2+	400D 0H30M 0.00S	34561800.00	9	2	2	BEGIN SEARCH	-0.
2+	400D 0H31M 0.00S	34561860.00	9	2	3	END SEARCH	-0.
-0+	400D 1H 1M 0.00S	34563660.00	8	-0	-0	DROP DEAD BAND	0.10000000E+00

FIGURE 39a. MISSION SCHEDULE 2

SCHEDULE NO. 2 (CONTINUED)

			3	0	5	UPDATE WITH ANY DSIF	-0.
-0.	400D 1H 2M 0.00S	34563720.00	5	2	-0	MAKE MIDCOURSE CORRECTION	-0.
			6	3	-0		-0.
			6	1	-0		-0.
			6	2	-0		-0.
			6	4	-0		-0.
			6	5	-0		-0.
			6	7	-0		-0.
-0	410D10H 4M 2.00S	35460242.00	99	2	-0	END OF THE SCHEDULE	-0.

OPT.=
- 0 FOR ALL SYSTEMS
- 1 FOR NON OPTICAL
- 2 FOR OPTICAL

FIGURE 39b. MISSION SCHEDULE 2 (Continued)

Typical Results

Level 1 and level 2 evaluations of several systems on schedules 1 and 2 were obtained. Level 1 evaluation produces a one-page report describing the penalty evaluation. Level 2 evaluation produces a multi-page report showing details of the error analysis as well as the penalty evaluation. Only level 1 evaluations are shown in this section. Level 2 evaluations are shown in Appendix B..

Level 1 Results for Reference System. The effectiveness evaluation of an astrionics system known as the reference system is shown in Figure 40. The reference system consists of three D4E accelerometers and three GG334A gyroscopes mounted on a strapdown inertial sensing unit. The ISU was designed by the program by evaluating several possible parts layouts and selecting a standard design known as Horizontal Design Number 4. The excitation energy and power, total probability of failure, and total weight of the ISU are shown on the right hand side of Figure 40. The evaluation assumes the inertial sensing unit is mounted on a variable thermal impedance, whose impedance may change by a ratio of 2:1. Heating power is then calculated and added to the ISU excitation energy and excitation power to give the total energy and total power for the ISU including the heaters.

The reference system includes a hypothetical computer known as the SRT computer utilizing a second order Runge-Kutta algorithm in the updating of the direction cosine matrix. A strapdown tracker, sun sensor, and a communications receiver complete the reference system. The system parameters of energy, power, probability of failure, and weight are shown again at the right side of Figure 40.

Calculation of the attitude control subsystem parameters is then performed using results of the schedule evaluation and the sensors fields of view. At the left hand side of Figure 40, the various thrust sizing requirements are shown for the roll, yaw, and pitch axes. The worst case on each axis is then taken as the design requirement yielding a thrust of 0.0099 pounds for the roll axis thrusters and 0.3778 pounds for the yaw and pitch axis thrusters. The large thrust requirements on the yaw and pitch axes are due to the need to steer the vehicle during the midcourse correction burn. Fuel consumption is calculated using the indicated design thrusts. The total impulse (pound-seconds) required for each axis is calculated as shown. It should be noted that searching is the dominate fuel consumption in roll and yaw, while deadband consumption dominates the pitch axis. From the total fuel consumption, the following are calculated: the number of thruster firings, the total impulse requirements, and the attitude control subsystem fuel weight. From these results, the total electrical energy and power, total probability of failure, and total weight are calculated.

The energy source weight is calculated as a function of the total power and total energy requirements. For the evaluations discussed in this

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                              PENALTY (MODE 3)

ERROR ANALYSIS (SCHEDULE NO. 1)

ISU COMPONENTS

        ACCELEROM.=  ARMA D-4E   ARMA D-4E   ARMA D-4E      GYROSCOPES=  GG 334-A    GG 334-A    GG 334-A

ISU DATA(HORIZONTAL DESIGN NUMBER  4  OPTIMUM)                  ON TIME (HR)=      2.517

        OUTSIDE DIMENSIONS        WEIGHT                  WEIGHT                          EXCIT.ENERGY=   109.511
        LENGTH=     9.350      BLOCK=     8.703     INSULATION=     1.345                 EXCIT.POWER =    43.500
         WIDTH=    10.450       BASE=     4.549    ELECTRONICS=    10.000                 TOTAL P.FAIL=    .00063
        HEIGHT=     5.450      COVER=     2.867     COMPONENTS=     6.000                 TOTAL WEIGHT=    33.463

ISU THERMAL ANALYSIS
                    MAX.HEATER POWER=    97.875       MAX.THERMAL COND.=    2.1750        TOTAL ENERGY=   176.711
                    MIN.HEATER POWER=    -.000        MIN.THERMAL COND.=    1.0875        TOTAL POWER =   141.375

SUBSYSTEM PARAMETERS
              COMPUTERS    STAR TRCKR   SUN SENSOR   ISU/C.P.S.   COM. SYST.   HORIZ.SEN.
              SPT RUK-2    ITT-LUN.08   ADCL-1402      NONE       MCR-503        NONE
       TIME=      2.517       10.849       10.849       0.000     9601.033        0.000       0.000
     ENERGY=    226.575       86.793       54.246       0.000    33603.617        0.000       0.000    TOTAL ENERGY= 33971.231
      POWER=     90.000        8.000        5.000       0.000        3.500        0.000       0.000    TOTAL POWER =   106.500
     P.FAIL=     .00042       .00012       .00011     0.00000       .09155      0.00000     0.00000    TOTAL P.FAIL=    .09213
     WEIGHT=     36.000        7.000        2.000       0.000        3.100        0.000       0.000    TOTAL WEIGHT=    48.100

ATTITUDE CONTROL SYSTEM ANALYSIS                                ON TIME (HR)=    10.849

     THRUST SIZING (LB)                                     FUEL CONSUMPTION (LB-SEC)
                ROLL.        YAW        PITCH                       ROLL         YAW        PITCH
 SOLAR PRES=    .0000       .0000       .0000
 MET.IMPACT=    .0000       .0000       .0001       SEARCHING=     4.0585      2.3060       .0031
 MANEUVERS =    .0099       .0099       .0099       DEAD BAND=      .0001       .4445       .2560
 MIDCOURSE =   0.0000       .3778       .3778       MANEUVERS=      .2793       .1547       .1917    TOTAL ENERGY=   108.492
 MAX.THRUST=    .0099       .3778       .3778       TOTAL IMP=     4.3379      2.9052       .4508    TOTAL POWER =    10.000
                                                                                                   TOTAL P.FAIL=    .00278
 NO. OF FIRINGS=    22440     TOTAL IMPULSE=    7.6940        FUEL WEIGHT=   .137393               TOTAL WEIGHT=    21.215

ENERGY SOURCE DATA
                    TOTAL POWER=   257.875     TOTAL ENERGY= 34256.434                             TOTAL WEIGHT=   102.167

WIRING                                                                                             TOTAL WEIGHT=   110.000

MIDCOURSE ENGINE
        EXPECTED DELTA-V=    14.985 DOF=1.000 CAPABILITY=    28.147                                TOTAL WEIGHT=    28.515

PENALTY SUMMATION                PROBABILITIES                             WEIGHT
                  INSUF.MIDCOURSE FUEL=      .06053           ASTRIONICS=    343.460
                  EXCESSIVE TGT. MISS =     0.00000           SPACECRAFT=   1656.540
                  UNRELIABILITY       =      .09523                TOTAL=   2000.000
                  ASTRIONICS TOTAL    =      .15000
                                                                      PENALTY(MODE 3)=           343.45989
EXECUTION TIMES. START= 19.87, END= 33.19, ELAPSED=13.322(SEC.)
                                                                          02/18/69    143806    PAGE 1
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FIGURE 40. MODE 3 EVALUATION OF REFERENCE SYSTEM FOR MISSION SCHEDULE 1

report, an RTG was assumed. The weight of this type of energy source is a function only of the total power requirement and the energy calculations are not used. The weight of the energy source was estimated to be 102.167 pounds. An additional 110 pounds is included to account for electrical distribution wiring.

The midcourse correction subsystem is next designed under the assumption that enough fuel is carried to insure a probability of having sufficient fuel such that the overall astrionics acceptable probability of failure is not exceeded. The probability calculations are shown in the lower left hand corner of Figure 40. The acceptable probability of astrionics failure is 0.15, the probability of failure due to lack of sufficient reliability is 0.09, and the probability of excessive target miss is essentially zero. This combination requires the probability of having insufficient midcourse fuel to be 0.06. From the expected midcourse ΔV of 14.985 feet/second with 1 degree-of-freedom, the midcourse ΔV capability requirement, 28.147 feet/second, is then calculated. This results in a midcourse propulsion system weight, including nozzles, tankage, and fuel, of 28.5 pounds.

The weights of all of the astrionics subsystems discussed above are then totalled to obtain the effectiveness index or penalty of 343.46 pounds. The total spacecraft was assumed to weigh 2,000 pounds. Thus, 1656.54 pounds remain for structure and scientific payload.

Figure 41 is an evaluation of the reference system when operated on mission schedule 2. This schedule differed from schedule 1 primarily by the addition of a third midcourse correction. This is reflected in the penalty which is 343.70 lb, an increase of 0.24 lb over the penalty obtained by operating the reference system on schedule 1. The evaluations in Figure 40 and 41 do not reflect the difference in target miss, R_T, which is shown in the level 2 analyses contained in Appendix B. Since the reference system, when operated on schedule 1 or 2, meets the acceptable target miss, X_{MISS}, the third midcourse in schedule 2 indicates that the total scientific payload decreases if schedule 2 is used. As shown in a later table, the decreased R_T resulting from using schedule 2 rather than 1, is paid for by a decrease in scientific payload. For this reason, mission planners and spacecraft designers should specify, as accurately as possible, the acceptable target miss, X_{MISS}.

<u>Sensitivity Analysis of Reference System on Schedule 1</u>. Sensitivity analyses for the reference system on schedule 1 are shown in Figures 42 and 43. Figure 42 shows the sensitivity analysis using a 10 percent change. Each sensitivity is found by changing the data item in question by 10 percent and computing the percent change in penalty per percent change in the data. The sensitivities of Figure 43 were obtained using a 1 percent change. Comparison of the sensitivities using the two step sizes gives an indication of the linearity of the penalty as a function of the data item. For most data items, very little change in the sensitivity is noted with the change in the step size. However, it should be noted that the sensitivity to the pitch gyro

ISU COMPONENTS

ACCELEROM.= ARMA D-4E ARMA D-4E ARMA D-4E GYROSCOPES= GG 334-A GG 334-A GG 334-A

ISU DATA(HORIZONTAL DESIGN NUMBER 4 OPTIMUM) ON TIME (HR)= 3.551

OUTSIDE DIMENSIONS		WEIGHT		WEIGHT			
LENGTH=	9.350	BLOCK=	8.703	INSULATION=	1.345	EXCIT.ENERGY=	154.461
WIDTH=	10.450	BASE=	4.549	ELECTRONICS=	10.000	EXCIT.POWER =	43.500
HEIGHT=	5.450	COVER=	2.867	COMPONENTS=	6.000	TOTAL P.FAIL=	.00089
						TOTAL WEIGHT=	33.463

ISU THERMAL ANALYSIS

MAX.HEATER POWER=	97.875	MAX.THERMAL COND.=	2.1750	TOTAL ENERGY=	249.244
MIN.HEATER POWER=	-.000	MIN.THERMAL COND.=	1.0875	TOTAL POWER =	141.375

SUBSYSTEM PARAMETERS

	COMPUTERS	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.			
	SRT RUK-2	ITT-LUN.08	ADCL-1402	NONE	MCR-503	NONE			
TIME=	3.551	11.882	11.882	0.000	9601.033	0.000	0.000	TOTAL ENERGY=	34077.664
ENERGY=	319.575	95.060	59.412	0.000	33603.617	0.000	0.000	TOTAL POWER =	106.500
POWER=	90.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL P.FAIL=	.09231
P.FAIL=	.00059	.00013	.00012	0.00000	.09155	0.00000	0.00000	TOTAL WEIGHT=	48.100
WEIGHT=	36.000	7.000	2.000	0.000	3.100	0.000	0.000		

ON TIME (HR)= 11.882

ATTITUDE CONTROL SYSTEM ANALYSIS

THRUST SIZING (LB)	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)	ROLL	YAW	PITCH
SEARCHING=	8.1155	4.6111	.0031
DEAD BAND=	.0001	.5220	.3196
MANEUVERS=	.2836	.1592	.1947
TOTAL IMP=	8.3993	5.2924	.5174

TOTAL ENERGY=	118.825
TOTAL POWER =	10.000
TOTAL P.FAIL=	.00492
TOTAL WEIGHT=	21.397

NO. OF FIRINGS= 43358 TOTAL IMPULSE= 14.2091 FUEL WEIGHT= .253734

ENERGY SOURCE DATA TOTAL POWER= 257.875 TOTAL ENERGY= 34445.733 TOTAL WEIGHT= 102.167

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE TOTAL WEIGHT= 28.571
EXPECTED DELTA-V= 14.945 DOF=1.000 CAPABILITY= 28.339

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.05809	ASTRIONICS=	343.698
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1656.302
UNRELIABILITY =	.09758	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 343.69770

EXECUTION TIMES, START= 19.83, END= 58.51, ELAPSED=38.678(SEC.)

FIGURE 41. MODE 3 EVALUATION OF REFERENCE SYSTEM FOR MISSION SCHEDULE 2.

SENSITIVITY ANALYSIS

SENSITIVITY= PER CENT CHANGE IN PENALTY PER PERCENT CHANGE IN DATA (BASED ON A 10 PERCENT STEP)

SPACECRAFT/MISSION DATA (SECTION 1)

1	TOTAL WEIGHT (LB)=	2000.0000	.02391803	2	NONASTRIONICS WEIGHT (LB)=	1500.0000	0.00000000
3	PROBABILITY OF ASTRIONICS FAIL=	.1500	-.01360197	4	TARGET MISS DISTANCE (FT)=	78087800.0000	0.00000000
5	VIBRATION(MILLIRAD/SEC)**2/CPS=	.3046	0.00000000	6	VIBRATION UPPER FREQ. (CPS)=	100.0000	0.00000000
7	WIRING WEIGHT (LB)=	110.0000	.32027029	8	ROLL MOM. OF INER.(SLUG-FT**2)=	1100.0000	.00046843
9	YAW MOM. OF INERT.(SLUG-FT**2)=	625.0000	.00011904	10	PIT MOM. OF INERT.(SLUG-FT**2)=	563.0000	-.00006665
11	ROLL MOMENT ARM (FT)=	7.0000	-.00032047	12	YAW MOMENT ARM (FT)=	7.0000	-.00021463
13	PITCH MOMENT ARM (FT)=	7.0000	-.00003330	14	ROLL MAX. ARM (FT)=	3.5000	0.00000000
15	YAW MAX. ARM (FT)=	3.5000	0.00000000	16	PITCH MAX. ARM (FT)=	3.5000	0.00000000

MIDCOURSE ENG./ENERGY SOURCE (SECTION 2)

1	SPECIFIC IMPULSE (SEC.)=	233.0000	-.02170657	2	MIDCOURSE THRUST (LB)=	50.0000	.00011754
3	MIDCOURSE SYSTEM COEF.(LB/LB)=	1.0960	.02391803	4	MIDCOURSE SYSTEM CON. (LB)=	20.3000	.05910443
5	ENERGY SOURCE CONSTANT (LB)=	13.2000	.03843244	6	ENERGY SOURCE COEF. (LB/W)=	.3450	.25903134
7	ENERGY SOURCE COEF. (LB/W-HR)=	0.0000	0.00000000	8	MIDCOURSE ENGINE ARM (FT)=	3.5000	.00004941
9	MIDCOURSE ENG. OFFSET UNC.(FT)=	.0200	.00006521	10	MIDCOURSE ENG. ANG. UNC. (RAD)=	.0044	.00004941

I. S. UNIT DESIGN DATA (SECTION 3)

1	BLOCK DENSITY (LB/IN**3)=	.0970	.02533962	2	BASE DENSITY (LB/IN**3)=	.0970	.01324374
3	COVER DENSITY (LB/IN**3)=	.0970	.00834686	4	INSULATION DENSITY (LB/IN**3)=	.0910	.00391528
5	ISU COMPONENT SEPARATION (IN)=	.2500	.02485097	6	BASE OFFSET (IN)=	1.5000	.01338650
7	COVER CLEARANCE (IN)=	.2500	.00040245	8	BASE THICKNESS (IN)=	.5000	.01324374
9	COVER THICKNESS (IN)=	.1000	.00834686	10	INSULATION THICKNESS (IN)=	.0500	.00391528
11	ELECTRONICS WEIGHT (LB)=	10.0000	.02911548	12	ELECTRONICS MTBF (HR)=	10000.0000	-.00001966
13	ELECTRONICS POWER (WATTS)=	30.0000	.09793720	14	DESIGN NO. (0=OPTIMUM) =	0.0000	0.00000000
15	1=HORIZONTAL, 2=VERTICAL =	1.0000	0.00000000				

THERMAL CONTROL DATA (SECTION 4)

1	OPERATING TEMPERATURE(DEG-F)=	160.0000	-.53405071	2	MAX.AMBIENT TEMPERATURE(DEG-F)=	140.0000	3.31354193
3	AVE.AMBIENT TEMPERATURE(DEG-F)=	60.0000	0.00000000	4	MIN.AMBIENT TEMPERATURE(DEG-F)=	30.0000	-.03277129
5	THERMAL CONDUCTANCE (W/DEG-F)=	0.0000	0.00000000	6	MIN. THERMAL CONDUCTANCE RATIO=	.5000	.14200894

ATTITUDE CONTROL DATA (SECTION 5)

1	ROLL SOLAR PRESS. AREA(FT**2)=	113.0000	0.00000000	2	YAW SOLAR PRESS. AREA(FT**2)=	32.0000	0.00000000
3	PITCH SOLAR PRESS. AREA(FT**2)=	32.0000	0.00000000	4	ROLL CG-CP ARM (FT)=	.2500	0.00000000
5	YAW CG-CP ARM (FT)=	1.0000	0.00000000	6	PITCH CG-CP ARM (FT)=	1.0000	0.00000000
7	SIZING OPTION (1 SETS=THRUSTS)=	0.0000	0.00000000	8	A/C SPECIFIC IMPULSE (SEC.)=	56.0000	-.00056840
9	EMPTY DATA SPACE =	0.0000	0.00000000	10	IMPULSE TIME (SEC)=	.0200	.00001955
11	RECHARGE TIME (SEC)=	.0400	-.00008166	12	METEORITE IMPACT IMP. (LB-SEC)=	.0140	0.00000000
13	AT.CONT.RELIB. (FAIL/1000IMP.)=	.0001	.00019309	14	A.C. ELECTRONICS MTBF (HR)=	20000.0000	-.00004236
15	A.C. ELECTRONICS POWER (WATTS)=	10.0000	.01004484	16	ATT. CONT. WEIGHT CONS. (LB)=	21.0000	.06114251
17	ATT. CONT. COEF. (LB/LB)=	1.5630	.00062524	18	ATTITUDE TOLERANCE (DEG)=	1.0000	0.00000000

FIGURE 42a. REFERENCE SYSTEM SENSITIVITY ANALYSIS FOR MODE 3 USING A 10 PERCENT STEP.

HARDWARE SENSITIVITIES

YAW ACC.=ARMA D-4E		SENSITIVITY
WEIGHT =	3.500000E-01	.00101904
POWER =	1.500000E+00	.00489686
MTTF =	1.000000E+05	-.00000197
ALPHA =	1.000000E+00	-.00001441
LENGTH =	1.300000E+00	.00439161
DIAMETER =	2.700000E+00	.00969026
WIDTH =	-0.	0.00000000
K0=	6.700000E-06	.00000505
K1=	1.000000E-05	.00000000

PITCH ACC.=ARMA D-4E		SENSITIVITY
WEIGHT =	3.500000E-01	.00101904
POWER =	1.500000E+00	.00489686
MTTF =	1.000000E+05	-.00000197
ALPHA =	1.000000E+00	-.00001441
LENGTH =	1.300000E+00	.00165746
DIAMETER =	2.700000E+00	.00822307
WIDTH =	-0.	0.00000000
K0=	6.700000E-06	.00000048
K1=	1.000000E-05	0.00000000

ROLL ACC.=ARMA D-4E		SENSITIVITY
WEIGHT =	3.500000E-01	.00101904
POWER =	1.500000E+00	.00489686
MTTF =	1.000000E+05	-.00000197
ALPHA =	1.000000E+00	-.00001441
LENGTH =	1.300000E+00	.00439161
DIAMETER =	2.700000E+00	.00969026
WIDTH =	-0.	0.00000000
K0=	6.700000E-06	.00000243
K1=	1.000000E-05	.00005220

YAW GYRO=GG 334-A		SENSITIVITY
WEIGHT =	1.650000E+00	.00480405
POWER =	3.000000E+00	.00979372
MTTF =	2.500000E+04	-.00000787
ALPHA =	1.000000E+00	-.00005335
LENGTH =	4.700000E+00	.00543064
DIAMETER =	2.500000E+00	.00921199
WIDTH =	-0.	0.00000000
R=	5.000000E-02	.00049308
UI=	6.000000E-02	0.00000000

PITCH GYRO=GG 334-A		SENSITIVITY
WEIGHT =	1.650000E+00	.00480405
POWER =	3.000000E+00	.00979372
MTTF =	2.500000E+04	-.00000787
ALPHA =	1.000000E+00	-.00005335
LENGTH =	4.700000E+00	.01299667
DIAMETER =	2.500000E+00	.01253765
WIDTH =	-0.	0.00000000
R=	5.000000E-02	.01414695
UI=	6.000000E-02	-.00000000

ROLL GYRO=GG 334-A		SENSITIVITY
WEIGHT =	1.650000E+00	.00480405
POWER =	3.000000E+00	.00979372
MTTF =	2.500000E+04	-.00000787
ALPHA =	1.000000E+00	-.00005335
LENGTH =	4.700000E+00	.01299667
DIAMETER =	2.500000E+00	.01253765
WIDTH =	-0.	0.00000000
R=	5.000000E-02	.00031956
UI=	6.000000E-02	0.00000000

COMPUTERS =SRT RUK-2		SENSITIVITY
WEIGHT =	3.600000E+01	.10481573
POWER =	9.000000E+01	.09040357
MTTF =	6.000000E+03	-.00003277
ALPHA =	1.000000E+00	-.00020088
LENGTH =	-0.	0.00000000
DIAMETER =	-0.	0.00000000
WIDTH =	-0.	0.00000000
BITS=	3.200000E+01	-.00047779
COMP.FREQ.=	1.280000E+02	.00010175

PLATFORMS = DESIGNED		SENSITIVITY
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000

STAR TRCKR=ITT-LUN.08		SENSITIVITY
WEIGHT =	7.000000E+00	.02038084
POWER =	8.000000E+00	.00803587
MTTF =	9.000000E+04	-.00000942
ALPHA =	1.000000E+00	-.00006314
LENGTH =	-0.	0.00000000
DIAMETER =	-0.	0.00000000
WIDTH =	-0.	0.00000000
ERROR(DEG)=	1.400000E-02	-.00025821
FOV (DEG)=	8.000000E+00	-.00002781

SUN SENSOR=ADCL-1402		SENSITIVITY
WEIGHT =	2.000000E+00	.00582310
POWER =	5.000000E+00	.00502242
MTTF =	1.000000E+05	-.00000847
ALPHA =	1.000000E+00	-.00005721
LENGTH =	-0.	0.00000000
DIAMETER =	-0.	0.00000000
WIDTH =	-0.	0.00000000
ERROR(DEG)=	4.000000E-02	-.00012669
FOV (DEG)=	6.400000E+01	.00000977

ISU/C.P.S.= NONE		SENSITIVITY
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000

COM. SYST.=MCR-503		SENSITIVITY
WEIGHT =	3.100000E+00	.00902580
POWER =	3.500000E+00	.00351569
MTTF =	1.000000E+05	-.00711076
ALPHA =	1.000000E+00	-.01733664
LENGTH =	5.250000E+00	0.00000000
DIAMETER =	3.375000E+00	0.00000000
WIDTH =	4.563000E+00	0.00000000
=	0.	0.00000000
=	0.	0.00000000

HORIZ.SEN.= NONE		SENSITIVITY
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000

FIGURE 42b. REFERENCE SYSTEM SENSITIVITY ANALYSIS FOR MODE 3 USING A 10 PERCENT STEP (Continued)

SENSITIVITY ANALYSIS

SENSITIVITY= PER CENT CHANGE IN PENALTY PER PERCENT CHANGE IN DATA (BASED ON A 1 PERCENT STEP)

SPACECRAFT/MISSION DATA (SECTION 1)

1	TOTAL WEIGHT (LB)=	2000.0000	.02391803	2	NONASTRIONICS WEIGHT (LB)=	1500.0000	0.00000000
3	PROBABILITY OF ASTRIONICS FAIL=	.1500	-.01500621	4	TARGET MISS DISTANCE (FT)=	78087800.0000	0.00000000
5	VIBRATION(MILLIRAD/SEC)**2/CPS=	.3046	0.00000000	6	VIBRATION UPPER FREQ. (CPS)=	100.0000	0.00000000
7	WIRING WEIGHT (LB)=	110.0000	.32027029	8	ROLL MOM. OF INER.(SLUG-FT**2)=	1100.0000	.00047134
9	YAW MOM. OF INERT.(SLUG-FT**2)=	625.0000	.00011420	10	PIT MOM. OF INERT.(SLUG-FT**2)=	563.0000	-.00007108
11	ROLL MOMENT ARM (FT)=	7.0000	-.00034903	12	YAW MOMENT ARM (FT)=	7.0000	-.00023375
13	PITCH MOMENT ARM (FT)=	7.0000	-.00003627	14	ROLL MAX. ARM (FT)=	3.5000	0.00000000
15	YAW MAX. ARM (FT)=	3.5000	0.00000000	16	PITCH MAX. ARM (FT)=	3.5000	0.00000000

MIDCOURSE ENG./ENERGY SOURCE (SECTION 2)

1	SPECIFIC IMPULSE (SEC.)=	233.0000	-.02363722	2	MIDCOURSE THRUST (LB)=	50.0000	.00011217
3	MIDCOURSE SYSTEM COEF.(LB/LB)=	1.0960	.02391803	4	MIDCOURSE SYSTEM CON. (LB)=	20.3000	.05910443
5	ENERGY SOURCE CONSTANT (LB)=	13.2000	.03843244	6	ENERGY SOURCE COEF. (LB/W)=	.3450	.25903134
7	ENERGY SOURCE COEF. (LB/W-HR)=	0.0000	0.00000000	8	MIDCOURSE ENGINE ARM (FT)=	3.5000	.00004840
9	MIDCOURSE ENG. OFFSET UNC.(FT)=	.0200	.00006348	10	MIDCOURSE ENG. ANG. UNC. (RAD)=	.0044	.00004840

I. S. UNIT DESIGN DATA (SECTION 3)

1	BLOCK DENSITY (LB/IN**3)=	.0970	.02533962	2	BASE DENSITY (LB/IN**3)=	.0970	.01324374
3	COVER DENSITY (LB/IN**3)=	.0970	.00834686	4	INSULATION DENSITY (LB/IN**3)=	.0910	.00391528
5	ISU COMPONENT SEPARATION (IN)=	.2500	.02459577	6	BASE OFFSET (IN)=	1.5000	.01323851
7	COVER CLEARANCE (IN)=	.2500	.00040245	8	BASE THICKNESS (IN)=	.5000	.01324374
9	COVER THICKNESS (IN)=	.1000	.00834686	10	INSULATION THICKNESS (IN)=	.0500	.00391528
11	ELECTRONICS WEIGHT (LB)=	10.0000	.02911548	12	ELECTRONICS MTBF (HR)=	10000.0000	-.00002142
13	ELECTRONICS POWER (WATTS)=	30.0000	.09793720	14	DESIGN NO. (0=OPTIMUM) =	0.0000	0.00000000
15	1=HORIZONTAL, 2=VERTICAL =	1.0000	0.00000000				

THERMAL CONTROL DATA (SECTION 4)

1	OPERATING TEMPERATURE(DEG-F)=	160.0000	-.89008452	2	MAX.AMBIENT TEMPERATURE(DEG-F)=	140.0000	1.06888449
3	AVE.AMBIENT TEMPERATURE(DEG-F)=	60.0000	0.00000000	4	MIN.AMBIENT TEMPERATURE(DEG-F)=	30.0000	-.03277129
5	THERMAL CONDUCTANCE (W/DEG-F)=	0.0000	0.00000000	6	MIN. THERMAL CONDUCTANCE RATIO=	.5000	.14200894

ATTITUDE CONTROL DATA (SECTION 5)

1	ROLL SOLAR PRESS. AREA(FT**2)=	113.0000	0.00000000	2	YAW SOLAR PRESS. AREA(FT**2)=	32.0000	0.00000000
3	PITCH SOLAR PRESS. AREA(FT**2)=	32.0000	0.00000000	4	ROLL CG-CP ARM (FT)=	.2500	0.00000000
5	YAW CG-CP ARM (FT)=	1.0000	0.00000000	6	PITCH CG-CP ARM (FT)=	1.0000	0.00000000
7	SIZING OPTION (1 SETS=THRUSTS)=	0.0000	0.00000000	8	A/C SPECIFIC IMPULSE (SEC.)=	56.0000	-.00061905
9	EMPTY DATA SPACE =	0.0000	0.00000000	10	IMPULSE TIME (SEC)=	.0200	.00001851
11	RECHARGE TIME (SEC)=	.0400	-.00009425	12	METEORITE IMPACT IMP. (LB-SEC)=	.0140	0.00000000
13	AT.CONT.RELIB. (FAIL/1000IMP.)=	.0001	.00019284	14	A.C. ELECTRONICS MTBF (HR)=	20000.0000	-.00004615
15	A.C. ELECTRONICS POWER (WATTS)=	10.0000	.01004484	16	ATT. CONT. WEIGHT CONS. (LB)=	21.0000	.06114251
17	ATT. CONT. COEF. (LB/LB)=	1.5630	.00062524	18	ATTITUDE TOLERANCE (DEG)=	1.0000	0.00000000

FIGURE 43a. REFERENCE SYSTEM SENSITIVITY ANALYSIS FOR MODE 3 USING A 1 PERCENT STEP

YAW ACC.=ARMA D-4E		SENSITIVITY
WEIGHT =	3.500000E-01	.00101904
POWER =	1.500000E+00	.00489686
MTTF =	1.000000E+05	-.00000214
ALPHA =	1.000000E+00	-.00002248
LENGTH =	1.300000E+00	.00439161
DIAMETER =	2.700000E+00	.00959224
WIDTH =	-0.	0.00000000
K0=	6.700000E-06	.00000483
K1=	1.000000E-05	0.00000000

PITCH ACC.=ARMA D-4E		SENSITIVITY
WEIGHT =	3.500000E-01	.00101904
POWER =	1.500000E+00	.00489686
MTTF =	1.000000E+05	-.00000214
ALPHA =	1.000000E+00	-.00002248
LENGTH =	1.300000E+00	.00165746
DIAMETER =	2.700000E+00	.00904962
WIDTH =	-0.	0.00000000
K0=	6.700000E-06	.00000046
K1=	1.000000E-05	0.00000000

ROLL ACC.=ARMA D-4E		SENSITIVITY
WEIGHT =	3.500000E-01	.00101904
POWER =	1.500000E+00	.00489686
MTTF =	1.000000E+05	-.00000214
ALPHA =	1.000000E+00	-.00002248
LENGTH =	1.300000E+00	.00439161
DIAMETER =	2.700000E+00	.00959224
WIDTH =	-0.	0.00000000
K0=	6.700000E-06	.00000233
K1=	1.000000E-05	.00005064

YAW GYRO=GG 334-A		SENSITIVITY
WEIGHT =	1.650000E+00	.00480405
POWER =	3.000000E+00	.00979372
MTTF =	2.500000E+04	-.00000857
ALPHA =	1.000000E+00	-.00007909
LENGTH =	4.700000E+00	.00543064
DIAMETER =	2.500000E+00	.00796044
WIDTH =	-0.	0.00000000
R=	5.000000E-02	.00047191
UI=	6.000000E-02	0.00000000

PITCH GYRO=GG 334-A		SENSITIVITY
WEIGHT =	1.650000E+00	.00480405
POWER =	3.000000E+00	.00979372
MTTF =	2.500000E+04	-.00000857
ALPHA =	1.000000E+00	-.00007909
LENGTH =	4.700000E+00	.01299667
DIAMETER =	2.500000E+00	.01321843
WIDTH =	-0.	0.00000000
R=	5.000000E-02	-.01574242
UI=	6.000000E-02	0.00000000

ROLL GYRO=GG 334-A		SENSITIVITY
WEIGHT =	1.650000E+00	.00480405
POWER =	3.000000E+00	.00979372
MTTF =	2.500000E+04	-.00000857
ALPHA =	1.000000E+00	-.00007909
LENGTH =	4.700000E+00	.01299667
DIAMETER =	2.500000E+00	.01321843
WIDTH =	-0.	0.00000000
R=	5.000000E-02	.00030732
UI=	6.000000E-02	0.00000000

COMPUTERS =SRT RUK-2		SENSITIVITY
WEIGHT =	3.000000E+01	.10481573
POWER =	9.000000E+01	.09040357
MTTF =	6.000000E+03	-.00003569
ALPHA =	1.000000E+00	-.00028241
LENGTH =	-0.	0.00000000
DIAMETER =	-0.	0.00000000
WIDTH =	-0.	0.00000000
BITS=	3.200000E+01	0.00000000
COMP.FREQ.=	1.280000E+02	.00009742

PLATFORMS = DESIGNED		SENSITIVITY
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000

STAR TRCKR=ITT-LUN.OB		SENSITIVITY
WEIGHT =	7.000000E+00	.02038084
POWER =	8.000000E+00	.00803587
MTTF =	9.000000E+04	-.00001026
ALPHA =	1.000000E+00	-.00009298
LENGTH =	-0.	0.00000000
DIAMETER =	-0.	0.00000000
WIDTH =	-0.	0.00000000
ERROR(DEG)=	1.400000E-02	-.00026618
FOV (DEG)=	8.000000E+00	-.00003020

SUN SENSOR=ADCL-1402		SENSITIVITY
WEIGHT =	2.000000E+00	.00582310
POWER =	5.000000E+00	.00502242
MTTF =	1.000000E+05	-.00000923
ALPHA =	1.000000E+00	-.00008458
LENGTH =	-0.	0.00000000
DIAMETER =	-0.	0.00000000
WIDTH =	-0.	0.00000000
ERROR(DEG)=	4.000000E-02	-.00014974
FOV (DEG)=	6.400000E+01	.00000899

ISU/C.P.S.= NONE		SENSITIVITY
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000

COM. SYST.=MCR-503		SENSITIVITY
WEIGHT =	3.100000E+00	.00902580
POWER =	3.500000E+00	.00351569
MTTF =	1.000000E+05	-.00811814
ALPHA =	1.000000E+00	-.02182645
LENGTH =	5.250000E+00	0.00000000
DIAMETER =	3.375000E+00	0.00000000
WIDTH =	4.563000E+00	0.00000000
=	0.	0.00000000
=	0.	0.00000000

HORIZ.SEN.= NONE		SENSITIVITY
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000
=	0.	0.00000000

FIGURE 43b. REFERENCE SYSTEM HARDWARE SENSITIVITIES FOR MODE 3 USING A 1 PERCENT STEP (Continued)

fixed drift (R) is 0.014 with a 10 percent step, and -0.016 with a 1 percent step. The latter answer is especially interesting since it indicates increasing the gyro fixed drift from the nominal by 1 percent gives a decrease in the penalty. Similarly, the sensitivity to sun-sensor and star tracker errors are negative. This also indicates a decrease in the penalty with an increase in star tracker or sun-sensor error. To investigate these results, detailed studies were made by obtaining tables and plots of penalty versus sensor error. Plots of penalty versus sensor error are shown in the following section.

Plotting of Penalty Versus Component Accuracy. Plots and tables of the penalty versus gyro fixed drift, accelerometer bias, star tracker pointing error, and sun sensor pointing error were obtained using the plotting routine PARSWP. These results have been redrawn on expanded scales and are shown in Figures 44 to 47.

Figure 44 shows the penalty versus gyro fixed drift with the assumption that all three gyro drifts are equal. The penalty is saturated due to target miss for drift greater than 1°/hour. It should be noted that drifts less than 0.02°/hour yield very little improvement in the penalty. Thus, only 5 pounds could be gained by improving the reference system gyro drift.

Figure 45 shows the penalty versus accelerometer bias assuming all three biases are equal. The penalty is saturated due to target miss for bias above 670 μg and little improvement for bias less than 67 μg. Thus, the bias of the accelerometers used in the reference system are an order of magnitude better than needed.

Figure 46 shows the penalty versus star tracker accuracy on a very expanded scale. The very slight dependence of the penalty on star tracker accuracy is due to the use of the Kalman filtered update with the sun sensor prior to star updates. The correlations between components of the attitude errors allow the filter to make a very good estimate of attitude with only the sun sensor. If the celestial body acquisition sequence was changed from sun-star to star-sun the dependence on star tracker accuracy would be greater. The slight decrease in the penalty with increased star tracker error is due to the decrease in midcourse correction ΔV with less accurate state estimation as discussed in a following section.

As discussed above, Figure 47 shows increase in penalty for sun sensor errors above 2°. The negative slope is also seen in the region of 0.01° to 0.1°.

Search for Optimum System on Schedule 1. A search for an optimum system operating on mission schedule 1 was conducted. The list of candidate components included four gyroscopes, four accelerometers, and three computers. A strapdown star tracker and sun sensor were specified. Earlier studies showed the strapdown star tracker yielded lower penalty than a gimballed or no star tracker. Only one communication receiver was in the list, so no optimization

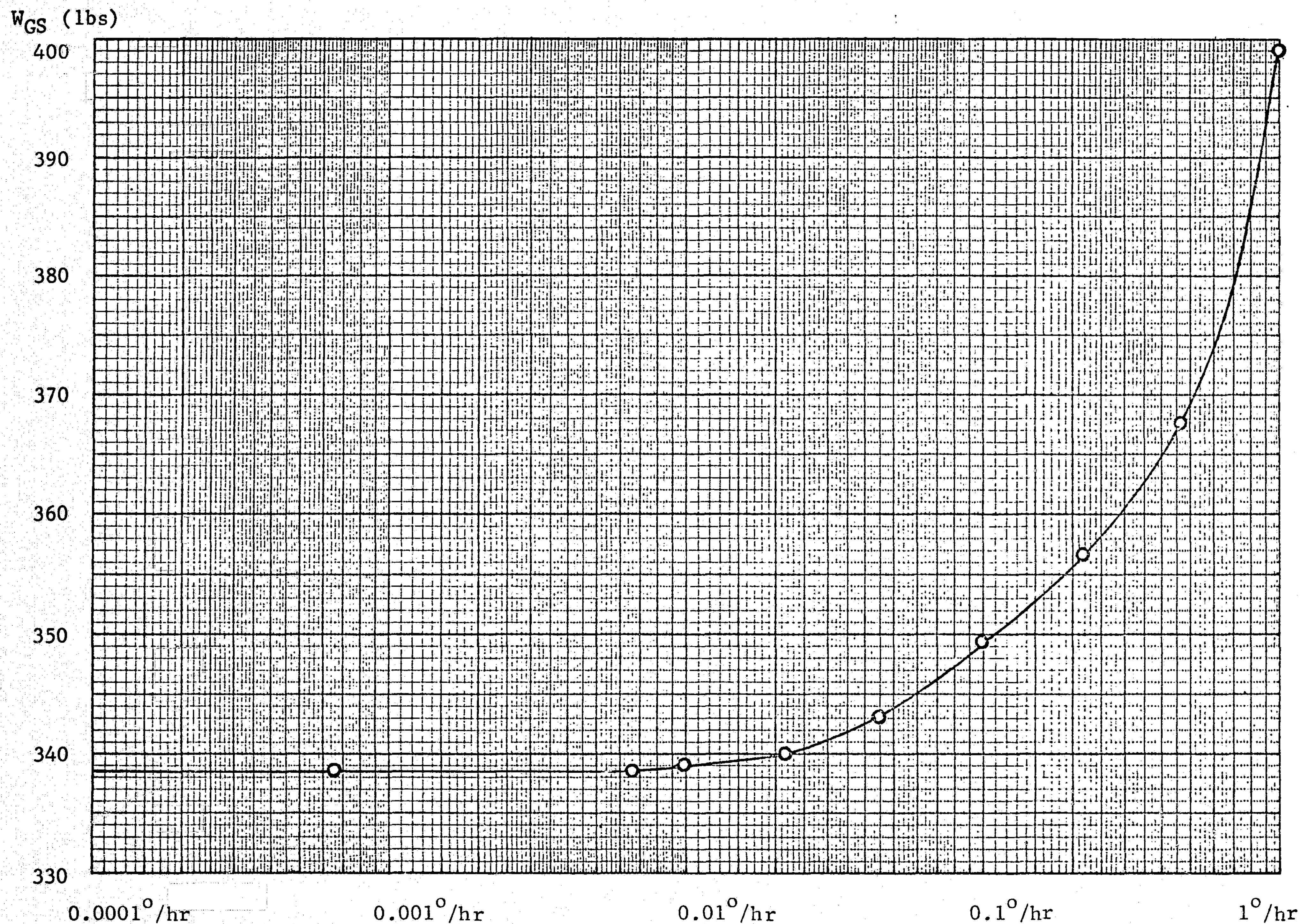

FIGURE 44. PLOT OF PENALTY, W_{GS}, VERSUS GYRO FIXED DRIFT, D_{FR}, FOR ALL GYROS

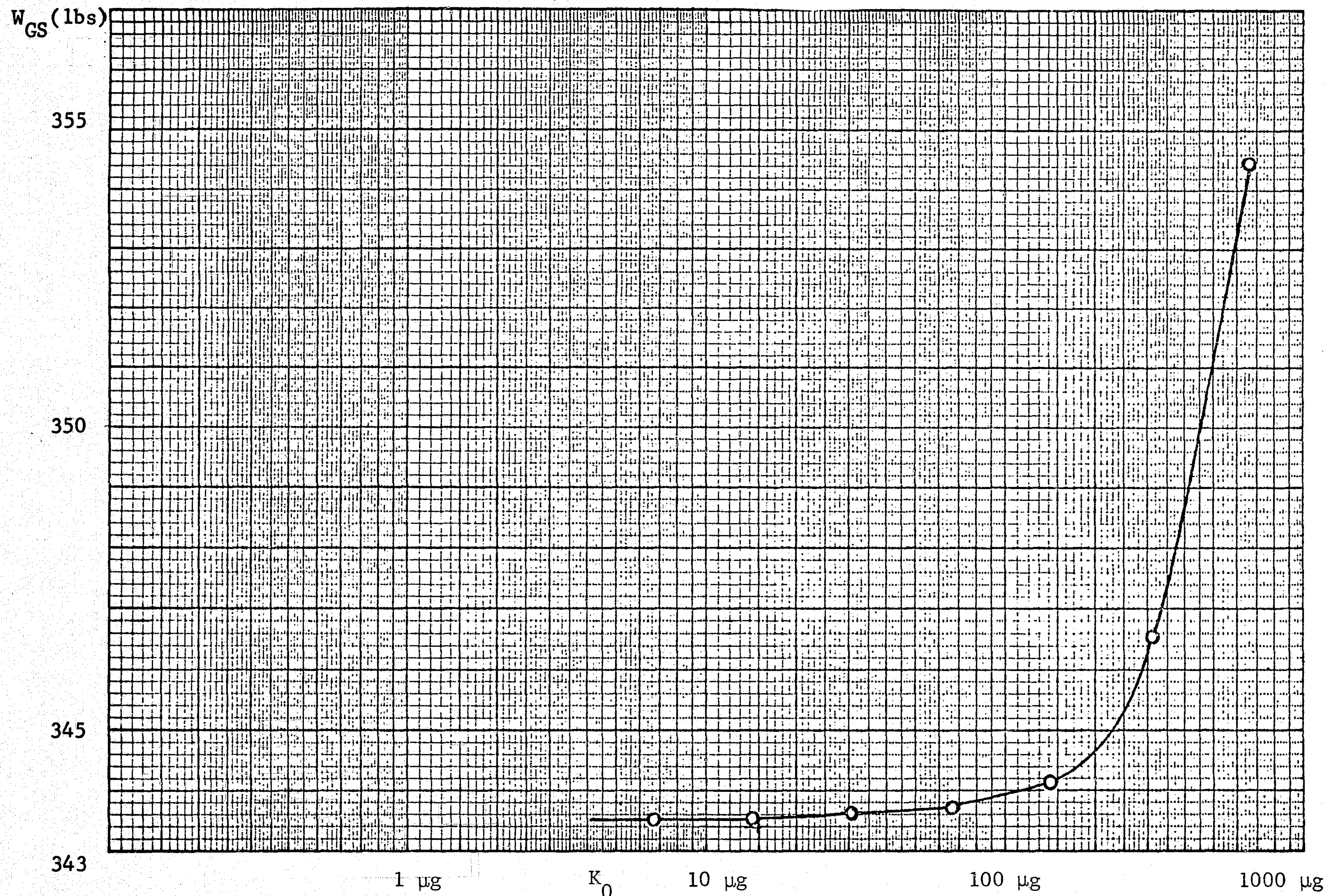

FIGURE 45. PLOT OF PENALTY, W_{GS}, VERSUS ACCELEROMETER BIAS, K_0, FOR ALL ACCELEROMETERS

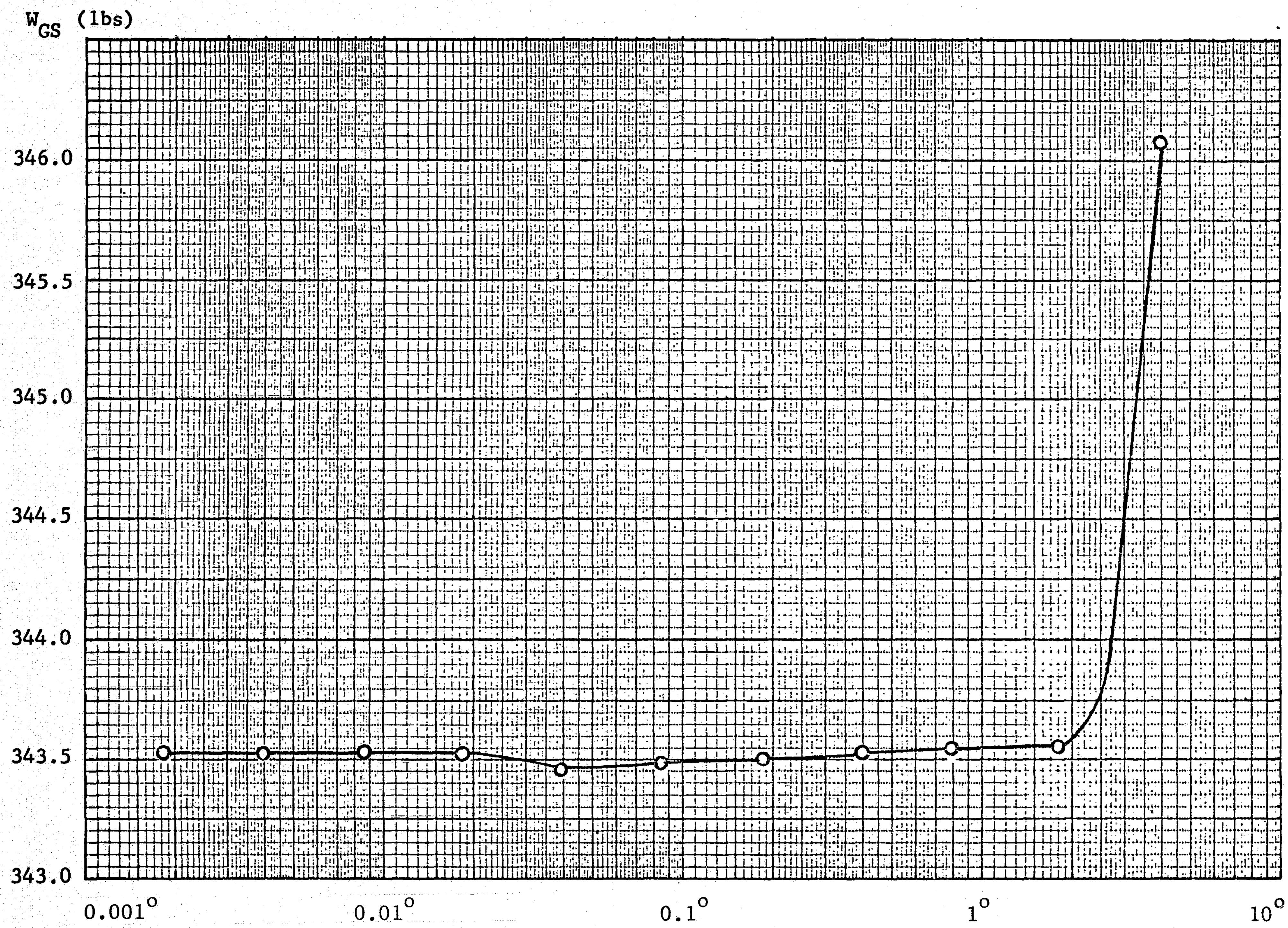

FIGURE 46 . PLOT OF PENALTY, W_{GS}, VERSUS SUN SENSOR POINTING ERROR

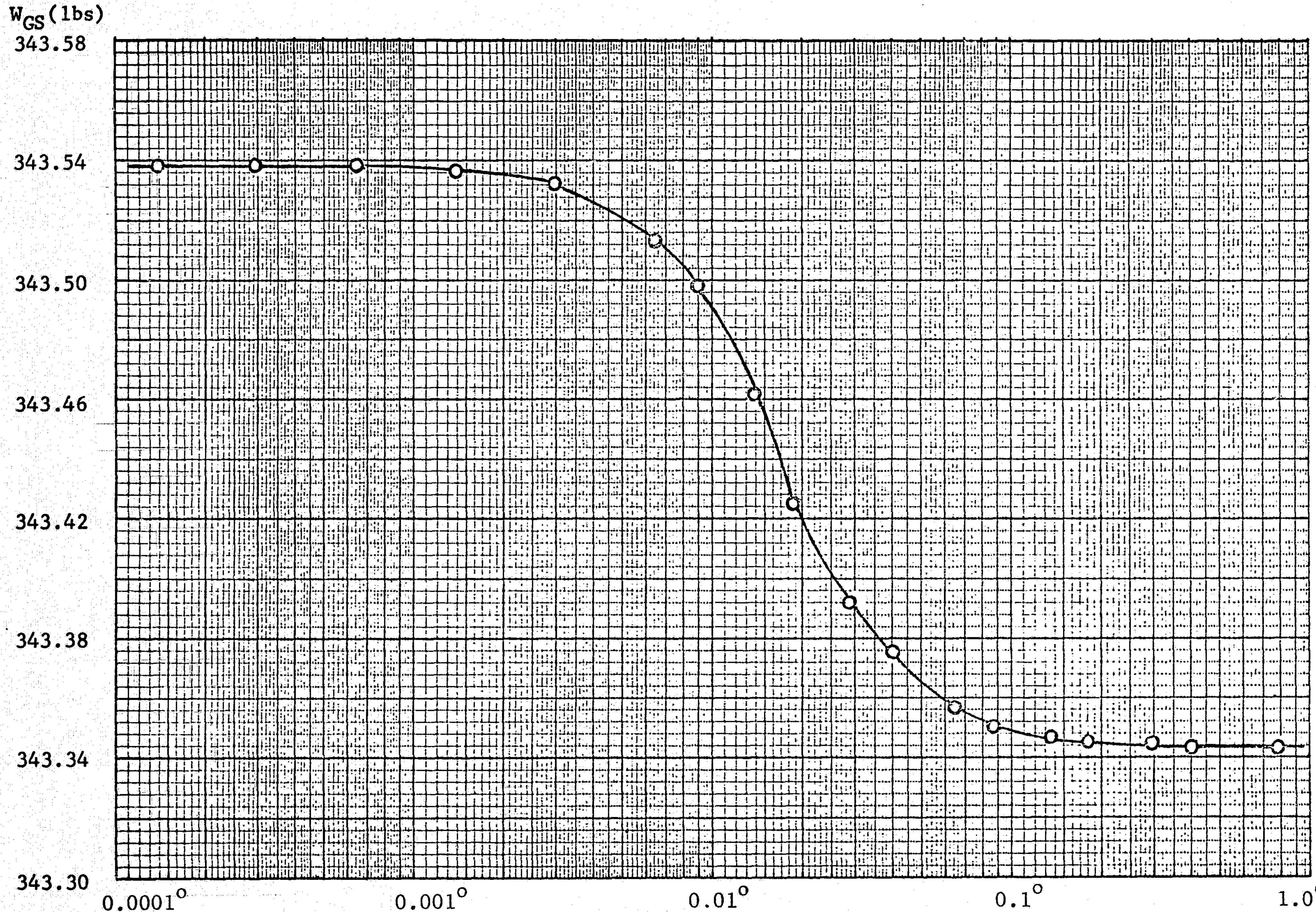

FIGURE 47 . PLOT OF PENALTY, W_{GS}, VERSUS STAR TRACKER POINTING ERROR

of this subsystem was performed. The evaluation considered the possibility of not using electro-optical sensors. The search for the optimum system is shown in Figure 48 and its effectiveness evaluation is shown in Figure 49. The optimum system consists of GG177 accelerometers, 18 IRIG-B gyroscopes, a SIGN III computer, and the strapdown star tracker and sun sensor used in the reference system. It is noteworthy that the optimum inertial sensors and computer found in the previous study (Reference 1) are identical to these. The penalty for the optimum system is 331.45 pounds compared to 343.46 pounds for the reference system.

Results for an Aided System with a Specified Strapdown ISU and Computer. Figure 50 presents the results of the evaluation of an aided system whose subsystems are the H-429 strapdown ISU, the SIGN III computer, the power supply for these two subsystems, and the electro-optical sensors and communications receiver considered in the evaluation of the reference system. The approximate increase of 26 pounds over the penalty of the reference system is primarily due to the increased weight of the electrical energy source.

Results for an Aided System with a Specified Gimballed ISU and Computer. The results of the evaluation of an aided system whose subsystems are the Centaur IMG platform, a conceptual Teledyne computer, and the electro-optical sensors and communications receiver considered in the evaluation of the reference system, are shown in Figure 51. The principal difference in the penalty, when compared to the reference system penalty, is the increased physical weight of the platform over that of the reference ISU. The required electrical energy is very nearly equal to that of the specified H-429 ISU and other subsystems shown in Figure 50.

Summary of Evaluations

Various systems were evaluated on both schedules 1 and 2. These evaluations are summarized in this section.

Horizon Sensors. During the early phases of the work covered by this report, the use of horizon sensors during the parking orbit of the reference mission was investigated. The results of this investigation are summarized in Table XVI. It should be noted that no weight has been added to the penalty for the weight of the horizon sensors and their contribution to the energy source weight. It can be seen that the state-of-the-art (0.2^{o}) horizon sensors would have to have less than 0.583 pounds combined weight (physical and energy source) to be effective. Perfect horizon sensors would be effective only if their combined weight was less than 6.77 pounds. These results are for Kalman filtering of the aid information when updating the inertial system. Simple updating would result in less improvement in penalty. It should also be noted

1 ACCELEROM. FROM 1 TO 4 IN 4 STEPS
2 ACCELEROM. FROM 1 TO 4 IN 4 STEPS
3 ACCELEROM. FROM 1 TO 4 IN 4 STEPS
4 GYROSCOPES FROM 1 TO 4 IN 4 STEPS
5 GYROSCOPES FROM 1 TO 4 IN 4 STEPS
6 GYROSCOPES FROM 1 TO 4 IN 4 STEPS
7 COMPUTERS FROM 1 TO 3 IN 3 STEPS

STEPS= 12288 FINITE ENUM., 41 DESCENT

COUNT	SYSTEM														SATURATION	PENALTY	MIN.PEN.
1	1	1	1	1	1	1	1	0	1	1	0	1	0	0		343.45929	*00000000.00000
	BETTER SYSTEM																
	ESTIMATED JOB TIME= 563 SEC.(9.4 MIN.)																
2	2	1	1	1	1	1	1	0	1	1	0	1	0	0		342.53903	343.45929
	BETTER SYSTEM																
3	3	1	1	1	1	1	1	0	1	1	0	1	0	0		349.36615	342.53903
4	4	1	1	1	1	1	1	0	1	1	0	1	0	0		344.82735	342.53903
5	2	2	1	1	1	1	1	0	1	1	0	1	0	0		341.47192	342.53903
	BETTER SYSTEM																
6	2	3	1	1	1	1	1	0	1	1	0	1	0	0		349.02259	341.47192
7	2	4	1	1	1	1	1	0	1	1	0	1	0	0		344.27293	341.47192
8	2	2	2	1	1	1	1	0	1	1	0	1	0	0		340.66387	341.47192
	BETTER SYSTEM																
9	2	2	3	1	1	1	1	0	1	1	0	1	0	0		348.20329	340.66387
10	2	2	4	1	1	1	1	0	1	1	0	1	0	0		343.52947	340.66387
11	2	2	2	2	1	1	1	0	1	1	0	1	0	0		341.88787	340.66387
12	2	2	2	3	1	1	1	0	1	1	0	1	0	0		339.15530	340.66387
	BETTER SYSTEM																
13	2	2	2	4	1	1	1	0	1	1	0	1	0	0		340.31197	339.15530
14	2	2	2	3	2	1	1	0	1	1	0	1	0	0		349.82060	339.15530
15	2	2	2	3	3	1	1	0	1	1	0	1	0	0		334.15162	339.15530
	BETTER SYSTEM																
16	2	2	2	3	4	1	1	0	1	1	0	1	0	0		338.85719	334.15162
17	2	2	2	3	3	2	1	0	1	1	0	1	0	0		335.73227	334.15162
18	2	2	2	3	3	3	1	0	1	1	0	1	0	0		331.67227	334.15162
	BETTER SYSTEM																
19	2	2	2	3	3	4	1	0	1	1	0	1	0	0		333.13335	331.67227
20	2	2	2	3	3	3	2	0	1	1	0	1	0	0		331.44713	331.67227
	BETTER SYSTEM																
21	2	2	2	3	3	3	3	0	1	1	0	1	0	0		359.81579	331.44713
22	1	2	2	3	3	3	2	0	1	1	0	1	0	0		332.57074	331.44713
23	3	2	2	3	3	3	2	0	1	1	0	1	0	0		339.07007	331.44713
24	4	2	2	3	3	3	2	0	1	1	0	1	0	0		334.17619	331.44713
25	2	1	2	3	3	3	2	0	1	1	0	1	0	0		332.69384	331.44713
26	2	3	2	3	3	3	2	0	1	1	0	1	0	0		339.08506	331.44713
27	2	4	2	3	3	3	2	0	1	1	0	1	0	0		334.28027	331.44713
28	2	2	1	3	3	3	2	0	1	1	0	1	0	0		332.40628	331.44713
29	2	2	3	3	3	3	2	0	1	1	0	1	0	0		339.03656	331.44713
30	2	2	4	3	3	3	2	0	1	1	0	1	0	0		334.32862	331.44713
31	2	2	2	1	3	3	2	0	1	1	0	1	0	0		333.10863	331.44713

FIGURE 48a. SEARCH FOR OPTIMUM MODE 3 SYSTEM ON SCHEDULE 1

32	2	2	2	2	3	3	2	0	1	1	0	1	0	0	335.12121	331.44713
33	2	2	2	4	3	3	2	0	1	1	0	1	0	0	332.68942	331.44713
34	2	2	2	3	1	3	2	0	1	1	0	1	0	0	337.76025	331.44713
35	2	2	2	3	2	3	2	0	1	1	0	1	0	0	350.77637	331.44713
36	2	2	2	3	4	3	2	0	1	1	0	1	0	0	336.72124	331.44713
37	2	2	2	3	3	1	2	0	1	1	0	1	0	0	333.90452	331.44713
38	2	2	2	3	3	2	2	0	1	1	0	1	0	0	335.47725	331.44713
39	2	2	2	3	3	4	2	0	1	1	0	1	0	0	332.88612	331.44713

OPTIMUM SYSTEM

2 2 2 3 3 3 2 0 1 1 0 1 0 0 PENALTY= 331.44713

ACTUAL TIME= 536 8.9

FIGURE 48b. SEARCH FOR OPTIMUM MODE 3 SYSTEM ON SCHEDULE 1 (Continued)

PENALTY (MODE 3)

ERROR ANALYSIS (SCHEDULE NO. 1)

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= 18-IRIG-B 18-IRIG-B 18-IRIG-B

ISU DATA(HORIZONTAL DESIGN NUMBER 5 OPTIMUM) ON TIME (HR)= 2.517

OUTSIDE DIMENSIONS		WEIGHT		WEIGHT			
LENGTH=	10.200	BLOCK=	5.407	INSULATION=	1.019	EXCIT.ENERGY=	108.001
WIDTH=	7.500	BASE=	3.540	ELECTRONICS=	10.000	EXCIT.POWER =	42.900
HEIGHT=	4.610	COVER=	2.171	COMPONENTS=	4.500	TOTAL P.FAIL=	.00062
						TOTAL WEIGHT=	26.637

ISU THERMAL ANALYSIS

MAX.HEATER POWER=	96.525	MAX.THERMAL COND.=	2.1450	TOTAL ENERGY=	174.274
MIN.HEATER POWER=	-.000	MIN.THERMAL COND.=	1.0725	TOTAL POWER =	139.425

SUBSYSTEM PARAMETERS

	COMPUTERS SIGN III	STAR TRCKR ITT-LUN.OB	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	2.517	10.849	10.849	0.000	9601.033	0.000	0.000		
ENERGY=	289.512	86.793	54.246	0.000	33603.617	0.000	0.000	TOTAL ENERGY=	34034.168
POWER=	115.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL POWER =	131.500
P.FAIL=	.00045	.00012	.00011	0.00000	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09216
WEIGHT=	27.000	7.000	2.000	0.000	3.100	0.000	0.000	TOTAL WEIGHT=	39.100

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 10.849

THRUST SIZING (LB)

	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)

	ROLL	YAW	PITCH
SEARCHING=	4.0598	2.3060	.0007
DEAD BAND=	.0001	.4445	.2560
MANEUVERS=	.2793	.1547	.1917
TOTAL IMP=	4.3392	2.9052	.4484

NO. OF FIRINGS= 22446 TOTAL IMPULSE= 7.6928 FUEL WEIGHT= .137372

TOTAL ENERGY= 108.492
TOTAL POWER = 10.000
TOTAL P.FAIL= .00278
TOTAL WEIGHT= 21.215

ENERGY SOURCE DATA

TOTAL POWER= 280.925 TOTAL ENERGY= 34316.934 TOTAL WEIGHT= 110.119

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 7.428 DOF=1.000 CAPABILITY= 13.953 TOTAL WEIGHT= 24.376

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.06051	ASTRIONICS=	331.447
EXCESSIVE TGT. MISS =	.00000	SPACECRAFT=	1668.553
UNRELIABILITY =	.09525	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 331.44713

EXECUTION TIMES, START=536.26, END=549.58, ELAPSED=13.316(SEC.)

FIGURE 49. MODE 3 EVALUATION OF OPTIMUM SYSTEM ON SCHEDULE 1

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= GG 334-A GG 334-A GG 334-A

ISU DATA ON TIME (HR)= 2.517

H-429 (STRAPDOWN) SPECIFIED

TOTAL ENERGY=	251.750
TOTAL POWER =	100.000
TOTAL P.FAIL=	.00126
TOTAL WEIGHT=	30.000

SUBSYSTEM PARAMETERS

	COMPUTERS SIGN III	STAR TRCKR ITT-LUN.08	SUN SENSOR ADCL-1402	ISU/C.P.S. H-429 SYS	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	2.517	10.849	10.849	2.517	9601.033	0.000	0.000		
ENERGY=	289.512	86.793	54.246	213.987	33603.617	0.000	0.000	TOTAL ENERGY=	34248.156
POWER=	115.000	8.000	5.000	85.000	3.500	0.000	0.000	TOTAL POWER =	216.500
P.FAIL=	.00045	.00012	.00011	.00025	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09239
WEIGHT=	27.000	7.000	2.000	14.250	3.100	0.000	0.000	TOTAL WEIGHT=	53.350

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 10.849

THRUST SIZING (LB)

	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)

	ROLL	YAW	PITCH
SEARCHING=	4.0585	2.3060	.0032
DEAD BAND=	.0001	.4445	.2560
MANEUVERS=	.2793	.1547	.1917
TOTAL IMP=	4.3379	2.9052	.4509

NO. OF FIRINGS= 22440 TOTAL IMPULSE= 7.6940 FUEL WEIGHT= .137393

TOTAL ENERGY=	108.492
TOTAL POWER =	10.000
TOTAL P.FAIL=	.00278
TOTAL WEIGHT=	21.215

ENERGY SOURCE DATA

TOTAL POWER= 326.500 TOTAL ENERGY= 34608.397 TOTAL WEIGHT= 125.842

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 15.975 DOF=1.000 CAPABILITY= 30.105 TOTAL WEIGHT= 29.085

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.05968	ASTRIONICS=	369.492
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1630.508
UNRELIABILITY =	.09606	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 369.49242

EXECUTION TIMES, START=836.33, END=864.60, ELAPSED=28.268(SEC.)

FIGURE 50. MODE 3, SCHEDULE 1, EVALUATION OF A SPECIFIED AIDED SYSTEM UTILIZING AN EXISTING STRAPDOWN ISU

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= GG-49 GG-49 GG-49

ISU DATA

ON TIME (HR)= 2.517

TOTAL ENERGY= 566.437
TOTAL POWER = 225.000
TOTAL P.FAIL= .00186
TOTAL WEIGHT= 80.000

CENT.IMG (GIMBALED) SPECIFIED

SUBSYSTEM PARAMETERS

	COMPUTERS TELEDYNE	STAR TRCKR ITT-LUN.OB	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE	
TIME=	2.517	10.849	10.849	0.000	9601.033	0.000	0.000
ENERGY=	176.225	86.793	54.246	0.000	33603.617	0.000	0.000
POWER=	70.000	8.000	5.000	0.000	3.500	0.000	0.000
P.FAIL=	.00050	.00012	.00011	0.00000	.09155	0.00000	0.00000
WEIGHT=	30.000	7.000	2.000	0.000	3.100	0.000	0.000

TOTAL ENERGY= 33920.881
TOTAL POWER = 86.500
TOTAL P.FAIL= .09221
TOTAL WEIGHT= 42.100

ATTITUDE CONTROL SYSTEM ANALYSIS

ON TIME (HR)= 10.849

THRUST SIZING (LB)

	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)

	ROLL	YAW	PITCH
SEARCHING=	4.0637	2.3089	0.0000
DEAD BAND=	.0001	.4445	.2560
MANEUVERS=	.2793	.1547	.1917
TOTAL IMP=	4.3431	2.9082	.4477

NO. OF FIRINGS= 22466 TOTAL IMPULSE= 7.6989 FUEL WEIGHT= .137481

TOTAL ENERGY= 108.492
TOTAL POWER = 10.000
TOTAL P.FAIL= .00279
TOTAL WEIGHT= 21.215

ENERGY SOURCE DATA

TOTAL POWER= 321.500 TOTAL ENERGY= 34595.810

TOTAL WEIGHT= 124.117

WIRING

TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 13.435 DOF=1.000 CAPABILITY= 25.357

TOTAL WEIGHT= 27.702

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.05929	ASTRIONICS=	405.134
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1594.866
UNRELIABILITY =	.09643	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 405.13426

EXECUTION TIMES, START=864.61, END=892.17, ELAPSED=27.564(SEC.)

FIGURE 51. MODE 3, SCHEDULE 1, EVALUATION OF A SPECIFIED AIDED SYSTEM UTILIZING A GIMBALLED PLATFORM

that the reference system inertial components were used in this evaluation. Because the Kalman filter weights depend on the hardware errors, less accurate hardware would perhaps make the state-of-the-art horizon sensors more attractive. Based upon the results in Table XVI, horizon sensors were not considered in subsequent system evaluations.

TABLE XVI. RESULTS OF EVALUATION OF HORIZON SENSORS FOR UPDATES IN THE PARKING ORBIT

Parking Orbit Update	Decrease in Penalty Assuming No Horizon Sensor Weight
None	None
State-of-the-art horizon sensors	0.583 lbs
Perfect horizon sensors	6.77 lbs
Perfect update of all errors	9.48 lbs

Systems Evaluated. Four principal systems were evaluated on mission schedule 1. Five variations of the reference system and one variation of the optimum system were also evaluated using mission schedule 1. The components which made up the ten systems evaluated using mission schedule 1 are listed in Table XVII.

The reference, system E, and the optimum system were evaluated using mission schedule 2. The results of all systems evaluated are shown in summary form in Table XVIII. The values shown for R_T were extracted from the level 2 evaluations, some of which are shown in Appendix B. The other information, R_V, W_{AC}, W_{DV}, and W_{GS}, is taken from the level 1 evaluations discussed in earlier sections of this report.

The variation denoted as System A shows a slight increase in the expected target miss, R_T, when compared to the value of R_T for the reference system. This increase has little effect on the penalty, since R is still much less than the target miss constraint of 78.09 x 10^6 feet. The increased drift of the pitch gyro also increases the expected midcourse ΔV, R_V, and hence the midcourse propulsion system weight W_{DV}. The improvement in attitude control system weight, W_{AC}, is due to the fact that the search strategy changes rotational axes of the search pattern as discussed in the Technical Discussion section of this report. The result of all these effects is a slight decrease in the penalty for the one percent increase in pitched gyro fixed drift as predicted in the sensitivity analysis.

TABLE XVII. DESCRIPTION OF SYSTEMS EVALUATED

System	Accelerometer	Gyro	Computer	Sun Sensor	Star Tracker	Com. Receiver
Reference	D-4E	GG 344A	SRT RUK-2	Adcole 1402	ITT Lunar Orbiter	MCR-503
A	Same as reference except pitch gyro R increased 1%.					
B	Same as reference except pitch gyro R increased 10%.					
C	Same as reference except sun sensor error is 0.0086°.					
D	Same as reference except sun sensor error is 4.0°.					
E	Same as reference except USBS-30 radar range rate error was 0.5 ft/sec.					
Optimum	GG 177	18-IRIG-B	SIGN III	Adcole 1402	ITT Lunar Orbiter	MCR-503
F	Same as optimum except USBS-30 radar range rate error was 0.5 ft/sec.					
H-429*	GG 177	G 334A	SIGN III	Adcole 1402	ITT Lunar Orbiter	MCR-503
Centaur IMG	GG 177	GG 49	Teledyne	Adcole 1402	ITT Lunar Orbiter	MCR-503

* The H-429 also requires an ISU/computer power supply.

TABLE XVIII. SUMMARY OF EVALUATIONS

System*	R_T (ft)	R_V (ft/sec)	W_{AC} (lbs)	W_{DV} (lbs)	W_{GS} (lbs)
		Schedule 1			
Reference	1.545×10^6	14.985	21.215	28.515	343.45989
A	1.556×10^6	15.096	21.159	28.516	343.40582
B	1.575×10^6	16.090	21.159	29.056	343.94578
C	1.512×10^6	15.088	21.215	28.571	343.51620
D	39.394×10^6	15.069	21.215	31.140	346.08498
E	5.490×10^6	14.984	21.215	28.514	343.45929
Optimum	1.899×10^6	7.430	21.215	24.377	331.44832
F	5.520×10^6	7.428	21.215	24.376	331.44713
H-429	1.818×10^6	15.975	21.215	29.085	369.49242
Centaur IMG	2.173×10^6	13.435	21.215	27.702	405.13426
		Schedule 2			
Reference	0.153×10^6	14.945	21.397	28.571	343.6977
E	---	14.944	21.397	28.570	343.69709
Optimum	0.255×10^6	7.386	21.397	24.392	331.64468

* Refer to Table XVII for system descriptions.

The system with the pitch gyro R increased by 10 percent, system B has a penalty larger than the reference system penalty because the R_T and R_V effects are greater than the improvement in W_{AC}.

The reference system with the improved sun sensor, system C, shows a decrease in R_T. However, since R_T is already very much less than the miss constraint, this has a negligible effect on the penalty. The improved state estimation using the improved sun sensor results in a larger expected midcourse ΔV, R_V, and a heavier midcourse correction propulsion system. The net result then for an improved sun sensor is an increase in the overall penalty, W_{GS}.

These results could imply that a system would be improved by deliberate degradation of sensor errors. In actual operation, however, the best state estimate possible should always be made. The increase in the penalty comes from correcting back to the nominal target location, even though a smaller correction would bring the target condition within the target miss constraint. Thus, partial midcourse corrections should be used when the accuracy is sufficient to give an expected target miss much less than the target miss constraint.

The reference system with the sun sensor error increased to 4 degrees, system D, results in R_T increasing to approximately half the target miss constraint. This increase in R_T is not negligible. The expected midcourse correction velocity, R_V, is very close to those values obtained with the other systems. However, the midcourse propulsion system must carry more fuel to ensure smaller probability of failure due to having insufficient midcourse fuel. This is necessary to compensate for the increased probability of missing the target due to excessive target miss. Thus, the overall penalty is increased for this system.

The reference system with degraded ground based radar, system E, has an increased R_T. The penalty, W_{GS}, is slightly less due to the less accurate state estimate which is reflected in a slightly smaller R_V and hence W_{DV}.

The optimum system has an overall penalty approximately 12 pounds less than the reference system. It is interesting to note that the expected target miss, R_T, is approximately 20 percent greater than R_T for the reference system. This expected miss is well within the miss constraint and so does not effect the penalty. This serves to emphasize the importance of selecting the proper miss constraint for the mission. The optimum system was also studied with a degraded ground based radar, system F, and increases similar to those obtained with degraded radar on the reference system are obtained.

The specified strapdown system, H-429, has an expected target miss similar to that obtained with the reference system but a slightly larger R_V. The overall penalty is higher, however, due to increased astrionics hardware weight, especially that of the electrical energy source computer power supply subsystem needed with this system. Similarly, the specified gimballed system, Centaur IMG, yields a much higher penalty due to the physical weight of the ISU.

Three of the systems discussed above were also evaluated using mission schedule 2. Schedule 2 includes a third midcourse 400 days into the mission or approximately 10 days prior to nominal perijove. As expected, the target miss is much less than that obtained with schedule 1. However, because the target misses obtained with schedule 1 are already well within the miss constraint, this gives very little improvement in the penalty. In fact, the net penalty is increased due to the increase in midcourse correction needed for the third midcourse and the weight of the attitude control system due to the necessity of stabilizing the spacecraft for the updates and the third midcourse correction.

CONCLUSIONS

An evaluation technique was developed for astrionics systems designed for interplanetary missions. This technique is useful for selection of astrionics subsystems, for evaluating astrionics mission operation schedule, as an aid in the preliminary design of conceptual subsystems, and in determining research needed to improve system performance.

The system parameters used in the evaluation technique can be estimated using techniques that are relatively unsophisticated but are of sufficient accuracy to accomplish the desired result.

These techniques were implemented in computer programs which were exercised on a Jupiter flyby mission. Results indicate that present day hardware, utilizing Kalman filtered updates, can provide the needed astrionics functions to accomplish a Jupiter flyby mission if the mission schedules used are acceptable to spacecraft designers.

To have any reasonable probability of mission success, $1 - P_{FG}$, it is necessary to turn certain astrionics subsystems off and on due to their relatively low reliabilities when operated on long (300 to 400 day) missions. This necessitates having the ability to reestablish the attitude reference by acquiring celestial bodies with electro-optical sensors and reestablish the direction cosines in the computer or realign the gimbals.

The influence of the mission schedule on the astrionics evaluation should not be overlooked. Earlier work with the reference system examined a schedule with two midcourse corrections, the first being made at 21 hours after launch and the second being made at 10 days (Reference 43). The schedules used in deriving the results presented in this report assumed the first midcourse correction was made at 10 hours and 31 minutes after launch. The subsequent midcourse corrections made on schedules 1 and 2 were very small compared to the magnitude of the first midcourse. The midcourse corrections reported in this report were about 60 percent of the magnitude of those involved in the earlier work. This is principally due to the fact that the earlier time of midcourse correction requires a smaller ΔV due to the injection errors propagation being smaller. This points out the need for making the first midcourse correction as soon as sufficient tracking data is available to establish the state. Subsequent midcourse corrections later in the mission are required to remove the errors induced during the earlier correction and meet the target accuracy requirements.

The system found to be optimum on the schedule and mission considered in this work has an ISU and computer identical to that found to be optimum in the unaided study (Reference 1).

RECOMMENDATIONS

The techniques developed, the computer programs implementing these techniques, and the results from exercising these computer programs on a Jupiter flyby mission lead to the following recommendations.

Investigation of the effects of switching on and off the various astrionics subsystems should be conducted. Items of concern include the reliability implications of the switching and the necessity to reestablish the direction cosine matrix in the digital computer for the case of the strapdown ISU.

Tradeoffs between alternate attitude control mechanizations should be made. This requires addition of alternate mechanizations, such as control moment gyroscopes, to the computer programs.

For the Jupiter flyby mission studied, a concentrated effort on reduction of system power requirements, and hence power source weight, is recommended. The direction to be followed in this research depends upon cost and other factors such as the likelihood of success of each research approach to power (or power source weight) reduction.

It is recommended that attention be directed toward improving the reliability of astrionics systems which might be used for a Jupiter flyby mission. This effort should consider not only improvement in the mean time to failure (MTTF) of the hardware, but also investigate reliability models for the astrionics systems and methods of testing to verify these models. As shown in the exercise cases previously discussed, an improvement in the MTTF of the astrionics system hardware must be made if the system is to operate continuously from launch, or the probability of mission failure attributable to astrionics must be relaxed.

Finally, the dearth of data required for evaluation of astrionics necessitates the recommendation that NASA/ERC establish a testing program for all candidate astrionics subsystems and components with the goal of gathering the needed data.

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APPENDIX A

CALCULATED MOMENTS OF INERTIA FOR NOMINAL SPACECRAFT

APPENDIX A

CALCULATED MOMENTS OF INERTIA FOR NOMINAL SPACECRAFT

This Appendix presents the calculations used in estimating the moments of inertia for the nominal spacecraft. The weights given in Reference A-1 for Design Concept D were used with the appropriate radii scaled from the drawing of Design Concept D. The principal moments of inertia were estimated for each subsystem of Design Concept D and summed for all subsystems to determine the estimated principal moments of inertia for Design Concept D. The moments of inertia of the nominal spacecraft were estimated by multiplying the principal moments of inertia of Design Concept D by the ratio of the weights of the nominal spacecraft and Design Concept D.

Inertias for Design Concept D

The moments of inertia about each of the three principal axes are shown in Tables A-1 through A-9 for each of the subsystems. Table A-10 presents the summation of the estimated moments of inertia about each of the three principal axes for spacecraft Design Concept D.

TABLE A-1. SCIENCE SUBSYSTEM

Instrument	Wt (lb)	Distance (ft) from Axis			I (lb-ft^2)		
		Roll	Pitch	Yaw	Roll	Pitch	Yaw
Extended Magnetometer	8.0	1.9	2.5 (est)	1.0 (est)	28.9	50.0	8.0
Energetic Particle Detector	2.5	1.5	1.2	1.9	5.6	3.6	9.0
Cosmic Dust Detector	2.5	3.7	4.0	1.5	34.2	40.0	5.6
Expanded Photometer	6.0	6.8	6.8	0.5	277.0	277.0	1.5
TV Camera (TV-II)	30.0	6.7	6.7	0.5	1350.0	1350.0	7.5
Plasma Probe	7.0	5.7	4.3	3.7	227.0	129.5	96.0
Microwave Radiometer	28.0	6.7	6.5	0.3	1258.0	1183.0	2.5
Infrared Radiometer	5.0	6.7	6.5	0.3	225.0	211.0	0.5
Ion Chamber	3.0	1.5	3.3	3.0	6.7	32.7	27.0
Infrafed Spectrometer	16.0	6.4	6.4	0.5	656.0	656.0	4.0
High Energy Proton Directional Monitor	4.0	2.1	1.2	2.3	17.7	5.8	21.2
Cosmic Ray Spectrum Analyzer	18.0	2.1	1.2	2.3	79.5	25.9	95.3
UV - Visible Spectrometer	20.0	6.3	6.4	0.3	795.0	820.0	1.8
Medium Energy Proton Directional Monitor	3.0	1.5	1.2	1.9	6.7	4.3	10.8
Bistatic Radar	15.0	6.6	6.6	0.2	653.0	653.0	0.6
Radio Noise Detector	5.0	6.4	6.5	1.0	205.0	211.0	5.0
Null Radio Seeker	5.0	6.6	6.6	0.2	218.0	218.0	0.2
Radar Altimeter	25.0	6.4	6.4	0	1025.0	1025.0	0
					7068.3	6895.8	296.5

TABLE A-2. COMMUNICATIONS SUBSYSTEM

Component	Wt (lb)	Distance (ft) from Axis Roll	Pitch	Yaw	I (lb-ft^2) Roll	Pitch	Yaw
Omni Antenna (2)		6.7	4.8	4.7	180.0	92.2	88.4
Parabolic Antenna	25	(K)*	5.0 (approx)	5.0 (approx)	306.5	625.0	625.0
Amplifier (2)	8						
Power Monitor (2)	2						
Circulator (6)	6						
Exciter (2)	10						
APC Receiver (2)	18						
Exciter Control	2						
Receiver Monitor	1						
Amplifier Control	2						
Power Supply, HV (2)	16						
Cabling, etc	4						
	69**	2.0	2.0	0.4 (K)	276.0	276.0	11.0
					762.5	993.2	724.4

* K = radius of gyration
** Assume these components on (+) yaw axis, 2 feet from roll and pitch axes.

TABLE A-3. DATA MANAGEMENT SUBSYSTEM

Weight = 90 Pounds

$$I_{Roll*} = 90\ (1)^2 = 90.0\ \text{lb-ft}^2$$

$$I_{Pitch*} = 90\ (1)^2 = 90.0\ \text{lb-ft}^2$$

$$I_{Yaw*} = 90\ (\tfrac{1}{2})^2 = 22.5\ \text{lb-ft}^2$$

TABLE A-4. SPACECRAFT CONTROL SUBSYSTEM

Component	Wt (lb)	Distance (ft) from Axis Roll	Pitch	Yaw	I (lb-ft^2) Roll	Pitch	Yaw
Fine Angle Sun Sensor	1	5.8	4.1	3.9	33.7	16.8	15.2
Coarse Sun Sensors (4)	4	5.7	4.2	3.9	130.0	70.6	60.8
Earth Sensor	6	5.7	3.9	3.9	195.0	91.3	91.3
Startrackers (4)	40	4.7	4.7	1.6	884.0	884.0	102.5
Jupiter Sensor	6	6.9	7.0	0.3	286.0	294.0	0.5
Computer	45*	2.0	2.0	0	180.0	180.0	0
Attitude Control Electronics	20*	2.0	2.0	0	80.0	80.0	0
Gyros (6)	6	0	0	0	Insignificant		
Accelerometer	1	0	0	0	Insignificant		
Jupiter Moon Tracker	6	6.9 (est)	7.0 (est)	0.3 (est)	286.0	294.0	0.5
					2074.7	1910.7	270.8

* Assumed on (-) yaw axis, 2 feet from roll and pitch axes.

TABLE A-5. ATTITUDE CONTROL PROPULSION SUBSYSTEM

Weight = 110 Pounds

For the jets:

$$I_{Roll*} = 4\,(6.0)^2 = 144 \text{ lb-ft}^2$$

$$I_{Pitch*} = 4\,(4.5)^2 = 81 \text{ lb-ft}^2$$

$$I_{Yaw*} = 4\,(4.5)^2 = 81 \text{ lb-ft}^2$$

* Assumed the gas jets (4 per axis at 1 lb/jet) to comprise 12 lbs of the total 110.

Note that the radii used are less than the radii used in the program for the thruster location. This will not significantly alter the total moments of inertia.

Assumed the remaining weight to lie on the pitch axis, and to have a radius of gyration of 1.5 ft for roll and yaw, and 1/2 ft for pitch. Then, for these remaining components,

$$I_{Roll} = 98\,(1.5)^2 = 220 \text{ lb-ft}^2$$

$$I_{Pitch} = 98\,(1/2)^2 = 24.5 \text{ lb-ft}^2$$

$$I_{Yaw} = 98\,(1.5)^2 = 220 \text{ lb-ft}^2$$

Total inertias are:

$$I_{Roll} = 144 + 220 = 364 \text{ lb-ft}^2$$

$$I_{Pitch} = 81 + 24.5 = 105.5 \text{ lb-ft}^2$$

$$I_{Yaw} = 81 + 220 = 301 \text{ lb-ft}^2$$

TABLE A-6. MIDCOURSE PROPULSION SUBSYSTEM

Weight = 105.6 Pounds

I_{Roll*}	=	$105.6\ (1/2)^2$	=	26.4 $lb\text{-}ft^2$
I_{Pitch*}	=	$105.6\ (1.3)^2$	=	178.5 $lb\text{-}ft^2$
I_{Yaw*}	=	$105.6\ (1.3)^2$	=	178.5 $lb\text{-}ft^2$

* Located on roll axis, with radius of gyration of 1.3 ft for pitch and yaw, and 1/2 ft for roll.

TABLE A-7. ELECTRICAL POWER SUBSYSTEM

Weight of RTG's (4) = 264 Pounds

Remaining Components = 173 Pounds

Total = 437

For the RTG's

$$I_{Roll} = 264\ (6.7)^2 = 11{,}850\ \text{lb-ft}^2$$

$$I_{Pitch} = 264\ (0.57)^2 = 86\ \text{lb-ft}^2$$

$$I_{Yaw} = 264\ (6.7)^2 = 11{,}850\ \text{lb-ft}^2$$

For the remaining components, assumed location on the yaw axis, with radius of gyration of 3 ft for roll and pitch, and 1/2 ft for yaw.

$$I_{Roll} = 173\ (3)^2 = 1560\ \text{lb-ft}^2$$

$$I_{Pitch} = 173\ (3)^2 = 1560\ \text{lb-ft}^2$$

$$I_{Yaw} = 173\ (\tfrac{1}{2})^2 = 42\ \text{lb-ft}^2$$

Total inertias are:

$$I_{Roll} = 11{,}850 + 1560 = 13{,}410\ \text{lb-ft}^2$$

$$I_{Pitch} = 86 + 1560 = 1{,}646\ \text{lb-ft}^2$$

$$I_{Yaw} = 11{,}850 + 42 = 11{,}892\ \text{lb-ft}^2$$

TABLE A-8. STRUCTURAL/MECHANICAL AND METEOROID PROTECTION SUBSYSTEM

Weight = 375 Pounds

Assumed the following radii of gyration:

$$K_{Roll} = \frac{11.3}{\sqrt{12}} = 3.27 \text{ ft}$$

K_{Pitch} = 3.27 for half of weight and 1 for other half

K_{Yaw} = 3.27 for half of weight and 1 for other half

Therefore,

$$I_{Roll} = 375\ (3.27)^2 = 4000 \text{ lb-ft}^2$$

$$I_{Pitch} = 187.5\ (3.27)^2 + 187.5\ (1)^2 = 2208 \text{ lb-ft}^2$$

$$I_{Yaw} = 187.5\ (3.27)^2 + 187.5\ (1)^2 = 2208 \text{ lb-ft}^2$$

TABLE A-9. THERMAL CONTROL SUBSYSTEM

Weight = 27 Pounds

Assumed the following radii of gyration:

$$K_{Roll} = 3.3 \text{ ft}$$

$$K_{Pitch} = 3.3 \text{ ft}$$

$$K_{Yaw} = 0.8 \text{ ft}$$

Therefore,

$$I_{Roll} = 27\ (3.3)^2 = 294 \text{ lb-ft}^2$$

$$I_{Pitch} = 27\ (3.3)^2 = 294 \text{ lb-ft}^2$$

$$I_{Yaw} = 27\ (0.8)^2 = 17.3 \text{ lb-ft}^2$$

TABLE A-10. SUMMATION OF INERTIAS

I_{Roll}	I_{Pitch}	I_{Yaw}
7,068	6,896	296
762	993	724
90	90	22
2,075	1,911	271
364	106	301
26	178	178
13,410	1,646	11,892
4,000	2,208	2,208
294	294	17
28,089 $lb\text{-}ft^2$	14,322 $lb\text{-}ft^2$	15,909 $lb\text{-}ft^2$

Adjustment to Heavier (2000 lb) Spacecraft

The weight of the "D" - concept craft is 1581 pounds. For a 2000 pound craft, the values were adjusted as follows and converted to mass units.

$$I_{Roll} = \frac{28{,}089}{32.2} \times \frac{2000}{1581} = 1100 \text{ slug-ft}^2$$

$$I_{Pitch} = \frac{14{,}322}{32.2} \times \frac{2000}{1581} = 563 \text{ slug-ft}^2$$

$$I_{Yaw} = \frac{15{,}909}{32.2} \times \frac{2000}{1581} = 625 \text{ slug-ft}^2$$

<u>REFERENCES</u>

(A-1) "A Study of Jupiter Flyby Missions, Final Technical Report", General Dynamics, Fort Worth Division, FZM-4625, May 17, 1966.

APPENDIX B

LEVEL 2 EVALUATIONS

APPENDIX B

LEVEL 2 EVALUATIONS

Level 2 evaluations of the systems discussed in the body of this report are shown in this Appendix. Figure B-1, the level 2 evaluation of the reference system on schedule 1, will be discussed in detail. The other level 2 evaluations have a similar format.

The level 2 evaluation begins at the instant of launch from which all subsequent mission operations are timed. The top of Figure B-1a indicates the penalty, mode 3, and related error analysis are for mission schedule 1. Repeated blocks of information describe the state of the system and the errors for various mission operations. Lines of astericks separate the information describing the system at a point in time and the information describing the transition of the system from one time to another.

The information between the first lines of astericks describe the state of the system as the vehicle sits on the launch pad. The altitude, expressed in feet, of the vehicle is essentially zero, and the inertial velocity, expressed in feet per second, is that due to rotation of the Earth. The angle between the position and velocity vectors is then 90° and the latitude and longitude are 28.5° and -80.5°, respectively. Perfect alignment of the system is assumed, so all computed deviations, deviations, and errors are zero as shown. At time equal zero, the communication subsystem is turned on and the subsystems are operating as shown by the subsystem and status lines of the printout (1 = ON, 0 = OFF). At the end of this operation, the computed deviations, deviations, and errors are still zero.

The vehicle requires 565 seconds of stage action time to achieve the 100 NM parking orbit. The errors incurred during the launch are propagated through a coast of 935 seconds in the parking orbit. The second block of information is printed while the vehicle is in the parking orbit, as indicated by the word "PARK". The time from launch is equal to 25 minutes, 0 seconds (denoted as OD OH 25M 0.00S). The altitude, velocity, angle, latitude, and longitude of the ground track are shown.

At this point the position and velocity deviations and errors are equal since no updates have been performed. The computed deviations are equal to zero. Notice, however, that there are attitude computed deviations, expressed in radians, equal to the attitude control subsystem dead zone width. At this point it should again be emphasized that the attitude control subsystem operation during park assumes that thrusters attached to the launch vehicle are used for stabilization. Thus, spacecraft attitude control unit fuel consumption and thruster sizing while in the parking orbit are not considered in the penalty evaluation.

At this point in time, a ground based radar update is made using the Ascension Island TPQ-18 radar. The measurement information is printed as shown. The range is 2.87×10^6 feet. The range rate is 1.525×10^4 units and the vehicle is at an azimuth of 73° and elevation of 8.3° with respect to the tracking radar. The sun angle is 111.6°. The sun angle is printed to ensure that the sun does not lie between the earth and the spacecraft when updates are made later in the mission. The inertial system errors, expressed in terms of range, elevation, azimuth, and range dot, are then printed, followed by the TPQ-18 measurement errors. It should be noted that the TPQ-18 radar has an indicated range rate error of zero. This does not imply perfect measurement, but rather an unmeasured measurement component. The range measurement is two orders of magnitude better than the inertial system range information, while elevation and azimuth are approximately 1 order of magnitude better. The error information in the form of computed deviations, deviations, and errors after the Kalman update are then printed. Since an update has been made, computed deviations do exist. Note that the errors have also decreased by approximately one order of magnitude in position and velocity. A slight decrease is noted in attitude error. The decrease in attitude error since attitude is unmeasured, is due to correlation effects in the Kalman filter.

After the update, the vehicle continues in the parking orbit for 81.3 seconds. The second or injection burn of 941.5 seconds duration is made, and the burn errors are added to error analysis. A very short coast of 0.2 seconds occurs before the next block of information is printed.

Forty-two minutes, three seconds, into the mission, the spacecraft separates from the launch vehicle and from this point on the attitude of the spacecraft is indicated by three direction cosine matrices. These direction cosine matrices relate the three axes systems, inertial, local, and body. At this point, the attitude control system is turned on and the deadbands are set to 20°. The star tracker and sun sensor are then turned on, and the maneuvering to locate the sun and Canopus is begun. Nine hundred seconds is then allowed for maneuvering to require the nominal locations of the sun and Canopus. During this 900 seconds, the deadbands are set to 20, 8, and 20°, as shown. This setting of the deadbands is automatic to insure that the optical sensors will be able to keep the celestial bodies within the fields of view. This coasting flight, due to translation of the spacecraft around the sun and orientation maneuvering, requires pitching 124.6°, yawing -70°, and rolling 59.86°. After these maneuvers, the searching for the sun and Canopus is begun as indicated at the top of Figure B-1c. Sixty seconds is allowed for searching with the deadbands set as indicated. The times for searching for the sun and Canopus are prorated as discussed in the Technical Discussion section of this report. In this case, 35.4 seconds is allocated to search for the sun and 24.6 seconds to search for Canopus. The attitude rates for the search are very small as shown by the small pitch rate required. This very small maneuvering is required because prior to the search the attitude errors are very small. Later searches, with larger initial errors, show significant rates in roll and yaw.

From this point in the mission until some maneuver which requires losing the track on the celestial bodies, the spacecraft will be oriented with the electro-optical sensors locked on the celestial bodies. The fact that the sensors are locked on the sun and Canopus are indicated by the words "CANOPUS ACQUIRED" printed beside the direction cosine matrices describing the attitude.

Detailed description of the flight continues for the entire schedule with the final conditions shown on Figure B-1i, when the spacecraft arrives at the target, 410 days, 10 hours, 4 minutes, 2 seconds into the mission. At this point, the deviations in cross range position represent the perijove error and are used as the RMS target miss, R_T, needed by the penalty analysis. In addition the program keeps track of the operating times of the various subsystems in seconds as shown in Figure B-1j.

The error analysis also computes the total midcourse correction ΔV requirements in terms of degrees of freedom and RMS values as well as the various attitude control subsystem sizing and fuel consumption parameters.

The mode 3 penalty evaluation for this system on schedule 1 is repeated in Figure B-1k for comparison.

The remaining figures in this Appendix describe in a similar fashion the optimum system on schedule 1 and other systems as shown in the Table of Contents.

```
                              PENALTY (MODE 3)

     ERROR ANALYSIS (SCHEDULE NO. 1)

     LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   AT    0D 0H 0M 0.00S
     T=          0  ALT= -4.7683716E-07  VEL=  2.3196861E+02  ANG=    90.000  LAT=    28.5000  LONG=   -80.5000
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
            COMP. DEV.  0.            0.            0.            0.            0.            0.            0.            0.            0.
            DEVIATIONS  0.            0.            0.            0.            0.            0.            0.            0.            0.
             ERRORS     0.            0.            0.            0.            0.            0.            0.            0.            0.
        SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
          STATUS      1          1          0          0          0          1          0          0          0          0
     COM. SYST. TURNED ON
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
            COMP. DEV.  0.            0.            0.            0.            0.            0.            0.            0.            0.
            DEVIATIONS  0.            0.            0.            0.            0.            0.            0.            0.            0.
             ERRORS     0.            0.            0.            0.            0.            0.            0.            0.            0.

     LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  BURN FOR     565.000 SEC.
  ADD BURN ERRORS
  PARK  FOR       935.00 SEC.   (  0D 0H15M35.00S)

     PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   AT    0D 0H25M 0.00S
     T=       1500  ALT=  6.0761100E+05  VEL=  2.4239262E+04  ANG=    90.000  LAT=    -5.7054  LONG=    -7.0921
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
            COMP. DEV.  0.            0.            0.            0.            0.            0.            2.272E-04     2.272E-04     2.272E-04
            DEVIATIONS  6.777E+03     4.031E+03     3.324E+03     9.338E+00     1.489E+00     6.281E-01     1.558E-04     4.086E-04     2.207E-04
             ERRORS     6.777E+03     4.031E+03     3.324E+03     9.338E+00     1.489E+00     6.281E-01     2.643E-04     4.610E-04     4.034E-04
        SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
          STATUS      1          1          0          0          0          1          1          0          0          0

             STATION       RANGE          RANGE DOT          AZM       ELE.     SUN ANG.
            ASCENSION   2.8752678E+06  1.5257582E+04    73.154      8.373    111.615
              MEASUREMENT ERRORS      RANGE          ELEVATION          AZIMUTH          RANGE DOT
                 INERTIAL SYSTEM     4.082872E+03    1.794594E-03    1.902463E-03    6.163322E+00
                     TPQ-18          6.700000E+01    4.500000E-04    4.500000E-04   -0.
     AFTER KALMAN UPDATE
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
            COMP. DEV.  6.712E+03     3.965E+03     3.252E+03     9.219E+00     1.296E+00     5.573E-01     2.462E-04     3.176E-04     2.778E-04
            DEVIATIONS  6.777E+03     4.031E+03     3.324E+03     9.338E+00     1.489E+00     6.281E-01     1.558E-04     4.086E-04     2.207E-04
             ERRORS     9.306E+02     7.242E+02     6.844E+02     1.487E+00     7.328E-01     2.897E-01     2.552E-04     3.404E-04     3.160E-04

     PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  PARK  FOR       81.30 SEC.   (  0D 0H 1M21.30S)
  BURN FOR     941.500 SEC.
  ADD BURN ERRORS
  COAST FOR         .20 SEC.   (  0D 0H 0M   .20S)
```

FIGURE B-1a. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION

```
ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D 0H42M 3.00S
 T=        2523  ALT=  1.2568513E+07  VEL=  4.7908635E+04  ANG=     42.609  LAT=  -28.4248  LONG=   47.9456
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  0.          0.          0.          0.          0.          0.          4.951E-08   4.951E-08   4.951E-08
          DEVIATIONS  4.240E+03   5.712E+03   5.037E+03   4.763E+00   1.316E+01   1.043E+01   6.082E-04   5.063E-04   5.513E-04
          ERRORS      4.240E+03   5.712E+03   5.037E+03   4.763E+00   1.316E+01   1.043E+01   6.082E-04   5.063E-04   5.513E-04

          ATTITUDE         ROLL     YAW      PITCH          DR       CR       OP            ROLL     YAW      PITCH
                      XI  -.1872   -.9823    .0083    XI   -.1872   -.9823    .0083    DR  1.0000   -.0000    .0000
                      YI  -.8845    .1722    .4335    YI   -.8846    .1722    .4335    CR   .0000   1.0000   -.0000
                      ZI  -.4272    .0738   -.9011    ZI   -.4272    .0738   -.9011    OP  -.0000    .0000   1.0000

    SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS       1         1          0          0          0          1          1          0          0          0
   ATT. CONT. TURNED ON
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  0.          0.          0.          0.          0.          0.          7.125E-03   7.125E-03   7.125E-03
          DEVIATIONS  4.240E+03   5.712E+03   5.037E+03   4.763E+00   1.316E+01   1.043E+01   7.151E-03   7.143E-03   7.147E-03
           ERRORS     4.240E+03   5.712E+03   5.037E+03   4.763E+00   1.316E+01   1.043E+01   6.082E-04   5.063E-04   5.513E-04
   DEADBAND ON AXIS  1 CHANGED TO   20.00000 DEG.
   DEADBAND ON AXIS  2 CHANGED TO   20.00000 DEG.
   DEADBAND ON AXIS  3 CHANGED TO   20.00000 DEG.
   STAR TRCKR TURNED ON
   SUN SENSOR TURNED ON
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  0.          0.          0.          0.          0.          0.          1.425E-01   1.425E-01   1.425E-01
          DEVIATIONS  4.240E+03   5.712E+03   5.037E+03   4.763E+00   1.316E+01   1.043E+01   1.425E-01   1.425E-01   1.425E-01
           ERRORS     4.240E+03   5.712E+03   5.037E+03   4.763E+00   1.316E+01   1.043E+01   6.082E-04   5.063E-04   5.513E-04

          BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

   ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 COAST FOR      900.00 SEC.  (  0D 0H15M 0.00S)

             ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

             DEAD BANDS    SET     MAX.
                   ROLL   20.00   64.00
                    YAW    8.00    8.00
                  PITCH   20.00   28.68
          MANEUVERS
                  PITCH 124.634DEG.   YAW -70.015DEG.  ROLL   59.862DEG. IN       900SEC.

   ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D 0H57M 3.00S
 T=        3423  ALT=  4.8308954E+07  VEL=  4.3313231E+04  ANG=     16.593  LAT=  -29.7368  LONG=   74.2506
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  0.         -1.726E-04   0.         -3.372E-07   0.          0.          1.418E-01   7.036E-02   1.372E-01
          DEVIATIONS  8.623E+03   1.749E+04   1.407E+04   5.137E+00   1.333E+01   9.884E+00   1.418E-01   7.036E-02   1.372E-01
          ERRORS      8.623E+03   1.749E+04   1.407E+04   5.137E+00   1.333E+01   9.884E+00   5.945E-04   4.459E-04   6.271E-04
```

FIGURE B-1b. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2321	.9305	-.2834	XI	-.1224	-.9924	.0083	DR	-.2123	.1112	.9709
	YI	.6276	-.0793	-.7745	YI	-.8939	.1138	.4335	CR	.2679	-.9488	.1673
	ZI	-.7431	-.3576	-.5656	ZI	-.4312	.0456	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.32, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.68

MANEUVERS

PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

SEARCH FOR SUN IN 35.4 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL 0.00000 ,YAW 0.00000 ,PITCH -.00002

SEARCH FOR CANOPUS IN 24.6 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL 0.00000 ,YAW 0.00000 ,PITCH -.00002

ESCAPE *

AT 0D 0H58M 3.00S

T= 3483 ALT= 5.0840061E+07 VEL= 4.3117281E+04 ANG= 15.672 LAT= -29.6689 LONG= 74.9188

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.950E+03	1.218E+04	1.207E+04	1.113E+00	8.783E+00	7.984E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	8.921E+03	1.828E+04	1.466E+04	5.150E+00	1.337E+01	9.865E+00	1.417E-01	7.042E-02	1.372E-01
ERRORS	8.721E+03	1.394E+04	8.968E+03	5.031E+00	1.027E+01	6.176E+00	2.041E-04	2.078E-04	4.096E-04

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2321	.9305	-.2834	XI	-.1202	-.9927	.0083	DR	-.2128	.1133	.9705
	YI	.6276	-.0793	-.7745	YI	-.8942	.1119	.4335	CR	.2674	-.9486	.1694
	ZI	-.7431	-.3576	-.5656	ZI	-.4313	.0447	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END SEARCH FOR SUN-CANOPUS

COMPUTER TURNED OFF
I. S. U. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.950E+03	1.218E+04	1.207E+04	1.113E+00	8.783E+00	7.984E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	8.921E+03	1.828E+04	1.466E+04	5.150E+00	1.337E+01	9.865E+00	1.417E-01	7.042E-02	1.372E-01

FIGURE B-1c. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ERRORS	8.721E+03	1.394E+04	8.968E+03	5.031E+00	1.027E+01	6.176E+00	2.041E-04	2.078E-04	4.096E-04

ESCAPE *

COAST FOR 32517.00 SEC. (0D 9H 1M57.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.21, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.79

MANEUVERS

PITCH -.053DEG. YAW -.094DEG. ROLL -.515DEG. IN 32517SEC.

TRACKING STAR NO. 2

ESCAPE *

AT 0D10H 0M 0.00S

T= 36000 ALT= 1.3681588E+09 VEL= 9.8762677E+04 ANG= 66.018 LAT= -25.6796 LONG= -36.9497

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.876E+04	3.234E+05	2.585E+05	1.510E+00	9.723E+00	7.542E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.762E+05	5.023E+05	3.306E+05	5.160E+00	1.516E+01	9.730E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.693E+05	3.903E+05	2.157E+05	4.935E+00	1.181E+01	6.412E+00	2.496E-04	2.696E-04	6.885E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2334	.9328	-.2746	XI	-.0997	-.9950	.0082	DR	-.2168	.1239	.9683
YI	.6264	-.0718	-.7762	YI	-.8963	.0934	.4335	CR	.2641	-.9475	.1804
ZI	-.7437	-.3532	-.5676	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1727

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	1	1	1	0	1	0	0	0

COMPUTER TURNED ON

I. S. U. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.876E+04	3.234E+05	2.585E+05	1.510E+00	9.723E+00	7.542E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.762E+05	5.023E+05	3.306E+05	5.160E+00	1.516E+01	9.730E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.693E+05	3.903E+05	2.157E+05	4.935E+00	1.181E+01	6.412E+00	2.496E-04	2.696E-04	6.885E-04

ESCAPE *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.80

MANEUVERS

PITCH -.003DEG. YAW -.005DEG. ROLL -.028DEG. IN 1800SEC.

ESCAPE *

AT 0D10H30M 0.00S

T= 37800 ALT= 1.4404029E+09 VEL= 1.0315087E+05 ANG= 67.105 LAT= -25.6632 LONG= -44.3869

FIGURE B-1d. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  5.147E+04   3.409E+05   2.721E+05   1.511E+00   9.727E+00   7.541E+00   1.416E-01   7.065E-02   1.372E-01
          DEVIATIONS  1.855E+05   5.296E+05   3.481E+05   5.160E+00   1.517E+01   9.731E+00   1.416E-01   7.065E-02   1.372E-01
           ERRORS     1.782E+05   4.115E+05   2.272E+05   4.934E+00   1.181E+01   6.414E+00   5.037E-04   5.139E-04   8.157E-04

            ATTITUDE          ROLL     YAW    PITCH          DR       CR        OP          ROLL     YAW     PITCH
 CANOPUS    ACQUIRED      XI  -.2335   .9329  -.2741   XI  -.0997   -.9950   .0082   DR  -.2168   .1234   .9684
                          YI   .6264  -.0713  -.7763   YI  -.8963    .0934   .4335   CR   .2641  -.9476   .1799
                          ZI  -.7438  -.3529  -.5677   ZI  -.4321    .0358  -.9011   OP   .9398   .2948   .1728

      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS      1          1          1          1          1          1          1          0          0          0
    DEADBAND ON AXIS  1 CHANGED TO      .10000 DEG.
    DEADBAND ON AXIS  2 CHANGED TO      .10000 DEG.
    DEADBAND ON AXIS  3 CHANGED TO      .10000 DEG.

          STATION        RANGE          RANGE DOT          AZM        ELE.      SUN ANG.
          ASCENSION  1.4439360E+09  4.0809058E+04  -125.447      55.969     80.860
            MEASUREMENT ERRORS      RANGE         ELEVATION        AZIMUTH        RANGE DOT
               INERTIAL SYSTEM    1.826899E+05   2.946660E-04   1.356025E-04   2.240125E+01
                    USBS-30       6.700000E+01   1.780000E-03   1.780000E-03   1.240000E-01
    AFTER KALMAN UPDATE
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  1.855E+05   5.243E+05   2.994E+05   5.160E+00   1.501E+01   8.369E+00   7.125E-04   7.125E-04   7.125E-04
          DEVIATIONS  1.855E+05   5.296E+05   3.481E+05   5.160E+00   1.517E+01   9.731E+00   7.978E-04   8.773E-04   1.081E-03
           ERRORS     1.814E+03   5.570E+04   1.909E+05   5.262E-03   1.681E+00   5.320E+00   3.590E-04   5.118E-04   8.127E-04

    ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 COAST FOR      60.00 SEC.  (  0D 0H 1M 0.00S)

             ANGLE BETWEEN CELESTIAL BODIES=  97.20, BETWEEN OPTICAL AIDS=   90.00

             DEAD BANDS   SET    MAX.
                  ROLL    .10   64.00
                   YAW    .10    8.00
                 PITCH    .10   28.80
          MANEUVERS
                 PITCH    -.000DEG.   YAW    -.000DEG.  ROLL    -.001DEG. IN       60SEC.

    ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   AT   0D10H31M 0.00S
    T=      37860  ALT=  1.4428110E+09  VEL=  1.0329770E+05  ANG=     67.140  LAT=  -25.6627  LONG=  -44.6349
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  1.858E+05   5.252E+05   2.999E+05   5.160E+00   1.501E+01   8.369E+00   7.125E-04   7.125E-04   7.125E-04
          DEVIATIONS  1.858E+05   5.305E+05   3.487E+05   5.160E+00   1.517E+01   9.731E+00   8.007E-04   8.846E-04   1.087E-03
           ERRORS     1.814E+03   5.580E+04   1.912E+05   5.264E-03   1.681E+00   5.320E+00   3.654E-04   5.242E-04   8.205E-04

            ATTITUDE          ROLL     YAW    PITCH          DR       CR        OP          ROLL     YAW     PITCH
 CANOPUS    ACQUIRED      XI  -.2335   .9329  -.2741   XI  -.0997   -.9950   .0082   DR  -.2168   .1234   .9684
                          YI   .6264  -.0713  -.7763   YI  -.8963    .0934   .4335   CR   .2641  -.9476   .1799
                          ZI  -.7438  -.3529  -.5677   ZI  -.4321    .0358  -.9011   OP   .9398   .2948   .1728

      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS      1          1          1          1          1          1          1          0          0          0
```

FIGURE B-1e. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

AFTER MIDCOURSE CORRECTION, RMV= 1.493423E+01 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.858E+05	5.252E+05	2.999E+05	5.491E+00	4.217E+00	7.230E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.858E+05	5.305E+05	3.487E+05	5.491E+00	4.632E+00	8.696E+00	8.007E-04	8.846E-04	1.087E-03
ERRORS	1.814E+03	5.580E+04	1.912E+05	1.516E-02	1.681E+00	5.320E+00	3.654E-04	5.242E-04	8.205E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.858E+05	5.252E+05	2.999E+05	5.491E+00	4.217E+00	7.230E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.858E+05	5.305E+05	3.487E+05	5.491E+00	4.632E+00	8.696E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.814E+03	5.580E+04	1.912E+05	1.516E-02	1.681E+00	5.320E+00	7.854E-01	7.854E-01	7.854E-01

ESCAPE *

COAST FOR 34522140.00 SEC. (399D13H29M 0.00S)

TARGET CT. *

AT 400D 0H 0M 0.00S
T= 34560000 ALT= 2.6049048E+12 VEL= 1.8816539E+08 ANG= 90.010 LAT= -6.5116 LONG= 155.7267

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.564E+08	1.713E+07	1.172E+08	1.034E+00	2.982E+00	1.031E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	2.313E+00	1.471E+01	5.900E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	4.520E+07	2.096E+08	1.511E+08	2.057E+00	1.459E+01	5.871E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2335	.9329	-.2741	XI	.1881	.1202	.9748	DR	-.3299	.3738	.8669
YI	.6264	-.0713	-.7763	YI	-.9062	.4039	.1251	CR	.8994	.4034	.1683
ZI	-.7438	-.3529	-.5677	ZI	-.3787	-.9069	.1849	OP	-.2868	.8352	-.4693

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	0	0	0	0	1	0	0	0

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.564E+08	1.713E+07	1.172E+08	1.034E+00	2.982E+00	1.031E+00	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	2.313E+00	1.471E+01	5.900E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	4.520E+07	2.096E+08	1.511E+08	2.057E+00	1.459E+01	5.871E+00	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

```
               ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS  SET    MAX.
                    ROLL  20.00  64.00
                     YAW   8.00   8.00
                   PITCH  20.00  22.66
           MANEUVERS
                   PITCH   5.360DEG.   YAW   5.335DEG.  ROLL-133.476DEG. IN      1800SEC.

      TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    AT 400D 0H30M 0.00S
      T=  34561800  ALT=  2.6048474E+12  VEL=  1.8816163E+08  ANG=    90.010  LAT=   -6.5106  LONG=  148.2286
                            P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
           COMP. DEV.  1.564E+08  1.713E+07  1.172E+08  1.028E+00  2.987E+00  1.028E+00  8.357E-02  1.324E-01  1.391E-01
           DEVIATIONS  1.611E+08  2.093E+08  1.850E+08  2.317E+00  1.473E+01  5.904E+00  7.854E-01  7.854E-01  7.854E-01
            ERRORS     4.520E+07  2.096E+08  1.511E+08  2.065E+00  1.461E+01  5.875E+00  7.854E-01  7.854E-01  7.854E-01

            ATTITUDE         ROLL     YAW     PITCH          DR       CR       OP           ROLL     YAW    PITCH
                         XI  -.1192   -.4462   .8869    XI   .1881    .1202    .9748   DR  -.3728   -.8838  -.2827
                         YI   .6864    .6084   .3983    YI  -.9062    .4039    .1251   CR   .9135   -.4031   .0555
                         ZI  -.7173    .6563   .2338    ZI  -.3787   -.9069    .1849   OP  -.1630   -.2375   .9576

        SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
          STATUS      1          1          1          1          1          1          1          0          0          0

           END MANEUVERING.BEGIN SEARCH FOR SUN-CANOPUS

      TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   COAST FOR       60.00 SEC.  (  0D 0H 1M 0.00S)

               ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS  SET    MAX.
                    ROLL  20.00  64.00
                     YAW   8.00   8.00
                   PITCH  20.00  22.66
           MANEUVERS
                   PITCH    .000DEG.   YAW    .000DEG.  ROLL    -.000DEG. IN          60SEC.

           SEARCH FOR SUN        IN    30.4 SECONDS WITH   1.00000 PASSES
                              ANGULAR RATES (RAD/SEC)=ROLL      .02583      ,YAW     0.00000     ,PITCH  0.00000

           SEARCH FOR CANOPUS    IN    29.6 SECONDS WITH   1.00000 PASSES
                              ANGULAR RATES (RAD/SEC)=ROLL      .00000      ,YAW      .02583     ,PITCH  0.00000

      TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    AT 400D 0H31M 0.00S
      T=  34561860  ALT=  2.6048455E+12  VEL=  1.8816150E+08  ANG=    90.010  LAT=   -6.5106  LONG=  147.9787
                            P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
```

FIGURE B-1g. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

COMP. DEV.	1.564E+08	1.713E+07	1.172E+08	1.027E+00	2.987E+00	1.028E+00	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	2.317E+00	1.473E+01	5.904E+00	8.357E-02	1.324E-01	1.391E-01
ERRORS	4.520E+07	2.096E+08	1.511E+08	2.065E+00	1.461E+01	5.875E+00	2.829E-04	7.055E-04	2.322E-04

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4462	.8869	XI	.1881	.1202	.9748	DR	-.3728	-.8838	-.2827
	YI	.6864	.6084	.3983	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
	ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END SEARCH FOR SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.66

MANEUVERS

PITCH .000DEG. YAW .000DEG. ROLL -.001DEG. IN 1800SEC.

TARGET CT. *

AT 400D 1H 1M 0.00S

T= 34563660 ALT= 2.6047888E+12 VEL= 1.8815780E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.4806

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.564E+08	1.713E+07	1.172E+08	1.011E+00	3.000E+00	1.019E+00	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	2.329E+00	1.479E+01	5.912E+00	8.357E-02	1.324E-01	1.391E-01
ERRORS	4.519E+07	2.096E+08	1.511E+08	2.088E+00	1.467E+01	5.884E+00	5.331E-04	8.378E-04	5.080E-04

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
	YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
	ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
CANBERRA	2.6047916E+12	-3.1699020E+04	-17.455	60.115	68.370

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	1.574114E+08	4.430884E-05	6.729072E-05	1.434203E+04
DSIF	-0.	-0.	-0.	4.100000E-02

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.611E+08	2.093E+08	1.850E+08	2.329E+00	1.479E+01	5.912E+00	7.125E-04	7.125E-04	7.125E-04

FIGURE B-1h. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	2.329E+00	1.479E+01	5.912E+00	8.564E-04	1.090E-03	8.716E-04
ERRORS	3.436E+05	7.887E+05	7.895E+05	7.574E-03	3.480E-02	1.546E-02	4.751E-04	8.245E-04	5.020E-04

TARGET CT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	22.66

MANEUVERS

PITCH .000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

TARGET CT. *

AT 400D 1H 2M 0.00S

T= 34563720 ALT= 2.6047869E+12 VEL= 1.8815768E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.2307

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.611E+08	2.093E+08	1.850E+08	2.329E+00	1.480E+01	5.912E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	2.329E+00	1.480E+01	5.912E+00	8.620E-04	1.095E-03	8.791E-04
ERRORS	3.436E+05	7.887E+05	7.895E+05	7.574E-03	3.480E-02	1.546E-02	4.852E-04	8.317E-04	5.148E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

AFTER MIDCOURSE CORRECTION, RMV= 1.232863E+00 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.611E+08	2.093E+08	1.850E+08	3.176E+00	1.405E+01	5.585E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	3.176E+00	1.405E+01	5.585E+00	8.620E-04	1.095E-03	8.791E-04
ERRORS	3.436E+05	7.887E+05	7.895E+05	7.633E-03	3.479E-02	1.552E-02	4.852E-04	8.317E-04	5.148E-04

ATT. CONT. TURNED OFF
COMPUTER TURNED OFF
I. S. U. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF
COM. SYST. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.611E+08	2.093E+08	1.850E+08	3.176E+00	1.405E+01	5.585E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.611E+08	2.093E+08	1.850E+08	3.176E+00	1.405E+01	5.585E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	3.436E+05	7.887E+05	7.895E+05	7.633E-03	3.479E-02	1.552E-02	7.854E-01	7.854E-01	7.854E-01

TARGET CT. *

COAST FOR 896522.00 SEC. (10D 9H 2M 2.00S)

TARGET CT. *

FIGURE B-1i. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

AT 410D10H 4M 2.00S
T= 35460242 ALT= 2.5764392E+12 VEL= 1.8630775E+08 ANG= 90.006 LAT= -6.0886 LONG= 5.4976

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.589E+08	-8.086E+01	2.231E+08	2.260E+04	3.064E+04	5.965E+03	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	5.589E+08	1.545E+06	2.231E+08	2.260E+04	3.064E+04	5.965E+03	7.854E-01	7.854E-01	7.854E-01
ERRORS	2.810E+05	1.545E+06	1.053E+06	8.949E+00	2.428E+01	3.611E+01	7.854E-01	7.854E-01	7.854E-01

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4463	.8869	XI	.1142	.1908	.9750	DR	-.7448	-.6072	-.2768
	YI	.6864	.6084	.3984	YI	-.9909	-.0483	.1256	CR	.6474	-.7580	-.0792
	ZI	-.7173	.6563	.2338	ZI	.0710	-.9804	.1836	OP	-.1617	-.2382	.9577

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	-0	-0	-0	0	-0	0	0	0

TARGET MISS, RMS= 1.54468766E+06, DOF=1.000

COMPUTER	9063.00 SEC.
I. S. U.	9063.00 SEC.
ATT. CONT.	39057.00 SEC.
STAR TRCKR	39057.00 SEC.
SUN SENSOR	39057.00 SEC.
ISU/C.P.S.	9063.00 SEC.
COM. SYST.	34563720.00 SEC.
HORIZ.SEN.	0.00 SEC.

FIGURE B-1j. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ISU COMPONENTS

ACCELEROM.=	ARMA D-4E	ARMA D-4E	ARMA D-4E	GYROSCOPES=	GG 334-A	GG 334-A	GG 334-A

ISU DATA(HORIZONTAL DESIGN NUMBER 4 OPTIMUM) ON TIME (HR)= 2.517

OUTSIDE DIMENSIONS		WEIGHT		WEIGHT			
LENGTH=	9.350	BLOCK=	8.703	INSULATION=	1.345	EXCIT.ENERGY=	109.511
WIDTH=	10.450	BASE=	4.549	ELECTRONICS=	10.000	EXCIT.POWER =	43.500
HEIGHT=	5.450	COVER=	2.867	COMPONENTS=	6.000	TOTAL P.FAIL=	.00063
						TOTAL WEIGHT=	33.463

ISU THERMAL ANALYSIS

MAX.HEATER POWER=	97.875	MAX.THERMAL COND.=	2.1750	TOTAL ENERGY=	176.711
MIN.HEATER POWER=	-.000	MIN.THERMAL COND.=	1.0875	TOTAL POWER =	141.375

SUBSYSTEM PARAMETERS

	COMPUTERS SKT RUK-2	STAR TRCKR ITT-LUN.08	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	2.517	10.849	10.849	0.000	9601.033	0.000	0.000		
ENERGY=	226.575	86.793	54.246	0.000	33603.617	0.000	0.000	TOTAL ENERGY=	33971.231
POWER=	90.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL POWER =	106.500
P.FAIL=	.00042	.00012	.00011	0.00000	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09213
WEIGHT=	36.000	7.000	2.000	0.000	3.100	0.000	0.000	TOTAL WEIGHT=	48.100

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 10.849

THRUST SIZING (LB)

	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)

	ROLL	YAW	PITCH		
SEARCHING=	4.0585	2.3060	.0031		
DEAD BAND=	.0001	.4445	.2560		
MANEUVERS=	.2793	.1547	.1917	TOTAL ENERGY=	108.492
TOTAL IMP=	4.3379	2.9052	.4508	TOTAL POWER =	10.000
				TOTAL P.FAIL=	.00278

NO. OF FIRINGS= 22440 TOTAL IMPULSE= 7.6940 FUEL WEIGHT= .137393 TOTAL WEIGHT= 21.215

ENERGY SOURCE DATA

TOTAL POWER= 257.875 TOTAL ENERGY= 34256.434 TOTAL WEIGHT= 102.167

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 14.985 DOF=1.000 CAPABILITY= 28.147 TOTAL WEIGHT= 28.515

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.06053	ASTRIONICS=	343.460
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1656.540
UNRELIABILITY =	.09523	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 343.45989

EXECUTION TIMES, START= 23.03, END= 51.35, ELAPSED=28.322(SEC.)

FIGURE B-1k. REFERENCE SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

PENALTY (MODE 3)

```
ERROR ANALYSIS (SCHEDULE NO. 1)

LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT   0D 0H 0M 0.00S
T=          0  ALT= -4.7683716E-07  VEL=  2.3196861E+02  ANG=    90.000  LAT=   28.5000  LONG=  -80.5000
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
   COMP. DEV.   0.          0.          0.          0.          0.          0.          0.          0.          0.
   DEVIATIONS   0.          0.          0.          0.          0.          0.          0.          0.          0.
   ERRORS       0.          0.          0.          0.          0.          0.          0.          0.          0.
 SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
   STATUS       1          1          0          0          0          1          0          0          0          0
COM. SYST. TURNED ON
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
   COMP. DEV.   0.          0.          0.          0.          0.          0.          0.          0.          0.
   DEVIATIONS   0.          0.          0.          0.          0.          0.          0.          0.          0.
   ERRORS       0.          0.          0.          0.          0.          0.          0.          0.          0.

LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

BURN FOR     565.000 SEC.
ADD BURN ERRORS
PARK  FOR       935.00 SEC.   (  0D 0H15M35.00S)

PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT   0D 0H25M 0.00S
T=       1500  ALT=  6.0761100E+05  VEL=  2.4239262E+04  ANG=    90.000  LAT=   -5.7054  LONG=   -7.0921
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
   COMP. DEV.   0.          0.          0.          0.          0.          0.          9.064E-05   9.064E-05   9.064E-05
   DEVIATIONS   8.686E+03   6.062E+03   2.556E+03   1.306E+01   4.388E+00   3.151E-01   6.681E-05   1.316E-04   2.397E-04
   ERRORS       8.686E+03   6.062E+03   2.556E+03   1.306E+01   4.388E+00   3.151E-01   1.082E-04   1.567E-04   2.749E-04
 SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
   STATUS       1          1          0          0          0          1          1          0          0          0

   STATION       RANGE          RANGE DOT        AZM        ELE.      SUN ANG.
   ASCENSION   2.8752678E+06  1.5257582E+04    73.154      8.373     111.615
     MEASUREMENT ERRORS       RANGE          ELEVATION       AZIMUTH        RANGE DOT
        INERTIAL SYSTEM    4.575809E+03    2.556166E-03    2.300783E-03   8.262418E+00
            TPQ-18         6.700000E+01    4.500000E-04    4.500000E-04   -0.
AFTER KALMAN UPDATE
                      P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
   COMP. DEV.   8.636E+03   5.953E+03   2.422E+03   1.292E+01   4.076E+00   2.728E-01   9.322E-05   9.383E-05   2.267E-04
   DEVIATIONS   8.686E+03   6.062E+03   2.556E+03   1.306E+01   4.388E+00   3.151E-01   6.681E-05   1.316E-04   2.397E-04
   ERRORS       9.307E+02   1.142E+03   8.181E+02   1.938E+00   1.624E+00   1.576E-01   1.070E-04   1.505E-04   1.687E-04

PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

PARK  FOR        81.30 SEC.   (  0D 0H 1M21.30S)
BURN FOR    941.500 SEC.
ADD BURN ERRORS
COAST FOR          .20 SEC.   (  0D 0H 0M   .20S)
```

FIGURE B-2a. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION

ESCAPE *

AT 0D 0H42M 3.00S

T= 2523 ALT= 1.2568513E+07 VEL= 4.7908635E+04 ANG= 42.609 LAT= -28.4248 LONG= 47.9456

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	-3.453E-04	0.	-6.104E-05	-3.372E-07	0.	0.	1.975E-08	1.975E-08	1.975E-08
DEVIATIONS	4.356E+03	2.958E+03	2.787E+03	5.330E+00	5.816E+00	5.319E+00	2.171E-04	2.262E-04	2.533E-04
ERRORS	4.356E+03	2.958E+03	2.787E+03	5.330E+00	5.816E+00	5.319E+00	2.171E-04	2.262E-04	2.533E-04

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1872	-.9823	.0083	XI	-.1872	-.9823	.0083	DR	1.0000	-.0000	.0000
	YI	-.8845	.1722	.4335	YI	-.8846	.1722	.4335	CR	.0000	1.0000	-.0000
	ZI	-.4272	.0738	-.9011	ZI	-.4272	.0738	-.9011	OP	-.0000	.0000	1.0000

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	0	0	0	1	1	0	0	0

ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	-3.453E-04	0.	-6.104E-05	-3.372E-07	0.	0.	7.125E-03	7.125E-03	7.125E-03
DEVIATIONS	4.356E+03	2.958E+03	2.787E+03	5.330E+00	5.816E+00	5.319E+00	7.129E-03	7.129E-03	7.130E-03
ERRORS	4.356E+03	2.958E+03	2.787E+03	5.330E+00	5.816E+00	5.319E+00	2.171E-04	2.262E-04	2.533E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
STAR TRCKR TURNED ON
SUN SENSOR TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	-3.453E-04	0.	-6.104E-05	-3.372E-07	0.	0.	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	4.356E+03	2.958E+03	2.787E+03	5.330E+00	5.816E+00	5.319E+00	1.425E-01	1.425E-01	1.425E-01
ERRORS	4.356E+03	2.958E+03	2.787E+03	5.330E+00	5.816E+00	5.319E+00	2.171E-04	2.262E-04	2.533E-04

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

ESCAPE *

COAST FOR 900.00 SEC. (0D 0H15M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.32, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.68

MANEUVERS

PITCH 124.634DEG. YAW -70.015DEG. ROLL 59.862DEG. IN 900SEC.

ESCAPE *

AT 0D 0H57M 3.00S

T= 3423 ALT= 4.8308954E+07 VEL= 4.3313231E+04 ANG= 16.593 LAT= -29.7368 LONG= 74.2506

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	0.	-8.632E-05	0.	0.	0.	0.	1.418E-01	7.036E-02	1.372E-01
DEVIATIONS	9.306E+03	7.829E+03	7.364E+03	5.597E+00	5.908E+00	5.085E+00	1.418E-01	7.036E-02	1.372E-01
ERRORS	9.306E+03	7.829E+03	7.364E+03	5.597E+00	5.908E+00	5.085E+00	2.120E-04	1.916E-04	2.809E-04

FIGURE B-2b. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2321	.9305	-.2834	XI	-.1224	-.9924	.0083	DR	-.2123	.1112	.9709
YI	.6276	-.0793	-.7745	YI	-.8939	.1138	.4335	CR	.2679	-.9488	.1673
ZI	-.7431	-.3576	-.5656	ZI	-.4312	.0456	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM.	SYST.	HORIZ.SEN.
STATUS	1	1	1	1	1	1	1	0	0	0

END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.32, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.68

MANEUVERS
PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

SEARCH FOR SUN IN 31.4 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL .00001 ,YAW 0.00000 ,PITCH 0.00000

SEARCH FOR CANOPUS IN 28.6 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL 0.00000 ,YAW 0.00000 ,PITCH -.00001

ESCAPE *

AT 0D 0H58M 3.06S
T= 3483 ALT= 5.0840061E+07 VEL= 4.3117281E+04 ANG= 15.672 LAT= -29.6689 LONG= 74.9188

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	6.163E+02	3.559E+03	3.895E+03	2.969E-01	2.575E+00	2.533E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	9.640E+03	8.171E+03	7.669E+03	5.596E+00	5.927E+00	5.077E+00	1.417E-01	7.042E-02	1.372E-01
ERRORS	9.622E+03	7.429E+03	6.656E+03	5.589E+00	5.390E+00	4.429E+00	1.441E-04	1.411E-04	2.325E-04

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2321	.9305	-.2834	XI	-.1202	-.9927	.0083	DR	-.2128	.1133	.9705
	YI	.6276	-.0793	-.7745	YI	-.8942	.1119	.4335	CR	.2674	-.9486	.1694
	ZI	-.7431	-.3576	-.5656	ZI	-.4313	.0447	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM.	SYST.	HORIZ.SEN.
STATUS	1	1	1	1	1	1	1	0	0	0

END SEARCH FOR SUN-CANOPUS

COMPUTER TURNED OFF
I. S. U. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.163E+02	3.559E+03	3.895E+03	2.969E-01	2.575E+00	2.533E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	9.640E+03	8.171E+03	7.669E+03	5.596E+00	5.927E+00	5.077E+00	1.417E-01	7.042E-02	1.372E-01

FIGURE B-2c. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
          ERRORS     9.622E+03  7.429E+03  6.656E+03  5.589E+00  5.390E+00  4.429E+00  1.441E-04  1.411E-04  2.325E-04

      ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  COAST FOR     32517.00 SEC.   (   0D 9H 1M57.00S)

                 ANGLE BETWEEN CELESTIAL BODIES=   97.21, BETWEEN OPTICAL AIDS=   90.00

                 DEAD BANDS    SET     MAX.
                       ROLL  20.00   64.00
                        YAW   8.00    8.00
                      PITCH  20.00   28.79
            MANEUVERS
                      PITCH  -.053DEG.    YAW    -.094DEG.  ROLL    -.515DEG. IN     32517SEC.
            TRACKING STAR NO.    2

      ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    AT    0D10H 0M 0.00S
      T=      36000  ALT=  1.3681588E+09  VEL=  9.8762677E+04  ANG=     66.018  LAT=  -25.6796  LONG=  -36.9497
                            P-DR       P-CR       P-OP        V-DR       V-CR       V-OP        A-DR       A-CR       A-OP
            COMP. DEV.   1.205E+04  9.249E+04  8.016E+04  3.701E-01  2.769E+00  2.323E+00  1.416E-01  7.067E-02  1.372E-01
            DEVIATIONS   1.835E+05  2.249E+05  1.709E+05  5.309E+00  6.808E+00  5.027E+00  1.416E-01  7.067E-02  1.372E-01
             ERRORS      1.831E+05  2.066E+05  1.516E+05  5.296E+00  6.267E+00  4.475E+00  2.496E-04  2.696E-04  6.835E-04

              ATTITUDE          ROLL     YAW    PITCH          DR      CR        OP            ROLL     YAW     PITCH
  CANOPUS     ACQUIRED       XI  -.2334   .9328  -.2746   XI  -.0997  -.9950   .0082   DR  -.2168   .1239   .9683
                             YI   .6264  -.0718  -.7762   YI  -.8963   .0934   .4335   CR   .2641  -.9475   .1804
                             ZI  -.7437  -.3532  -.5676   ZI  -.4321   .0358  -.9011   OP   .9398   .2948   .1727

         SUBSYSTEM  COMPUTER   I. S. U.    ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
           STATUS      -0          -0          1          1          1          0          1          0          0          0
      COMPUTER    TURNED ON
      I. S. U.    TURNED ON
                            P-DR       P-CR       P-OP        V-DR       V-CR       V-OP        A-DR       A-CR       A-OP
            COMP. DEV.   1.205E+04  9.249E+04  8.016E+04  3.701E-01  2.769E+00  2.323E+00  1.416E-01  7.067E-02  1.372E-01
            DEVIATIONS   1.835E+05  2.249E+05  1.709E+05  5.309E+00  6.808E+00  5.027E+00  1.416E-01  7.067E-02  1.372E-01
             ERRORS      1.831E+05  2.066E+05  1.516E+05  5.296E+00  6.267E+00  4.475E+00  2.496E-04  2.696E-04  6.885E-04

      ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  COAST FOR     1800.00 SEC.   (   0D 0H30M 0.00S)

                 ANGLE BETWEEN CELESTIAL BODIES=   97.20, BETWEEN OPTICAL AIDS=   90.00

                 DEAD BANDS    SET     MAX.
                       ROLL  20.00   64.00
                        YAW   8.00    8.00
                      PITCH  20.00   28.80
            MANEUVERS
                      PITCH   -.003DEG.    YAW    -.005DEG.  ROLL    -.028DEG.  IN      1800SEC.

      ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    AT    0D10H30M 0.00S
      T=      37800  ALT=  1.4404029E+09  VEL=  1.0315087E+05  ANG=     67.105  LAT=  -25.6632  LONG=  -44.3869
```

FIGURE B-2d. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.272E+04	9.747E+04	8.434E+04	3.702E-01	2.770E+00	2.323E+00	1.416E-01	7.065E-02	1.372E-01
DEVIATIONS	1.931E+05	2.372E+05	1.799E+05	5.307E+00	6.812E+00	5.027E+00	1.416E-01	7.065E-02	1.372E-01
ERRORS	1.927E+05	2.179E+05	1.596E+05	5.294E+00	6.270E+00	4.475E+00	3.045E-04	3.212E-04	7.103E-04

CANOPUS	ATTITUDE ACQUIRED	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
	YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
	ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
ASCENSION	1.4439360E+09	4.0809058E+04	-125.447	55.969	80.860

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	1.947298E+05	1.568034E-04	1.001109E-04	1.228915E+01
USBS-30	6.700000E+01	1.780000E-03	1.780000E-03	1.240000E-01

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.931E+05	2.330E+05	1.121E+05	5.307E+00	6.682E+00	3.149E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.931E+05	2.372E+05	1.799E+05	5.307E+00	6.812E+00	5.027E+00	7.598E-04	7.815E-04	1.006E-03
ERRORS	1.346E+03	4.132E+04	1.416E+05	2.126E-02	1.245E+00	3.941E+00	2.637E-04	3.209E-04	7.103E-04

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	28.80

MANEUVERS

PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

ESCAPE *

AT 0D10H31M 0.00S

T= 37860 ALT= 1.4428110E+09 VEL= 1.0329770E+05 ANG= 67.140 LAT= -25.6627 LONG= -44.6349

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.334E+05	1.122E+05	5.307E+00	6.682E+00	3.149E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	5.307E+00	6.812E+00	5.027E+00	7.601E-04	7.828E-04	1.007E-03
ERRORS	1.346E+03	4.139E+04	1.419E+05	2.126E-02	1.245E+00	3.941E+00	2.647E-04	3.241E-04	7.117E-04

CANOPUS	ATTITUDE ACQUIRED	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
	YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
	ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

FIGURE B-2e. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

AFTER MIDCOURSE CORRECTION. RMV= 7.373560E+00 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.334E+05	1.122E+05	3.949E+00	2.567E+00	2.544E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	3.949E+00	2.864E+00	4.656E+00	7.601E-04	7.828E-04	1.007E-03
ERRORS	1.346E+03	4.139E+04	1.419E+05	2.603E-02	1.245E+00	3.940E+00	2.647E-04	3.241E-04	7.117E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.334E+05	1.122E+05	3.949E+00	2.567E+00	2.544E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	3.949E+00	2.864E+00	4.656E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.346E+03	4.139E+04	1.419E+05	2.603E-02	1.245E+00	3.940E+00	7.854E-01	7.854E-01	7.854E-01

ESCAPE *

COAST FOR 34522140.00 SEC. (399D13H29M 0.00S)

TARGET CT. *

AT 400D 0H 0M 0.00S
T= 34560000 ALT= 2.6049048E+12 VEL= 1.8816539E+08 ANG= 90.010 LAT= -6.5116 LONG= 155.7267

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.132E+08	1.166E+07	4.779E+07	6.974E-01	1.007E+00	3.435E-01	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.178E+08	1.554E+08	1.210E+08	1.678E+00	1.083E+01	4.355E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	3.342E+07	1.551E+08	1.119E+08	1.523E+00	1.080E+01	4.346E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2335	.9329	-.2741	XI	.1881	.1202	.9748	DR	-.3299	.3738	.8669
	YI	.6264	-.0713	-.7763	YI	-.9062	.4039	.1251	CR	.8994	.4034	.1683
	ZI	-.7438	-.3529	-.5677	ZI	-.3787	-.9069	.1849	OP	-.2868	.8352	-.4693

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	0	0	0	0	1	0	0	0

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.132E+08	1.166E+07	4.779E+07	6.974E-01	1.007E+00	3.435E-01	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	1.178E+08	1.554E+08	1.210E+08	1.678E+00	1.083E+01	4.355E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	3.342E+07	1.551E+08	1.119E+08	1.523E+00	1.080E+01	4.346E+00	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

FIGURE B-2f. OPTIMUM SYSTEM ON SCHEDULE 1 LEVEL 2 EVALUATION (Continued)

```
ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

DEAD BANDS   SET     MAX.
      ROLL  20.00   64.00
       YAW   8.00    8.00
     PITCH  20.00   22.66
MANEUVERS
     PITCH    5.360DEG.   YAW    5.335DEG.  ROLL-133.476DEG. IN      1800SEC.

TARGET CI. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT 400D 0H30M 0.00S
  T=  34561800  ALT=  2.0048474E+12   VEL=  1.8816163E+08   ANG=    90.010  LAT=    -6.5106   LONG=  148.2286
                       P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV.  1.132E+08   1.166E+07   4.780E+07   6.925E-01   1.008E+00   3.421E-01   8.357E-02   1.324E-01   1.391E-01
        DEVIATIONS  1.178E+08   1.555E+08   1.210E+08   1.681E+00   1.085E+01   4.357E+00   7.854E-01   7.854E-01   7.854E-01
         ERRORS     3.341E+07   1.551E+08   1.119E+08   1.529E+00   1.082E+01   4.349E+00   7.854E-01   7.854E-01   7.854E-01

        ATTITUDE        ROLL      YAW     PITCH          DR       CR       OP           ROLL      YAW      PITCH
                  XI   -.1192   -.4462    .8869    XI    .1881    .1202    .9748    DR  -.3728   -.8838   -.2827
                  YI    .6864    .6084    .3983    YI   -.9062    .4039    .1251    CR   .9135   -.4031    .0555
                  ZI   -.7173    .6563    .2338    ZI   -.3787   -.9069    .1849    OP  -.1630   -.2375    .9576

   SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
    STATUS       1          1          1          1          1          1          1          0          0          0

      END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

TARGET CI. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
COAST FOR        60.00 SEC.  (  0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

DEAD BANDS   SET     MAX.
      ROLL  20.00   64.00
       YAW   8.00    8.00
     PITCH  20.00   22.66
MANEUVERS
     PITCH    .000DEG.    YAW     .000DEG.  ROLL    -.000DEG. IN        60SEC.

SEARCH FOR SUN         IN    30.4 SECONDS WITH   1.00000 PASSES
              ANGULAR RATES (RAD/SEC)=ROLL      .02583      ,YAW     0.00000      ,PITCH  0.00000

SEARCH FOR CANOPUS     IN    29.6 SECONDS WITH   1.00000 PASSES
              ANGULAR RATES (RAD/SEC)=ROLL      .00000      ,YAW      .02583      ,PITCH  0.00000

TARGET CI. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
AT 400D 0H31M 0.00S
  T=  34561860  ALT=  2.6048455E+12   VEL=  1.8816150E+08   ANG=    90.010  LAT=    -6.5106   LONG=  147.9787
                       P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
```

FIGURE B-2g. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
        COMP. DEV.   1.132E+08  1.166E+07  4.780E+07  6.923E-01  1.008E+00  3.421E-01  8.357E-02  1.324E-01  1.391E-01
        DEVIATIONS   1.178E+08  1.555E+08  1.210E+08  1.681E+00  1.085E+01  4.357E+00  8.357E-02  1.324E-01  1.391E-01
         ERRORS      3.341E+07  1.551E+08  1.119E+08  1.529E+00  1.082E+01  4.349E+00  2.826E-04  7.053E-04  2.318E-04

           ATTITUDE        ROLL     YAW     PITCH        DR      CR      OP          ROLL     YAW     PITCH
CANOPUS    ACQUIRED    XI  -.1192  -.4462   .8869   XI   .1881   .1202   .9748   DR  -.3728  -.8838  -.2827
                       YI   .6864   .6084  -.3983   YI  -.9062   .4039   .1251   CR   .9135  -.4031   .0555
                       ZI  -.7173   .6563   .2338   ZI  -.3787  -.9069   .1849   OP  -.1630  -.2375   .9576

     SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS       1         1         1          1          1          1          1         0         0         0

        END SEARCH FOR SUN-CANOPUS

    TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR      1800.00 SEC.  (  0D 0H30M 0.00S)

           ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

           DEAD BANDS   SET    MAX.
                 ROLL  20.00  64.00
                  YAW   8.00   8.00
                PITCH  20.00  22.66
        MANEUVERS
                PITCH    .000DEG.   YAW    .000DEG.  ROLL   -.001DEG. IN     1800SEC.

    TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT 400D 1H 1M 0.00S
    T=  34563660  ALT=  2.6047888E+12  VEL=  1.8815780E+08  ANG=    90.010  LAT=   -6.5096  LONG=  140.4806
                        P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
        COMP. DEV.   1.132E+08  1.166E+07  4.780E+07  6.783E-01  1.012E+00  3.381E-01  8.357E-02  1.324E-01  1.391E-01
        DEVIATIONS   1.178E+08  1.555E+08  1.210E+08  1.691E+00  1.089E+01  4.364E+00  8.357E-02  1.324E-01  1.391E-01
         ERRORS      3.341E+07  1.552E+08  1.119E+08  1.546E+00  1.086E+01  4.356E+00  3.352E-04  7.280E-04  2.936E-04

           ATTITUDE        ROLL     YAW     PITCH        DR      CR      OP          ROLL     YAW     PITCH
CANOPUS    ACQUIRED    XI  -.1192  -.4463   .8869   XI   .1881   .1202   .9748   DR  -.3729  -.8838  -.2827
                       YI   .6864   .6084   .3984   YI  -.9062   .4039   .1251   CR   .9135  -.4031   .0555
                       ZI  -.7173   .6563   .2338   ZI  -.3787  -.9069   .1849   OP  -.1630  -.2375   .9576

     SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS       1         1         1          1          1          1          1         0         0         0
    DEADBAND ON AXIS  1 CHANGED TO     .10000 DEG.
    DEADBAND ON AXIS  2 CHANGED TO     .10000 DEG.
    DEADBAND ON AXIS  3 CHANGED TO     .10000 DEG.

         STATION        RANGE          RANGE DOT          AZM       ELE.     SUN ANG.
        CANBERRA    2.6047916E+12  -3.1699020E+04   -17.455    60.115    68.370
          MEASUREMENT ERRORS        RANGE          ELEVATION        AZIMUTH         RANGE DOT
            INERTIAL SYSTEM     1.165378E+08   3.281150E-05   4.979318E-05    1.061374E+04
                 DSIF              -0.            -0.             -0.           4.100000E-02
    AFTER KALMAN UPDATE
                        P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
        COMP. DEV.   1.178E+08  1.555E+08  1.210E+08  1.690E+00  1.089E+01  4.364E+00  7.125E-04  7.125E-04  7.125E-04
```

FIGURE B-2h. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

DEVIATIONS	1.178E+08	1.555E+08	1.210E+08	1.691E+00	1.089E+01	4.364E+00	7.808E-04	1.018E-03	7.694E-04
ERRORS	5.959E+05	9.103E+05	9.411E+05	1.178E-02	5.046E-02	2.120E-02	3.192E-04	7.275E-04	2.903E-04

TARGET CT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	22.66

MANEUVERS

PITCH .0000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

TARGET CT. *

AT 400D 1H 2M 0.00S

T= 34563720 ALT= 2.6047869E+12 VEL= 1.8815768E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.2307

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.178E+08	1.555E+08	1.210E+08	1.691E+00	1.089E+01	4.364E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.178E+08	1.555E+08	1.210E+08	1.691E+00	1.089E+01	4.364E+00	7.817E-04	1.019E-03	7.707E-04
ERRORS	5.959E+05	9.103E+05	9.410E+05	1.178E-02	5.047E-02	2.121E-02	3.215E-04	7.290E-04	2.938E-04

CANOPUS	ATTITUDE ACQUIRED		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
		XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
		YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
		ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

AFTER MIDCOURSE CORRECTION, RMV= 9.125208E-01 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.178E+08	1.555E+08	1.210E+08	2.326E+00	1.033E+01	4.119E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.178E+08	1.555E+08	1.210E+08	2.326E+00	1.033E+01	4.119E+00	7.817E-04	1.019E-03	7.707E-04
ERRORS	5.959E+05	9.103E+05	9.410E+05	1.112E-02	5.102E-02	2.099E-02	3.215E-04	7.290E-04	2.938E-04

ATT. CONT. TURNED OFF
COMPUTER TURNED OFF
I. S. U. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF
COM. SYST. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.178E+08	1.555E+08	1.210E+08	2.326E+00	1.033E+01	4.119E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.178E+08	1.555E+08	1.210E+08	2.326E+00	1.033E+01	4.119E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	5.959E+05	9.103E+05	9.410E+05	1.112E-02	5.102E-02	2.099E-02	7.854E-01	7.854E-01	7.854E-01

TARGET CT. *

COAST FOR 896522.00 SEC. (10D 9H 2M 2.00S)

TARGET CT. *

FIGURE B-2i. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
AT 410D10H 4M 2.00S
   T=  35460242  ALT=  2.5764392E+12  VEL=  1.8630775E+08  ANG=    90.006  LAT=   -6.0886  LONG=     5.4976
                         P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV.   4.105E+08  -8.574E+01  1.507E+08   1.680E+04   2.272E+04   4.399E+03   7.854E-01   7.854E-01   7.854E-01
        DEVIATIONS   4.105E+08   1.899E+06  1.507E+08   1.680E+04   2.272E+04   4.399E+03   7.854E-01   7.854E-01   7.854E-01
        ERRORS       3.918E+05   1.899E+06  1.139E+06   2.884E+01   2.958E+01   4.263E+01   7.854E-01   7.854E-01   7.854E-01

        ATTITUDE          ROLL      YAW     PITCH          DR       CR       OP          ROLL     YAW     PITCH
                     XI  -.1192   -.4463    .8869    XI    .1142    .1908    .9750   DR  -.7448   -.6072   -.2768
                     YI   .6864    .6084    .3984    YI  -.9909   -.0483    .1256   CR   .6474   -.7580   -.0792
                     ZI  -.7173    .6563    .2338    ZI   .0710   -.9804    .1836   OP  -.1617   -.2382    .9577

    SUBSYSTEM  COMPUTER.  I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
     STATUS       -0         -0         -0         -0         -0          0         -0          0          0          0

                  TARGET MISS, RMS=  1.89889608E+06, DOF=1.000

        COMPUTER                       9063.00 SEC.
        I. S. U.                       9063.00 SEC.
        ATT. CONT.                    39057.00 SEC.
        STAR TRCKR                    39057.00 SEC.
        SUN SENSOR                    39057.00 SEC.
        ISU/C.P.S.                     9063.00 SEC.
        COM. SYST.                 34563720.00 SEC.
        HORIZ.SEN.                        0.00 SEC.
```

FIGURE B-2j. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= 18-IRIG-B 18-IRIG-B 18-IRIG-B

ISU DATA(HORIZONTAL DESIGN NUMBER 5 OPTIMUM) ON TIME (HR)= 2.517

OUTSIDE DIMENSIONS		WEIGHT		WEIGHT			
LENGTH=	10.200	BLOCK=	5.407	INSULATION=	1.019	EXCIT.ENERGY=	108.001
WIDTH=	7.500	BASE=	3.540	ELECTRONICS=	10.000	EXCIT.POWER =	42.900
HEIGHT=	4.610	COVER=	2.171	COMPONENTS=	4.500	TOTAL P.FAIL=	.00062
						TOTAL WEIGHT=	26.637

ISU THERMAL ANALYSIS

MAX.HEATER POWER=	96.525	MAX.THERMAL COND.=	2.1450	TOTAL ENERGY=	174.274
MIN.HEATER POWER=	-.000	MIN.THERMAL COND.=	1.0725	TOTAL POWER =	139.425

SUBSYSTEM PARAMETERS

	COMPUTERS SIGN III	STAR TRCKR ITT-LUN.08	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	2.517	10.849	10.849	0.000	9601.033	0.000	0.000		
ENERGY=	289.512	86.793	54.246	0.000	33603.617	0.000	0.000	TOTAL ENERGY=	34034.168
POWER=	115.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL POWER =	131.500
P.FAIL=	.00045	.00012	.00011	0.00000	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09216
WEIGHT=	27.000	7.000	2.000	0.000	3.100	0.000	0.000	TOTAL WEIGHT=	39.100

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 10.849

THRUST SIZING (LB)	ROLL	YAW	PITCH	FUEL CONSUMPTION (LB-SEC)	ROLL	YAW	PITCH		
SOLAR PRES=	.0000	.0000	.0000						
MET.IMPACT=	.0000	.0000	.0001	SEARCHING=	4.0598	2.3060	.0007		
MANEUVERS =	.0099	.0099	.0099	DEAD BAND=	.0001	.4445	.2560		
MIDCOURSE =	0.0000	.3778	.3778	MANEUVERS=	.2793	.1547	.1917	TOTAL ENERGY=	108.492
MAX.THRUST=	.0099	.3778	.3778	TOTAL IMP=	4.3392	2.9052	.4484	TOTAL POWER =	10.000
								TOTAL P.FAIL=	.00278

NO. OF FIRINGS= 22446 TOTAL IMPULSE= 7.6928 FUEL WEIGHT= .137372 TOTAL WEIGHT= 21.215

ENERGY SOURCE DATA

TOTAL POWER= 280.925 TOTAL ENERGY= 34316.934 TOTAL WEIGHT= 110.119

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 7.430 DOF=1.000 CAPABILITY= 13.957 TOTAL WEIGHT= 24.377

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.06051	ASTRIONICS=	331.448
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1668.552
UNRELIABILITY =	.09525	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 331.44832

EXECUTION TIMES, START=808.04, END=836.33, ELAPSED=28.288(SEC.)

FIGURE B-2k. OPTIMUM SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
                              PENALTY (MODE 3)

      ERROR ANALYSIS (SCHEDULE NO. 1)


      LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    AT    0D 0H 0M 0.00S
      T=          0  ALT= -4.7683716E-07  VEL=  2.3196861E+02  ANG=    90.000  LAT=    28.5000  LONG=  -80.5000
                              P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
              COMP. DEV.  0.         0.          0.          0.          0.          0.          0.          0.          0.
              DEVIATIONS  0.         0.          0.          0.          0.          0.          0.          0.          0.
               ERRORS     0.         0.          0.          0.          0.          0.          0.          0.          0.
        SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
          STATUS      1          1          0          0          0          1          0          0          0          0
      COM. SYST. TURNED ON
                              P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
              COMP. DEV.  0.         0.          0.          0.          0.          0.          0.          0.          0.
              DEVIATIONS  0.         0.          0.          0.          0.          0.          0.          0.          0.
               ERRORS     0.         0.          0.          0.          0.          0.          0.          0.          0.

      LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   BURN FOR     565.000 SEC.
   ADD BURN ERRORS
   PARK   FOR       935.00 SEC.   (  0D 0H15M35.00S)

      PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    AT    0D 0H25M 0.00S
      T=       1500  ALT=  6.0761100E+05  VEL=  2.4239262E+04  ANG=    90.000  LAT=    -5.7054  LONG=    -7.0921
                              P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
              COMP. DEV.  0.         0.          0.          0.          0.          0.          2.344E-04   2.344E-04   2.344E-04
              DEVIATIONS  1.018E+04  6.901E+03   3.395E+03   1.511E+01   4.549E+00   6.405E-01   1.590E-04   4.099E-04   3.189E-04
               ERRORS     1.018E+04  6.901E+03   3.395E+03   1.511E+01   4.549E+00   6.405E-01   2.717E-04   4.653E-04   4.723E-04
        SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
          STATUS      1          1          0          0          0          1          1          0          0          0

              STATION        RANGE          RANGE DOT          AZM        ELE.      SUN ANG.
             ASCENSION   2.8752678E+06   1.5257582E+04      73.154      8.373    111.615
               MEASUREMENT ERRORS     RANGE          ELEVATION         AZIMUTH          RANGE DOT
                   INERTIAL SYSTEM   5.477570E+03    2.940241E-03    2.722631E-03    9.645061E+00
                          TPQ-18     6.700000E+01    4.500000E-04    4.500000E-04    -0.
      AFTER KALMAN UPDATE
                              P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
              COMP. DEV.  1.013E+04  6.806E+03   3.290E+03   1.499E+01   4.245E+00   5.641E-01   2.526E-04   3.178E-04   3.638E-04
              DEVIATIONS  1.018E+04  6.901E+03   3.395E+03   1.511E+01   4.549E+00   6.405E-01   1.590E-04   4.099E-04   3.189E-04
               ERRORS     9.478E+02  1.142E+03   8.377E+02   1.944E+00   1.635E+00   3.035E-01   2.632E-04   3.495E-04   3.332E-04

      PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   PARK   FOR       81.30 SEC.   (  0D 0H 1M21.30S)
   BURN FOR    941.500 SEC.
   ADD BURN ERRORS
   COAST FOR          .20 SEC.   (  0D 0H 0M   .20S)
```

FIGURE B-3a. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION

```
   ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D 0H42M 3.00S
   T=         2523  ALT=  1.2568513E+07  VEL=  4.7908635E+04  ANG=     42.609  LAT=  -28.4248  LONG=    47.9456
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV. -3.453E-04  0.         -1.221E-04  -3.372E-07  0.         -1.192E-07   5.108E-08   5.108E-08   5.108E-08
        DEVIATIONS  4.505E+03  6.047E+03   5.218E+03   5.371E+00  1.386E+01   1.069E+01   6.187E-04   5.227E-04   5.799E-04
         ERRORS     4.505E+03  6.047E+03   5.218E+03   5.371E+00  1.386E+01   1.069E+01   6.187E-04   5.227E-04   5.800E-04

         ATTITUDE      ROLL      YAW     PITCH          DR       CR       OP         ROLL      YAW     PITCH
                  XI  -.1872   -.9823    .0083    XI  -.1872   -.9823    .0083   DR  1.0000   -.0000    .0000
                  YI  -.8845    .1722    .4335    YI  -.8846    .1722    .4335   CR   .0000   1.0000   -.0000
                  ZI  -.4272    .0738   -.9011    ZI  -.4272    .0738   -.9011   OP  -.0000    .0000   1.0000

     SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
       STATUS      1         1         0          0          0          1          1          0          0          0
   ATT. CONT. TURNED ON
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV. -3.453E-04  0.         -1.221E-04  -3.372E-07  0.         -1.192E-07   7.125E-03   7.125E-03   7.125E-03
        DEVIATIONS  4.505E+03  6.047E+03   5.218E+03   5.371E+00  1.386E+01   1.069E+01   7.152E-03   7.144E-03   7.149E-03
         ERRORS     4.505E+03  6.047E+03   5.218E+03   5.371E+00  1.386E+01   1.069E+01   6.187E-04   5.227E-04   5.800E-04
   DEADBAND ON AXIS  1 CHANGED TO   20.00000 DEG.
   DEADBAND ON AXIS  2 CHANGED TO   20.00000 DEG.
   DEADBAND ON AXIS  3 CHANGED TO   20.00000 DEG.
   STAR TRCKR TURNED ON
   SUN SENSOR TURNED ON
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV. -3.453E-04  0.         -1.221E-04  -3.372E-07  0.         -1.192E-07   1.425E-01   1.425E-01   1.425E-01
        DEVIATIONS  4.505E+03  6.047E+03   5.218E+03   5.371E+00  1.386E+01   1.069E+01   1.425E-01   1.425E-01   1.425E-01
         ERRORS     4.505E+03  6.047E+03   5.218E+03   5.371E+00  1.386E+01   1.069E+01   6.187E-04   5.227E-04   5.800E-04

        BEGIN MANEUVERING TO LOCATE SUN-CANOPUS


   ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 COAST FOR      900.00 SEC.  (  0D 0H15M 0.00S)

           ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

           DEAD BANDS   SET    MAX.
                 ROLL  20.00  64.00
                  YAW   8.00   8.00
                PITCH  20.00  28.68
        MANEUVERS
                PITCH 124.634DEG.   YAW -70.015DEG.  ROLL  59.862DEG. IN      900SEC.
   ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D 0H57M 3.00S
   T=         3423  ALT=  4.0308954E+07  VEL=  4.3313231E+04  ANG=     16.593  LAT=  -29.7368  LONG=    74.2506
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV. -6.905E-04  0.         -2.441E-04  -3.372E-07 -2.107E-08  -1.686E-07   1.418E-01   7.036E-02   1.372E-01
        DEVIATIONS  9.412E+03  1.836E+04   1.445E+04   5.765E+00  1.410E+01   1.012E+01   1.418E-01   7.036E-02   1.372E-01
         ERRORS     9.412E+03  1.836E+04   1.445E+04   5.765E+00  1.410E+01   1.012E+01   6.046E-04   4.582E-04   6.581E-04
```

FIGURE B-3b. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2321	.9305	-.2834	XI	-.1224	-.9924	.0083	DR	-.2123	.1112	.9709
	YI	.6276	-.0793	-.7745	YI	-.8939	.1138	.4335	CR	.2679	-.9488	.1673
	ZI	-.7431	-.3576	-.5656	ZI	-.4312	.0456	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.32, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.68

MANEUVERS

PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

SEARCH FOR SUN IN 35.6 SECONDS WITH 1.00000 PASSES

ANGULAR RATES (RAD/SEC)=ROLL 0.00000 ,YAW 0.00000 ,PITCH -.00002

SEARCH FOR CANOPUS IN 24.4 SECONDS WITH 1.00000 PASSES

ANGULAR RATES (RAD/SEC)=ROLL 0.00000 ,YAW 0.00000 ,PITCH -.00002

ESCAPE *

AT 0D 0H58M 3.00S

T= 3483 ALT= 5.0840061E+07 VEL= 4.3117281E+04 ANG= 15.672 LAT= -29.6689 LONG= 74.9188

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.356E+03	1.298E+04	1.242E+04	1.047E+00	9.500E+00	8.169E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	9.746E+03	1.919E+04	1.506E+04	5.780E+00	1.414E+01	1.010E+01	1.417E-01	7.042E-02	1.372E-01
ERRORS	9.657E+03	1.446E+04	9.166E+03	5.684E+00	1.069E+01	6.313E+00	2.048E-04	2.096E-04	4.199E-04

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2321	.9305	-.2834	XI	-.1202	-.9927	.0083	DR	-.2128	.1133	.9705
	YI	.6276	-.0793	-.7745	YI	-.8942	.1119	.4335	CR	.2674	-.9486	.1694
	ZI	-.7431	-.3576	-.5656	ZI	-.4313	.0447	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END SEARCH FOR SUN-CANOPUS

COMPUTER TURNED OFF

I. S. U. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.356E+03	1.298E+04	1.242E+04	1.047E+00	9.500E+00	8.169E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	9.746E+03	1.919E+04	1.506E+04	5.780E+00	1.414E+01	1.010E+01	1.417E-01	7.042E-02	1.372E-01

FIGURE B-3c. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ERRORS	9.657E+03	1.446E+04	9.166E+03	5.684E+00	1.069E+01	6.313E+00	2.048E-04	2.096E-04	4.199E-04

ESCAPE *

COAST FOR 32517.00 SEC. (0D 9H 1M57.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.21, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.79

MANEUVERS

PITCH -.053DEG. YAW -.094DEG. ROLL -.515DEG. IN 32517SEC.

TRACKING STAR NO. 2

ESCAPE *

AT 0D10H 0M 0.00S

T= 36000 ALT= 1.3681588E+09 VEL= 9.8762677E+04 ANG= 66.018 LAT= -25.6796 LONG= -36.9497

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.115E+04	3.503E+05	2.644E+05	1.607E+00	1.054E+01	7.710E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.975E+05	5.317E+05	3.385E+05	5.787E+00	1.606E+01	9.966E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.908E+05	4.064E+05	2.209E+05	5.559E+00	1.230E+01	6.569E+00	2.496E-04	2.696E-04	6.885E-04

	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS ACQUIRED	XI	-.2334	.9328	-.2746	XI	-.0997	-.9950	.0082	DR	-.2168	.1239	.9683
	YI	.6264	-.0718	-.7762	YI	-.8963	.0934	.4335	CR	.2641	-.9475	.1804
	ZI	-.7437	-.3532	-.5676	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1727

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	1	1	1	0	1	0	0	0

COMPUTER TURNED ON

I. S. U. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.115E+04	3.503E+05	2.644E+05	1.607E+00	1.054E+01	7.710E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.975E+05	5.317E+05	3.385E+05	5.787E+00	1.606E+01	9.966E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.908E+05	4.064E+05	2.209E+05	5.559E+00	1.230E+01	6.569E+00	2.496E-04	2.696E-04	6.885E-04

ESCAPE *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.80

MANEUVERS

PITCH -.003DEG. YAW -.005DEG. ROLL -.028DEG. IN 1800SEC.

ESCAPE *

AT 0D10H30M 0.00S

T= 37800 ALT= 1.4404029E+09 VEL= 1.0315087E+05 ANG= 67.105 LAT= -25.6632 LONG= -44.3869

FIGURE B-3d. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.404E+04	3.693E+05	2.782E+05	1.608E+00	1.054E+01	7.710E+00	1.416E-01	7.065E-02	1.372E-01
DEVIATIONS	2.079E+05	5.606E+05	3.565E+05	5.786E+00	1.607E+01	9.966E+00	1.416E-01	7.065E-02	1.372E-01
ERRORS	2.008E+05	4.286E+05	2.327E+05	5.558E+00	1.231E+01	6.571E+00	5.158E-04	5.257E-04	8.232E-04

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS ACQUIRED	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
	YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
	ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
ASCENSION	1.4439360E+09	4.0809058E+04	-125.447	55.969	80.860

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	2.056991E+05	3.064811E-04	1.384297E-04	2.314961E+01
USBS-30	6.700000E+01	1.780000E-03	1.780000E-03	1.240000E-01

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	2.079E+05	5.551E+05	3.045E+05	5.786E+00	1.590E+01	8.517E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	2.079E+05	5.606E+05	3.565E+05	5.786E+00	1.607E+01	9.966E+00	8.018E-04	8.846E-04	1.086E-03
ERRORS	1.884E+03	5.785E+04	1.984E+05	2.134E-02	1.743E+00	5.525E+00	3.677E-04	5.242E-04	8.198E-04

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	28.80

MANEUVERS

PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

ESCAPE *

AT 0D1OH31M 0.00S

T= 37860 ALT= 1.4428110E+09 VEL= 1.0329770E+05 ANG= 67.140 LAT= -25.6627 LONG= -44.6349

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	2.083E+05	5.561E+05	3.050E+05	5.786E+00	1.590E+01	8.517E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	2.083E+05	5.616E+05	3.571E+05	5.786E+00	1.607E+01	9.966E+00	8.050E-04	8.923E-04	1.092E-03
ERRORS	1.884E+03	5.795E+04	1.987E+05	2.134E-02	1.743E+00	5.525E+00	3.745E-04	5.371E-04	8.279E-04

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS ACQUIRED	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
	YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
	ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

FIGURE B-3e. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

AFTER MIDCOURSE CORRECTION, RMV= 1.592339E+01 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	2.083E+05	5.561E+05	3.050E+05	5.725E+00	4.318E+00	7.430E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	2.083E+05	5.616E+05	3.571E+05	5.725E+00	4.749E+00	8.970E+00	8.050E-04	8.923E-04	1.092E-03
ERRORS	1.884E+03	5.795E+04	1.987E+05	3.415E-02	1.742E+00	5.525E+00	3.745E-04	5.371E-04	8.279E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	2.083E+05	5.561E+05	3.050E+05	5.725E+00	4.318E+00	7.430E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	2.083E+05	5.616E+05	3.571E+05	5.725E+00	4.749E+00	8.970E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.884E+03	5.795E+04	1.987E+05	3.415E-02	1.742E+00	5.525E+00	7.854E-01	7.854E-01	7.854E-01

ESCAPE *

COAST FOR 34522140.00 SEC. (399D13H29M 0.00S)

TARGET CT. *

AT 400D 0H 0M 0.00S
T= 34560000 ALT= 2.6049048E+12 VEL= 1.8816539E+08 ANG= 90.010 LAT= -6.5116 LONG= 155.7267

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.628E+08	1.750E+07	1.198E+08	1.088E+00	3.058E+00	1.058E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.678E+08	2.171E+08	1.910E+08	2.404E+00	1.526E+01	6.120E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	4.685E+07	2.173E+08	1.568E+08	2.134E+00	1.514E+01	6.090E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2335	.9329	-.2741	XI	.1881	.1202	.9748	DR	-.3299	.3738	.8669
	YI	.6264	-.0713	-.7763	YI	-.9062	.4039	.1251	CR	.8994	.4034	.1683
	ZI	-.7438	-.3529	-.5677	ZI	-.3787	-.9069	.1849	OP	-.2868	.8352	-.4693

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS -0 -0 0 0 0 0 1 0 0 0

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.628E+08	1.750E+07	1.198E+08	1.088E+00	3.058E+00	1.058E+00	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	1.678E+08	2.171E+08	1.910E+08	2.404E+00	1.526E+01	6.120E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	4.685E+07	2.173E+08	1.568E+08	2.134E+00	1.514E+01	6.090E+00	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

FIGURE B-3f. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.66

MANEUVERS
PITCH 5.360DEG. YAW 5.335DEG. ROLL-133.476DEG. IN 1800SEC.

TARGET CT. *

AT 400D 0H30M 0.00S
T= 34561800 ALT= 2.6048474E+12 VEL= 1.8816163E+08 ANG= 90.010 LAT= -6.5106 LONG= 148.2286

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.628E+08	1.750E+07	1.198E+08	1.082E+00	3.063E+00	1.055E+00	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.678E+08	2.171E+08	1.910E+08	2.409E+00	1.528E+01	6.123E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	4.684E+07	2.174E+08	1.568E+08	2.143E+00	1.516E+01	6.094E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4462	.8869	XI	.1881	.1202	.9748	DR	-.3728	-.8838	-.2827
	YI	.6864	.6084	.3983	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
	ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

TARGET CT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.66

MANEUVERS
PITCH -.000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

SEARCH FOR SUN IN 30.4 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL .02583 ,YAW 0.00000 ,PITCH 0.00000

SEARCH FOR CANOPUS IN 29.6 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL .00000 ,YAW .02583 ,PITCH 0.00000

TARGET CT. *

AT 400D 0H31M 0.00S
T= 34561860 ALT= 2.6048455E+12 VEL= 1.8816150E+08 ANG= 90.010 LAT= -6.5106 LONG= 147.9787

P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP

FIGURE B-3g. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

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     COMP. DEV.   1.628E+08  1.750E+07  1.198E+08  1.081E+00  3.063E+00  1.054E+00  8.357E-02  1.324E-01  1.391E-01
     DEVIATIONS   1.678E+08  2.171E+08  1.910E+08  2.409E+00  1.528E+01  6.123E+00  8.357E-02  1.324E-01  1.391E-01
     ERRORS       4.684E+07  2.174E+08  1.568E+08  2.143E+00  1.516E+01  6.094E+00  2.829E-04  7.055E-04  2.322E-04

            ATTITUDE           ROLL     YAW     PITCH          DR       CR      OP          ROLL     YAW     PITCH
CANOPUS     ACQUIRED      XI  -.1192  -.4462   .8869    XI   .1881   .1202   .9748   DR  -.3728  -.8838  -.2827
                          YI   .6864   .6084  -.3983    YI  -.9062   .4039   .1251   CR   .9135  -.4031   .0555
                          ZI  -.7173   .6563   .2338    ZI  -.3787  -.9069   .1849   OP  -.1630  -.2375   .9576

     SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS      1          1          1          1          1          1          1          0          0          0

          END SEARCH FOR SUN-CANOPUS


     TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR      1800.00 SEC.  (   0D 0H30M 0.00S)

              ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

              DEAD BANDS    SET     MAX.
                   ROLL    20.00   64.00
                    YAW     8.00    8.00
                  PITCH    20.00   22.66
         MANEUVERS
                  PITCH     .000DEG.   YAW    .000DEG.  ROLL    -.001DEG. IN      1800SEC.

     TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT 400D 1H 1M 0.00S
     T=  34563660  ALT=  2.6047888E+12  VEL=  1.8815780E+08  ANG=    90.010  LAT=   -6.5096  LONG=  140.4806
                    P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
     COMP. DEV.   1.628E+08  1.751E+07  1.198E+08  1.064E+00  3.077E+00  1.045E+00  8.357E-02  1.324E-01  1.391E-01
     DEVIATIONS   1.678E+08  2.172E+08  1.910E+08  2.421E+00  1.534E+01  6.132E+00  8.357E-02  1.324E-01  1.391E-01
     ERRORS       4.684E+07  2.174E+08  1.568E+08  2.166E+00  1.522E+01  6.104E+00  5.453E-04  8.456E-04  5.208E-04

            ATTITUDE           ROLL     YAW     PITCH          DR       CR      OP          ROLL     YAW     PITCH
CANOPUS     ACQUIRED      XI  -.1192  -.4463   .8869    XI   .1881   .1202   .9748   DR  -.3729  -.8838  -.2827
                          YI   .6864   .6084   .3984    YI  -.9062   .4039   .1251   CR   .9135  -.4031   .0555
                          ZI  -.7173   .6563   .2338    ZI  -.3787  -.9069   .1849   OP  -.1630  -.2375   .9576

     SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS      1          1          1          1          1          1          1          0          0          0
   DEADBAND ON AXIS  1 CHANGED TO    .10000 DEG.
   DEADBAND ON AXIS  2 CHANGED TO    .10000 DEG.
   DEADBAND ON AXIS  3 CHANGED TO    .10000 DEG.

          STATION        RANGE         RANGE DOT          AZM         ELE.       SUN ANG.
          CANBERRA   2.6047916E+12 -3.1699020E+04   -17.455       60.115      68.370
            MEASUREMENT ERRORS       RANGE           ELEVATION          AZIMUTH         RANGE DOT
              INERTIAL SYSTEM     1.632866E+08    4.599680E-05     6.978675E-05    1.487602E+04
                  DSIF              -0.             -0.               -0.            4.100000E-02
   AFTER KALMAN UPDATE
                    P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
     COMP. DEV.   1.678E+08  2.172E+08  1.910E+08  2.421E+00  1.534E+01  6.132E+00  7.125E-04  7.125E-04  7.125E-04
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FIGURE B-3h. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
DEVIATIONS	1.678E+08	2.172E+08	1.910E+08	2.421E+00	1.534E+01	6.132E+00	8.623E-04	1.095E-03	8.784E-04
ERRORS	7.892E+05	9.630E+05	1.137E+06	1.467E-02	6.077E-02	2.482E-02	4.857E-04	8.319E-04	5.137E-04

TARGET CT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	22.66

MANEUVERS

PITCH .000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

TARGET CT. *

AT 400D 1H 2M 0.00S

T= 34563720 ALT= 2.0047869E+12 VEL= 1.8815768E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.2307

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.678E+08	2.172E+08	1.910E+08	2.421E+00	1.535E+01	6.132E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.678E+08	2.172E+08	1.910E+08	2.422E+00	1.535E+01	6.132E+00	8.683E-04	1.101E-03	8.862E-04
ERRORS	7.892E+05	9.630E+05	1.137E+06	1.467E-02	6.077E-02	2.482E-02	4.962E-04	8.395E-04	5.270E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
		YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
		ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

AFTER MIDCOURSE CORRECTION, RMV= 1.278652E+00 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.678E+08	2.172E+08	1.910E+08	3.298E+00	1.457E+01	5.792E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.678E+08	2.172E+08	1.910E+08	3.298E+00	1.457E+01	5.792E+00	8.683E-04	1.101E-03	8.862E-04
ERRORS	7.892E+05	9.630E+05	1.137E+06	1.581E-02	6.158E-02	2.452E-02	4.962E-04	8.395E-04	5.270E-04

ATT. CONT. TURNED OFF
COMPUTER TURNED OFF
I. S. U. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF
COM. SYST. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.678E+08	2.172E+08	1.910E+08	3.298E+00	1.457E+01	5.792E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.678E+08	2.172E+08	1.910E+08	3.298E+00	1.457E+01	5.792E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	7.892E+05	9.630E+05	1.137E+06	1.581E-02	6.158E-02	2.452E-02	7.854E-01	7.854E-01	7.854E-01

TARGET CT. *

COAST FOR 896522.00 SEC. (10D 9H 2M 2.00S)

TARGET CT. *

FIGURE B-3i. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

AT 410010H 4M 2.005

T= 35460242 ALT= 2.5764392E+12 VEL= 1.8630775E+08 ANG= 90.006 LAT= -6.0886 LONG= 5.4976

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.795E+08	8.913E+01	2.308E+08	2.345E+04	3.178E+04	6.187E+03	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	5.795E+08	1.818E+06	2.308E+08	2.345E+04	3.179E+04	6.187E+03	7.854E-01	7.854E-01	7.854E-01
ERRORS	8.420E+05	1.818E+06	1.161E+06	1.148E+01	6.575E+01	3.993E+01	7.854E-01	7.854E-01	7.854E-01

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4463	.8869	XI	.1142	.1908	.9750	DR	-.7448	-.6072	-.2768
	YI	.6864	.6084	.3984	YI	-.9909	-.0483	.1256	CR	.6474	-.7580	-.0792
	ZI	-.7173	.6563	.2338	ZI	.0710	-.9804	.1836	OP	-.1617	-.2382	.9577

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	-0	-0	-0	0	-0	0	0	0

TARGET MISS, RMS= 1.81761994E+06, DOF=1.000

COMPUTER	9063.00	SEC.
I. S. U.	9063.00	SEC.
ATT. CONT.	39057.00	SEC.
STAR TRCKR	39057.00	SEC.
SUN SENSOR	39057.00	SEC.
ISU/C.P.S.	9063.00	SEC.
COM. SYST.	34563720.00	SEC.
HORIZ.SEN.	0.00	SEC.

FIGURE B-3j. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= GG 334-A GG 334-A GG 334-A

ISU DATA ON TIME (HR)= 2.517

H-429 : (STRAPDOWN) SPECIFIED

TOTAL ENERGY= 251.750
TOTAL POWER = 100.000
TOTAL P.FAIL= .00126
TOTAL WEIGHT= 30.000

SUBSYSTEM PARAMETERS

	COMPUTERS SIGN III	STAR TRCKR ITT-LUN.08	SUN SENSOR ADCL-1402	ISU/C.P.S. H-429 SYS	COM. SYST. MCR-503	HORIZ.SEN. NONE		
TIME=	2.517	10.849	10.849	2.517	9601.033	0.000	0.000	
ENERGY=	289.512	86.793	54.246	213.987	33603.617	0.000	0.000	TOTAL ENERGY= 34248.156
POWER=	115.000	8.000	5.000	85.000	3.500	0.000	0.000	TOTAL POWER = 216.500
P.FAIL=	.00045	.00012	.00011	.00025	.09155	0.00000	0.00000	TOTAL P.FAIL= .09239
WEIGHT=	27.000	7.000	2.000	14.250	3.100	0.000	0.000	TOTAL WEIGHT= 53.350

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 10.849

THRUST SIZING (LB)	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)	ROLL	YAW	PITCH
SEARCHING=	4.0585	2.3060	.0032
DEAD BAND=	.0001	.4445	.2560
MANEUVERS=	.2793	.1547	.1917
TOTAL IMP=	4.3379	2.9052	.4509

NO. OF FIRINGS= 22440 TOTAL IMPULSE= 7.6940 FUEL WEIGHT= .137393

TOTAL ENERGY= 108.492
TOTAL POWER = 10.000
TOTAL P.FAIL= .00278
TOTAL WEIGHT= 21.215

ENERGY SOURCE DATA

TOTAL POWER= 326.500 TOTAL ENERGY= 34608.397 TOTAL WEIGHT= 125.842

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 15.975 DOF=1.000 CAPABILITY= 30.105 TOTAL WEIGHT= 29.085

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.05968	ASTRIONICS=	369.492
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1630.508
UNRELIABILITY =	.09606	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 369.49242

EXECUTION TIMES. START=836.33, END=864.60, ELAPSED=28.268(SEC.)

FIGURE B-3k. AIDED H-429 SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

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                              PENALTY (MODE 3)

    ERROR ANALYSIS (SCHEDULE NO. 1)


    LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  AT    0D 0H 0M 0.00S
    T=         0  ALT= -4.7683716E-07  VEL=  2.3196861E+02  ANG=     90.000  LAT=    28.5000  LONG=  -80.5000
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.   0.          0.          0.          0.          0.          0.          0.          0.          0.
          DEVIATIONS   0.          0.          0.          0.          0.          0.          0.          0.          0.
           ERRORS      0.          0.          0.          0.          0.          0.          0.          0.          0.
       SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
         STATUS       1          1          0          0          0          1          0          0          0          0
    COM. SYST. TURNED ON
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.   0.          0.          0.          0.          0.          0.          0.          0.          0.
          DEVIATIONS   0.          0.          0.          0.          0.          0.          0.          0.          0.
           ERRORS      0.          0.          0.          0.          0.          0.          0.          0.          0.

    LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 BURN FOR     565.000 SEC.
 ADD BURN ERRORS
 PARK  FOR        935.00 SEC.   (  0D 0H15M35.00S)

    PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  AT    0D 0H25M 0.00S
    T=      1500  ALT=  6.0761100E+05  VEL=  2.4239262E+04  ANG=     90.000  LAT=    -5.7054  LONG=   -7.0921
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.   0.          0.          0.          0.          0.          0.          4.261E-04   4.261E-04   4.261E-04
          DEVIATIONS   1.970E+03   2.283E+03   1.538E+03   3.810E+00   3.725E+00   6.288E-01   2.765E-04   2.795E-04   2.752E-04
           ERRORS      1.970E+03   2.283E+03   1.538E+03   3.810E+00   3.725E+00   6.288E-01   4.998E-04   6.816E-04   5.073E-04
       SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
         STATUS       1          1          0          0          0          1          1          0          0          0

           STATION       RANGE         RANGE DOT          AZM       ELE.     SUN ANG.
          ASCENSION   2.8752678E+06  1.5257582E+04     73.154     8.373    111.615
            MEASUREMENT ERRORS      RANGE          ELEVATION         AZIMUTH         RANGE DOT
               INERTIAL SYSTEM   1.835217E+03   8.631241E-04    4.833212E-04    2.312257E+00
                    TPQ-18       6.700000E+01   4.500000E-04    4.500000E-04    -0.
    AFTER KALMAN UPDATE
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.   1.849E+03   2.007E+03   1.383E+03   3.379E+00   3.303E+00   5.246E-01   2.932E-04   3.824E-04   3.906E-04
          DEVIATIONS   1.970E+03   2.283E+03   1.538E+03   3.810E+00   3.725E+00   6.288E-01   2.765E-04   2.795E-04   2.752E-04
           ERRORS      6.804E+02   1.088E+03   6.715E+02   1.760E+00   1.722E+00   3.467E-01   3.187E-04   5.276E-04   4.552E-04

    PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 PARK  FOR        81.30 SEC.   (  0D 0H 1M21.30S)
 BURN FOR    941.500 SEC.
 ADD BURN ERRORS
 COAST FOR          .20 SEC.   (  0D 0H 0M   .20S)
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FIGURE B-4a. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION

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ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT    0D 0H42M 3.00S
 T=        2523  ALT=  1.2568513E+07  VEL=  4.7908635E+04  ANG=     42.609  LAT=  -28.4248  LONG=    47.9456
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  -2.441E-04  -8.632E-05   0.          0.         -5.268E-09  -2.384E-07  -7.276E-12  -1.029E-11   9.284E-08
          DEVIATIONS   6.514E+03   2.883E+03   4.533E+03   1.335E+01   3.555E+00   9.020E+00   8.550E-04   9.408E-04   9.231E-04
          ERRORS       6.514E+03   2.883E+03   4.533E+03   1.335E+01   3.555E+00   9.020E+00   8.550E-04   9.408E-04   9.231E-04

            ATTITUDE       ROLL      YAW     PITCH           DR       CR       OP          ROLL      YAW     PITCH
                      XI  -.1872   -.9823    .0083    XI  -.1872   -.9823    .0083   DR   1.0000   -.0000    .0000
                      YI  -.8845    .1722    .4335    YI  -.8846    .1722    .4335   CR    .0000   1.0000   -.0000
                      ZI  -.4272    .0738   -.9011    ZI  -.4272    .0738   -.9011   OP   -.0000    .0000   1.0000

     SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
       STATUS       1          1          0          0          0          1          1          0          0          0
   ATT. CONT. TURNED ON
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  -2.441E-04  -8.632E-05   0.          0.         -5.268E-09  -2.384E-07   7.125E-03   7.125E-03   7.125E-03
          DEVIATIONS   6.514E+03   2.883E+03   4.533E+03   1.335E+01   3.555E+00   9.020E+00   7.176E-03   7.187E-03   7.185E-03
           ERRORS      6.514E+03   2.883E+03   4.533E+03   1.335E+01   3.555E+00   9.020E+00   8.550E-04   9.408E-04   9.231E-04
   DEADBAND ON AXIS  1 CHANGED TO   20.00000 DEG.
   DEADBAND ON AXIS  2 CHANGED TO   20.00000 DEG.
   DEADBAND ON AXIS  3 CHANGED TO   20.00000 DEG.
   STAR TRCKR TURNED ON
   SUN SENSOR TURNED ON
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  -2.441E-04  -8.632E-05   0.          0.         -5.268E-09  -2.384E-07   1.425E-01   1.425E-01   1.425E-01
          DEVIATIONS   6.514E+03   2.883E+03   4.533E+03   1.335E+01   3.555E+00   9.020E+00   1.425E-01   1.425E-01   1.425E-01
           ERRORS      6.514E+03   2.883E+03   4.533E+03   1.335E+01   3.555E+00   9.020E+00   8.550E-04   9.408E-04   9.231E-04

          BEGIN MANEUVERING TO LOCATE SUN-CANOPUS


ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR       900.00 SEC.   (  0D 0H15M 0.00S)

               ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS    SET     MAX.
                     ROLL   20.00   64.00
                      YAW    8.00    8.00
                    PITCH   20.00   28.68
          MANEUVERS
                    PITCH 124.634DEG.   YAW -70.015DEG.   ROLL  59.862DEG. IN       900SEC.

ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT    0D 0H57M 3.00S
 T=        3423  ALT=  4.8308954E+07  VEL=  4.3313231E+04  ANG=     16.593  LAT=  -29.7368  LONG=    74.2506
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  -4.883E-04   0.         -3.453E-04   0.         -4.215E-08  -1.686E-07   1.418E-01   7.036E-02   1.372E-01
          DEVIATIONS   1.898E+04   6.466E+03   1.230E+04   1.427E+01   5.120E+00   8.887E+00   1.418E-01   7.037E-02   1.372E-01
           ERRORS      1.898E+04   6.466E+03   1.230E+04   1.427E+01   5.120E+00   8.887E+00   8.674E-04   9.295E-04   1.151E-03
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FIGURE B-4b. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2321	.9305	-.2834	XI	-.1224	-.9924	.0083	DR	-.2123	.1112	.9709
	YI	.6276	-.0793	-.7745	YI	-.8939	.1138	.4335	CR	.2679	-.9488	.1673
	ZI	-.7431	-.3576	-.5656	ZI	-.4312	.0456	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS 1 1 1 1 1 1 1 0 0 0

END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.32, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.68

MANEUVERS
PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

SEARCH FOR SUN IN 33.0 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL .00003 ,YAW 0.00000 ,PITCH 0.00000

SEARCH FOR CANOPUS IN 27.0 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL .00000 ,YAW .00003 ,PITCH 0.00000

ESCAPE *

AT 0D 0H58M 3.00S
T= 3483 ALT= 5.0840061E+07 VEL= 4.3117281E+04 ANG= 15.672 LAT= -29.6689 LONG= 74.9188

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.225E+04	4.401E+03	5.604E+03	9.048E+00	3.534E+00	3.796E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	1.983E+04	6.747E+03	1.282E+04	1.429E+01	5.208E+00	8.887E+00	1.417E-01	7.042E-02	1.372E-01
ERRORS	1.622E+04	5.233E+03	1.157E+04	1.152E+01	3.983E+00	8.044E+00	2.281E-04	2.542E-04	5.606E-04

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS ACQUIRED	XI	-.2321	.9305	-.2834	XI	-.1202	-.9927	.0083	DR	-.2128	.1133	.9705
	YI	.6276	-.0793	-.7745	YI	-.8942	.1119	.4335	CR	.2674	-.9486	.1694
	ZI	-.7431	-.3576	-.5656	ZI	-.4313	.0447	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS 1 1 1 1 1 1 1 0 0 0

END SEARCH FOR SUN-CANOPUS

COMPUTER TURNED OFF
I. S. U. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.225E+04	4.401E+03	5.604E+03	9.048E+00	3.534E+00	3.796E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	1.983E+04	6.747E+03	1.282E+04	1.429E+01	5.208E+00	8.887E+00	1.417E-01	7.042E-02	1.372E-01

FIGURE B-4c. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
       ERRORS      1.622E+04  5.233E+03  1.157E+04  1.152E+01  3.983E+00  8.044E+00  2.281E-04  2.542E-04  5.606E-04

  ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR    32517.00 SEC.  (  0D 9H 1M57.00S)

             ANGLE BETWEEN CELESTIAL BODIES=   97.21, BETWEEN OPTICAL AIDS=   90.00

             DEAD BANDS    SET     MAX.
                  ROLL   20.00   64.00
                   YAW    8.00    8.00
                 PITCH   20.00   28.79
         MANEUVERS
                 PITCH   -.053DEG.   YAW   -.094DEG.  ROLL   -.515DEG. IN    32517SEC.
         TRACKING STAR NO.    2

  ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D10H 0M 0.00S
   T=      36000  ALT=  1.3681588E+09  VEL=  9.8762677E+04  ANG=    66.018  LAT=  -25.6796  LONG=  -36.9497
                       P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
         COMP. DEV.  2.994E+05  1.585E+05  1.388E+05  8.765E+00  4.906E+00  4.152E+00  1.416E-01  7.067E-02  1.372E-01
         DEVIATIONS  4.707E+05  2.339E+05  3.048E+05  1.376E+01  7.247E+00  9.012E+00  1.416E-01  7.067E-02  1.372E-01
          ERRORS     3.783E+05  1.784E+05  2.717E+05  1.105E+01  5.532E+00  8.012E+00  2.496E-04  2.696E-04  6.885E-04

            ATTITUDE       ROLL     YAW    PITCH         DR      CR      OP          ROLL     YAW    PITCH
CANOPUS    ACQUIRED     XI  -.2334   .9328  -.2746   XI  -.0997  -.9950   .0082   DR  -.2168   .1239   .9683
                        YI   .6264  -.0718  -.7762   YI  -.8963   .0934   .4335   CR   .2641  -.9475   .1804
                        ZI  -.7437  -.3532  -.5676   ZI  -.4321   .0358  -.9011   OP   .9398   .2948   .1727

     SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
       STATUS     -0          -0         1          1          1          0          1          0          0          0
    COMPUTER   TURNED ON
    I. S. U.   TURNED ON
                       P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
         COMP. DEV.  2.994E+05  1.585E+05  1.388E+05  8.765E+00  4.906E+00  4.152E+00  1.416E-01  7.067E-02  1.372E-01
         DEVIATIONS  4.707E+05  2.339E+05  3.048E+05  1.376E+01  7.247E+00  9.012E+00  1.416E-01  7.067E-02  1.372E-01
          ERRORS     3.783E+05  1.784E+05  2.717E+05  1.105E+01  5.532E+00  8.012E+00  2.496E-04  2.696E-04  6.885E-04

  ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR     1800.00 SEC.  (  0D 0H30M 0.00S)

             ANGLE BETWEEN CELESTIAL BODIES=   97.20, BETWEEN OPTICAL AIDS=   90.00

             DEAD BANDS    SET     MAX.
                  ROLL   20.00   64.00
                   YAW    8.00    8.00
                 PITCH   20.00   28.80
         MANEUVERS
                 PITCH   -.003DEG.   YAW   -.005DEG.  ROLL   -.028DEG. IN     1800SEC.

  ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D10H30M 0.00S
   T=      37800  ALT=  1.4404029E+09  VEL=  1.0315087E+05  ANG=    67.105  LAT=  -25.6632  LONG=  -44.3869
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FIGURE B-4d. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	3.151E+05	1.674E+05	1.463E+05	8.763E+00	4.910E+00	4.153E+00	1.416E-01	7.065E-02	1.372E-01
DEVIATIONS	4.954E+05	2.469E+05	3.210E+05	1.376E+01	7.253E+00	9.013E+00	1.416E-01	7.065E-02	1.372E-01
ERRORS	3.981E+05	1.883E+05	2.862E+05	1.105E+01	5.537E+00	8.012E+00	2.496E-04	2.696E-04	1.071E-03

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
		YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
		ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
ASCENSION	1.4439360E+09	4.080905AE+04	-125.447	55.969	80.860

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	4.027823E+05	1.438971E-04	1.838561E-04	6.891378E+00
USBS-30	6.700000E+01	1.780000E-03	1.780000E-03	1.240000E-01

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.954E+05	2.379E+05	2.303E+05	1.376E+01	6.981E+00	6.513E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	4.954E+05	2.469E+05	3.210E+05	1.376E+01	7.253E+00	9.013E+00	7.550E-04	7.618E-04	1.256E-03
ERRORS	2.129E+03	6.540E+04	2.241E+05	4.766E-02	1.946E+00	6.242E+00	2.496E-04	2.696E-04	1.034E-03

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	28.80

MANEUVERS
PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

ESCAPE *

AT 0D10H31M 0.00S
T= 37860 ALT= 1.4428110E+09 VEL= 1.0329770E+05 ANG= 67.140 LAT= -25.6627 LONG= -44.6349

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.963E+05	2.383E+05	2.306E+05	1.376E+01	6.981E+00	6.513E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	4.962E+05	2.474E+05	3.215E+05	1.376E+01	7.253E+00	9.013E+00	7.550E-04	7.618E-04	1.272E-03
ERRORS	2.129E+03	6.552E+04	2.245E+05	4.766E-02	1.946E+00	6.242E+00	2.496E-04	2.696E-04	1.053E-03

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
		YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
		ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

FIGURE B-4e. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

AFTER MIDCOURSE CORRECTION, RMV= 1.335799E+01 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.963E+05	2.383E+05	2.306E+05	7.854E+00	4.743E+00	4.320E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	4.962E+05	2.474E+05	3.215E+05	7.855E+00	5.119E+00	7.572E+00	7.550E-04	7.618E-04	1.272E-03
ERRORS	2.129E+03	6.552E+04	2.245E+05	4.821E-02	1.943E+00	6.241E+00	2.496E-04	2.696E-04	1.053E-03

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF.
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.963E+05	2.383E+05	2.306E+05	7.854E+00	4.743E+00	4.320E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	4.962E+05	2.474E+05	3.215E+05	7.855E+00	5.119E+00	7.572E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	2.129E+03	6.552E+04	2.245E+05	4.821E-02	1.943E+00	6.241E+00	7.854E-01	7.854E-01	7.854E-01

ESCAPE *

COAST FOR 34522140.00 SEC. (399D13H29M 0.00S)

TARGET CT. *

AT 400D 0H 0M 0.00S
T= 34560000 ALT= 2.0049048E+12 VEL= 1.8816539E+08 ANG= 90.010 LAT= -6.5116 LONG= 155.7267

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	2.259E+08	2.464E+07	8.109E+07	1.417E+00	1.805E+00	6.218E-01	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	2.323E+08	2.456E+08	1.943E+08	2.778E+00	1.711E+01	6.872E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	5.280E+07	2.443E+08	1.767E+08	2.399E+00	1.702E+01	6.847E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2335	.9329	-.2741	XI	.1881	.1202	.9748	DR	-.3299	.3738	.8669
YI	.6264	-.0713	-.7763	YI	-.9062	.4039	.1251	CR	.8994	.4034	.1683
ZI	-.7438	-.3529	-.5677	ZI	-.3787	-.9069	.1849	OP	-.2868	.8352	-.4693

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.			
STATUS	-0	-0	0	0	0	0	1	0	0	0	

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	2.259E+08	2.464E+07	8.109E+07	1.417E+00	1.805E+00	6.218E-01	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	2.323E+08	2.456E+08	1.943E+08	2.778E+00	1.711E+01	6.872E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	5.280E+07	2.443E+08	1.767E+08	2.399E+00	1.702E+01	6.847E+00	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

FIGURE B-4f. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
                 ANGLE BETWEEN CELESTIAL BODIES=    76.66, BETWEEN OPTICAL AIDS=    90.00

                 DEAD BANDS    SET     MAX.
                       ROLL   20.00   64.00
                        YAW    8.00    8.00
                      PITCH   20.00   22.66
             MANEUVERS
                      PITCH    5.360DEG.    YAW    5.335DEG.  ROLL-133.476DEG. IN      1800SEC.

       TARGET CI. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

     AT 400D 0H30M 0.00S
       T=  34561800  ALT=  2.6048474E+12  VEL=  1.8816163E+08  ANG=    90.010  LAT=   -6.5106  LONG=  148.2286
                               P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
             COMP. DEV.    2.259E+08   2.464E+07   8.109E+07   1.407E+00   1.807E+00   6.196E-01   8.357E-02   1.324E-01   1.391E-01
             DEVIATIONS    2.323E+08   2.456E+08   1.943E+08   2.781E+00   1.713E+01   6.877E+00   7.854E-01   7.854E-01   7.854E-01
              ERRORS       5.280E+07   2.443E+08   1.767E+08   2.408E+00   1.704E+01   6.852E+00   7.854E-01   7.854E-01   7.854E-01

              ATTITUDE          ROLL      YAW     PITCH          DR       CR       OP          ROLL     YAW     PITCH
                           XI  -.1192   -.4462    .8869    XI   .1881    .1202    .9748   DR  -.3728   -.8838   -.2827
                           YI   .6864    .6084    .3983    YI  -.9062    .4039    .1251   CR   .9135   -.4031    .0555
                           ZI  -.7173    .6563    .2338    ZI  -.3787   -.9069    .1849   OP  -.1630   -.2375    .9576

         SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSUR ISU/C.P.S. COM. SYST. HORIZ.SEN.
          STATUS      1          1          1          1          1          1          1          0          0          0

             END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

       TARGET CI. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    COAST FOR        60.00 SEC.   (  0D 0H 1M 0.00S)

                 ANGLE BETWEEN CELESTIAL BODIES=    76.66, BETWEEN OPTICAL AIDS=    90.00

                 DEAD BANDS    SET     MAX.
                       ROLL   20.00   64.00
                        YAW    8.00    8.00
                      PITCH   20.00   22.66
             MANEUVERS
                      PITCH    .000DEG.    YAW    .000DEG.   ROLL    -.000DEG. IN       60SEC.

             SEARCH FOR SUN          IN     30.4 SECONDS WITH    1.00000 PASSES
                                 ANGULAR RATES (RAD/SEC)=ROLL     .02583     ,YAW    0.00000     ,PITCH  0.00000

             SEARCH FOR CANOPUS      IN     29.6 SECONDS WITH    1.00000 PASSES
                                 ANGULAR RATES (RAD/SEC)=ROLL     .00000     ,YAW     .02583     ,PITCH  0.00000

       TARGET CI. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

     AT 400D 0H31M 0.00S
       T=  34561860  ALT=  2.6048455E+12  VEL=  1.8816150E+08  ANG=    90.010  LAT=   -6.5106  LONG=  147.9787
                               P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
```

FIGURE B-4g. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
    COMP. DEV.   2.259E+08  2.464E+07  8.109E+07  1.406E+00  1.807E+00  6.196E-01  8.357E-02  1.324E-01  1.391E-01
    DEVIATIONS   2.323E+08  2.456E+08  1.943E+08  2.781E+00  1.713E+01  6.877E+00  8.357E-02  1.324E-01  1.391E-01
     ERRORS      5.280E+07  2.443E+08  1.767E+08  2.409E+00  1.704E+01  6.852E+00  2.825E-04  7.058E-04  2.318E-04

          ATTITUDE           ROLL     YAW     PITCH        DR      CR      OP         ROLL     YAW     PITCH
CANOPUS   ACQUIRED      XI  -.1192  -.4462   .8869   XI   .1881   .1202   .9748  DR  -.3728  -.8838  -.2827
                        YI   .6864   .6084   .3983   YI  -.9062   .4039   .1251  CR   .9135  -.4031   .0555
                        ZI  -.7173   .6563   .2338   ZI  -.3787  -.9069   .1849  OP  -.1630  -.2375   .9576

      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
       STATUS       1          1           1          1          1          1          1          0          0          0

    END SEARCH FOR SUN-CANOPUS


   TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR      1800.00 SEC.   (  0D 0H30M 0.00S)

           ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

           DEAD BANDS   SET     MAX.
                ROLL   20.00   64.00
                 YAW    8.00    8.00
               PITCH   20.00   22.66
    MANEUVERS
               PITCH     .000DEG.    YAW      .000DEG.   ROLL    -.001DEG. IN      1800SEC.

   TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT 400D 1H 1M 0.00S
   T=  34563660   ALT=  2.6047888E+12   VEL=  1.8815780E+08   ANG=    90.010  LAT=    -6.5096  LONG=  140.4806
                   P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
    COMP. DEV.   2.259E+08  2.464E+07  8.109E+07  1.378E+00  1.814E+00  6.131E-01  8.357E-02  1.324E-01  1.391E-01
    DEVIATIONS   2.322E+08  2.457E+08  1.943E+08  2.790E+00  1.720E+01  6.887E+00  8.357E-02  1.324E-01  1.391E-01
     ERRORS      5.279E+07  2.443E+08  1.767E+08  2.435E+00  1.711E+01  6.863E+00  2.857E-04  1.098E-03  2.481E-04

          ATTITUDE           ROLL     YAW     PITCH        DR      CR      OP         ROLL     YAW     PITCH
CANOPUS   ACQUIRED      XI  -.1192  -.4463   .8869   XI   .1881   .1202   .9748  DR  -.3729  -.8838  -.2827
                        YI   .6864   .6084   .3984   YI  -.9062   .4039   .1251  CR   .9135  -.4031   .0555
                        ZI  -.7173   .6563   .2338   ZI  -.3787  -.9069   .1849  OP  -.1630  -.2375   .9576

      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
       STATUS       1          1           1          1          1          1          1          0          0          0
    DEADBAND ON AXIS  1 CHANGED TO     .10000 DEG.
    DEADBAND ON AXIS  2 CHANGED TO     .10000 DEG.
    DEADBAND ON AXIS  3 CHANGED TO     .10000 DEG.

        STATION        RANGE          RANGE DOT          AZM       ELE.      SUN ANG.
       CANBERRA   2.6047916E+12  -3.1699020E+04   -17.455    60.115    68.370
         MEASUREMENT ERRORS       RANGE         ELEVATION        AZIMUTH        RANGE DOT
            INERTIAL SYSTEM   1.834227E+08    5.186116E-05   7.851536E-05   1.674180E+04
                   DSIF      -0.              -0.            -0.            4.100000E-02
    AFTER KALMAN UPDATE
                   P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
    COMP. DEV.   2.322E+08  2.457E+08  1.944E+08  2.789E+00  1.720E+01  6.887E+00  7.125E-04  7.125E-04  7.125E-04
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FIGURE B-4h. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
 DEVIATIONS 2.322E+08  2.457E+08  1.943E+08  2.790E+00  1.720E+01  6.887E+00  7.677E-04  1.306E-03  7.544E-04
 ERRORS     1.109E+06  1.133E+06  1.297E+06  2.058E-02  8.390E-02  3.358E-02  2.857E-04  1.094E-03  2.478E-04

 TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR       60.00 SEC.   (  0D 0H 1M 0.00S)

          ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

          DEAD BANDS   SET    MAX.
               ROLL    .10   64.00
               YAW     .10    8.00
               PITCH   .10   22.66
    MANEUVERS
               PITCH   .000DEG.   YAW    .000DEG.  ROLL   -.000DEG. IN      60SEC.

 TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT 400D 1H 2M 0.00S
 T=  34563720  ALT=  2.6047869E+12  VEL=  1.8815768E+08  ANG=    90.010  LAT=   -6.5096  LONG=  140.2307
                  P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
     COMP. DEV.  2.322E+08  2.457E+08  1.944E+08  2.790E+00  1.720E+01  6.887E+00  7.125E-04  7.125E-04  7.125E-04
     DEVIATIONS  2.322E+08  2.457E+08  1.943E+08  2.790E+00  1.720E+01  6.887E+00  7.677E-04  1.323E-03  7.547E-04
      ERRORS     1.109E+06  1.133E+06  1.297E+06  2.058E-02  8.392E-02  3.358E-02  2.859E-04  1.115E-03  2.489E-04

            ATTITUDE          ROLL     YAW     PITCH          DR       CR       OP          ROLL     YAW     PITCH
CANOPUS   ACQUIRED       XI  -.1192  -.4463   .8869    XI   .1881    .1202    .9748   DR  -.3729  -.8838  -.2827
                         YI   .6864   .6084   .3984    YI  -.9062    .4039    .1251   CR   .9135  -.4031   .0555
                         ZI  -.7173   .6563   .2338    ZI  -.3787   -.9069    .1849   OP  -.1630  -.2375   .9576

     SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS       1         1          1          1          1          1          1          0          0          0

   AFTER MIDCOURSE CORRECTION, RMV=    1.436577E+00 (FT/SEC) ,DOF=1.000

                  P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
     COMP. DEV.  2.322E+08  2.457E+08  1.944E+08  3.752E+00  1.632E+01  6.501E+00  7.125E-04  7.125E-04  7.125E-04
     DEVIATIONS  2.322E+08  2.457E+08  1.943E+08  3.752E+00  1.632E+01  6.501E+00  7.677E-04  1.323E-03  7.547E-04
      ERRORS     1.109E+06  1.133E+06  1.297E+06  2.050E-02  8.376E-02  3.371E-02  2.859E-04  1.115E-03  2.489E-04
   ATT. CONT. TURNED OFF
   COMPUTER   TURNED OFF
   I. S. U.   TURNED OFF
   STAR TRCKR TURNED OFF
   SUN SENSOR TURNED OFF
   COM. SYST. TURNED OFF
                  P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
     COMP. DEV.  2.322E+08  2.457E+08  1.944E+08  3.752E+00  1.632E+01  6.501E+00  7.854E-01  7.854E-01  7.854E-01
     DEVIATIONS  2.322E+08  2.457E+08  1.943E+08  3.752E+00  1.632E+01  6.501E+00  7.854E-01  7.854E-01  7.854E-01
      ERRORS     1.109E+06  1.133E+06  1.297E+06  2.050E-02  8.376E-02  3.371E-02  7.854E-01  7.854E-01  7.854E-01

   TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 COAST FOR   896522.00 SEC.   ( 10D 9H 2M 2.00S)

   TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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FIGURE B-4i. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

AT 410D10H 4M 2.00S

T= 35460242 ALT= 2.5764392E+12 VEL= 1.8630775E+08 ANG= 90.006 LAT= -6.0886 LONG= 5.4976

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	6.478E+08	1.265E+02	2.365E+08	2.663E+04	3.579E+04	6.940E+03	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	6.479E+08	2.173E+06	2.367E+08	2.664E+04	3.580E+04	6.940E+03	7.854E-01	7.854E-01	7.854E-01
ERRORS	8.487E+05	2.173E+06	1.314E+06	2.306E+01	6.420E+01	4.025E+01	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.1192	-.4463	.8869	XI	.1142	.1908	.9750	DR	-.7448	-.6072	-.2768
YI	.6864	.6084	.3984	YI	-.9909	-.0483	.1256	CR	.6474	-.7580	-.0792
ZI	-.7173	.6563	.2338	ZI	.0710	-.9804	.1836	OP	-.1617	-.2382	.9577

```
SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT.  STAR TRCKR  SUN SENSOR  ISU/C.P.S.  COM. SYST.  HORIZ.SEN.
  STATUS      -0        -0         -0          -0          -0           0          -0           0          0          0
```

TARGET MISS, RMS= 2.17328510E+06, DOF=1.000

COMPUTER	9063.00	SEC.
I. S. U.	9063.00	SEC.
ATT. CONT.	39057.00	SEC.
STAR TRCKR	39057.00	SEC.
SUN SENSOR	39057.00	SEC.
ISU/C.P.S.	9063.00	SEC.
COM. SYST.	34563720.00	SEC.
HORIZ.SEN.	0.00	SEC.

FIGURE B-4j. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= GG-49 GG-49 GG-49

ISU DATA

ON TIME (HR)= 2.517

CENT.IMG (GIMBALED) SPECIFIED

TOTAL ENERGY= 566.437
TOTAL POWER = 225.000
TOTAL P.FAIL= .00186
TOTAL WEIGHT= 80.000

SUBSYSTEM PARAMETERS

	COMPUTERS TELEDYNE	STAR TRCKR ITT-LUN.OB	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	2.517	10.849	10.849	0.000	9601.033	0.000	0.000		
ENERGY=	176.225	86.793	54.246	0.000	33603.617	0.000	0.000	TOTAL ENERGY=	33920.881
POWER=	70.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL POWER =	86.500
P.FAIL=	.00050	.00012	.00011	0.00000	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09221
WEIGHT=	30.000	7.000	2.000	0.000	3.100	0.000	0.000	TOTAL WEIGHT=	42.100

ATTITUDE CONTROL SYSTEM ANALYSIS

ON TIME (HR)= 10.849

THRUST SIZING (LB)

	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)

	ROLL	YAW	PITCH
SEARCHING=	4.0637	2.3089	0.0000
DEAD BAND=	.0001	.4445	.2560
MANEUVERS=	.2793	.1547	.1917
TOTAL IMP=	4.3431	2.9082	.4477

NO. OF FIRINGS= 22466 TOTAL IMPULSE= 7.6989 FUEL WEIGHT= .137481

TOTAL ENERGY= 108.492
TOTAL POWER = 10.000
TOTAL P.FAIL= .00279
TOTAL WEIGHT= 21.215

ENERGY SOURCE DATA

TOTAL POWER= 321.500 TOTAL ENERGY= 34595.810 TOTAL WEIGHT= 124.117

WIRING

TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 13.435 DOF=1.000 CAPABILITY= 25.357 TOTAL WEIGHT= 27.702

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.05929	ASTRIONICS=	405.134
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1594.866
UNRELIABILITY =	.09643	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 405.13426

EXECUTION TIMES, START=864.61, END=892.17, ELAPSED=27.564(SEC.)

FIGURE B-4k. AIDED CENTAUR SYSTEM ON SCHEDULE 1, LEVEL 2 EVALUATION (Continued)

```
                         PENALTY (MODE 3)

ERROR ANALYSIS (SCHEDULE NO. 1)

LAUNCH      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT   0D 0H 0M 0.00S
 T=          0  ALT= -4.7683716E-07  VEL=  2.3196861E+02  ANG=     90.000  LAT=   28.5000  LONG=  -80.5000
                          P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
          COMP. DEV.  0.         0.         0.         0.         0.         0.         0.         0.         0.
          DEVIATIONS  0.         0.         0.         0.         0.         0.         0.         0.         0.
           ERRORS     0.         0.         0.         0.         0.         0.         0.         0.         0.
   SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
     STATUS      1          1          0          0          0          1          0          0          0          0
COM. SYST. TURNED ON
                          P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
          COMP. DEV.  0.         0.         0.         0.         0.         0.         0.         0.         0.
          DEVIATIONS  0.         0.         0.         0.         0.         0.         0.         0.         0.
           ERRORS     0.         0.         0.         0.         0.         0.         0.         0.         0.

LAUNCH      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

BURN FOR    565.000 SEC.
ADD BURN ERRORS
PARK  FOR      935.00 SEC.  (  0D 0H15M35.00S)

PARK        * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT   0D 0H25M 0.00S
 T=       1500  ALT=  6.0761100E+05  VEL=  2.4239262E+04  ANG=     90.000  LAT=   -5.7054  LONG=   -7.0921
                          P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
          COMP. DEV.  0.         0.         0.         0.         0.         0.         9.064E-05  9.064E-05  9.064E-05
          DEVIATIONS  8.686E+03  6.062E+03  2.556E+03  1.306E+01  4.388E+00  3.151E-01  6.681E-05  1.316E-04  2.397E-04
           ERRORS     8.686E+03  6.062E+03  2.556E+03  1.306E+01  4.388E+00  3.151E-01  1.082E-04  1.567E-04  2.749E-04
   SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
     STATUS      1          1          0          0          0          1          1          0          0          0

          STATION       RANGE         RANGE DOT          AZM        ELE.      SUN ANG.
          ASCENSION   2.8752678E+06  1.5257582E+04     73.154      8.373    111.615
            MEASUREMENT ERRORS       RANGE           ELEVATION         AZIMUTH          RANGE DOT
               INERTIAL SYSTEM     4.575809E+03     2.556166E-03     2.300783E-03     8.262418E+00
                    TPQ-18         6.700000E+01     4.500000E-04     4.500000E-04     -0.
AFTER KALMAN UPDATE
                          P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
          COMP. DEV.  8.636E+03  5.953E+03  2.422E+03  1.292E+01  4.076E+00  2.728E-01  9.322E-05  9.383E-05  2.267E-04
          DEVIATIONS  8.686E+03  6.062E+03  2.556E+03  1.306E+01  4.388E+00  3.151E-01  6.681E-05  1.316E-04  2.397E-04
           ERRORS     9.307E+02  1.142E+03  8.181E+02  1.938E+00  1.624E+00  1.576E-01  1.070E-04  1.505E-04  1.687E-04

PARK        * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

PARK  FOR      81.30 SEC.  (  0D 0H 1M21.30S)
BURN FOR    941.500 SEC.
ADD BURN ERRORS
COAST FOR        .20 SEC.  (  0D 0H 0M   .20S)
```

FIGURE B-5a. OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION

```
ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT   0D 0H42M 3.00S
T=       2523  ALT=  1.2568513E+07  VEL=  4.7908635E+04  ANG=     42.609  LAT=  -28.4248  LONG=   47.9456
                   P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
      COMP. DEV. -3.453E-04  0.         -6.104E-05  -3.372E-07  0.          0.          1.975E-08   1.975E-08   1.975E-08
      DEVIATIONS  4.356E+03  2.958E+03   2.787E+03   5.330E+00  5.816E+00   5.319E+00   2.171E-04   2.262E-04   2.533E-04
       ERRORS     4.356E+03  2.958E+03   2.787E+03   5.330E+00  5.816E+00   5.319E+00   2.171E-04   2.262E-04   2.533E-04

       ATTITUDE          ROLL     YAW    PITCH          DR      CR       OP          ROLL     YAW     PITCH
                    XI  -.1872  -.9823   .0083    XI  -.1872  -.9823   .0083    DR  1.0000  -.0000    .0000
                    YI  -.8845   .1722   .4335    YI  -.8846   .1722   .4335    CR   .0000  1.0000   -.0000
                    ZI  -.4272   .0738  -.9011    ZI  -.4272   .0738  -.9011    OP  -.0000   .0000   1.0000

   SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
     STATUS       1          1          0          0          0          1          1          0          0          0
  ATT. CONT. TURNED ON
                   P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
      COMP. DEV. -3.453E-04  0.         -6.104E-05  -3.372E-07  0.          0.          7.125E-03   7.125E-03   7.125E-03
      DEVIATIONS  4.356E+03  2.958E+03   2.787E+03   5.330E+00  5.816E+00   5.319E+00   7.129E-03   7.129E-03   7.130E-03
       ERRORS     4.356E+03  2.958E+03   2.787E+03   5.330E+00  5.816E+00   5.319E+00   2.171E-04   2.262E-04   2.533E-04
  DEADBAND ON AXIS  1 CHANGED TO   20.00000 DEG.
  DEADBAND ON AXIS  2 CHANGED TO   20.00000 DEG.
  DEADBAND ON AXIS  3 CHANGED TO   20.00000 DEG.
  STAR TRCKR TURNED ON
  SUN SENSOR TURNED ON
                   P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
      COMP. DEV. -3.453E-04  0.         -6.104E-05  -3.372E-07  0.          0.          1.425E-01   1.425E-01   1.425E-01
      DEVIATIONS  4.356E+03  2.958E+03   2.787E+03   5.330E+00  5.816E+00   5.319E+00   1.425E-01   1.425E-01   1.425E-01
       ERRORS     4.356E+03  2.958E+03   2.787E+03   5.330E+00  5.816E+00   5.319E+00   2.171E-04   2.262E-04   2.533E-04

      BEGIN MANEUVERING TO LOCATE SUN-CANOPUS


ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR       900.00 SEC.  (  0D 0H15M 0.00S)

            ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

            DEAD BANDS   SET     MAX.
                  ROLL  20.00   64.00
                   YAW   8.00    8.00
                 PITCH  20.00   28.68
      MANEUVERS
                 PITCH 124.634DEG.   YAW -70.015DEG.  ROLL  59.862DEG. IN      900SEC.
ESCAPE      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT   0D 0H57M 3.00S
T=       3423  ALT=  4.8308954E+07  VEL=  4.3313231E+04  ANG=     16.593  LAT=  -29.7368  LONG=   74.2506
                   P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
      COMP. DEV.  0.        -8.632E-05  0.          0.          0.          0.          1.418E-01   7.036E-02   1.372E-01
      DEVIATIONS  9.306E+03  7.829E+03   7.364E+03   5.597E+00  5.908E+00   5.085E+00   1.418E-01   7.036E-02   1.372E-01
       ERRORS     9.306E+03  7.829E+03   7.364E+03   5.597E+00  5.908E+00   5.085E+00   2.120E-04   1.916E-04   2.809E-04
```

FIGURE B-5b. OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION (Continued)

```
                ATTITUDE          ROLL      YAW    PITCH          DR        CR       OP            ROLL       YAW     PITCH
                             XI  -.2321    .9305  -.2834    XI  -.1224   -.9924    .0083    DR   -.2123     .1112    .9709
                             YI   .6276   -.0793  -.7745    YI  -.8939    .1138    .4335    CR    .2679    -.9488    .1673
                             ZI  -.7431   -.3576  -.5656    ZI  -.4312    .0456   -.9011    OP    .9398     .2956    .1716

         SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
           STATUS      1          1          1          1          1          1          1          0          0          0

              END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

       ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
    COAST FOR         60.00 SEC.  (  0D 0H 1M 0.00S)

                 ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

                 DEAD BANDS    SET      MAX.
                        ROLL  20.00   64.00
                         YAW   8.00    8.00
                       PITCH  20.00   28.68
              MANEUVERS
                       PITCH    -.000DEG.   YAW    -.000DEG.  ROLL    -.001DEG. IN          60SEC.

              SEARCH FOR SUN          IN     31.4 SECONDS WITH    1.00000 PASSES
                                  ANGULAR RATES (RAD/SEC)=ROLL      .00001      ,YAW     0.00000      ,PITCH  0.00000

              SEARCH FOR CANOPUS      IN     28.6 SECONDS WITH    1.00000 PASSES
                                  ANGULAR RATES (RAD/SEC)=ROLL    0.00000      ,YAW     0.00000      ,PITCH  -.00001

       ESCAPE     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
     AT    0D 0H58M 3.00S
       T=      3483  ALT=  5.0840061E+07  VEL=  4.3117281E+04  ANG=     15.672  LAT=  -29.6689  LONG=   74.9188
                             P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
              COMP. DEV.  6.163E+02    3.559E+03    3.895E+03    2.969E-01    2.575E+00    2.533E+00    1.417E-01    7.042E-02    1.372E-01
              DEVIATIONS  9.640E+03    8.171E+03    7.669E+03    5.596E+00    5.927E+00    5.077E+00    1.417E-01    7.042E-02    1.372E-01
               ERRORS     9.622E+03    7.429E+03    6.656E+03    5.589E+00    5.390E+00    4.429E+00    1.441E-04    1.411E-04    2.325E-04
                ATTITUDE          ROLL      YAW    PITCH          DR        CR       OP            ROLL       YAW     PITCH
    CANOPUS    ACQUIRED      XI  -.2321    .9305  -.2834    XI  -.1202   -.9927    .0083    DR   -.2128     .1133    .9705
                             YI   .6276   -.0793  -.7745    YI  -.8942    .1119    .4335    CR    .2674    -.9486    .1694
                             ZI  -.7431   -.3576  -.5656    ZI  -.4313    .0447   -.9011    OP    .9398     .2956    .1716

         SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
           STATUS      1          1          1          1          1          1          1          0          0          0

              END SEARCH FOR SUN-CANOPUS

       COMPUTER   TURNED OFF
       I. S. U.   TURNED OFF
                             P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
              COMP. DEV.  6.163E+02    3.559E+03    3.895E+03    2.969E-01    2.575E+00    2.533E+00    1.417E-01    7.042E-02    1.372E-01
              DEVIATIONS  9.640E+03    8.171E+03    7.669E+03    5.596E+00    5.927E+00    5.077E+00    1.417E-01    7.042E-02    1.372E-01
```

FIGURE B-5c. OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION (Continued)

ERRORS	9.622E+03	7.429E+03	6.656E+03	5.589E+00	5.390E+00	4.429E+00	1.441E-04	1.411E-04	2.325E-04

ESCAPE *

COAST FOR 32517.00 SEC. (0D 9H 1M57.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.21, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.79

MANEUVERS

PITCH -.053DEG. YAW -.094DEG. ROLL -.515DEG. IN 32517SEC.

TRACKING STAR NO. 2

ESCAPE *

AT 0D10H 0M 0.00S

T= 36000 ALT= 1.3681588E+09 VEL= 9.8762677E+04 ANG= 66.018 LAT= -25.6796 LONG= -36.9497

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.205E+04	9.249E+04	8.016E+04	3.701E-01	2.769E+00	2.323E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.835E+05	2.249E+05	1.709E+05	5.309E+00	6.808E+00	5.027E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.831E+05	2.066E+05	1.516E+05	5.296E+00	6.267E+00	4.475E+00	2.496E-04	2.696E-04	6.885E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2334	.9328	-.2746	XI	-.0997	-.9950	.0082	DR	-.2168	.1239	.9683
YI	.6264	-.0718	-.7762	YI	-.8963	.0934	.4335	CR	.2641	-.9475	.1804
ZI	-.7437	-.3532	-.5676	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1727

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	1	1	1	0	1	0	0	0

COMPUTER TURNED ON

I. S. U. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.205E+04	9.249E+04	8.016E+04	3.701E-01	2.769E+00	2.323E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.835E+05	2.249E+05	1.709E+05	5.309E+00	6.808E+00	5.027E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.831E+05	2.066E+05	1.516E+05	5.296E+00	6.267E+00	4.475E+00	2.496E-04	2.696E-04	6.885E-04

ESCAPE *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.80

MANEUVERS

PITCH -.003DEG. YAW -.005DEG. ROLL -.028DEG. IN 1800SEC.

ESCAPE *

AT 0D10H30M 0.00S

T= 37800 ALT= 1.4404029E+09 VEL= 1.0315087E+05 ANG= 67.105 LAT= -25.6632 LONG= -44.3869

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.272E+04	9.747E+04	8.434E+04	3.702E-01	2.770E+00	2.323E+00	1.416E-01	7.065E-02	1.372E-01
DEVIATIONS	1.931E+05	2.372E+05	1.799E+05	5.307E+00	6.812E+00	5.027E+00	1.416E-01	7.065E-02	1.372E-01
ERRORS	1.927E+05	2.179E+05	1.596E+05	5.294E+00	6.270E+00	4.475E+00	3.045E-04	3.212E-04	7.103E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
		YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
		ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
ASCENSION	1.4439360E+09	4.0809058E+04	-125.447	55.969	80.860

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	1.947298E+05	1.568034E-04	1.001109E-04	1.228915E+01
USBS-30	6.700000E+01	1.780000E-03	1.780000E-03	5.000000E-01

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.931E+05	2.329E+05	1.121E+05	5.307E+00	6.678E+00	3.149E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.931E+05	2.372E+05	1.799E+05	5.307E+00	6.812E+00	5.027E+00	7.598E-04	7.815E-04	1.006E-03
ERRORS	1.364E+03	4.208E+04	1.416E+05	2.145E-02	1.266E+00	3.941E+00	2.638E-04	3.209E-04	7.103E-04

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	28.80

MANEUVERS

PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

ESCAPE *

AT 0D10H31M 0.00S

T= 37860 ALT= 1.4428110E+09 VEL= 1.0329770E+05 ANG= 67.140 LAT= -25.6627 LONG= -44.6349

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.333E+05	1.122E+05	5.307E+00	6.678E+00	3.149E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	5.307E+00	6.812E+00	5.027E+00	7.601E-04	7.828E-04	1.007E-03
ERRORS	1.364E+03	4.216E+04	1.419E+05	2.145E-02	1.266E+00	3.941E+00	2.648E-04	3.241E-04	7.117E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
		YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
		ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

FIGURE B-5e OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION (Continued)

AFTER MIDCOURSE CORRECTION, RMV= 7.370912E+00 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.333E+05	1.122E+05	3.948E+00	2.566E+00	2.543E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	3.948E+00	2.872E+00	4.656E+00	7.601E-04	7.828E-04	1.007E-03
ERRORS	1.364E+03	4.216E+04	1.419E+05	2.618E-02	1.265E+00	3.940E+00	2.648E-04	3.241E-04	7.117E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.333E+05	1.122E+05	3.948E+00	2.566E+00	2.543E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	3.948E+00	2.872E+00	4.656E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.364E+03	4.216E+04	1.419E+05	2.618E-02	1.265E+00	3.940E+00	7.854E-01	7.854E-01	7.854E-01

ESCAPE *

COAST FOR 34522140.00 SEC. (399D13H29M 0.00S)

TARGET CT. *

AT 400D 0H 0M 0.00S
T= 34560000 ALT= 2.6049048E+12 VEL= 1.8816539E+08 ANG= 90.010 LAT= -6.5116 LONG= 155.7267

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.132E+08	1.166E+07	4.779E+07	6.972E-01	1.007E+00	3.435E-01	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.178E+08	1.561E+08	1.211E+08	1.682E+00	1.087E+01	4.369E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	3.351E+07	1.557E+08	1.120E+08	1.528E+00	1.083E+01	4.360E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2335	.9329	-.2741	XI	.1881	.1202	.9748	DR	-.3299	.3738	.8669
YI	.6264	-.0713	-.7763	YI	-.9062	.4039	.1251	CR	.8994	.4034	.1683
ZI	-.7438	-.3529	-.5677	ZI	-.3787	-.9069	.1849	OP	-.2868	.8352	-.4693

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	0	0	0	0	1	0	0	0

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.132E+08	1.166E+07	4.779E+07	6.972E-01	1.007E+00	3.435E-01	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	1.178E+08	1.561E+08	1.211E+08	1.682E+00	1.087E+01	4.369E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	3.351E+07	1.557E+08	1.120E+08	1.528E+00	1.083E+01	4.360E+00	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

FIGURE B-5f OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS 30 RADAR, LEVEL 2 EVALUATION (Continued)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.66

MANEUVERS

PITCH 5.360DEG. YAW 5.335DEG. ROLL-133.476DEG. IN 1800SEC.

TARGET CT. *

AT 400D 0H30M 0.00S

T= 34561800 ALT= 2.6048474E+12 VEL= 1.8816163E+08 ANG= 90.010 LAT= -6.5106 LONG= 148.2286

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.132E+08	1.166E+07	4.779E+07	6.923E-01	1.008E+00	3.421E-01	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.178E+08	1.561E+08	1.211E+08	1.686E+00	1.088E+01	4.372E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	3.351E+07	1.557E+08	1.120E+08	1.534E+00	1.085E+01	4.363E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.1192	-.4462	.8869	XI	.1881	.1202	.9748	DR	-.3728	-.8838	-.2827
YI	.6864	.6084	.3983	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

TARGET CT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.66

MANEUVERS

PITCH .000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

SEARCH FOR SUN IN 30.4 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL .02583 ,YAW 0.00000 ,PITCH 0.00000

SEARCH FOR CANOPUS IN 29.6 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL .00000 ,YAW .02583 ,PITCH 0.00000

TARGET CT. *

AT 400D 0H31M 0.00S

T= 34561860 ALT= 2.6048455E+12 VEL= 1.8816150E+08 ANG= 90.010 LAT= -6.5106 LONG= 147.9787

P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP

FIGURE B-5g. OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION (Continued)

COMP. DEV.	1.132E+08	1.166E+07	4.779E+07	6.921E-01	1.008E+00	3.421E-01	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.178E+08	1.561E+08	1.211E+08	1.686E+00	1.088E+01	4.372E+00	8.357E-02	1.324E-01	1.391E-01
ERRORS	3.351E+07	1.557E+08	1.120E+08	1.534E+00	1.085E+01	4.363E+00	2.826E-04	7.053E-04	2.318E-04

CANOPUS ACQUIRED

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4462	.8869	XI	.1881	.1202	.9748	DR	-.3728	-.8838	-.2827
	YI	.6864	.6084	.3983	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
	ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END SEARCH FOR SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.66

MANEUVERS

PITCH .000DEG. YAW .000DEG. ROLL -.001DEG. IN 1800SEC.

TARGET CT. *

AT 400D 1H 1M 0.00S

T= 34563660 ALT= 2.6047888E+12 VEL= 1.8815780E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.4806

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.132E+08	1.166E+07	4.779E+07	6.781E-01	1.012E+00	3.381E-01	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.178E+08	1.561E+08	1.211E+08	1.695E+00	1.093E+01	4.378E+00	8.357E-02	1.324E-01	1.391E-01
ERRORS	3.350E+07	1.558E+08	1.120E+08	1.551E+00	1.089E+01	4.370E+00	3.352E-04	7.280E-04	2.936E-04

CANOPUS ACQUIRED

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
	YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
	ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
CANBERRA	2.6047916E+12	-3.1699020E+04	-17.455	60.115	68.370

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	1.170199E+08	3.283253E-05	4.994530E-05	1.064133E+04
DSIF	-0.	-0.	-0.	4.100000E-02

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.178E+08	1.561E+08	1.211E+08	1.695E+00	1.092E+01	4.378E+00	7.125E-04	7.125E-04	7.125E-04

FIGURE B-51 OPTIMUM SYSTEM ...

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      DEVIATIONS  1.178E+08  1.561E+08  1.211E+08  1.695E+00  1.093E+01  4.378E+00  7.808E-04  1.018E-03  7.694E-04
       ERRORS     6.093E+05  2.782E+06  3.000E+06  1.724E-02  9.205E-02  4.480E-02  3.193E-04  7.275E-04  2.903E-04

  TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR       60.00 SEC.  (  0D 0H 1M 0.00S)

              ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

              DEAD BANDS   SET    MAX.
                   ROLL    .10   64.00
                    YAW    .10    8.00
                  PITCH    .10   22.66
      MANEUVERS
                  PITCH    .000DEG.   YAW    .000DEG.  ROLL   -.000DEG. IN        60SEC.

  TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT 400D 1H 2M 0.00S
  T=  34563720  ALT=  2.6047869E+12  VEL=  1.8815768E+08  ANG=    90.010  LAT=   -6.5096  LONG=  140.2307
                     P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
      COMP. DEV.  1.178E+08  1.561E+08  1.211E+08  1.695E+00  1.093E+01  4.378E+00  7.125E-04  7.125E-04  7.125E-04
      DEVIATIONS  1.178E+08  1.561E+08  1.211E+08  1.695E+00  1.093E+01  4.379E+00  7.817E-04  1.019E-03  7.707E-04
       ERRORS     6.093E+05  2.782E+06  3.000E+06  1.725E-02  9.206E-02  4.482E-02  3.216E-04  7.290E-04  2.937E-04

              ATTITUDE          ROLL     YAW     PITCH         DR      CR       OP           ROLL    YAW    PITCH
CANOPUS    ACQUIRED         XI -.1192  -.4463   .8869   XI  .1881   .1202   .9748   DR  -.3729  -.8838  -.2827
                            YI  .6864   .6084   .3984   YI -.9062   .4039   .1251   CR   .9135  -.4031   .0555
                            ZI -.7173   .6563   .2338   ZI -.3787  -.9069   .1849   OP  -.1630  -.2375   .9576

    SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
     STATUS       1          1          1          1          1          1          1          0          0          0

  AFTER MIDCOURSE CORRECTION, RMV=   9.162126E-01 (FT/SEC) ,DOF=1.000

                     P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
      COMP. DEV.  1.178E+08  1.561E+08  1.211E+08  2.333E+00  1.036E+01  4.132E+00  7.125E-04  7.125E-04  7.125E-04
      DEVIATIONS  1.178E+08  1.561E+08  1.211E+08  2.333E+00  1.037E+01  4.132E+00  7.817E-04  1.019E-03  7.707E-04
       ERRORS     6.093E+05  2.782E+06  3.000E+06  1.779E-02  9.176E-02  4.472E-02  3.216E-04  7.290E-04  2.937E-04
  ATT. CONT. TURNED OFF
  COMPUTER   TURNED OFF
  I. S. U.   TURNED OFF
  STAR TRCKR TURNED OFF
  SUN SENSOR TURNED OFF
  COM. SYST. TURNED OFF
                     P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
      COMP. DEV.  1.178E+08  1.561E+08  1.211E+08  2.333E+00  1.036E+01  4.132E+00  7.854E-01  7.854E-01  7.854E-01
      DEVIATIONS  1.178E+08  1.561E+08  1.211E+08  2.333E+00  1.037E+01  4.132E+00  7.854E-01  7.854E-01  7.854E-01
       ERRORS     6.093E+05  2.782E+06  3.000E+06  1.779E-02  9.176E-02  4.472E-02  7.854E-01  7.854E-01  7.854E-01
  TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR    896522.00 SEC.  ( 10D 9H 2M 2.00S)

  TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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FIGURE B-5i. OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION (Continued)

AT 410D10H 4M 2.00S

T= 35460242 ALT= 2.5764392E+12 VEL= 1.8630775E+08 ANG= 90.006 LAT= -6.0886 LONG= 5.4976

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.121E+08	-2.809E+01	1.516E+08	1.687E+04	2.280E+04	4.414E+03	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	4.122E+08	5.520E+06	1.517E+08	1.687E+04	2.281E+04	4.417E+03	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.043E+06	5.520E+06	3.803E+06	3.066E+01	7.040E+01	1.362E+02	7.854E-01	7.854E-01	7.854E-01

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4463	.8869	XI	.1142	.1908	.9750	DR	-.7448	-.6072	-.2768
	YI	.6864	.6084	.3984	YI	-.9909	-.0483	.1256	CR	.6474	-.7580	-.0792
	ZI	-.7173	.6563	.2338	ZI	.0710	-.9804	.1836	OP	-.1617	-.2382	.9577

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	-0	-0	-0	0	-0	0	0	0

TARGET MISS, RMS= 5.51993082E+06, DOF=1.000

COMPUTER	9063.00 SEC.
I. S. U.	9063.00 SEC.
ATT. CONT.	39057.00 SEC.
STAR TRCKR	39057.00 SEC.
SUN SENSOR	39057.00 SEC.
ISU/C.P.S.	9063.00 SEC.
COM. SYST.	34563720.00 SEC.
HORIZ.SEN.	0.00 SEC.

FIGURE B-5j. OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION (Continued)

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= 18-IRIG-B 18-IRIG-B 18-IRIG-B

ISU DATA(HORIZONTAL DESIGN NUMBER 5 OPTIMUM) ON TIME (HR)= 2.517

OUTSIDE DIMENSIONS		WEIGHT		WEIGHT			
LENGTH=	10.200	BLOCK=	5.407	INSULATION=	1.019	EXCIT.ENERGY=	108.001
WIDTH=	7.500	BASE=	3.540	ELECTRONICS=	10.000	EXCIT.POWER =	42.900
HEIGHT=	4.610	COVER=	2.171	COMPONENTS=	4.500	TOTAL P.FAIL=	.00062
						TOTAL WEIGHT=	26.637

ISU THERMAL ANALYSIS

MAX.HEATER POWER=	96.525	MAX.THERMAL COND.=	2.1450	TOTAL ENERGY=	174.274
MIN.HEATER POWER=	-.000	MIN.THERMAL COND.=	1.0725	TOTAL POWER =	139.425

SUBSYSTEM PARAMETERS

	COMPUTERS SIGN III	STAR TRCKR ITT-LUN.OB	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	2.517	10.849	10.849	0.000	9601.033	0.000	0.000		
ENERGY=	289.512	86.793	54.246	0.000	33603.617	0.000	0.000	TOTAL ENERGY=	34034.168
POWER=	115.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL POWER =	131.500
P.FAIL=	.00045	.00012	.00011	0.00000	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09216
WEIGHT=	27.000	7.000	2.000	0.000	3.100	0.000	0.000	TOTAL WEIGHT=	39.100

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 10.849

THRUST SIZING (LB)

	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)

	ROLL	YAW	PITCH		
SEARCHING=	4.0598	2.3060	.0007		
DEAD BAND=	.0001	.4445	.2560		
MANEUVERS=	.2793	.1547	.1917	TOTAL ENERGY=	108.492
TOTAL IMP=	4.3392	2.9052	.4484	TOTAL POWER =	10.000
				TOTAL P.FAIL=	.00278

NO. OF FIRINGS= 22446 TOTAL IMPULSE= 7.6928 FUEL WEIGHT= .137372 TOTAL WEIGHT= 21.215

ENERGY SOURCE DATA

TOTAL POWER= 280.925 TOTAL ENERGY= 34316.934 TOTAL WEIGHT= 110.119

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 7.428 DOF=1.000 CAPABILITY= 13.953 TOTAL WEIGHT= 24.376

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.06051	ASTRIONICS=	331.447
EXCESSIVE TGT. MISS =	.00000	SPACECRAFT=	1668.553
UNRELIABILITY =	.09525	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 331.44713

EXECUTION TIMES, START=549.58, END=577.90, ELAPSED=28.314(SEC.)

FIGURE B-5k. OPTIMUM SYSTEM ON SCHEDULE 1 WITH DEGRADED USBS-30 RADAR, LEVEL 2 EVALUATION (Continued)

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                              PENALTY (MODE 3)

     ERROR ANALYSIS (SCHEDULE NO. 2)


     LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  AT    0D 0H 0M 0.00S
     T=          0  ALT= -4.7683716E-07  VEL=  2.3196861E+02  ANG=    90.000  LAT=    28.5000  LONG=  -80.5000
                          P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
            COMP. DEV.  0.           0.           0.           0.           0.           0.           0.           0.           0.
            DEVIATIONS  0.           0.           0.           0.           0.           0.           0.           0.           0.
             ERRORS     0.           0.           0.           0.           0.           0.           0.           0.           0.
      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS      1          1          0          0          0          1          0          0          0          0
     COM. SYST. TURNED ON
                          P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
            COMP. DEV.  0.           0.           0.           0.           0.           0.           0.           0.           0.
            DEVIATIONS  0.           0.           0.           0.           0.           0.           0.           0.           0.
             ERRORS     0.           0.           0.           0.           0.           0.           0.           0.           0.

     LAUNCH     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  BURN FOR     565.000 SEC.
  ADD BURN ERRORS
  PARK  FOR        935.00 SEC.   (  0D 0H15M35.00S)

     PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  AT    0D 0H25M 0.00S
     T=       1500  ALT=  6.0761100E+05  VEL=  2.4239262E+04  ANG=    90.000  LAT=   -5.7054  LONG=   -7.0921
                          P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
            COMP. DEV.  0.           0.           0.           0.           0.           0.           2.272E-04    2.272E-04    2.272E-04
            DEVIATIONS  6.777E+03    4.031E+03    3.324E+03    9.338E+00    1.489E+00    6.281E-01    1.558E-04    4.086E-04    2.207E-04
             ERRORS     6.777E+03    4.031E+03    3.324E+03    9.338E+00    1.489E+00    6.281E-01    2.643E-04    4.610E-04    4.034E-04
      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS      1          1          0          0          0          1          1          0          0          0

             STATION       RANGE        RANGE DOT          AZM        ELE.     SUN ANG.
            ASCENSION   2.8752678E+06  1.5257582E+04    73.154      8.373    111.615
              MEASUREMENT ERRORS      RANGE          ELEVATION        AZIMUTH         RANGE DOT
                 INERTIAL SYSTEM     4.082872E+03    1.794594E-03    1.902463E-03    6.163322E+00
                       TPQ-18        6.700000E+01    4.500000E-04    4.500000E-04    -0.
     AFTER KALMAN UPDATE
                          P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
            COMP. DEV.  6.712E+03    3.965E+03    3.252E+03    9.219E+00    1.296E+00    5.573E-01    2.462E-04    3.176E-04    2.778E-04
            DEVIATIONS  6.777E+03    4.031E+03    3.324E+03    9.338E+00    1.489E+00    6.281E-01    1.558E-04    4.086E-04    2.207E-04
             ERRORS     9.306E+02    7.242E+02    6.844E+02    1.487E+00    7.328E-01    2.897E-01    2.552E-04    3.404E-04    3.160E-04

     PARK       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  PARK  FOR        81.30 SEC.   (  0D 0H 1M21.30S)
  BURN FOR     941.500 SEC.
  ADD BURN ERRORS
  COAST FOR         .20 SEC.   (  0D 0H 0M   .20S)
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FIGURE B-6a. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION

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ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT    0D 0H42M 3.00S
 T=        2523  ALT=  1.2568513E+07  VEL=  4.7908635E+04  ANG=      42.609  LAT=  -28.4248  LONG=    47.9456
                      P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
        COMP. DEV.  0.           0.           0.           0.           0.           0.           4.951E-08    4.951E-08    4.951E-08
        DEVIATIONS  4.240E+03    5.712E+03    5.037E+03    4.763E+00    1.316E+01    1.043E+01    6.082E-04    5.063E-04    5.513E-04
         ERRORS     4.240E+03    5.712E+03    5.037E+03    4.763E+00    1.316E+01    1.043E+01    6.082E-04    5.063E-04    5.513E-04

          ATTITUDE        ROLL      YAW     PITCH          DR       CR       OP             ROLL      YAW     PITCH
                    XI   -.1872   -.9823    .0083   XI   -.1872   -.9823    .0083   DR   1.0000   -.0000    .0000
                    YI   -.8845    .1722    .4335   YI   -.8846    .1722    .4335   CR    .0000   1.0000   -.0000
                    ZI   -.4272    .0738   -.9011   ZI   -.4272    .0738   -.9011   OP   -.0000    .0000   1.0000

   SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
     STATUS      1          1          0          0          0          1          1          0          0          0
 ATT. CONT. TURNED ON
                      P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
        COMP. DEV.  0.           0.           0.           0.           0.           0.           7.125E-03    7.125E-03    7.125E-03
        DEVIATIONS  4.240E+03    5.712E+03    5.037E+03    4.763E+00    1.316E+01    1.043E+01    7.151E-03    7.143E-03    7.147E-03
         ERRORS     4.240E+03    5.712E+03    5.037E+03    4.763E+00    1.316E+01    1.043E+01    6.082E-04    5.063E-04    5.513E-04
 DEADBAND ON AXIS  1 CHANGED TO    20.00000 DEG.
 DEADBAND ON AXIS  2 CHANGED TO    20.00000 DEG.
 DEADBAND ON AXIS  3 CHANGED TO    20.00000 DEG.
 STAR TRCKR TURNED ON
 SUN SENSOR TURNED ON
                      P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
        COMP. DEV.  0.           0.           0.           0.           0.           0.           1.425E-01    1.425E-01    1.425E-01
        DEVIATIONS  4.240E+03    5.712E+03    5.037E+03    4.763E+00    1.316E+01    1.043E+01    1.425E-01    1.425E-01    1.425E-01
         ERRORS     4.240E+03    5.712E+03    5.037E+03    4.763E+00    1.316E+01    1.043E+01    6.082E-04    5.063E-04    5.513E-04

        BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR      900.00 SEC.   (  0D 0H15M 0.00S)

            ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

            DEAD BANDS   SET    MAX.
                  ROLL  20.00  64.00
                   YAW   8.00   8.00
                 PITCH  20.00  28.68
        MANEUVERS
                 PITCH 124.634DEG.   YAW -70.015DEG.  ROLL  59.862DEG. IN       900SEC.

ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT    0D 0H57M 3.00S
 T=        3423  ALT=  4.8308954E+07  VEL=  4.3313231E+04  ANG=      16.593  LAT=  -29.7368  LONG=    74.2506
                      P-DR         P-CR         P-OP         V-DR         V-CR         V-OP         A-DR         A-CR         A-OP
        COMP. DEV.  0.          -1.726E-04    0.          -3.372E-07    0.           0.           1.418E-01    7.036E-02    1.372E-01
        DEVIATIONS  8.623E+03    1.749E+04    1.407E+04    5.137E+00    1.333E+01    9.884E+00    1.418E-01    7.036E-02    1.372E-01
         ERRORS     8.623E+03    1.749E+04    1.407E+04    5.137E+00    1.333E+01    9.884E+00    5.945E-04    4.459E-04    6.271E-04
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FIGURE B-6b. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2321	.9305	-.2834	XI	-.1224	-.9924	.0083	DR	-.2123	.1112	.9709
YI	.6276	-.0793	-.7745	YI	-.8939	.1138	.4335	CR	.2679	-.9488	.1673
ZI	-.7431	-.3576	-.5656	ZI	-.4312	.0456	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS 1 1 1 1 1 1 1 0 0 0

END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.32, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.68

MANEUVERS
PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

SEARCH FOR SUN IN 35.4 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL 0.00000 ,YAW 0.00000 ,PITCH -.00002

SEARCH FOR CANOPUS IN 24.6 SECONDS WITH 1.00000 PASSES
ANGULAR RATES (RAD/SEC)=ROLL 0.00000 ,YAW 0.00000 ,PITCH -.00002

ESCAPE *

AT 0D 0H58M 3.00S
T= 3483 ALT= 5.0840061E+07 VEL= 4.3117281E+04 ANG= 15.672 LAT= -29.6689 LONG= 74.9188

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.950E+03	1.218E+04	1.207E+04	1.113E+00	8.783E+00	7.984E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	8.921E+03	1.828E+04	1.466E+04	5.150E+00	1.337E+01	9.865E+00	1.417E-01	7.042E-02	1.372E-01
ERRORS	8.721E+03	1.394E+04	8.968E+03	5.031E+00	1.027E+01	6.176E+00	2.041E-04	2.078E-04	4.096E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2321	.9305	-.2834	XI	-.1202	-.9927	.0083	DR	-.2128	.1133	.9705
YI	.6276	-.0793	-.7745	YI	-.8942	.1119	.4335	CR	.2674	-.9486	.1694
ZI	-.7431	-.3576	-.5656	ZI	-.4313	.0447	-.9011	OP	.9398	.2956	.1716

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS 1 1 1 1 1 1 1 0 0 0

END SEARCH FOR SUN-CANOPUS

COMPUTER TURNED OFF
I. S. U. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.950E+03	1.218E+04	1.207E+04	1.113E+00	8.783E+00	7.984E+00	1.417E-01	7.042E-02	1.372E-01
DEVIATIONS	8.921E+03	1.828E+04	1.466E+04	5.150E+00	1.337E+01	9.865E+00	1.417E-01	7.042E-02	1.372E-01

FIGURE B-6c. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
ERRORS	8.721E+03	1.394E+04	8.968E+03	5.031E+00	1.027E+01	6.176E+00	2.041E-04	2.078E-04	4.096E-04

ESCAPE *

COAST FOR 32517.00 SEC. (0D 9H 1M57.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.21, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.79

MANEUVERS
PITCH -.053DEG. YAW -.094DEG. ROLL -.515DEG. IN 32517SEC.
TRACKING STAR NO. 2

ESCAPE *

AT 0D10H 0M 0.00S
T= 36000 ALT= 1.3681588E+09 VEL= 9.8762677E+04 ANG= 66.018 LAT= -25.6796 LONG= -36.9497

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.876E+04	3.234E+05	2.585E+05	1.510E+00	9.723E+00	7.542E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.762E+05	5.023E+05	3.306E+05	5.160E+00	1.516E+01	9.730E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.693E+05	3.903E+05	2.157E+05	4.935E+00	1.181E+01	6.412E+00	2.496E-04	2.696E-04	6.885E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2334	.9328	-.2746	XI	-.0997	-.9950	.0082	DR	-.2168	.1239	.9683
YI	.6264	-.0718	-.7762	YI	-.8963	.0934	.4335	CR	.2641	-.9475	.1804
ZI	-.7437	-.3532	-.5676	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1727

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	1	1	1	0	1	0	0	0

COMPUTER TURNED ON
I. S. U. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.876E+04	3.234E+05	2.585E+05	1.510E+00	9.723E+00	7.542E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.762E+05	5.023E+05	3.306E+05	5.160E+00	1.516E+01	9.730E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.693E+05	3.903E+05	2.157E+05	4.935E+00	1.181E+01	6.412E+00	2.496E-04	2.696E-04	6.885E-04

ESCAPE *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.80

MANEUVERS
PITCH -.003DEG. YAW -.005DEG. ROLL -.028DEG. IN 1800SEC.

ESCAPE *

AT 0D10H30M 0.00S
T= 37800 ALT= 1.4404029E+09 VEL= 1.0315087E+05 ANG= 67.105 LAT= -25.6632 LONG= -44.3869

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.147E+04	3.409E+05	2.721E+05	1.511E+00	9.727E+00	7.541E+00	1.416E-01	7.065E-02	1.372E-01
DEVIATIONS	1.855E+05	5.296E+05	3.481E+05	5.160E+00	1.517E+01	9.731E+00	1.416E-01	7.065E-02	1.372E-01
ERRORS	1.782E+05	4.115E+05	2.272E+05	4.934E+00	1.181E+01	6.414E+00	5.037E-04	5.139E-04	8.157E-04

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
	YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
	ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
ASCENSION	1.4439360E+09	4.0809058E+04	-125.447	55.969	80.860

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	1.826899E+05	2.946660E-04	1.356025E-04	2.246125E+01
USBS-30	6.700000E+01	1.780000E-03	1.780000E-03	1.240000E-01

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.855E+05	5.243E+05	2.994E+05	5.160E+00	1.501E+01	8.369E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.855E+05	5.296E+05	3.481E+05	5.160E+00	1.517E+01	9.731E+00	7.978E-04	8.773E-04	1.081E-03
ERRORS	1.814E+03	5.570E+04	1.909E+05	5.262E-03	1.681E+00	5.320E+00	3.590E-04	5.118E-04	8.127E-04

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	28.80

MANEUVERS
PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

ESCAPE *

AT 0D10H31M 0.00S
T= 37860 ALT= 1.4428110E+09 VEL= 1.0329770E+05 ANG= 67.140 LAT= -25.6627 LONG= -44.6349

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.858E+05	5.252E+05	2.999E+05	5.160E+00	1.501E+01	8.369E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.858E+05	5.305E+05	3.487E+05	5.160E+00	1.517E+01	9.731E+00	8.007E-04	8.846E-04	1.087E-03
ERRORS	1.814E+03	5.580E+04	1.912E+05	5.264E-03	1.681E+00	5.320E+00	3.654E-04	5.242E-04	8.205E-04

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
	YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
	ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

FIGURE B-6e. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

AFTER MIDCOURSE CORRECTION, RMV= 1.493423E+01 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.858E+05	5.252E+05	2.999E+05	5.491E+00	4.217E+00	7.230E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.858E+05	5.305E+05	3.487E+05	5.491E+00	4.632E+00	8.696E+00	8.007E-04	8.846E-04	1.087E-03
ERRORS	1.814E+03	5.580E+04	1.912E+05	1.516E-02	1.681E+00	5.320E+00	3.654E-04	5.242E-04	8.205E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.858E+05	5.252E+05	2.999E+05	5.491E+00	4.217E+00	7.230E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.858E+05	5.305E+05	3.487E+05	5.491E+00	4.632E+00	8.696E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.814E+03	5.580E+04	1.912E+05	1.516E-02	1.681E+00	5.320E+00	7.854E-01	7.854E-01	7.854E-01

ESCAPE *

COAST FOR 17242140.00 SEC. (199D13H29M 0.00S)

HELIOCENT. *

AT 200D 0H 0M 0.00S

T= 17280000 ALT= 1.4347029E+12 VEL= 9.4528212E+07 ANG= 89.915 LAT= -24.9460 LONG= 108.9401

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	9.939E+07	1.189E+07	7.791E+07	4.169E+00	1.466E+00	2.882E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.024E+08	6.698E+07	1.029E+08	4.558E+00	6.751E+00	4.937E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	2.858E+07	6.513E+07	7.261E+07	2.019E+00	6.672E+00	4.204E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2335	.9329	-.2741	XI	.7075	-.7067	.0034	DR	-.3571	.8071	.4701
YI	.6264	-.0713	-.7763	YI	-.6462	-.6450	.4080	CR	-.0227	-.5107	.8595
ZI	-.7438	-.3529	-.5677	ZI	-.2862	-.2908	-.9130	OP	.9338	.2963	.2007

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS -0 -0 0 0 0 0 1 0 0 0

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	9.939E+07	1.189E+07	7.791E+07	4.169E+00	1.466E+00	2.882E+00	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	1.024E+08	6.698E+07	1.029E+08	4.558E+00	6.751E+00	4.937E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	2.858E+07	6.513E+07	7.261E+07	2.019E+00	6.672E+00	4.204E+00	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

HELIOCENT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

FIGURE B-6f. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

```
ANGLE BETWEEN CELESTIAL BODIES=   76.48, BETWEEN OPTICAL AIDS=   90.00

DEAD BANDS   SET     MAX.
      ROLL  20.00   64.00
       YAW   8.00    8.00
     PITCH  20.00   22.48
MANEUVERS
     PITCH    7.363DEG.    YAW   6.578DEG.  ROLL-114.837DEG. IN      1800SEC.

HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT 200D 0H30M 0.00S
T=  17281800  ALT=  1.4349578E+12  VEL=  9.4546111E+07  ANG=    89.915  LAT=  -24.9445  LONG=  101.4460
                      P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
   COMP. DEV.   9.940E+07  1.189E+07  7.791E+07  4.168E+00  1.466E+00  2.881E+00  1.031E-01  1.228E-01  1.348E-01
   DEVIATIONS   1.024E+08  6.699E+07  1.029E+08  4.558E+00  6.751E+00  4.937E+00  7.854E-01  7.854E-01  7.854E-01
    ERRORS      2.858E+07  6.514E+07  7.262E+07  2.019E+00  6.672E+00  4.204E+00  7.854E-01  7.854E-01  7.854E-01

    ATTITUDE          ROLL      YAW     PITCH          DR        CR        OP          ROLL      YAW      PITCH
                 XI  -.0799   -.1424    .9866   XI   .7075   -.7067    .0034   DR  -.3029   -.7532    .5839
                 YI   .6969    .6996    .1574   YI  -.6462   -.6450    .4080   CR  -.1858   -.5542   -.8114
                 ZI  -.7127    .7002    .0434   ZI  -.2862   -.2908   -.9130   OP   .9347   -.3543    .0279

 SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
   STATUS      1          1          1          1          1          1          1          0          0          0

   END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
COAST FOR      60.00 SEC.  (  0D 0H 1M 0.00S)
           ANGLE BETWEEN CELESTIAL BODIES=   76.48, BETWEEN OPTICAL AIDS=   90.00

           DEAD BANDS   SET     MAX.
                 ROLL  20.00   64.00
                  YAW   8.00    8.00
                PITCH  20.00   22.48
MANEUVERS
                PITCH    -.000DEG.   YAW    .000DEG.  ROLL    -.000DEG. IN       60SEC.

   SEARCH FOR SUN        IN     30.4 SECONDS WITH    1.00000 PASSES
                       ANGULAR RATES (RAD/SEC)=ROLL     .02582      ,YAW     0.00000      ,PITCH  0.00000

   SEARCH FOR CANOPUS    IN     29.6 SECONDS WITH    1.00000 PASSES
                       ANGULAR RATES (RAD/SEC)=ROLL     .00000      ,YAW      .02582      ,PITCH  0.00000

HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
AT 200D 0H31M 0.00S
T=  17281860  ALT=  1.4349663E+12  VEL=  9.4545707E+07  ANG=    89.915  LAT=  -24.9445  LONG=  101.1962
                      P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
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FIGURE B-6g. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

```
COMP. DEV.   9.940E+07  1.189E+07  7.791E+07  4.168E+00  1.466E+00  2.881E+00  1.031E-01  1.228E-01  1.348E-01
DEVIATIONS   1.024E+08  6.699E+07  1.029E+08  4.558E+00  6.751E+00  4.937E+00  1.031E-01  1.228E-01  1.348E-01
 ERRORS      2.858E+07  6.514E+07  7.262E+07  2.019E+00  6.672E+00  4.204E+00  2.748E-04  2.641E-04  6.980E-04

                ATTITUDE         ROLL     YAW    PITCH        DR      CR      OP         ROLL     YAW    PITCH
CANOPUS   ACQUIRED           XI  -.0799  -.1424   .9866   XI  .7075  -.7067   .0034   DR  -.3029  -.7532   .5839
                             YI   .6969   .6996   .1574   YI -.6462  -.6450   .4080   CR  -.1858  -.5542  -.8114
                             ZI  -.7127   .7002   .0434   ZI -.2862  -.2908  -.9130   OP   .9347  -.3543   .0279

  SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
   STATUS       1         1          1         1          1          1          1          0          0          0

     END SEARCH FOR SUN-CANOPUS

  HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
COAST FOR      1800.00 SEC.  (   0D 0H30M 0.00S)

          ANGLE BETWEEN CELESTIAL BODIES=   76.48, BETWEEN OPTICAL AIDS=   90.00

          DEAD BANDS   SET    MAX.
                ROLL  20.00  64.00
                 YAW   8.00   8.00
               PITCH  20.00  22.48
     MANEUVERS
               PITCH   -.000DEG.   YAW    .000DEG.  ROLL   -.003DEG. IN    1800SEC.

  HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT 200D 1H 1M 0.00S
  T=  17283660  ALT=  1.4352183E+12  VEL=  9.4564402E+07  ANG=    89.915  LAT=  -24.9431  LONG=    93.7020
                P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
COMP. DEV.   9.940E+07  1.189E+07  7.792E+07  4.168E+00  1.466E+00  2.881E+00  1.031E-01  1.228E-01  1.348E-01
DEVIATIONS   1.024E+08  6.701E+07  1.030E+08  4.558E+00  6.752E+00  4.937E+00  1.031E-01  1.228E-01  1.348E-01
 ERRORS      2.859E+07  6.515E+07  7.262E+07  2.019E+00  6.673E+00  4.204E+00  5.288E-04  5.233E-04  8.315E-04

                ATTITUDE         ROLL     YAW    PITCH        DR      CR      OP         ROLL     YAW    PITCH
CANOPUS   ACQUIRED           XI  -.0799  -.1425   .9866   XI  .7075  -.7067   .0034   DR  -.3029  -.7532   .5838
                             YI   .6969   .6996   .1575   YI -.6462  -.6450   .4080   CR  -.1858  -.5542  -.8114
                             ZI  -.7127   .7002   .0434   ZI -.2861  -.2908  -.9130   OP   .9347  -.3543   .0279

  SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
   STATUS       1         1          1         1          1          1          1          0          0          0
DEADBAND ON AXIS  1 CHANGED TO     .10000 DEG.
DEADBAND ON AXIS  2 CHANGED TO     .10000 DEG.
DEADBAND ON AXIS  3 CHANGED TO     .10000 DEG.

     STATION        RANGE        RANGE DOT         AZM       ELE.     SUN ANG.
    CANBERRA    1.4352253E+12  1.4163268E+05   -93.579    41.574    83.658
      MEASUREMENT ERRORS      RANGE          ELEVATION       AZIMUTH        RANGE DOT
         INERTIAL SYSTEM    5.628197E+07    1.052880E-05    5.804570E-05    1.516652E+03
              DSIF              -0.             -0.             -0.         4.100000E-02
AFTER KALMAN UPDATE
                P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
COMP. DEV.   1.024E+08  6.700E+07  1.029E+08  4.558E+00  6.750E+00  4.936E+00  7.125E-04  7.125E-04  7.125E-04
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FIGURE B-6h. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

DEVIATIONS	1.024E+08	6.701E+07	1.030E+08	4.558E+00	6.752E+00	4.937E+00	8.602E-04	8.723E-04	1.087E-03
ERRORS	7.416E+05	1.075E+06	2.247E+06	4.774E-02	1.339E-01	1.093E-01	4.818E-04	5.032E-04	8.206E-04

HELIOCENT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.48, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	22.48

MANEUVERS
PITCH -.000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

HELIOCENT. *

AT 200D 1H 2M 0.00S
T= 17283720 ALT= 1.4352267E+12 VEL= 9.4564991E+07 ANG= 89.915 LAT= -24.9430 LONG= 93.4522

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.024E+08	6.700E+07	1.029E+08	4.557E+00	6.750E+00	4.936E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.024E+08	6.701E+07	1.030E+08	4.558E+00	6.752E+00	4.937E+00	8.661E-04	8.792E-04	1.092E-03
ERRORS	7.416E+05	1.075E+06	2.248E+06	4.774E-02	1.339E-01	1.093E-01	4.925E-04	5.150E-04	8.280E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.0799	-.1425	.9866	XI	.7075	-.7067	.0034	DR	-.3029	-.7532	.5838
		YI	.6969	.6996	.1575	YI	-.6462	-.6450	.4080	CR	-.1858	-.5542	-.8114
		ZI	-.7127	.7002	.0434	ZI	-.2861	-.2908	-.9130	OP	.9347	-.3543	.0279

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

AFTER MIDCOURSE CORRECTION, RMV= 5.743055E-01 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.024E+08	6.700E+07	1.029E+08	4.410E+00	6.375E+00	4.816E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.024E+08	6.701E+07	1.030E+08	4.411E+00	6.376E+00	4.818E+00	8.661E-04	8.792E-04	1.092E-03
ERRORS	7.416E+05	1.075E+06	2.248E+06	4.773E-02	1.339E-01	1.093E-01	4.925E-04	5.150E-04	8.280E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.024E+08	6.700E+07	1.029E+08	4.410E+00	6.375E+00	4.816E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.024E+08	6.701E+07	1.030E+08	4.411E+00	6.376E+00	4.818E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	7.416E+05	1.075E+06	2.248E+06	4.773E-02	1.339E-01	1.093E-01	7.854E-01	7.854E-01	7.854E-01

HELIOCENT. *

COAST FOR 17276280.00 SEC. (199D22H58M 0.00S)

FIGURE B-6i. REFERENCE SYSTEM ON SCHEDULE 2., LEVEL 2 EVALUATION (Continued)

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TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT 400D 0H 0M 0.00S
T=  34560000  ALT=  2.6049048E+12  VEL=  1.8816539E+08  ANG=    90.010  LAT=    -6.5116  LONG=  155.7267
                    P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
   COMP. DEV.  1.592E+08  2.036E+08  1.839E+08  3.374E+00  1.400E+01  5.592E+00  7.854E-01  7.854E-01  7.854E-01
   DEVIATIONS  1.592E+08  2.036E+08  1.840E+08  3.374E+00  1.400E+01  5.593E+00  7.854E-01  7.854E-01  7.854E-01
   ERRORS      1.172E+06  4.041E+06  4.143E+06  4.226E-02  3.076E-01  1.218E-01  7.854E-01  7.854E-01  7.854E-01

   ATTITUDE         ROLL     YAW    PITCH         DR      CR      OP        ROLL     YAW    PITCH
               XI  -.0799  -.1425   .9866   XI   .1881   .1202   .9748  DR  -.3767  -.9259   .0265
               YI   .6969   .6996   .1575   YI  -.9062   .4039   .1251  CR   .9182  -.3695   .1428
               ZI  -.7127   .7002   .0434   ZI  -.3787  -.9069   .1849  OP  -.1225   .0781   .9894

 SUBSYSTEM  COMPUTER  I. S. U.  ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
   STATUS     -0        -0        0          0          0          0          1          0          0          0
COMPUTER    TURNED ON
I. S. U.    TURNED ON
SUN SENSOR  TURNED ON
STAR TRCKR  TURNED ON
ATT. CONT.  TURNED ON
                    P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
   COMP. DEV.  1.592E+08  2.036E+08  1.839E+08  3.374E+00  1.400E+01  5.592E+00  1.425E-01  1.425E-01  1.425E-01
   DEVIATIONS  1.592E+08  2.036E+08  1.840E+08  3.374E+00  1.400E+01  5.593E+00  7.854E-01  7.854E-01  7.854E-01
   ERRORS      1.172E+06  4.041E+06  4.143E+06  4.226E-02  3.076E-01  1.218E-01  7.854E-01  7.854E-01  7.854E-01

   BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR     1800.00 SEC.  (  0D 0H30M 0.00S)

        ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

        DEAD BANDS   SET    MAX.
             ROLL  20.00  64.00
              YAW   8.00   8.00
            PITCH  20.00  22.66
   MANEUVERS
            PITCH    -.288DEG.   YAW   2.330DEG.  ROLL -18.434DEG. IN      1800SEC.

TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT 400D 0H30M 0.00S
T=  34561800  ALT=  2.6048474E+12  VEL=  1.8816163E+08  ANG=    90.010  LAT=    -6.5106  LONG=  148.2286
                    P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
   COMP. DEV.  1.592E+08  2.036E+08  1.840E+08  3.383E+00  1.402E+01  5.590E+00  8.357E-02  1.324E-01  1.391E-01
   DEVIATIONS  1.592E+08  2.037E+08  1.840E+08  3.383E+00  1.402E+01  5.591E+00  7.854E-01  7.854E-01  7.854E-01
   ERRORS      1.172E+06  4.042E+06  4.143E+06  4.243E-02  3.080E-01  1.218E-01  7.854E-01  7.854E-01  7.854E-01

   ATTITUDE         ROLL     YAW    PITCH         DR      CR      OP        ROLL     YAW    PITCH
               XI  -.1192  -.4462   .8869   XI   .1881   .1202   .9748  DR  -.3728  -.8838  -.2827
               YI   .6864   .6084   .3983   YI  -.9062   .4039   .1251  CR   .9135  -.4031   .0555
               ZI  -.7173   .6563   .2338   ZI  -.3787  -.9069   .1849  OP  -.1630  -.2375   .9576
```

FIGURE B-6j. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

```
 SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
  STATUS       1          1          1          1          1          1          1          0          0          0

          END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS


     TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  COAST FOR         60.00 SEC.   (  0D 0H 1M 0.00S)

               ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS    SET     MAX.
                    ROLL  20.00   64.00
                     YAW   8.00    8.00
                   PITCH  20.00   22.66
          MANEUVERS
                   PITCH     .000DEG.   YAW     .000DEG.  ROLL    -.000DEG. IN        60SEC.

          SEARCH.FOR SUN         IN     30.4 SECONDS WITH   1.00000 PASSES
                        ANGULAR RATES (RAD/SEC)=ROLL     .02583     ,YAW     0.00000     ,PITCH  0.00000


          SEARCH FOR CANOPUS     IN     29.6 SECONDS WITH   1.00000 PASSES
                        ANGULAR RATES (RAD/SEC)=ROLL     .00000     ,YAW     .02583      ,PITCH  0.00000


     TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  .AT 400D 0H31M 0.00S
     T=  34561860  ALT=  2.6048455E+12  VEL=  1.8816150E+08  ANG=     90.010  LAT=   -6.5106  LONG=  147.9787
                          P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
          COMP. DEV.  -1.592E+08  2.036E+08  1.840E+08  3.383E+00  1.402E+01  5.590E+00  8.357E-02  1.324E-01  1.391E-01
          DEVIATIONS   1.592E+08  2.037E+08  1.840E+08  3.383E+00  1.402E+01  5.591E+00  8.357E-02  1.324E-01  1.391E-01
           ERRORS      1.172E+06  4.042E+06  4.143E+06  4.244E-02  3.080E-01  1.218E-01  2.829E-04  7.055E-04  2.322E-04

             ATTITUDE         ROLL     YAW     PITCH         DR       CR       OP          ROLL     YAW     PITCH
  CANOPUS     ACQUIRED    XI  -.1192  -.4462   .8869    XI   .1881    .1202    .9748   DR  -.3728  -.8838  -.2827
                          YI   .6864   .6084   .3983    YI  -.9062    .4039    .1251   CR   .9135  -.4031   .0555
                          ZI  -.7173   .6563   .2338    ZI  -.3787   -.9069    .1849   OP  -.1630  -.2375   .9576

 SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
  STATUS       1          1          1          1          1          1          1          0          0          0

          END SEARCH FOR SUN-CANOPUS


     TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  COAST FOR       1800.00 SEC.   (  0D 0H30M 0.00S)

               ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS    SET     MAX.
                    ROLL  20.00   64.00
                     YAW   8.00    8.00
```

FIGURE B-6k. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

PITCH 20.00 22.66
MANEUVERS
PITCH .000DEG. YAW .000DEG. ROLL -.001DEG. IN 1800SEC.

TARGET CT. *

AT 400D 1H 1M 0.00S
T= 34563660 ALT= 2.6047888E+12 VEL= 1.8815780E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.4806

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.592E+08	2.037E+08	1.840E+08	3.419E+00	1.408E+01	5.595E+00	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.592E+08	2.037E+08	1.840E+08	3.419E+00	1.408E+01	5.596E+00	8.357E-02	1.324E-01	1.391E-01
ERRORS	1.172E+06	4.042E+06	4.144E+06	4.291E-02	3.093E-01	1.219E-01	5.331E-04	8.378E-04	5.080E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
		YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
		ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
CANBERRA	2.6047916E+12	-3.1699020E+04	-17.455	60.115	68.370

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	2.917660E+06	1.301273E-06	1.481094E-06	3.299661E+02
DSIF	-0.	-0.	-0.	4.100000E-02

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.592E+08	2.037E+08	1.840E+08	3.419E+00	1.408E+01	5.596E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.59[illegible]+08	2.037E+08	1.840E+08	3.419E+00	1.408E+01	5.596E+00	8.896E-04	1.100E-03	8.751E-04
ERRORS	3.3[illegible]+05	1.032E+05	4.605E+05	5.285E-03	1.950E-02	7.104E-03	5.326E-04	8.377E-04	5.080E-04

TARGET CT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	22.66

MANEUVERS
PITCH .000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

TARGET CT. *

AT 400D 1H 2M 0.00S
T= 34563720 ALT= 2.6047869E+12 VEL= 1.8815768E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.2307

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.592E+08	2.037E+08	1.840E+08	3.421E+00	1.408E+01	5.596E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.592E+08	2.037E+08	1.840E+08	3.421E+00	1.408E+01	5.596E+00	8.971E-04	1.106E-03	8.827E-04
ERRORS	3.333E+05	1.032E+05	4.605E+05	5.284E-03	1.950E-02	7.103E-03	5.450E-04	8.457E-04	5.210E-04

FIGURE B-61. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

CANOPUS ACQUIRED	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
	YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
	ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

AFTER MIDCOURSE CORRECTION, RMV= 2.298503E-02 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.592E+08	2.037E+08	1.840E+08	3.421E+00	1.408E+01	5.596E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.592E+08	2.037E+08	1.840E+08	3.421E+00	1.408E+01	5.596E+00	8.971E-04	1.106E-03	8.827E-04
ERRORS	3.333E+05	1.032E+05	4.605E+05	5.284E-03	1.950E-02	7.103E-03	5.450E-04	8.457E-04	5.210E-04

ATT. CONT. TURNED OFF
COMPUTER TURNED OFF
I. S. U. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF
COM. SYST. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.592E+08	2.037E+08	1.840E+08	3.421E+00	1.408E+01	5.596E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.592E+08	2.037E+08	1.840E+08	3.421E+00	1.408E+01	5.596E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	3.333E+05	1.032E+05	4.605E+05	5.284E-03	1.950E-02	7.103E-03	7.854E-01	7.854E-01	7.854E-01

TARGET CT. *

COAST FOR 896522.00 SEC. (10D 9H 2M 2.00S)

TARGET CT. *

AT 410D10H 4M 2.00S
T= 35460242 ALT= 2.5764392E+12 VEL= 1.8630775E+08 ANG= 90.006 LAT= -6.0886 LONG= 5.4976

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	5.557E+08	-1.046E+02	3.352E+08	2.199E+04	3.622E+04	5.187E+03	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	5.557E+08	1.528E+05	3.352E+08	2.199E+04	3.622E+04	5.187E+03	7.854E-01	7.854E-01	7.854E-01
ERRORS	2.354E+05	1.528E+05	4.034E+05	4.121E+00	1.531E+01	3.058E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.1192	-.4463	.8869	XI	.1142	.1908	.9750	DR	-.7448	-.6072	-.2768
YI	.6864	.6084	.3984	YI	-.9909	-.0483	.1256	CR	.6474	-.7580	-.0792
ZI	-.7173	.6563	.2338	ZI	.0710	-.9804	.1836	OP	-.1617	-.2382	.9577

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	-0	-0	-0	0	-0	0	0	0

TARGET MISS, RMS= 1.52759866E+05, DOF=1.000

COMPUTER	12783.00 SEC.
I. S. U.	12783.00 SEC.
ATT. CONT.	42777.00 SEC.
STAR TRCKR	42777.00 SEC.
SUN SENSOR	42777.00 SEC.
ISU/C.P.S.	12783.00 SEC.

FIGURE B-6m. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

ISU COMPONENTS

ACCELEROM.= ARMA D-4E ARMA D-4E ARMA D-4E GYROSCOPES= GG 334-A GG 334-A GG 334-A

ISU DATA(HORIZONTAL DESIGN NUMBER 4 OPTIMUM) ON TIME (HR)= 3.551

OUTSIDE DIMENSIONS		WEIGHT		WEIGHT			
LENGTH=	9.350	BLOCK=	8.703	INSULATION=	1.345	EXCIT.ENERGY=	154.461
WIDTH=	10.450	BASE=	4.549	ELECTRONICS=	10.000	EXCIT.POWER =	43.500
HEIGHT=	5.450	COVER=	2.867	COMPONENTS=	6.000	TOTAL P.FAIL=	.00089
						TOTAL WEIGHT=	33.463

ISU THERMAL ANALYSIS

MAX.HEATER POWER=	97.875	MAX.THERMAL COND.=	2.1750	TOTAL ENERGY=	249.244
MIN.HEATER POWER=	-.000	MIN.THERMAL COND.=	1.0875	TOTAL POWER =	141.375

SUBSYSTEM PARAMETERS

	COMPUTERS SRT RUK-2	STAR TRCKR ITT-LUN.08	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	3.551	11.882	11.882	0.000	9601.033	0.000	0.000		
ENERGY=	319.575	95.060	59.412	0.000	33603.617	0.000	0.000	TOTAL ENERGY=	34077.664
POWER=	90.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL POWER =	106.500
P.FAIL=	.00059	.00013	.00012	0.00000	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09231
WEIGHT=	36.000	7.000	2.000	0.000	3.100	0.000	0.000	TOTAL WEIGHT=	48.100

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 11.882

THRUST SIZING (LB)	ROLL	YAW	PITCH	FUEL CONSUMPTION (LB-SEC)	ROLL	YAW	PITCH		
SOLAR PRES=	.0000	.0000	.0000						
MET.IMPACT=	.0000	.0000	.0001	SEARCHING=	8.1155	4.6111	.0031		
MANEUVERS =	.0099	.0099	.0099	DEAD BAND=	.0001	.5220	.3196		
MIDCOURSE =	0.0000	.3778	.3778	MANEUVERS=	.2836	.1592	.1947	TOTAL ENERGY=	118.825
MAX.THRUST=	.0099	.3778	.3778	TOTAL IMP=	8.3993	5.2924	.5174	TOTAL POWER =	10.000
								TOTAL P.FAIL=	.00492

NO. OF FIRINGS= 43358 TOTAL IMPULSE= 14.2091 FUEL WEIGHT= .253734 TOTAL WEIGHT= 21.397

ENERGY SOURCE DATA

TOTAL POWER= 257.875 TOTAL ENERGY= 34445.733 TOTAL WEIGHT= 102.167

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 14.945 DOF=1.000 CAPABILITY= 28.339 TOTAL WEIGHT= 28.571

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.05809	ASTRIONICS=	343.698
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1656.302
UNRELIABILITY =	.09758	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 343.69770

EXECUTION TIMES, START= 19.83, END= 58.51, ELAPSED=38.678(SEC.)

FIGURE B-6n. REFERENCE SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

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                              PENALTY (MODE 3)

     ERROR ANALYSIS (SCHEDULE NO. 2)


     LAUNCH    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   AT    0D 0H 0M 0.00S
     T=           0  ALT= -4.7683716E-07  VEL=  2.3196861E+02  ANG=    90.000  LAT=    28.5000  LONG=  -80.5000
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
          COMP. DEV.  0.            0.            0.            0.            0.            0.            0.            0.            0.
          DEVIATIONS  0.            0.            0.            0.            0.            0.            0.            0.            0.
           ERRORS     0.            0.            0.            0.            0.            0.            0.            0.            0.
      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS        1          1          0          0          0          1          0          0          0          0
     COM. SYST. TURNED ON
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
          COMP. DEV.  0.            0.            0.            0.            0.            0.            0.            0.            0.
          DEVIATIONS  0.            0.            0.            0.            0.            0.            0.            0.            0.
           ERRORS     0.            0.            0.            0.            0.            0.            0.            0.            0.

     LAUNCH    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  BURN FOR     565.000 SEC.
  ADD BURN ERRORS
  PARK  FOR        935.00 SEC.   (  0D 0H15M35.00S)

     PARK      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   AT    0D 0H25M 0.00S
     T=        1500  ALT=  6.0761100E+05  VEL=  2.4239262E+04  ANG=    90.000  LAT=   -5.7054  LONG=   -7.0921
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
          COMP. DEV. -0.            0.            0.            0.            0.            0.            9.064E-05     9.064E-05     9.064E-05
          DEVIATIONS  8.686E+03     6.062E+03     2.556E+03     1.306E+01     4.388E+00     3.151E-01     6.681E-05     1.316E-04     2.397E-04
           ERRORS     8.686E+03     6.062E+03     2.556E+03     1.306E+01     4.388E+00     3.151E-01     1.082E-04     1.567E-04     2.749E-04
      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS        1          1          0          0          0          1          1          0          0          0

          STATION       RANGE          RANGE DOT         AZM        ELE.      SUN ANG.
          ASCENSION   2.8752678E+06  1.5257582E+04     73.154      8.373    111.615
            MEASUREMENT ERRORS      RANGE          ELEVATION          AZIMUTH          RANGE DOT
              INERTIAL SYSTEM    4.575809E+03    2.556166E-03     2.300783E-03     8.262418E+00
                     TPQ-18      6.700000E+01    4.500000E-04     4.500000E-04    -0.
     AFTER KALMAN UPDATE
                          P-DR          P-CR          P-OP          V-DR          V-CR          V-OP          A-DR          A-CR          A-OP
          COMP. DEV.  8.636E+03     5.953E+03     2.422E+03     1.292E+01     4.076E+00     2.728E-01     9.322E-05     9.383E-05     2.267E-04
          DEVIATIONS  8.686E+03     6.062E+03     2.556E+03     1.306E+01     4.388E+00     3.151E-01     6.681E-05     1.316E-04     2.397E-04
           ERRORS     9.307E+02     1.142E+03     8.181E+02     1.938E+00     1.624E+00     1.576E-01     1.070E-04     1.505E-04     1.687E-04

     PARK      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  PARK  FOR        81.30 SEC.   (  0D 0H 1M21.30S)
  BURN FOR     941.500 SEC.
  ADD BURN ERRORS
  COAST FOR          .20 SEC.   (  0D 0H 0M   .20S)
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FIGURE B-7a. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION

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ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D 0H42M 3.00S
  T=        2523  ALT=  1.2568513E+07  VEL=  4.7908635E+04  ANG=      42.609  LAT=  -28.4248  LONG=    47.9456
                        P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV. -3.453E-04  0.          -6.104E-05 -3.372E-07  0.          0.          1.975E-08  1.975E-08  1.975E-08
        DEVIATIONS  4.356E+03  2.958E+03  2.787E+03  5.330E+00  5.816E+00  5.319E+00  2.171E-04  2.262E-04  2.533E-04
         ERRORS     4.356E+03  2.958E+03  2.787E+03  5.330E+00  5.816E+00  5.319E+00  2.171E-04  2.262E-04  2.533E-04

          ATTITUDE       ROLL     YAW    PITCH        DR      CR      OP          ROLL     YAW    PITCH
                     XI  -.1872  -.9823   .0083  XI  -.1872  -.9823   .0083  DR  1.0000  -.0000   .0000
                     YI  -.8845   .1722   .4335  YI  -.8846   .1722   .4335  CR   .0000  1.0000  -.0000
                     ZI  -.4272   .0738  -.9011  ZI  -.4272   .0738  -.9011  OP  -.0000   .0000  1.0000

    SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS      1          1          0          0          0          1          1          0          0          0
 ATT. CONT. TURNED ON
                        P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV. -3.453E-04  0.          -6.104E-05 -3.372E-07  0.          0.          7.125E-03  7.125E-03  7.125E-03
        DEVIATIONS  4.356E+03  2.958E+03  2.787E+03  5.330E+00  5.816E+00  5.319E+00  7.129E-03  7.129E-03  7.130E-03
         ERRORS     4.356E+03  2.958E+03  2.787E+03  5.330E+00  5.816E+00  5.319E+00  2.171E-04  2.262E-04  2.533E-04
 DEADBAND ON AXIS  1 CHANGED TO   20.00000 DEG.
 DEADBAND ON AXIS  2 CHANGED TO   20.00000 DEG.
 DEADBAND ON AXIS  3 CHANGED TO   20.00000 DEG.
 STAR TRCKR TURNED ON
 SUN SENSOR TURNED ON
                        P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV. -3.453E-04  0.          -6.104E-05 -3.372E-07  0.          0.          1.425E-01  1.425E-01  1.425E-01
        DEVIATIONS  4.356E+03  2.958E+03  2.787E+03  5.330E+00  5.816E+00  5.319E+00  1.425E-01  1.425E-01  1.425E-01
         ERRORS     4.356E+03  2.958E+03  2.787E+03  5.330E+00  5.816E+00  5.319E+00  2.171E-04  2.262E-04  2.533E-04

        BEGIN MANEUVERING TO LOCATE SUN-CANOPUS


ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR      900.00 SEC.   (  0D 0H15M 0.00S)

             ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

             DEAD BANDS    SET    MAX.
                    ROLL  20.00  64.00
                     YAW   8.00   8.00
                   PITCH  20.00  28.68
        MANEUVERS
                   PITCH 124.634DEG.   YAW -70.015DEG.  ROLL  59.862DEG. IN      900SEC.

ESCAPE    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT   0D 0H57M 3.00S
  T=        3423  ALT=  4.8308954E+07  VEL=  4.3313231E+04  ANG=      16.593  LAT=  -29.7368  LONG=    74.2506
                        P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
        COMP. DEV.  0.         -8.632E-05  0.          0.          0.          0.          1.418E-01  7.036E-02  1.372E-01
        DEVIATIONS  9.306E+03  7.829E+03  7.364E+03  5.597E+00  5.908E+00  5.085E+00  1.418E-01  7.036E-02  1.372E-01
         ERRORS     9.306E+03  7.829E+03  7.364E+03  5.597E+00  5.908E+00  5.085E+00  2.120E-04  1.916E-04  2.809E-04
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FIGURE B-7b. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

```
         ATTITUDE          ROLL      YAW     PITCH          DR       CR       OP         ROLL      YAW     PITCH
                      XI  -.2321    .9305   -.2834    XI  -.1224   -.9924    .0083   DR  -.2123    .1112    .9709
                      YI   .6276   -.0793   -.7745    YI  -.8939    .1138    .4335   CR   .2679   -.9488    .1673
                      ZI  -.7431   -.3576   -.5656    ZI  -.4312    .0456   -.9011   OP   .9398    .2956    .1716

      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS       1          1          1          1          1          1          1          0          0          0

             END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS


     ESCAPE       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  COAST FOR        60.00 SEC.  (  0D 0H 1M 0.00S)

               ANGLE BETWEEN CELESTIAL BODIES=   97.32, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS    SET     MAX.
                    ROLL   20.00   64.00
                     YAW    8.00    8.00
                   PITCH   20.00   28.68
            MANEUVERS
                   PITCH    -.000DEG.   YAW    -.000DEG.  ROLL    -.001DEG. IN        60SEC.

            SEARCH FOR SUN          IN     31.4 SECONDS WITH   1.00000 PASSES
                                ANGULAR RATES (RAD/SEC)=ROLL      .00001       ,YAW     0.00000      ,PITCH  0.00000

            SEARCH FOR CANOPUS     IN     28.6 SECONDS WITH   1.00000 PASSES
                                ANGULAR RATES (RAD/SEC)=ROLL     0.00000       ,YAW     0.00000      ,PITCH  -.00001


     ESCAPE       * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   AT   0D 0H58M 3.00S
     T=        3483  ALT=  5.0840061E+07  VEL=  4.3117281E+04  ANG=     15.672  LAT=  -29.6689  LONG=    74.9188
                              P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
            COMP. DEV.    6.163E+02  3.559E+03  3.895E+03  2.969E-01  2.575E+00  2.533E+00  1.417E-01  7.042E-02  1.372E-01
            DEVIATIONS    9.640E+03  8.171E+03  7.669E+03  5.596E+00  5.927E+00  5.077E+00  1.417E-01  7.042E-02  1.372E-01
             ERRORS       9.622E+03  7.429E+03  6.656E+03  5.589E+00  5.390E+00  4.429E+00  1.441E-04  1.411E-04  2.325E-04

             ATTITUDE          ROLL      YAW     PITCH          DR       CR       OP         ROLL      YAW     PITCH
  CANOPUS     ACQUIRED    XI  -.2321    .9305   -.2834    XI  -.1202   -.9927    .0083   DR  -.2128    .1133    .9705
                          YI   .6276   -.0793   -.7745    YI  -.8942    .1119    .4335   CR   .2674   -.9486    .1694
                          ZI  -.7431   -.3576   -.5656    ZI  -.4313    .0447   -.9011   OP   .9398    .2956    .1716

      SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
        STATUS       1          1          1          1          1          1          1          0          0          0

            END SEARCH FOR SUN-CANOPUS

     COMPUTER   TURNED OFF
     I. S. U.   TURNED OFF
                              P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
            COMP. DEV.    6.163E+02  3.559E+03  3.895E+03  2.969E-01  2.575E+00  2.533E+00  1.417E-01  7.042E-02  1.372E-01
            DEVIATIONS    9.640E+03  8.171E+03  7.669E+03  5.596E+00  5.927E+00  5.077E+00  1.417E-01  7.042E-02  1.372E-01
```

FIGURE B-7c. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

ERRORS	9.622E+03	7.429E+03	6.656E+03	5.589E+00	5.390E+00	4.429E+00	1.441E-04	1.411E-04	2.325E-04

ESCAPE *

COAST FOR 32517.00 SEC. (0D 9H 1M57.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.21, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.79

MANEUVERS

PITCH -.053DEG. YAW -.094DEG. ROLL -.515DEG. IN 32517SEC.

TRACKING STAR NO. 2

ESCAPE *

AT 0D10H 0M 0.00S

T= 36000 ALT= 1.3681588E+09 VEL= 9.8762677E+04 ANG= 66.018 LAT= -25.6796 LONG= -36.9497

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.205E+04	9.249E+04	8.016E+04	3.701E-01	2.769E+00	2.323E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.835E+05	2.249E+05	1.709E+05	5.309E+00	6.808E+00	5.027E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.831E+05	2.066E+05	1.516E+05	5.296E+00	6.267E+00	4.475E+00	2.496E-04	2.696E-04	6.885E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.2334	.9328	-.2746	XI	-.0997	-.9950	.0082	DR	-.2168	.1239	.9683
		YI	.6264	-.0718	-.7762	YI	-.8963	.0934	.4335	CR	.2641	-.9475	.1804
		ZI	-.7437	-.3532	-.5676	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1727

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.	
STATUS	-0	-0	1	1	1	0	1	0	0

COMPUTER TURNED ON

I. S. U. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.205E+04	9.249E+04	8.016E+04	3.701E-01	2.769E+00	2.323E+00	1.416E-01	7.067E-02	1.372E-01
DEVIATIONS	1.835E+05	2.249E+05	1.709E+05	5.309E+00	6.808E+00	5.027E+00	1.416E-01	7.067E-02	1.372E-01
ERRORS	1.831E+05	2.066E+05	1.516E+05	5.296E+00	6.267E+00	4.475E+00	2.496E-04	2.696E-04	6.885E-04

ESCAPE *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	28.80

MANEUVERS

PITCH -.003DEG. YAW -.005DEG. ROLL -.028DEG. IN 1800SEC.

ESCAPE *

AT 0D10H30M 0.00S

T= 37800 ALT= 1.4404029E+09 VEL= 1.0315087E+05 ANG= 67.105 LAT= -25.6632 LONG= -44.3869

FIGURE B-7d. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.272E+04	9.747E+04	8.434E+04	3.702E-01	2.770E+00	2.323E+00	1.416E-01	7.065E-02	1.372E-01
DEVIATIONS	1.931E+05	2.372E+05	1.799E+05	5.307E+00	6.812E+00	5.027E+00	1.416E-01	7.065E-02	1.372E-01
ERRORS	1.927E+05	2.179E+05	1.596E+05	5.294E+00	6.270E+00	4.475E+00	3.045E-04	3.212E-04	7.103E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS 1 1 1 1 1 1 1 0 0 0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
ASCENSION	1.4439360E+09	4.0809058E+04	-125.447	55.969	80.860

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	1.947298E+05	1.568034E-04	1.001109E-04	1.228915E+01
USBS-30	6.700000E+01	1.780000E-03	1.780000E-03	1.240000E-01

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.931E+05	2.330E+05	1.121E+05	5.307E+00	6.682E+00	3.149E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.931E+05	2.372E+05	1.799E+05	5.307E+00	6.812E+00	5.027E+00	7.598E-04	7.815E-04	1.006E-03
ERRORS	1.346E+03	4.132E+04	1.416E+05	2.126E-02	1.245E+00	3.941E+00	2.637E-04	3.209E-04	7.103E-04

ESCAPE *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 97.20, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	28.80

MANEUVERS
PITCH -.000DEG. YAW -.000DEG. ROLL -.001DEG. IN 60SEC.

ESCAPE *

AT 0D10H31M 0.00S
T= 37860 ALT= 1.4428110E+09 VEL= 1.0329770E+05 ANG= 67.140 LAT= -25.6627 LONG= -44.6349

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.334E+05	1.122E+05	5.307E+00	6.682E+00	3.149E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	5.307E+00	6.812E+00	5.027E+00	7.601E-04	7.828E-04	1.007E-03
ERRORS	1.346E+03	4.139E+04	1.419E+05	2.126E-02	1.245E+00	3.941E+00	2.647E-04	3.241E-04	7.117E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.2335	.9329	-.2741	XI	-.0997	-.9950	.0082	DR	-.2168	.1234	.9684
YI	.6264	-.0713	-.7763	YI	-.8963	.0934	.4335	CR	.2641	-.9476	.1799
ZI	-.7438	-.3529	-.5677	ZI	-.4321	.0358	-.9011	OP	.9398	.2948	.1728

SUBSYSTEM COMPUTER I. S. U. ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
STATUS 1 1 1 1 1 1 1 0 0 0

FIGURE B-7e. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

AFTER MIDCOURSE CORRECTION, RMV= 7.373560E+00 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.334E+05	1.122E+05	3.949E+00	2.567E+00	2.544E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	3.949E+00	2.864E+00	4.656E+00	7.601E-04	7.828E-04	1.007E-03
ERRORS	1.346E+03	4.139E+04	1.419E+05	2.603E-02	1.245E+00	3.940E+00	2.647E-04	3.241E-04	7.117E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.934E+05	2.334E+05	1.122E+05	3.949E+00	2.567E+00	2.544E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.934E+05	2.376E+05	1.802E+05	3.949E+00	2.864E+00	4.656E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.346E+03	4.139E+04	1.419E+05	2.603E-02	1.245E+00	3.940E+00	7.854E-01	7.854E-01	7.854E-01

ESCAPE *

COAST FOR 17242140.00 SEC. (199D13H29M 0.00S)

HELIOCENT. *

AT 200D 0H 0M 0.00S
T= 17280000 ALT= 1.4347029E+12 VEL= 9.4528212E+07 ANG= 89.915 LAT= -24.9460 LONG= 108.9401

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	7.198E+07	4.175E+06	3.102E+07	3.009E+00	9.851E-01	1.299E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	7.488E+07	4.845E+07	6.167E+07	3.350E+00	5.027E+00	3.356E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	2.113E+07	4.820E+07	5.377E+07	1.493E+00	4.938E+00	3.112E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
	XI	-.2335	.9329	-.2741	XI	.7075	-.7067	.0034	DR	-.3571	.8071	.4701
	YI	.6264	-.0713	-.7763	YI	-.6462	-.6450	.4080	CR	-.0227	-.5107	.8595
	ZI	-.7438	-.3529	-.5677	ZI	-.2862	-.2908	-.9130	OP	.9338	.2963	.2007

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	0	0	0	0	1	0	0	0

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	7.198E+07	4.175E+06	3.102E+07	3.009E+00	9.851E-01	1.299E+00	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	7.488E+07	4.845E+07	6.167E+07	3.350E+00	5.027E+00	3.356E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	2.113E+07	4.820E+07	5.377E+07	1.493E+00	4.938E+00	3.112E+00	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

HELIOCENT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

FIGURE B-7f. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

```
ANGLE BETWEEN CELESTIAL BODIES=   76.48, BETWEEN OPTICAL AIDS=   90.00

DEAD BANDS   SET    MAX.
     ROLL   20.00  64.00
      YAW    8.00   8.00
    PITCH   20.00  22.48
MANEUVERS
    PITCH    7.363DEG.   YAW    6.578DEG.  ROLL-114.837DEG. IN      1800SEC.

HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT 200D 0H30M 0.00S
 T=  17281800  ALT=  1.4349578E+12  VEL=  9.4546111E+07  ANG=   89.915  LAT=  -24.9445  LONG=  101.4460
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
     COMP. DEV.   7.198E+07   4.174E+06   3.102E+07   3.009E+00   9.851E-01   1.299E+00   1.031E-01   1.228E-01   1.348E-01
     DEVIATIONS   7.489E+07   4.846E+07   6.167E+07   3.350E+00   5.027E+00   3.356E+00   7.854E-01   7.854E-01   7.854E-01
      ERRORS      2.113E+07   4.821E+07   5.377E+07   1.493E+00   4.939E+00   3.112E+00   7.854E-01   7.854E-01   7.854E-01

      ATTITUDE        ROLL     YAW     PITCH          DR       CR       OP           ROLL     YAW     PITCH
                  XI  -.0799  -.1424   .9866    XI   .7075  -.7067    .0034    DR  -.3029  -.7532    .5839
                  YI   .6969   .6996   .1574    YI  -.6462  -.6450    .4080    CR  -.1858  -.5542   -.8114
                  ZI  -.7127   .7002   .0434    ZI  -.2862  -.2908   -.9130    OP   .9347  -.3543    .0279

  SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
   STATUS       1          1          1          1          1          1          1          0          0          0

     END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR       60.00 SEC.  (  0D 0H 1M 0.00S)

          ANGLE BETWEEN CELESTIAL BODIES=   76.48, BETWEEN OPTICAL AIDS=   90.00

          DEAD BANDS   SET    MAX.
               ROLL   20.00  64.00
                YAW    8.00   8.00
              PITCH   20.00  22.48
     MANEUVERS
              PITCH    -.000DEG.   YAW    .000DEG.  ROLL    -.000DEG. IN       60SEC.

     SEARCH FOR SUN         IN     30.4 SECONDS WITH   1.00000 PASSES
                         ANGULAR RATES (RAD/SEC)=ROLL     .02582     ,YAW    0.00000     ,PITCH  0.00000

     SEARCH FOR CANOPUS     IN     29.6 SECONDS WITH   1.00000 PASSES
                         ANGULAR RATES (RAD/SEC)=ROLL     .00000     ,YAW     .02582     ,PITCH  0.00000

HELIOCENT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

AT 200D 0H31M 0.00S
 T=  17281860  ALT=  1.4349663E+12  VEL=  9.4546707E+07  ANG=   89.915  LAT=  -24.9445  LONG=  101.1962
                     P-DR        P-CR        P-OP        V-DR        V-CR        V-OP        A-DR        A-CR        A-OP
```

FIGURE B-7g. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

COMP. DEV.	7.198E+07	4.174E+06	3.102E+07	3.009E+00	9.851E-01	1.299E+00	1.031E-01	1.228E-01	1.348E-01
DEVIATIONS	7.489E+07	4.846E+07	6.167E+07	3.350E+00	5.027E+00	3.356E+00	1.031E-01	1.228E-01	1.348E-01
ERRORS	2.113E+07	4.821E+07	5.377E+07	1.493E+00	4.939E+00	3.112E+00	2.745E-04	2.637E-04	6.979E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.0799	-.1424	.9866	XI	.7075	-.7067	.0034	DR	-.3029	-.7532	.5839
		YI	.6969	.6996	.1574	YI	-.6462	-.6450	.4080	CR	-.1858	-.5542	-.8114
		ZI	-.7127	.7002	.0434	ZI	-.2862	-.2908	-.9130	OP	.9347	-.3543	.0279

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

END SEARCH FOR SUN-CANOPUS

HELIOCENT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.48, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.48

MANEUVERS

PITCH -.000DEG. YAW .000DEG. ROLL -.003DEG. IN 1800SEC.

HELIOCENT. *

AT 200D 1H 1M 0.00S

T= 17283660 ALT= 1.4352183E+12 VEL= 9.4564402E+07 ANG= 89.915 LAT= -24.9431 LONG= 93.7020

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	7.199E+07	4.173E+06	3.102E+07	3.009E+00	9.851E-01	1.299E+00	1.031E-01	1.228E-01	1.348E-01
DEVIATIONS	7.489E+07	4.847E+07	6.168E+07	3.350E+00	5.028E+00	3.356E+00	1.031E-01	1.228E-01	1.348E-01
ERRORS	2.113E+07	4.822E+07	5.378E+07	1.493E+00	4.939E+00	3.112E+00	3.284E-04	3.194E-04	7.208E-04

	ATTITUDE		ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED	XI	-.0799	-.1425	.9866	XI	.7075	-.7067	.0034	DR	-.3029	-.7532	.5838
		YI	.6969	.6996	.1575	YI	-.6462	-.6450	.4080	CR	-.1858	-.5542	-.8114
		ZI	-.7127	.7002	.0434	ZI	-.2861	-.2908	-.9130	OP	.9347	-.3543	.0279

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
CANBERRA	1.4352253E+12	1.4163268E+05	-93.579	41.574	83.658

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	4.163017E+07	7.804545E-06	4.298010E-05	1.123306E+03
DSIF	-0.	-0.	-0.	4.100000E-02

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	7.489E+07	4.846E+07	6.164E+07	3.349E+00	5.026E+00	3.354E+00	7.125E-04	7.125E-04	7.125E-04

FIGURE B-7h. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

DEVIATIONS	7.489E+07	4.847E+07	6.168E+07	3.350E+00	5.028E+00	3.356E+00	7.783E-04	7.790E-04	1.013E-03
ERRORS	9.234E+05	1.186E+06	2.389E+06	5.582E-02	1.457E-01	1.169E-01	3.131E-04	3.149E-04	7.205E-04

HELIOCENT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.48, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	22.48

MANEUVERS

PITCH -.000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

HELIOCENT. *

AT 200D 1H 2M 0.00S

T= 17283720 ALT= 1.4352267E+12 VEL= 9.4564991E+07 ANG= 89.915 LAT= -24.9430 LONG= 93.4522

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	7.489E+07	4.846E+07	6.164E+07	3.349E+00	5.026E+00	3.354E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	7.490E+07	4.847E+07	6.168E+07	3.350E+00	5.028E+00	3.356E+00	7.793E-04	7.803E-04	1.014E-03
ERRORS	9.234E+05	1.186E+06	2.389E+06	5.582E-02	1.457E-01	1.169E-01	3.155E-04	3.180E-04	7.220E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.0799	-.1425	.9866	XI	.7075	-.7067	.0034	DR	-.3029	-.7532	.5838
YI	.6969	.6996	.1575	YI	-.6462	-.6450	.4080	CR	-.1858	-.5542	-.8114
ZI	-.7127	.7002	.0434	ZI	-.2861	-.2908	-.9130	OP	.9347	-.3543	.0279

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

AFTER MIDCOURSE CORRECTION, RMV= 4.250002E-01 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	7.489E+07	4.846E+07	6.164E+07	3.230E+00	4.747E+00	3.254E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	7.490E+07	4.847E+07	6.168E+07	3.231E+00	4.749E+00	3.255E+00	7.793E-04	7.803E-04	1.014E-03
ERRORS	9.234E+05	1.186E+06	2.389E+06	5.600E-02	1.456E-01	1.169E-01	3.155E-04	3.180E-04	7.220E-04

DEADBAND ON AXIS 1 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 2 CHANGED TO 20.00000 DEG.
DEADBAND ON AXIS 3 CHANGED TO 20.00000 DEG.
COMPUTER TURNED OFF
I. S. U. TURNED OFF
ATT. CONT. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	7.489E+07	4.846E+07	6.164E+07	3.230E+00	4.747E+00	3.254E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	7.490E+07	4.847E+07	6.168E+07	3.231E+00	4.749E+00	3.255E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	9.234E+05	1.186E+06	2.389E+06	5.600E-02	1.456E-01	1.169E-01	7.854E-01	7.854E-01	7.854E-01

HELIOCENT. *

COAST FOR 17276280.00 SEC. (199D22H58M 0.00S)

FIGURE B-7i. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued).

TARGET CT. *

AT 400D 0H 0M 0.00S
T= 34560000 ALT= 2.6049048E+12 VEL= 1.8816539E+08 ANG= 90.010 LAT= -6.5116 LONG= 155.7267

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.512E+08	1.201E+08	2.472E+00	1.029E+01	4.122E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.162E+08	1.512E+08	1.201E+08	2.472E+00	1.030E+01	4.124E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.463E+06	4.392E+06	4.418E+06	4.492E-02	3.310E-01	1.312E-01	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.0799	-.1425	.9866	XI	.1881	.1202	.9748	DR	-.3767	-.9259	.0265
YI	.6969	.6996	.1575	YI	-.9062	.4039	.1251	CR	.9182	-.3695	.1428
ZI	-.7127	.7002	.0434	ZI	-.3787	-.9069	.1849	OP	-.1225	.0781	.9894

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	0	0	0	0	1	0	0	0

COMPUTER TURNED ON
I. S. U. TURNED ON
SUN SENSOR TURNED ON
STAR TRCKR TURNED ON
ATT. CONT. TURNED ON

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.512E+08	1.201E+08	2.472E+00	1.029E+01	4.122E+00	1.425E-01	1.425E-01	1.425E-01
DEVIATIONS	1.162E+08	1.512E+08	1.201E+08	2.472E+00	1.030E+01	4.124E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.463E+06	4.392E+06	4.418E+06	4.492E-02	3.310E-01	1.312E-01	7.854E-01	7.854E-01	7.854E-01

BEGIN MANEUVERING TO LOCATE SUN-CANOPUS

TARGET CT. *

COAST FOR 1800.00 SEC. (0D 0H30M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	20.00	64.00
YAW	8.00	8.00
PITCH	20.00	22.66

MANEUVERS
PITCH -.288DEG. YAW 2.330DEG. ROLL -18.434DEG. IN 1800SEC.

TARGET CT. *

AT 400D 0H30M 0.00S
T= 34561800 ALT= 2.6048474E+12 VEL= 1.8816163E+08 ANG= 90.010 LAT= -6.5106 LONG= 148.2286

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.512E+08	1.201E+08	2.478E+00	1.030E+01	4.121E+00	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.162E+08	1.513E+08	1.201E+08	2.479E+00	1.031E+01	4.123E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	1.463E+06	4.393E+06	4.418E+06	4.510E-02	3.315E-01	1.312E-01	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.1192	-.4462	.8869	XI	.1881	.1202	.9748	DR	-.3728	-.8838	-.2827
YI	.6864	.6084	.3983	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

FIGURE B-7j. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

```
SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
 STATUS       1          1          1          1          1          1          1          0          0          0

        END MANEUVERING,BEGIN SEARCH FOR SUN-CANOPUS

   TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR       60.00 SEC.  (  0D 0H 1M 0.00S)

               ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS   SET    MAX.
                    ROLL  20.00   64.00
                     YAW   8.00    8.00
                   PITCH  20.00   22.66
           MANEUVERS
                   PITCH    .000DEG.   YAW    .000DEG.  ROLL    -.000DEG. IN        60SEC.

           SEARCH FOR SUN          IN    30.4 SECONDS WITH   1.00000 PASSES
                           ANGULAR RATES (RAD/SEC)=ROLL     .02583     ,YAW    0.00000    ,PITCH  0.00000

           SEARCH FOR CANOPUS      IN    29.6 SECONDS WITH   1.00000 PASSES
                           ANGULAR RATES (RAD/SEC)=ROLL     .00000     ,YAW     .02583    ,PITCH  0.00000

   TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 AT 400D 0H31M 0.00S
   T=  34561860  ALT=  2.6048455E+12  VEL=  1.8816150E+08  ANG=    90.010  LAT=   -6.5106  LONG=  147.9787
                          P-DR       P-CR       P-OP       V-DR       V-CR       V-OP       A-DR       A-CR       A-OP
          COMP. DEV.   1.162E+08  1.512E+08  1.201E+08  2.479E+00  1.031E+01  4.121E+00  8.357E-02  1.324E-01  1.391E-01
          DEVIATIONS   1.162E+08  1.513E+08  1.201E+08  2.479E+00  1.031E+01  4.123E+00  8.357E-02  1.324E-01  1.391E-01
           ERRORS      1.463E+06  4.393E+06  4.418E+06  4.511E-02  3.315E-01  1.312E-01  2.826E-04  7.053E-04  2.318E-04

                ATTITUDE        ROLL     YAW     PITCH          DR       CR       OP          ROLL     YAW     PITCH
CANOPUS    ACQUIRED          XI  -.1192   -.4462   .8869   XI   .1881    .1202    .9748   DR  -.3728   -.8838   -.2827
                             YI   .6864    .6084   .3983   YI  -.9062    .4039    .1251   CR   .9135   -.4031    .0555
                             ZI  -.7173    .6563   .2338   ZI  -.3787   -.9069    .1849   OP  -.1630   -.2375    .9576

     SUBSYSTEM  COMPUTER   I. S. U.   ATT. CONT. STAR TRCKR SUN SENSOR ISU/C.P.S. COM. SYST. HORIZ.SEN.
      STATUS       1          1          1          1          1          1          1          0          0          0

             END SEARCH FOR SUN-CANOPUS

   TARGET CT. * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

COAST FOR     1800.00 SEC.  (  0D 0H30M 0.00S)

               ANGLE BETWEEN CELESTIAL BODIES=   76.66, BETWEEN OPTICAL AIDS=   90.00

               DEAD BANDS   SET    MAX.
                    ROLL  20.00   64.00
                     YAW   8.00    8.00
```

FIGURE B-7k. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

MANEUVERS PITCH 20.00 22.66
PITCH .000DEG. YAW .000DEG. ROLL -.001DEG. IN 1800SEC.

TARGET CT. *

AT 400D 1H 1M 0.00S
T= 34563660 ALT= 2.6047888E+12 VEL= 1.8815780E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.4806

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.513E+08	1.201E+08	2.506E+00	1.035E+01	4.125E+00	8.357E-02	1.324E-01	1.391E-01
DEVIATIONS	1.162E+08	1.513E+08	1.202E+08	2.507E+00	1.035E+01	4.127E+00	8.357E-02	1.324E-01	1.391E-01
ERRORS	1.462E+06	4.393E+06	4.418E+06	4.563E-02	3.328E-01	1.313E-01	3.352E-04	7.280E-04	2.936E-04

CANOPUS ACQUIRED

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

DEADBAND ON AXIS 1 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 2 CHANGED TO .10000 DEG.
DEADBAND ON AXIS 3 CHANGED TO .10000 DEG.

STATION	RANGE	RANGE DOT	AZM	ELE.	SUN ANG.
CANBERRA	2.6047916E+12	-3.1699020E+04	-17.455	60.115	68.370

MEASUREMENT ERRORS	RANGE	ELEVATION	AZIMUTH	RANGE DOT
INERTIAL SYSTEM	3.122607E+06	1.380856E-06	1.641227E-06	3.615424E+02
DSIF	-0.	-0.	-0.	4.100000E-02

AFTER KALMAN UPDATE

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.513E+08	1.202E+08	2.506E+00	1.035E+01	4.127E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.162E+08	1.513E+08	1.202E+08	2.507E+00	1.035E+01	4.127E+00	7.874E-04	1.019E-03	7.707E-04
ERRORS	5.637E+05	1.791E+05	7.737E+05	9.290E-03	3.345E-02	1.218E-02	3.351E-04	7.280E-04	2.936E-04

TARGET CT. *

COAST FOR 60.00 SEC. (0D 0H 1M 0.00S)

ANGLE BETWEEN CELESTIAL BODIES= 76.66, BETWEEN OPTICAL AIDS= 90.00

DEAD BANDS	SET	MAX.
ROLL	.10	64.00
YAW	.10	8.00
PITCH	.10	22.66

MANEUVERS
PITCH .000DEG. YAW .000DEG. ROLL -.000DEG. IN 60SEC.

TARGET CT. *

AT 400D 1H 2M 0.00S
T= 34563720 ALT= 2.6047869E+12 VEL= 1.8815768E+08 ANG= 90.010 LAT= -6.5096 LONG= 140.2307

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.513E+08	1.202E+08	2.507E+00	1.035E+01	4.127E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.162E+08	1.513E+08	1.202E+08	2.508E+00	1.035E+01	4.127E+00	7.887E-04	1.020E-03	7.720E-04
ERRORS	5.637E+05	1.791E+05	7.737E+05	9.289E-03	3.346E-02	1.218E-02	3.382E-04	7.295E-04	2.972E-04

FIGURE B-71. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

	ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
CANOPUS	ACQUIRED XI	-.1192	-.4463	.8869	XI	.1881	.1202	.9748	DR	-.3729	-.8838	-.2827
	YI	.6864	.6084	.3984	YI	-.9062	.4039	.1251	CR	.9135	-.4031	.0555
	ZI	-.7173	.6563	.2338	ZI	-.3787	-.9069	.1849	OP	-.1630	-.2375	.9576

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	1	1	1	1	1	1	1	0	0	0

AFTER MIDCOURSE CORRECTION, RMV= 2.500012E-02 (FT/SEC) ,DOF=1.000

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.513E+08	1.202E+08	2.508E+00	1.035E+01	4.127E+00	7.125E-04	7.125E-04	7.125E-04
DEVIATIONS	1.162E+08	1.513E+08	1.202E+08	2.508E+00	1.035E+01	4.127E+00	7.887E-04	1.020E-03	7.720E-04
ERRORS	5.637E+05	1.791E+05	7.737E+05	9.313E-03	3.347E-02	1.217E-02	3.382E-04	7.295E-04	2.972E-04

ATT. CONT. TURNED OFF
COMPUTER TURNED OFF
I. S. U. TURNED OFF
STAR TRCKR TURNED OFF
SUN SENSOR TURNED OFF
COM. SYST. TURNED OFF

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	1.162E+08	1.513E+08	1.202E+08	2.508E+00	1.035E+01	4.127E+00	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	1.162E+08	1.513E+08	1.202E+08	2.508E+00	1.035E+01	4.127E+00	7.854E-01	7.854E-01	7.854E-01
ERRORS	5.637E+05	1.791E+05	7.737E+05	9.313E-03	3.347E-02	1.217E-02	7.854E-01	7.854E-01	7.854E-01

TARGET CT. *

COAST FOR 896522.00 SEC. (10D 9H 2M 2.00S)

TARGET CT. *

AT 410D10H 4M 2.00S

T= 35460242 ALT= 2.5764392E+12 VEL= 1.8630775E+08 ANG= 90.006 LAT= -6.0886 LONG= 5.4976

	P-DR	P-CR	P-OP	V-DR	V-CR	V-OP	A-DR	A-CR	A-OP
COMP. DEV.	4.081E+08	2.602E+01	2.372E+08	1.635E+04	2.685E+04	3.816E+03	7.854E-01	7.854E-01	7.854E-01
DEVIATIONS	4.081E+08	2.552E+05	2.373E+08	1.635E+04	2.685E+04	3.816E+03	7.854E-01	7.854E-01	7.854E-01
ERRORS	4.179E+05	2.552E+05	4.122E+05	5.227E+00	2.512E+01	3.711E+00	7.854E-01	7.854E-01	7.854E-01

ATTITUDE	ROLL	YAW	PITCH		DR	CR	OP		ROLL	YAW	PITCH
XI	-.1192	-.4463	.8869	XI	.1142	.1908	.9750	DR	-.7448	-.6072	-.2768
YI	.6864	.6084	.3984	YI	-.9909	-.0483	.1256	CR	.6474	-.7580	-.0792
ZI	-.7173	.6563	.2338	ZI	.0710	-.9804	.1836	OP	-.1617	-.2382	.9577

SUBSYSTEM	COMPUTER	I. S. U.	ATT. CONT.	STAR TRCKR	SUN SENSOR	ISU/C.P.S.	COM. SYST.	HORIZ.SEN.		
STATUS	-0	-0	-0	-0	-0	0	-0	0	0	0

TARGET MISS, RMS= 2.55245787E+05, DOF=1.000

COMPUTER	12783.00 SEC.
I. S. U.	12783.00 SEC.
ATT. CONT.	42777.00 SEC.
STAR TRCKR	42777.00 SEC.
SUN SENSOR	42777.00 SEC.
ISU/C.P.S.	12783.00 SEC.

FIGURE B-7m. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)

ISU COMPONENTS

ACCELEROM.= GG-177 GG-177 GG-177 GYROSCOPES= 18-IRIG-B 18-IRIG-B 18-IRIG-B

ISU DATA(HORIZONTAL DESIGN NUMBER 5 OPTIMUM) ON TIME (HR)= 3.551

OUTSIDE DIMENSIONS		WEIGHT		WEIGHT			
						EXCIT.ENERGY=	152.331
LENGTH=	10.200	BLOCK=	5.407	INSULATION=	1.019	EXCIT.POWER =	42.900
WIDTH=	7.500	BASE=	3.540	ELECTRONICS=	10.000	TOTAL P.FAIL=	.00087
HEIGHT=	4.610	COVER=	2.171	COMPONENTS=	4.500	TOTAL WEIGHT=	26.637

ISU THERMAL ANALYSIS

MAX.HEATER POWER=	96.525	MAX.THERMAL COND.=	2.1450	TOTAL ENERGY=	245.806
MIN.HEATER POWER=	-.000	MIN.THERMAL COND.=	1.0725	TOTAL POWER =	139.425

SUBSYSTEM PARAMETERS

	COMPUTERS SIGN III	STAR TRCKR ITT-LUN.08	SUN SENSOR ADCL-1402	ISU/C.P.S. NONE	COM. SYST. MCR-503	HORIZ.SEN. NONE			
TIME=	3.551	11.882	11.882	0.000	9601.033	0.000	0.000		
ENERGY=	408.346	95.060	59.412	0.000	33603.617	0.000	0.000	TOTAL ENERGY=	34166.435
POWER=	115.000	8.000	5.000	0.000	3.500	0.000	0.000	TOTAL POWER =	131.500
P.FAIL=	.00064	.00013	.00012	0.00000	.09155	0.00000	0.00000	TOTAL P.FAIL=	.09235
WEIGHT=	27.000	7.000	2.000	0.000	3.100	0.000	0.000	TOTAL WEIGHT=	39.100

ATTITUDE CONTROL SYSTEM ANALYSIS ON TIME (HR)= 11.882

THRUST SIZING (LB)	ROLL	YAW	PITCH
SOLAR PRES=	.0000	.0000	.0000
MET.IMPACT=	.0000	.0000	.0001
MANEUVERS =	.0099	.0099	.0099
MIDCOURSE =	0.0000	.3778	.3778
MAX.THRUST=	.0099	.3778	.3778

FUEL CONSUMPTION (LB-SEC)	ROLL	YAW	PITCH		
SEARCHING=	8.1168	4.6111	.0007		
DEAD BAND=	.0001	.5220	.3196		
MANEUVERS=	.2836	.1592	.1947	TOTAL ENERGY=	118.825
TOTAL IMP=	8.4006	5.2924	.5150	TOTAL POWER =	10.000
				TOTAL P.FAIL=	.00492

NO. OF FIRINGS= 43364 TOTAL IMPULSE= 14.2079 FUEL WEIGHT= .253713 TOTAL WEIGHT= 21.397

ENERGY SOURCE DATA

TOTAL POWER= 280.925 TOTAL ENERGY= 34531.066 TOTAL WEIGHT= 110.119

WIRING TOTAL WEIGHT= 110.000

MIDCOURSE ENGINE

EXPECTED DELTA-V= 7.386 DOF=1.000 CAPABILITY= 14.007 TOTAL WEIGHT= 24.392

PENALTY SUMMATION

PROBABILITIES		WEIGHT	
INSUF.MIDCOURSE FUEL=	.05806	ASTRIONICS=	331.645
EXCESSIVE TGT. MISS =	0.00000	SPACECRAFT=	1668.355
UNRELIABILITY =	.09760	TOTAL=	2000.000
ASTRIONICS TOTAL =	.15000		

PENALTY(MODE 3)= 331.64468

EXECUTION TIMES, START= 58.51, END= 97.19, ELAPSED=38.684(SEC.)

FIGURE B-7n. OPTIMUM SYSTEM ON SCHEDULE 2, LEVEL 2 EVALUATION (Continued)