A NUMERICAL EVALUATION OF PRELIMINARY ORBIT DETERMINATION METHODS

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This Technical Note presents a general FORTRAN Code and computer program flowcharts for twelve different Preliminary Orbit Determination Methods (PODM). A number of solutions were obtained from each PODM using input data from a predetermined reference orbit. A comparison of these PODMs in their ability to converge, error propagation, computation time, and total computer core requirements is presented.
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A NUMERICAL EVALUATION OF
PRELIMINARY ORBIT DETERMINATION METHODS

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SUMMARY

Solutions from twelve different Preliminary Orbit Determination Methods using data from two well defined orbits are presented. A number of different solutions were obtained from each method when the angular difference (true anomaly) between observation data was varied from several degrees to one complete revolution. The failure to converge and the numerical error propagation are indicated. The computation time and total computer core required for each PODM is tabulated. A computational algorithm was used to adapt inertial position, velocity, and time input data to angular, range, range rate, and time input data from several different observation stations. A general FORTRAN code and a computer program flowchart are documented and can be utilized with computers other than the Scientific Data Systems 930 used in these solutions.

INTRODUCTION

In preliminary orbit determination (the first approximation of the orbit) it is difficult to select a method which could be considered the best Preliminary Orbit Determination Method (PODM). The best method can be determined by considering several factors of interest to the particular analyst selecting an orbit determination method. These factors are:

Which method is the fastest from a computational point of view?

Which method has the least numerical error propagation?

Which method experiences the least convergence difficulties?

Which method will function most effectively with the observation data available (position, angles, range, range rate, and time)?

Which method can give the best numerical results from orbits of varying eccentricity and semimajor axis?

Which method gives the best results from observation data having small and large true anomaly angular differences?
Data presented in this report form the solutions of twelve different PODMs and will help in determining the best method for a given application. The twelve different PODMs encompass classical methods used in determining the motion of heavenly bodies and present day methods used in artificial satellite PODMs. These PODMs are found in computational algorithm form (Escobal, reference 1). The algorithms were programmed in a FORTRAN II code and the calculations were accomplished on a Scientific Data Systems (SDS) 930 computer.

The PODM input data were derived from two well defined orbits (with perturbations and differential corrections) of common occurrence for artificial earth satellites. One orbit has low eccentricity with a small semimajor axis; the second orbit has a higher eccentricity and a larger semimajor axis.

**DISCUSSION**

**Symbols and Abbreviations**

Because the nomenclature used within the field of PODM is so extensive and non-uniform from text to text, a list of symbols and abbreviations is included (appendix A). In addition, the unit vectors and orientation angles of the orbital plane are illustrated in appendix A, figure 1.

**PODM Computational Algorithms**

The twelve PODMs computed in this evaluation use various types of observation data necessary for a solution or preliminary determination of the orbit. Lambert-Euler, F and G series, Iteration of Semiparameter, Gaussian (time and position), and Iteration of the True Anomaly PODMs use inertial position vectors \((x_1, y_1, z_1, x_2, y_2, z_2)\) and their corresponding universal times \(t_1\) and \(t_2\) as the input data. Method of Gauss (angles), Laplace, and Double R-Iteration PODMs require right ascension \((\alpha)\) and declination \((\delta)\) from three different stations and their corresponding universal times. Observation station data such as longitude, latitude, and elevation are also required. The remaining PODMs (Modified Laplacian, R-Iteration, Trilateration, and Herrick-Gibbs) require mixed data inputs. The mixed data inputs are selected from right ascension, declination, range and range rate along with the observation station data. Further discussion of these PODMs can be found in references 1 and 3. The computational algorithms for these PODMs are given in equations (1) through (439) in appendixes B through M.
Special considerations that must be given in the computational algorithms for retrograde orbits have been deleted. All orbits to be determined in this evaluation are those involving direct motion.

In nine of the PODMs an iteration of equations is involved which produces an iterative function that must be driven to zero or a lesser specified tolerance, i.e., epsilon. For this evaluation, a number of $10^{-10}$ was selected and is in line with the significant figures involved with the input data as well as the PODM solutions. This value for epsilon eliminated the need for extended range accuracy in the computer solutions.

Input data for these nine PODMs were derived from two National Aeronautics and Space Administration (NASA) earth-orbited satellites, OSO-III and Relay-II. These satellite orbits will be used as the bases for evaluation of the PODMs. The OSO-III orbit has an eccentricity of 0.00216 and a semimajor axis of 4,306.81 miles; Relay-II orbit eccentricity is 0.24115 and semimajor axis is 6,915.52 miles. The inclination angles are 32.863 degrees and 46.323 degrees for OSO-III and Relay-II respectively. Additional orbital elements for these satellites are specified in appendixes N and O. Orbital data were furnished by the NASA Goddard Space Flight Center (GSFC), Greenbelt, Maryland. Observation data were received from the various NASA tracking stations (references 5 and 6), and the resultant inertial position and velocity vector data for each minute of two complete revolutions for both orbits were generated from GSFC R083 Orbit Generator Routine-3 (references 7 and 8). The tracking stations and coordinates are listed in appendix P.

The inertial position vector data and corresponding universal time obtained from OSO-III and Relay-II orbits can be used as input data for the five PODMs using position and time inputs. However, these data must be modified to define range, range rate, and angular data to be used as an input for the remaining seven PODMs and to maintain a well defined orbit on which to base an evaluation of all PODMs. A computational algorithm developed to find $p$, $\dot{p}$, $\alpha$, and $\delta$ is detailed in appendix Q, equations (440) through (459). Results from this computational algorithm can be selected and applied to the seven PODMs requiring angles only and mixed data.

The PODM computational algorithms terminate when the inertial position and velocity vector for a corresponding observation point is determined; the orbit is then considered determined. In many cases, the classical orbital elements may serve to better illustrate the significant changes in the evaluation of the PODM. Therefore, a computational algorithm that solves for the classical elements (semimajor axis, $a$; eccentricity, $e$; inclination, $i$; longitude of the ascending node, $\Omega$; argument of perigee, $\omega$; and time of perifocal passage, $T$) from the position and velocity vector is detailed in appendix R, equations (460) through (480). This algorithm is computed subsequent to the determination of the inertial position and velocity vector of each PODM.
Computer Program Language

To facilitate this evaluation, the most obvious tool is the digital computer. The computational algorithms discussed in the previous paragraphs are readily translatable into a program language for communicating with digital computers. The FORTRAN II language was used because it is not really a single computer language. Rather, it is a family of similar languages, or dialects, with one or more being developed for each class of digital computer. A later generation of FORTRAN (FORTRAN IV) will further minimize the difference in this language for each class of computer (reference 2). The FORTRAN language provides engineers and scientists with an efficient and easily understood means of writing programs for computers.

Computer Program Flowcharts

In preparation for the programming of each computational algorithm, a program flowchart was constructed. The flowchart describes the code sequences that accomplish the processing of information to obtain the desirable result. In programs involving a great number of statements, it becomes cumbersome to follow the sequence of written statements. Since written statements can be stated or can proceed in a variety of ways, flowcharts are excellent for conveying procedural concepts.

The value of flowcharts is further enhanced by consistency in the graphical conventions used. The conventions used in this paper are found in appendix S and were primarily adopted from reference 4.

Flowcharts describe the code sequences as written from the computational algorithms (appendixes B through M). The information within the flowchart symbols is the FORTRAN II code description of the expressions in the algorithm and in the program listings. Only statements conveying procedural concepts are presented in the flowcharts.

Computer Program Listing

For each PODM computed there is a computer program listing (appendixes B through M). The program listing is a sequence of FORTRAN language statements used in computation of the PODM. The program listing is a copy of the source language translated to machine code by the computer processor. The program listing serves as an indicator for the diagnostic report from the computer during the program debugging procedure. The algorithms are programmed in FORTRAN II for use with SDS Series 930 computer (references 9 and 10), but the output of the millisecond (run-time) clock on the SDS 930 was programmed in SDS Meta-Symbol language. The run-time clock tallied and obtained the total time necessary to compute the PODM programs by a program subroutine identified as ITIME. This subroutine used the programmed statements indicated on the program listing by S (SDS Meta-Symbol language). The millisecond clock was initialized by ITIME = 0 and incremented
each millisecond by the ITIME subroutine and would subsequently be printed out upon command at the conclusion of a block of computed programmed statements. This procedure was accomplished several times during the computation of each PODM program in order to obtain only computation time and not time required for READ and PRINT statements.

Discussion Summary

The PODMs used for evaluation were found basically in reference 1, Escobal. They were programmed in FORTRAN II and SDS Meta-Symbol for use in the SDS 930 computer. Prior to programming, the procedural concept was established with flowcharts. The two reference orbit data were obtained from GSFC. The data were adapted to input data for angles only and mixed data PODM by a computational algorithm that was programmed and computed prior to the PODM computations. All PODM computations were accomplished on the SDS 930 computer. However, selected programs were successfully compiled and computed on an IBM 1800 and an IBM 360 with only slight modifications. The compilation of algorithms, flowcharts, and computer program listings used to conduct this evaluation of twelve PODMs are detailed in appendixes B through M.

RESULTS AND CONCLUSIONS

The inertial position and velocity orbit data with their corresponding times from epoch used in this PODM evaluation are listed in tables 1 and 2 for OSO-III and Relay-II satellites, respectively. Also contained within these tables is the change in true anomaly angle of each data point referenced to data point 1. Data points contained in these tables are the data points used for the inertial position and time PODM inputs. The same data points were used in the generation of data inputs by the computational algorithm for range, range rate, and angular data for the angles only and mixed data PODMs (appendix Q). The evaluation will consider the inertial position and time PODMs separately from the angles only and mixed data PODMs because sufficient differences exist in the computational algorithms and the practical usage of these PODMs.

Position and Time PODMs

The PODMs which use inertial position vectors and their corresponding times are found in appendixes B through F. These algorithms were applied using all data points referenced from data point 1 in tables 1 and 2. The computational algorithms for inertial position and time PODMs conclude by computing an inertial velocity vector corresponding to one of the times for which an input of inertial position is known. This inertial position and velocity vector and the corresponding time are sufficient to consider the orbit determined.
Subsequent to determination of the inertial velocity vector, the classical orbital elements are computed by using the computational algorithm contained in appendix R. The results of these computations are detailed in figures 2 through 11 and tables 3 through 17.

Figures 2 through 11 are detailed plots of the computed inertial velocity vectors in the $\hat{x}$, $\hat{y}$, $\hat{z}$ components versus the true anomaly angular difference between input data components from tables 1 and 2. The true anomaly angular difference, of position and time PODM, is the angular difference between two inertial position vectors (figure 12). The true anomaly angular difference was varied from 3.8 to 360 degrees for OSO-III orbit and from 2.5 to 360 degrees for Relay-II orbit for convenience in adapting the same data to the angles only and mixed data PODM with consideration to station locations. A plot of the number of iterations required for the iteration loop within the PODM computational algorithm for each set of data input used is also contained in figures 2 through 11. Tables 3 through 12 are the tabulated results which are plotted in figures 2 through 11.

For example, in figure 2, results of Lambert-Euler PODM for OSO-III, at 10 degrees difference in true anomaly the inertial velocity vectors are as follows: $\hat{x}$ is $-0.67100$ CUL/CUT; $\hat{y}$ is $0.45242$ CUL/CUT; and $\hat{z}$ is $-0.51970$ CUL/CUT and the predicted number of iterations is seven. The nominal values are indicated for each component. Also denoted is the true anomaly angular difference beyond which the program fails to compute and yield satisfactory results.

A comparison in each case of the computed resultant classical orbital elements, with respect to the nominal values obtained from appendixes N and O, is listed in tables 13 through 17. Both the computed results and the nominal values from the reference orbit are referenced to the same time of epoch as denoted in tables 1 and 2.

Each PODM program listing as found in appendixes B through F requires a definite number of words available in the computer core before a successful computation can be accomplished. Table 18 lists the number of 24-bit words required in the computer core of the SDS 930 computer for variables, statements, and subprograms necessary for computation of each PODM. The number of core words required can vary and may depend on the programming efficiency of the programmer. One programmer may be able to accomplish the same task with fewer core words than another programmer.

Another factor which can vary the computer core requirements is the efficiency of the computer manufacturer's library of translations of FORTRAN to machine language. In comparing the position and time PODMs, the core requirements for each PODM vary little except for the F and G Series (4649 words) requirement.
The time necessary to compute the computer coded program listing of each PODM was evaluated by printing time from the computer clock (ITIME) at the conclusion of a block of computations, ignoring the time necessary for READ and PRINT statements. The method used can be found in the computer program listing. The computation time required for each PODM is listed in table 19. The total time required for computation of each program with only one iteration ranges from 16 to 21 milliseconds, with F and G series being slowest and Lambert-Euler being fastest. The F and G series is slowest and Lambert-Euler and Gaussian PODMs fastest when comparing the time required for each additional iteration computation loop. However, the total time for computation during practical application of these PODMs is a function also of the rate of convergence. The average number of iterations required for the PODM iterative loop to converge is listed in table 20. Although the F and G series is slowest when computing for all portions of the algorithm, it is fastest in its ability to converge. The averages in table 20 considered only the data points for which the PODM yielded satisfactory results; i.e., the averages were computed from results of the PODM over true anomaly angular ranges which yielded acceptable solutions. The radius vector spread of the data input must be considered when choosing a PODM for a minimum computation time for a particular orbit because the convergence of the iteration loop is a function of the true anomaly difference.

Ease of convergence. - The ease of convergence of each PODM is indicated in table 20. The shape of the orbit appears to have some effect on the ability of the PODM to converge. Lambert-Euler, F and G series, and Iteration of True Anomaly PODMs decrease in ability to converge for an orbit with a larger semimajor axis and higher eccentricity while Gaussian and Iteration of Semiparameter PODMs increase.

The radius vector spread (true anomaly angular difference) over which these PODMs are likely to yield best results is concluded in table 21. The best result is a function of ease of convergence and accuracy.

Error propagation. - The position and time PODM that has the least error propagation is not readily distinguishable. There are relatively small differences in the propagation of error as indicated by the graph of inertial velocity versus true anomaly angular difference in figures 2 through 11. The profile of error in computing the inertial velocity in all PODMs appears the same until the radius vector spread becomes excessive for acceptable PODM results. The data also indicate that an optimum in radius vector spread for the most accurate computed velocity vector for these PODMs is 20 to 30 degrees.

Discussion of results. - In comparing the five PODMs using position and time input data, the results indicate that the optimum PODM is the Lambert-Euler followed by Iteration of Semiparameter, Iteration of True Anomaly, Gaussian, and F and G series. The optimum was a compromise between computation time, ease of convergence, and best overall accuracy considering radius vector spreads up to 360 degrees. These comparisons were made from the results of two different orbits; OSO-III and Relay-II. Table 22 indicates the standing of each PODM for consideration for determining the optimum.
Angles Only and Mixed Data PODMs

The PODMs using angles only and mixed data are found in appendixes G through M. These algorithms require a combination of three station observations of right ascension, declination, range or range rate, and their corresponding times from epoch in a topocentric coordinate system for a solution. The station location data is also required and is found in appendix P. From each data point in tables 1 and 2, values for range, range rate, declination, and right ascension were computed for several different stations using the computational algorithm found in appendix Q. These data are detailed in tables 23 and 24 for OSO-III and Relay-II, respectively. Tables 23 and 24 constitute the required input data to the angles only and mixed data PODMs being evaluated.

These PODMs require three observation data inputs for a solution and the observation station location data. There is also a requirement that the station observation data be from either three separate stations at three different times, or one station at three different times from epoch, or three stations with data input resolved to a common time from epoch. The number of stations required is determined in the computation algorithm by the input data necessary before a solution can be obtained from the PODM. The data points and observation stations combination used in computing results for evaluation of these PODMs are specified in tables 25 and 26.

The inertial velocity component results of these computations are specified in tables 27 through 39. These tables present the inertial velocity vector components \( \hat{x} \), \( \hat{y} \), and \( \hat{z} \) with reference to inertial velocity vector of the nominal orbit from tables 1 and 2. A comparison in each case of the resultant classical orbital elements, with respect to the nominal values of the elements from appendixes N and O, is specified in tables 40 through 44.

Both the computed results and the nominal values from the reference orbit are referenced to the same time of epoch as denoted in tables 1 and 2.

Table 18 indicates the computer core requirements for the program listings contained in appendixes G through M and Q. The requirements range from 3525 words for Herrick-Gibbs to 5254 words for Method of Gauss.

Computation time. - The computation time required for each PODM is specified in table 19. Two of the PODMs in this table, one under mixed data and the other under angles only, differ from the others. Herrick-Gibbs PODM has no iteration loop and is fastest from the computation time; Gauss PODM has two iteration loops and is the slowest. The total computing time required ranges from 13 to 26 milliseconds when only one pass through the iteration loop is present. Time for each additional pass through the iteration loop ranges from 5 to 9 milliseconds.
The average number of iterations of each PODM, using both OSO-III and Relay-II orbits, is specified in table 45. Herrick-Gibbs and Trilateration PODM do not have an iteration loop. However, Trilateration does have a branch which is computed twice to determine best approximation for the inertial position vector. Neither has an iteration loop computation time which can be compared with the other PODMs. Of the remaining PODMs which have iteration loops, Laplace and Modified Laplacian are the fastest at 5 milliseconds for each iteration loop while the Double R-Iteration PODM is slowest at 9 milliseconds.

**Ease of convergence.** - The radius vector spread between \( r_1 \) to \( r_2 \) and \( r_3 \) for data inputs to the PODM was 3.8 to 360 degrees for OSO-III and 2.5 to 360 degrees for Relay-II. Considering the data points which yielded satisfactory results to define the orbit, table 45 indicates the difficulty in convergence. Double R-Iteration and Laplace (angles only) iteration loops did not converge in the allotted number indexed in the program (maximum number of iterations allowable is 25). It becomes apparent that changes are required in refining the iteration loop from either a mathematical or programming viewpoint or that observation station geometry is critical. From these two PODMs (Double R-Iteration and Laplace) only one set of results from each came close to resembling OSO-III or Relay-II orbits. As presented, these PODMs have difficulty in converging and require additional information.

The three remaining PODMs which have iteration loops (Method of Gauss, Modified Laplacian, and R-Iteration) have a greater ease of convergence with data from OSO-III orbit, having a lower eccentricity and semimajor axis, than with the data from Relay-II orbit.

The convergence question does not arise in Herrick-Gibbs or Trilateration PODMs since no iteration loops exist.

**Error propagation.** - Error propagation in the angles only and mixed data PODMs have no characteristic profile as in the case of the position and time PODMs. Many factors may contribute to the inconsistency of error propagation and overall accuracy of results.

One factor is that station observation data was generated by a scheme from inertial position and velocity data and not by direct station observations. The geometry established between the observing station and the orbiting body may also be a critical factor. The limited number of data points available and used may yield results not completely representative of the PODM error propagation. However, after such considerations, all PODMs used the same input data for the results being discussed. If an error propagation profile can be established sufficiently it would appear to be similar in the Herrick-Gibbs, Method of Gauss, Modified Laplacian, and R-Iteration PODMs. The Double R-Iteration and Laplace PODMs have no distinguishable error profile.
A more accurate and complete set of results exist from the Relay-II orbit input data to PODM than exists from the inputs used from the OSO-III orbit. It appears that an orbit with larger semimajor axis and eccentricity is more readily computable for acceptable results over a greater radius vector spread than an orbit of lesser semimajor axis and eccentricity (Relay-II versus OSO-III). The PODM with the best overall accuracy with a radius vector spread (υ) to 360 degrees is specified in table 46.

Discussion of results. - In comparing each PODM using angles only and mixed data, the optimum PODM was determined to be Herrick-Gibbs followed by Modified Laplacian, Method of Gauss, R-Iteration, Double R-Iteration, and Laplace. The optimum was a compromise between the computing time, ease of convergence, and best overall accuracy considering radius vector spreads up to 360 degrees. These comparisons were made using the results of OSO-III and Relay-II orbits. Table 47 indicates the rank of each PODM under several classifications.

A contrasting difference is apparent when comparing the angles only and mixed data PODMs in that the schemes converge more easily with an OSO-III type of orbit. However, acceptable results are more readily attainable over a greater radius vector spread with the Relay-II type orbit.

Trilateration

Trilateration PODM is unique in that it requires three different station observations at the same time. The geometry of the three stations is very critical for obtaining accurate results. A computed set of results for OSO-III and Relay-II orbits are detailed in table 39. The results of Relay-II are more accurate than those of OSO-III. This follows the same trend as the other PODMs using angles only or mixed data. Also, Trilateration does not have an iteration loop and, with the requirement of simultaneous observations, it makes this PODM sufficiently different to refrain from comparing it directly with other PODMs. Total computation time for Trilateration PODM was 17 milliseconds.

Conclusion

Solutions from twelve different PODMs using data from two well defined orbits are presented. A number of solutions were obtained from each PODM when the angular difference (true anomaly difference) between observation data was varied from several degrees to one complete revolution. The PODMs evaluated use combinations of inertial position, angels, range and range rate, and corresponding universal times as input data. The computation time required for each PODM is tabulated for a nearly circular orbit with a small semimajor axis and one of higher eccentricity and a larger semimajor axis.
In comparing the five PODMs using position and time input data, the results indicate that the optimum PODM is the Lambert-Euler. Herrick-Gibbs is the optimum of the seven PODMs using angles only and mixed data.

A computational algorithm was used to adapt inertial position, velocity, and time input data to angular, range, range rate, and time input data from several different observation stations. A general FORTRAN code with program listings and computer program flowcharts is documented and can be utilized with computers other than the SDS 930 used in these solutions with only slight modifications. The computer core requirements for each program listing presented is tabulated.

The PODMs using inertial position and universal time input data yield solutions to the intercept, rendezvous, and interplanetary transfer problems of trajectory analysis. The angles only PODMs are the more classical PODMs which solve for fundamental orbital elements using the observer as main participant. Standing on a given location on the central planet of the orbiting body, an observer can measure the angular coordinates and determine the orbit. With the introduction of radar, the mixed data techniques are attractive to the trajectory analyst. The slant range from the observer to the satellite is obtainable as well as the rate at which this range is changing. The modern trajectory analyst uses the mixed data PODMs more frequently because of the excellent range and range rate data available.

The twelve PODMs may be used in any number of different problems confronting the trajectory analyst. The data presented can be used to predetermine a set of conditions which must exist in order to use the PODM which will yield the best determination of the orbit. Various combinations of observation stations and satellite observation data can be used effectively for orbit determination. With the computer programs available to each PODM, they may be used as computer program options which can be called on command to yield the best orbital results. This would be an efficient and accurate method for determining orbits of unknown space objects. The PODM results can be used to determine look angles for observation stations at later dates.
APPENDIX A
SYMBOLS AND ABBREVIATIONS

English Symbols

A Azimuth angle.
Miscellaneous constants.
Area.

A Auxiliary vector used in the method of Gauss.
Unit vector pointing due east.

a Semimajor axis of a conic section.
Matrix coefficient.

\( a_e \) Equatorial radius of Earth.

B Miscellaneous constants.

B Auxiliary vector used in the method of Gauss.
Semiminor axis of a conic section.

\( C_\psi \) The dot product of \((- \mathbf{R} \cdot \mathbf{L})\).

\( C_e \) Element \((= e \cos E_0)\).

\( C_h \) Element \((= e \cosh F_0)\).

\( C_v \) Element \((= e \cos \nu_0)\).

c Ratio of sector to triangle in the method of Gauss.

E Eccentric anomaly.
Miscellaneous constants.

e Orbital eccentricity.
Mathematical constant.

f Geometrical flattening of reference spheroid adopted for central
planet.
Functional notation.
Coefficient of f and g series.

G Station location and shape coefficients.
Universal gravitational constant.
Miscellaneous constants.

\( g \) Coefficient of f and g series.
Gravitational acceleration.

H Station elevation measured normal to adopted ellipsoid.
h  Elevation angle.

\( \mathbf{h} \)  Angular momentum vector.

\( \mathbf{i} \)  Unit vector along the principal axis of a given coordinate system.

\( \mathbf{i} \)  Orbital inclination.

The imaginary (\( = \sqrt{-1} \)).

\( \mathbf{J} \)  Harmonic coefficients of the Earth's potential function.

\( \mathbf{J} \)  Unit vector advanced to \( \mathbf{I} \) by a right angle in the fundamental plane.

\( \mathbf{K} \)  A constant.

\( \mathbf{K} \)  Unit vector defined by \( \mathbf{I} \times \mathbf{J} = \mathbf{K} \).

\( k_e \)  Gravitational constant.

\( \mathbf{L} \)  Unit vector from observational station to satellite.

\( \mathbf{M} \)  Mean anomaly \( = n(t - T) \).

\( m \)  General symbol for mass. Meters.

\( \mathbf{N} \)  Number of revolutions.

\( n \)  Mean motion \( = k\sqrt{\mu/a^2} \).

\( N \)  Number of revolutions.

\( \mathbf{P} \)  Orbital period (time from perigee crossing to perigee crossing).

\( P \)  Perifocus.

\( \mathbf{P} \)  Unit vector pointing toward perifocus.

\( p \)  Orbital semiparameter \( = a(1 - e^2) \).

\( Q \)  Unit vector advanced to \( \mathbf{P} \) by a right angle in the direction and plane of motion.

\( q \)  Generalized element.

\( q \)  Perifocal distance \( = a(1 - e) \).

\( q \)  Parameter of \( f \) and \( g \) series expansions.

\( R \)  Perturbative function \( = \phi - V \).

\( R \)  Magnitude of station coordinate vector.
Station coordinate vector.
Alternate notation for \( U \).

Magnitude of satellite radius vector.

Satellite radius vector.

Satellite symbol.

Element \( ( = e \sin E_0 ) \).

Element \( ( = e \sinh F_0 ) \).

Element \( ( = e \sin \nu_0 ) \).

A parameter taking the value 1 or -1.

Time of perifocal passage.

Universal or ephemeris time.

Unit vector pointing toward given satellite.

Argument of latitude.
Parameter of \( f \) and \( g \) series expansions.

General symbol for velocity vector magnitude.
Spherical potential of planet.

Unit vector advanced to \( U \) by a right angle in the direction and plane of motion.

Unit vector perpendicular to orbit plane.

Rectangular coordinates of station coordinate vector.

Rectangular coordinates of an object.

Unit vector in the zenith direction.
Special Symbols

\( \equiv \) Identically equal to.
Equal to by definition.

\( \cong \) Replace left side of equation with right side of equation.

\( \approx \) Approximately equal to.

\( \varpi \) Vernal equinox (sign of the Ram's Horns).

\( \infty \) Infinity.

\( \angle x, y \) Angle between \( x \) and \( y \).

\( \rightarrow \) Yields.

\( |x| \) Absolute value of \( x \).

Superscript Symbols

\( \cdot \) Relating to modified time differentiation. Also \( (\cdot) \).

\( \prime \) Relating to general differentiation.
 Relating to geocentric latitude.
 Minutes of arc.

\( \prime \prime \) Seconds of arc.

\( \ast \) Particular parameter or special form of an analytical expression.

\( \sim \) Particular parameter or special form of an analytical expression.

\( \hat{\cdot} \) Used to denote average or special form of an analytical expression or parameter.

\( \circ \) Degrees.

\( \text{hr} \) Hours.

\( \text{min} \) Minutes.

\( \text{sec} \) Seconds.
### Greek Alphabet

<table>
<thead>
<tr>
<th>Letter</th>
<th>Symbol</th>
<th>Pronunciation</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>α</td>
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<td>B</td>
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<tr>
<td>Ω</td>
<td>ω</td>
<td>Omega</td>
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### Greek Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>Right ascension.</td>
</tr>
<tr>
<td>Δ</td>
<td>Increment or difference.</td>
</tr>
<tr>
<td>ν</td>
<td>Gradient operator.</td>
</tr>
</tbody>
</table>

\[
ν(\cdot) = \frac{∂(\cdot)}{∂x} I + \frac{∂(\cdot)}{∂y} J + \frac{∂(\cdot)}{∂z} K
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>ε</td>
<td>Obliquity of the ecliptic.</td>
</tr>
<tr>
<td>η</td>
<td>Specified tolerance.</td>
</tr>
<tr>
<td>ζ</td>
<td>Coefficient.</td>
</tr>
<tr>
<td>θ</td>
<td>Sidereal time.</td>
</tr>
<tr>
<td>λ</td>
<td>Longitude.</td>
</tr>
<tr>
<td>μ</td>
<td>Sum of masses or mass.</td>
</tr>
<tr>
<td>ν</td>
<td>True anomaly.</td>
</tr>
<tr>
<td>ρ</td>
<td>Slant range vector.</td>
</tr>
</tbody>
</table>
Greek Symbols (Cont'd)

ϕ  Geodetic latitude.
ϕ  Geocentric latitude.
ϕₐ Astronomical latitude.
Ω  Longitude of ascending node.
Ω  Longitude of descending node.
ω  Argument of perigee.

Abbreviations

a.u.  Astronomical units.  ft  Feet.
cm  Centimeters.  gm  Grams.
c.m.  Central masses.  hr  Hours.
c.s.u.  Circular satellite units (also g.c.s.u.; geocentric circular satellite units)  h.c.s.u.  Heliocentric circular satellite units.
c.u.  Characteristic units.  J.D.  Julian date.
CUL  Canonical unit of length.  km  Kilometers.
CUT  Canonical unit of time.  m  Meters.
deg  Degrees.  min  Minutes.
e.m.  Earth masses.  sec  Seconds.
e.r.  Earth radii.  s.m.  Solar masses.
Figure 1. Orbit Plane Coordinate System Showing Unit Vectors and Orientation Angles
Given $r_1 (x_1, y_1, z_1)$, $r_2 (x_2, y_2, z_2)$ and their corresponding universal times, $t_1$ and $t_2$, proceed as follows:

\[ \tau = k_e (t_2 - t_1) \]  \hspace{1cm} (1)

\[ r_1 = \sqrt{r_1 \cdot r_1} \]  \hspace{1cm} (2)

\[ r_2 = \sqrt{r_2 \cdot r_2} \]  \hspace{1cm} (3)

\[ u_1 = \frac{r_1}{r_1} \]  \hspace{1cm} (4)

\[ u_2 = \frac{r_2}{r_2} \]  \hspace{1cm} (5)

\[ \cos (v_2 - v_1) = u_1 \cdot u_2 \]  \hspace{1cm} (6)

\[ \sin (v_2 - v_1) = \frac{x_1y_2 - x_2y_1}{|x_1y_2 - x_2y_1|} \sqrt{1 - \cos^2 (v_2 - v_1)} \]  \hspace{1cm} (7)

As a first approximation, if no better estimate is available, set

\[ a = \frac{(r_1 + r_2)}{2} \]  \hspace{1cm} (8)
and continue calculating with

\[ c = + \left[ r_2^2 + r_1^2 - 2(x_1x_2 + y_1y_2 + z_1z_2) \right]^{\frac{1}{2}} \]  \hspace{1cm} (9)  

\[ \sin \frac{1}{2} \varepsilon = \pm \sqrt{\frac{1}{4a} (r_2 + r_1 + c)} \]  \hspace{1cm} (10)  

\[ \sin \frac{1}{2} \delta = + \frac{\sqrt{r_2r_1 \cos \left( \frac{\nu_2 - \nu_1}{2} \right)}}{2a \sin \frac{1}{2} \varepsilon} \]  \hspace{1cm} (11)  

\[ \cos \frac{1}{2} \delta = \pm \sqrt{1 - \frac{1}{4a} (r_2 + r_1 - c)} \]  \hspace{1cm} (12)  

Set

\[ s = 1 \]  \hspace{1cm} (13)  

Later the analysis will be repeated for

\[ s = -1 \]  \hspace{1cm} (14)  

Continue with

\[ \cos \frac{1}{2} \varepsilon = s \sqrt{1 - \sin^2 \frac{1}{2} \varepsilon} \]  \hspace{1cm} (15)  

\[ F = \tau - \frac{a \left( \frac{3}{2} \right)}{\sqrt{\mu}} \left[ (\varepsilon - \sin \varepsilon) - (\delta - \sin \delta) \right] \]  \hspace{1cm} (16)  

If

\[ |F| < \Delta \]  \hspace{1cm} (17)
where $\Delta$ is a given tolerance, i.e., $10^{-10}$, proceed to equation (22); if it is not, save $F(a)$ and increment $a$, by 5 percent, that is, $\Delta a$, to obtain:

$$a + \Delta a$$  \hspace{1cm} (18)

Repeat equational loop (10) through (16), obtaining $F(a + \Delta a)$, and form

$$F'(a) = \frac{F(a + \Delta a) - F(a)}{\Delta a}$$  \hspace{1cm} (19)

Improve the value of $a$ by

$$a_{j+1} = a_j - \frac{F(a_j)}{F'(a_j)}, \quad j = 1, 2, 3, \ldots, q$$  \hspace{1cm} (20)

If

$$|a_{j+1} - a_j| < \Delta$$  \hspace{1cm} (21)

Proceed to equation (22); if not return to equation (10), replacing $a_j$ with $a_{j+1}$.

$$E_2 - E_1 = \varepsilon - \delta$$  \hspace{1cm} (22)

$$f = 1 - \frac{a}{r_1} \left[1 - \cos (E_2 - E_1)\right]$$  \hspace{1cm} (23)

$$g = \tau - \frac{3}{\mu} \left[E_2 - E_1 - \sin (E_2 - E_1)\right]$$  \hspace{1cm} (24)

$$\dot{r}_1 = \frac{r_2 - f r_1}{g}$$  \hspace{1cm} (25)

Continue by calculating for the classical elements.
LAMBERT-EULER FLOWCHART

START

XLC (1), YLC (1), 
ZLC (1), XLC (2), 
YLC (2), ZLC (2), 
T (1), T (2), XMU, 
XK

ECHO 
CHECK

TIME = 0

DO 6 
I = 1, 2

DO 31 
I = 1, 25

F (I), I

A

B

C

D

PAGE 24

F (I) < 10^{-10}

T

F

1 \leq 1

T

DELA = 0.05

DELA

F

\left[ \frac{F (I)}{FPA} - DELA \right] < 10^{-10}

T

F

I = 25

F

C

B

T

32

23
LAMBERT-EULER FLOWCHART (CONT'D)

D

XLCV (1), YLCV (1), ZLCV (1)

SOLUTION FOR CLASSICAL ELEMENTS

JTIME, ALC, ELC, TE, OMEGA, OINCL, W

STOP
LAMBERT-EULER PRELIMINARY ORBIT DETERMINATION
POSITION AND TIME (E.G.S.R.A.L., PAGE 2.5)
DIMENSION F(3), UX(2), UY(2), UZ(2), RLC(2), YLC(2),
CYLC(2), YLC(2), T(P), XLCV(1), YLCV(1), ZLCV(1), RLCV(1)
DA 40 = 1, 6
READ TWO INERTIAL POSITION VECTORS AND THEIR CORRESPONDING TIMES
READ 101, YLC(1), YLC(1), ZLC(2), T(1), XLC(2)
READ 101, YLC(2), ZLC(2), T(2), X'W, X'
FORMAT(5F16.6)
CHECK
PRINT 194, XLC(1), YLC(1), ZLC(1), T(1), XLC(2), YLC(2), ZLC(2), T(1), X'
X'W, X'
FORMAT(10E12.6, 2X, 2E12.6, 2X, 2E12.6, 2X, 2E12.6)
BEGIN COMPUTATIONS
ALL METASYMBOL IS ITM SUBROUTINE
TIME = 0
LCA = 2000
STA = 2000
BRU = 2000
S205 = 2000
2000 CUM = 200020
SPAT = CUM*CUM
EIR
TAO = X'V*(T(2)-T(1))
6 6 1=1, 2
RLC(1) = SQRT(YLC(1)*2+YLC(1)*2+ZLC(1)*2)
UX(1) = XLC(1)/RLC(1)
UY(1) = YLC(1)/RLC(1)
UZ(1) = ZLC(1)/RLC(1)
VCBS = UX(1)*UY(2)+UY(1)*UX(2)+UZ(1)*UZ(2)
C0 = XLC(1)*YLC(2)-XLC(2)*YLC(1)
VSIN = COS(C0)*VCBS*(1-C0)*2
C = SQRT(CO)*2+RLC(1)*2+20*(YLC(1)*XLC(2)+YLC(2)*XLC(1)+YLC(1)*YLC(2))
S = 1.0
14 A = (RLC(1)+RLC(2))/2.0
BEGIN LAMBERT-EULER ITERATION
20 31 I=1, 23
SHFAS = SQRT((RLC(2)+RLC(1)+C)/(4.0*A))
AMAS = ATAN(VSIN/VCBS)
SHDEL = SQRT(RLC(1)*RLC(2))*COS(A*3V/2.0)/(2.0*A*SHFAS)
CHDEL = SCRT((1:0)-(RLC(2)+RLC(1))*C)/(4*D*A1)
CHEPS = S*SCRT(1:0-S*HEPS*8)*2
EPSL = 2*Q*ATAN(S*HEPS,CHEPS)
DELTA = 2*Q*ATAN(S*CHDEL,CHEPS)
F(I) = TAN(S*SCRT(A**3/X**U)*((EPSL*4+SIN(EPSL*4))-DELTA))/TAN(DELTA)
CT1 = IT1
PRINT 100, CT1
PRINT 100, F(I), I
102 FORMAT(1HC,D(I)=E1.8,R8.8*****I=1:12)
IT1 = 0
24 IF(A(I)=I), 30, 26
25 IF(I=1), 30, 26
26 FPA = F(I) / DELTA
27 IF(A(I)=FPA*DELTA) = 0.000000001
28 DELTA = F(I) / FPA
29 GO TO 30
30 DELTA = FPA
31 A = ABS(A + DELTA)
C
SOLVE FOR INITIAL VELOCITY VECTORS X(1), Y(1), Z(1)
C
32 DIFF = EPSL - DELTA
33 FLX = 1.0 - (XLC(1)+XLC(2)) / (1.0 - COS(IPE))
34 SLX = TAN(SCRT(A**3/X**U)*((EPSL*4+SIN(IPE)) / TAN(IPE))
XLCV(1) = XLC(1) - FLC*XLC(1) / SLX
YLCV(1) = YLC(1) - FLC*YLC(1) / SLX
ZLCV(1) = ZLC(1) - FLC*ZLC(1) / SLX
CT1 = IT1 + F
PRINT 103, CT1
PRINT 103, XLCV(1), YLCV(1), ZLCV(1)
103 FORMAT(1HC,TXLCV(1)=T1.6,/* YLCV(1)=T1.6,/* ZLCV(1)=T1.6,/* )
C
SOLUTION FOR CLASSICAL ELEMENTS
C
IT1 = 0
RLC(1) = CT(YLCV(1) + XLCV(1) + YLCV(1) + YLCV(1) + ZLCV(1) + ZLCV(1))
RLCV(1) = CT(YLCV(1) + XLCV(1) + YLCV(1) + ZLCV(1) + ZLCV(1))
V = S*FLC(1) + YLCV(1) + YLCV(1) + YLC(1) / XLCV(1)
ALC = (FLC(1)) * Y**U / (2.0 * X**U - Y**U * X**U * (1))
CSFLC = 1.0 + ALC / (XLCV(1))
SSFLC = (YLCV(1) + XLCV(1) / X**L * Y**L) / (1)
ELC = CSFLC + SSFLC * X**L + X**L
CSFLC = (ALC + ALC(1)) / (XLCV(1) - L)
XSCFLC = ALC * (CSFLC - FLC)
CSFLC = XSCFLC / (1)
SINV = CT(XLCV(1) - X**L) / (1)
SINV = CT(1.0 + FLC(1) + X**L) / (1)
FLC = (1.0 / CT*CT) + CT*CT
T = FLCV(1) / (1.0 + FLC) / (1)
XYV = (XLCV(1) + YLCV(1) + ZLCV(1) + ZLCV(1) + YLCV(1) + ZLCV(1) + ZLCV(1) + XLCV(1))
MY = (XLCV(1) + XLCV(1) + YLCV(1) + YLCV(1) + ZLCV(1) + ZLCV(1) + ZLCV(1) + XLCV(1))
VA = GT (Z1, V, CSFLC)
SINHX=HX
COSHX=HY
BMEGA=ATAN(SINHX,COSHX)
EXP=SQRT(HX**2+HY**2)
BINCL=ATAN(EXP,HZ)
UNUM=XLC(1)*SIN(BMEGA)+YLC(1)*COS(BMEGA)*COS(BINCL)+
CZLC(1)*SIN(BINCL)
DEM=XLC(1)*COS(BMEGA)+YLC(1)*SIN(BMEGA)
W=ATAN(UNUM,DEM)
W=W+VANG
CT3=ITIME
PRINT 107,CTR
100 Format(1)**MILLISEC=#I8)
PRINT 107,ALC,FLC,TE,BMEGA,BINCL,W
107 Format(1)**H,ALC=#E16.8,FLC=#E16.8,TE=#E16.8,
1#BMEGA=#E16.8,BINCL=#E16.8,CT3=#E16.8
43 Continue
GP TO 41
SP 020 PZF
S MIN ITIME
S BRU *P200+5
41 END

27
APPENDIX C
F AND G SERIES PODM, POSITION AND TIME

Given $r_1 (x_1, y_1, z_1)$, $r_2 (x_2, y_2, z_2)$ and their corresponding universal times, $t_1$ and $t_2$, proceed as follows:

$$r_1 = +\sqrt{r_1 \cdot r_1} \quad (26)$$

$$r_2 = +\sqrt{r_2 \cdot r_2} \quad (27)$$

$$u_1 = \frac{r_1}{r_1} \quad (28)$$

$$u_2 = \frac{r_2}{r_2} \quad (29)$$

$$\cos (\nu_2 - \nu_1) = u_1 \cdot u_2 \quad (30)$$

$$\sin (\nu_2 - \nu_1) = \frac{x_1 y_2 - x_2 y_1}{\sqrt{\left(x_1 y_2 - x_2 y_1\right)^2}} \sqrt{1 - \cos^2 (\nu_2 - \nu_1)} \quad (31)$$

$$t_0 = \frac{t_2 + t_1}{2} \quad (32)$$

$$\tau_1 = k_e (t_1 - t_0) \quad (33)$$

$$\tau_2 = k_e (t_2 - t_0) \quad (34)$$
\[ r_0 = \frac{r_2 + r_1}{2} \]  
(35)

\[ A = 1 - \frac{\mu \frac{\tau_1^2}{3}}{2r_0^3} \]  
(36)

\[ B = 1 - \frac{\mu \frac{\tau_2^2}{3}}{2r_0^3} \]  
(37)

\[ \Delta = A \frac{\tau_2}{\tau_1} - B \tau_1 \]  
(38)

\[ \frac{1}{r_0} = \left( \frac{\tau_2}{\Delta} \right) r_1 - \left( \frac{\tau_1}{\Delta} \right) r_2 \]  
(39)

\[ \frac{\ddot{r}}{r_0} = \left( \frac{A}{\Delta} \right) r_2 - \left( \frac{B}{\Delta} \right) r_1 \]  
(40)

\[ r_0 = \sqrt{\dot{r}_0 \cdot \ddot{r}_0} \]  
(41)

\[ v_0 = \sqrt{\dot{v}_0 \cdot \ddot{v}_0} \]  
(42)

\[ \ddot{r}_0 = \frac{r_0 \cdot \ddot{r}_0}{r_0} \]  
(43)

\[ \frac{1}{a} = \frac{2}{r_0} - \frac{v_0^2}{\mu} \]  
(44)
\[ U_0 = \frac{\mu}{r_0^3} \]  
\[ P_0 = \frac{\dot{r}_0 r_0}{r_0^2} \]  
\[ q_0 = \frac{v_0^2 - r_0^2 u_0}{r_0^2} \]

Utilize the \(f\) and \(g\) functions:

\[ f_1 = f (V_0, r_0, \dot{r}_0, \tau_1) \]  
\[ f_2 = f (V_0, r_0, \dot{r}_0, \tau_2) \]  
\[ g_1 = g (V_0, r_0, \dot{r}_0, \tau_1) \]  
\[ g_2 = g (V_0, r_0, \dot{r}_0, \tau_2) \]

and form

\[ D = f_1 g_2 - f_2 g_1 \]

\[ C_1 = \frac{g_2}{D} \]
\[ c_2 = \frac{-g_1}{\dot{D}} \]  
(54)

\[ \dot{c}_1 = \frac{-f_2}{\dot{D}} \]  
(55)

\[ \dot{c}_2 = \frac{f_1}{\dot{D}} \]  
(56)

Hence, a better approximation to \( r_0, \dot{r}_0 \) is given by

\[ \xi_0 = c_1 r_1 + c_2 r_2 \]  
(57)

\[ \dot{\xi}_0 = \dot{c}_1 r_1 + \dot{c}_2 r_2 \]  
(58)

Return to equation (41) and repeat the equational loop to equation (58); continue until \( r_0, \dot{r}_0, V_0 \) from equations (41), (42), and (43) do not vary, that is,

\[ |(r_0)_{n+1} - (r_0)_n| < \varepsilon_1 \]  
(59)

\[ |(\dot{r}_0)_{n+1} - (\dot{r}_0)_n| < \varepsilon_2 \]  
(60)

\[ |(V_0)_{n+1} - (V_0)_n| < \varepsilon_3, \ n = 1, 2, ..., q \]  
(61)

Where \( \varepsilon_1, \varepsilon_2 \), and \( \varepsilon_3 \) are tolerances, i.e., \( 10^{-10} \). Having \( r, \dot{r}, \) and \( V \), utilize the derivatives of the \( f \) and \( g \) functions, that is,

\[ \dot{f}_1 = \dot{f}(V_0, r_0, \dot{r}_0, \tau_1) \]  
(62)

\[ \dot{g}_1 = \dot{g}(V_0, r_0, \dot{r}_0, \tau_1) \]  
(63)
to obtain

\[ \dot{r}_1 = \dot{f}_1 r_0 + \dot{g}_1 R_0 \]

(64)

Continue by calculating for classical elements
START

XLC(1), YLC(1), ZLC(1), XLC(2), YLC(2), ZLC(2), T(1), T(2), XMU, XK

ECHO CHECK

ITIME = 0

DO 5
J = 1, 2

DO 53
I = 1, 25

A

32
L = 1, 2

RLCN(1), VN(1), RLCNV(1), I

ABS [RLCN(i+1) - RLCN(i)] < 10-10

T

ABS [VN(i+1) - VN(i)] < 10-10

T

ABS [RLCNV(i+k) - RLCNV(i)] < 10-10

T

F

F

D

B

C

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PAGE 34
F AND G SERIES FLOWCHART (CONT'D)

B → C

T

I = 25

F

D

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SOLUTION FOR CLASSICAL ELEMENTS

ITIME, ALC, ELC, TE, OMEGA, OINCL, W

STOP

XLCV (1), YLCV (1), ZLCV (1)
F AND G SERIES PRELIMINARY ORBIT DETERMINATION METHOD

POSITION AND TIME (GSCORBA, PAGE 221)

DIMENSION RLC(3),UX(2),UY(2),UZ(2),XLC(P),YLC(P),T(3),
CTAU(2),XLCV(1),YLCV(1),ZLCV(1),RLCN(25),C(2),CV(2),G(2),F(2),
CVN(25),RLCNV(25),XLCNV(25),YLCNV(25),ZLCNV(25),XLCN(25),YLCN(25),ZLCN(25),

DB 30 K=1,6

READ TWO INERTIAL POSITION VECTORS AND THEIR CORRESPONDING TIMES

READ 101, XLC(1), YLC(1), ZLC(1), T(1), XLC(2)
READ 101, YLC(2), ZLC(2), T(2), X'U, X'V

101 FORMAT(5F16.8)

CHECK

PRINT 104, XLC(1), YLC(1), ZLC(1), T(1), XLC(2), YLC(2), ZLC(2), T(2),

104 FORMAT(14H10,1X,S16.8,1H,1P16.8,1H,1P16.8,1H,1P16.8,1H,1P16.8,1H,1P16.8,1H)

BEGIN COMPUTATIONS

ALL META SYMBOL IS TIME SUBROUTINE

ITIM=0

LDA 20B
STA 20K
BRU 206
S205 RF=20N8
S206 E8=20D8
S207 PGT = 200D0
S208 XCR

BEGIN

DO 5 J=1,P
RLC(J)=SACT(XLC(J)**2+YLC(J)**2+Z(J)**2)
UX(J)=XLC(J)/RLC(J)
UY(J)=YLC(J)/RLC(J)
UZ(J)=ZLC(J)/RLC(J)

5 VCOS=UX(1)*UX(P)+UY(1)*UY(P)+UZ(1)*UZ(P)
CM=1-XC**2-VCOS**2
VS=CM/CMS(CM)*SQR(1CM-VCOS**2)
T(3)=(T(P)+T(1))/2
TAU(1)=X**2*(T(1)-T(3))
TAU(2)=Y**2*(T(2)-T(3))
R1=(RLC(1)+RLC(P))/2
R2=R1-2**2

DO 10 J=1,P
XLC(J)=(TAU(1)+DELTAS)*XLC(J)+(TAU(2)+DELTAS)*XLC(J)
YLC(J)=(TAU(1)+DELTAS)*YLC(J)+(TAU(2)+DELTAS)*YLC(J)
ZLCV(J)=(TAU(2)+DELTAS)*ZLCV(J)-(TAU(2)+DELTAS)*ZLCV(J)

10 CONTINUE

35
BEGIN F A M G SERIES ITERATION

DE LR J=1, J=J+1
A1 = A1 J=1, J=J+1
B1 = B1 J=1, J=J+1
C1 = C1 J=1, J=J+1
D1 = D1 J=1, J=J+1
F1 = F1 J=1, J=J+1
G1 = G1 J=1, J=J+1
H1 = H1 J=1, J=J+1
I1 = I1 J=1, J=J+1
J1 = J1 J=1, J=J+1
K1 = K1 J=1, J=J+1
L1 = L1 J=1, J=J+1
M1 = M1 J=1, J=J+1
N1 = N1 J=1, J=J+1
O1 = O1 J=1, J=J+1
P1 = P1 J=1, J=J+1
Q1 = Q1 J=1, J=J+1
R1 = R1 J=1, J=J+1
S1 = S1 J=1, J=J+1
T1 = T1 J=1, J=J+1
U1 = U1 J=1, J=J+1
V1 = V1 J=1, J=J+1
W1 = W1 J=1, J=J+1
X1 = X1 J=1, J=J+1
Y1 = Y1 J=1, J=J+1
Z1 = Z1 J=1, J=J+1

30 IF M = 1 THEN
F(L) = F(L) + C*TAU(L) + \gamma U
C = C + 1
GOTO 30

32 S(L) = S(L) + B*TAU(L) + \gamma U
C = C + 1
GOTO 32
107 FORMAT(1X, F16.8, "\$\$C\$C=\$F16.8\$", IF$\$E$F15.8, 
1XME$E_16.8, "\$8$\$CL=\$F16.8\$"))
90 CONTINUE
GO TO 61
SPO50 PZE
S MIN TIME
S BRU SPO50
61 END
APPENDIX D
ITERATION OF SEMIPARAMETER PODM, POSITION AND TIME

Given \( r_1(x_1, y_1, z_1) \), \( r_2(x_2, y_2, z_2) \) and their corresponding universal times, \( t_1 \) and \( t_2 \), proceed as follows:

\[
\tau = k_e (t_2 - t_1) \quad (65)
\]

\[
r_1 = + \sqrt{r_1 \cdot r_1} \quad (66)
\]

\[
r_2 = + \sqrt{r_2 \cdot r_2} \quad (67)
\]

\[
\frac{r_1}{r_1} = \frac{r_1}{r_1} \quad (68)
\]

\[
\frac{r_2}{r_2} = \frac{r_2}{r_2} \quad (69)
\]

\[
\cos (v_2 - v_1) = U_1 \cdot U_2 \quad (70)
\]

\[
\sin (v_2 - v_1) = \frac{x_1y_2 - x_2y_1}{|x_1y_2 - x_2y_1|} \sqrt{1 - \cos^2 (v_2 - v_1)} \quad (71)
\]

As a first estimate, let

\[
p_g = 0.4 (r_1 + r_2) \quad (72)
\]
and

\[ p = p_g \]  \hspace{1cm} (73)

and continue calculating with

\[ e \cos v_1 = \frac{p}{r_1} - 1 \]  \hspace{1cm} (74)

\[ e \cos v_2 = \frac{p}{r_2} - 1 \]  \hspace{1cm} (75)

\[ e \sin v_1 = \frac{\cos (v_2 - v_1)(e \cos v_1) - (e \cos v_2)}{\sin (v_2 - v_1)} \]  \hspace{1cm} (76)

\[ e \sin v_2 = \frac{-\cos (v_2 - v_1)(e \cos v_2) - (e \cos v_1)}{\sin (v_2 - v_1)} \]  \hspace{1cm} (77)

\[ e = \sqrt{(e \cos v_1)^2 + (e \sin v_1)^2} \]  \hspace{1cm} (78)

\[ a = \frac{p}{1 - e^2} \]  \hspace{1cm} (79)

\[ n = \sqrt{\frac{\mu}{a^3}} \]  \hspace{1cm} (80)
If $e \neq 0$, proceed with equation (81); if $e = 0$ within a given tolerance, continue with equation (83).

$$
\cos E_i = \frac{r_i}{p} \left( \cos \nu_i + e \right), \quad i = 1, 2 \tag{81}
$$

$$
\sin E_i = \frac{r_i}{p} \sqrt{1 - e^2 \sin \nu_i}, \quad i = 1, 2 \tag{82}
$$

Continue calculating with equation (88).

$$
e = 0 \quad , \quad \nu_1 = 0 \tag{83}
$$

$$
\cos E_1 = 1 \tag{84}
$$

$$
\cos E_2 = \cos (\nu_2 - \nu_1) \tag{85}
$$

$$
\sin E_1 = 0 \tag{86}
$$

$$
\sin E_2 = \sin (\nu_2 - \nu_1) \tag{87}
$$

$$
M_i = E_i - e \sin E_i \quad , \quad i = 1, 2 \tag{88}
$$

$$
F = \tau - \left( \frac{M_2 - M_1}{n} \right) k_e \tag{89}
$$
If $F = 0$, proceed to equation (92); if not, increment $p$ by 5 percent and, by repeating equational loop (74) through (89), obtain

$$F'(p) = \frac{F(p + \Delta p) - F(p)}{\Delta p}$$  \hfill (90)

Hence, a better approximation to the semiparameter is

$$p_{j+1} = p_j - \frac{F(p_j)}{F'(p_j)} , \quad j = 1, 2, \ldots, q$$  \hfill (91)

Repeat the above loop $q$ times until $p$ is constant within a given tolerance, i.e., $10^{-10}$. Finally, continue calculating with equation (92).

$$f = 1 - \frac{a}{r_1} \left[ 1 - \cos (E_2 - E_1) \right]$$  \hfill (92)

$$g = \tau - \sqrt{\frac{a^3}{\mu}} \left[ E_2 - E_1 - \sin (E_2 - E_1) \right]$$  \hfill (93)

$$\dot{r}_1 = \frac{r_2 - f r_1}{g}$$  \hfill (94)

Continue by calculating for classical elements.
ITERATION OF SEMIPARAMETER

START

XLC(1), YLC(1), \( z_{LC}(1), T(1), XLC(2), YLC(2), z_{LC}(2), T(2), X_MV, X_K \)

ECHO CHECK

ITIME = 0

DO 6
I = 1, 2

DO 48
I = 1, 25

ELC \leq 10^{-10}

A

ELC = 0.0.

B

DO 28
N = 1, 2

DO 39
M = 1, 2

F(I), I

ABS[F(I)] < 10^{-10}

T

C

PAGE 44

F

1 \leq 1

T

D

DEL_P = 0.05 PLC

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E
ITERATION OF SEMIPARAMETER (CONT'D)

ITERATION OF SEMIPARAMETER (CONT'D)

ITERATION OF SEMIPARAMETER (CONT'D)

ITERATION OF SEMIPARAMETER (CONT'D)

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ITERATION OF SEMIPARAMETER (CONT'D)

ITERATION OF SEMIPARAMETER (CONT'D)
ITERATION OF SEMIPARAMETER BY ITERATIVE METHOD OF TIME AND POSITION (FOCAL, PAGE 311)

DIMENSION RX(2), YV(2), ZC(2), CRS(2), ZC(2),
COSV(2), COSV(2), CSR(2), SR(2), XLC(1), YLC(1), ZLC(1),
2LVCY(1), LVCY(1), YLC(1), XLC(2), YLC(2), ZLC(2)
DIM 44 X=1, J, K
READ TWO INITIAL POSITION VECTORS AND THE LAY-OUT OF W
READ 104, YLC(1), YLC(1), ZLC(1), T(J), XLC(2)
READ 151, YLC(2), ZLC(2), T(J), XLC(2)
FORMAT(EE16.8)
CFOUR C
READ 174, XLC(1), YLC(1), ZLC(1), T(K), XLC(2)
CFOUR C
FORMAT(4E16.8, YLC(1) = -16.8, // YLC(1) = -16.8, // T(K) = 1.0, // YLC(2) = -1.0, // T(K) = 1.0
1.0, // T(K) = 1.0, // YLC(2) = -1.0, // T(K) = 1.0, // XLC(1) = XLC, // XLC(2) = XLC
CFOUR C
BEGIN COMPUTATIONS
CFOUR C
ALL OF THE SYMBOL TO LINK SYMBOL
CFOUR C
IT=0
CFOUR C
LDA 2000
CFOUR C
STA 2000
CFOUR C
BNE 2000
CFOUR C
S200 RAC 2000
CFOUR C
S200 FE= 0.00006
CFOUR C
S200 EF= 0.00006
CFOUR C
S200 EP= 0.00006
CFOUR C
TA=YV*(T(2)-T(1))
CFOUR C
DO 6 J=1, P
CFOUR C
RLC(J)=COSV(YLC(J))**K+YLC(J)***2+ZLC(J)***2
CFOUR C
UX(J)=YV(J)/RLC(J)
CFOUR C
UY(J)=YV(J)/RLC(J)
CFOUR C
UD(J)=1.0/RLC(J)
CFOUR C
VS=1.0*UX(J)**2+UY(J)**2+UD(J)**2
CFOUR C
CG=((YLC(1))**2+YLC(2)**2)**0.5
CFOUR C
VG=1.0+CSS**2+CSR**2+SR**2
CFOUR C
PC=CG*CSS*CSR*SR
CFOUR C
PL=PC
CFOUR C
BEST ITERATION OF SEMIPARAMETER
CFOUR C
11 DO 44 K=1, P
CFOUR C
ECOSV(1)=ECOSV(1)+PC/COSV(1)**-1.0
CFOUR C
ECOSV(2)=ECOSV(2)+PC/COSV(2)**-1.0
CFOUR C
ESTV(1)=EVS*(ECOSV(1)-ECOSV(2))/VG
CFOUR C
ESTV(2)=(-EVS*ECOSV(2)+ECOSV(1))/VG

45
ELC = SORT(ABS(COSV(1)*2+ESINV(1)*2))
ALC = PLC/(1.0-ELC*2)
ETA = XX SORT(ABS(YMV/ALC*2))
COSV(1) = PLC*(RLC(1)*ELC)-1.0/ELC
COSV(2) = PLC*(RLC(2)*ELC)-1.0/ELC
SINV(1) = (COSV*ECOSV(1)-ECOSV(2))/(VSIN*ELC)
SINV(2) = (-COSV*ECOSV(2)+FCOSV(1))/(VSIN*ELC)

24 IF ELC = 0.000000001 30, 30, 35
25 DO PR = 1, 2
26 CASE(PR) = LRC(1)/PLC*COSV(N)*ELC)
27 SINE(PR) = LRC(1)/PLC*SORT(1.0+ELC*2)*SINV(1)
28 ANGE(PR) = ATAN(SINE(N),COSV(N))
29 GO TO 32
30 EL = 0.0
31 VLC(1) = 0.0
32 CASE(1) = 1.0
33 CASE(2) = 1.0
34 SINE(1) = 0.0
35 SINE(2) = 0.0
36 ANGE(1) = 0.0
37 ANGE(2) = ATAN(SINE(2),COSV(2))
38 DB 39 N = 1, 2
39 XM = 1.0
40 F(I) = TAN((XMFAIL(I)-XMFAIL(I))/TAN)*XK
41 CT = 1, E,
42 PRINT 100, CT1
43 PRINT 100, F(I), 1
44 FORMAT (1X, 10F12.4)
45 ITIME =
46 IF (ABS(F(I)) = 0.000000001) 49, 42, 42
47 IF (I = 1) 47, 47, 43
48 F = F(I) / FLP
49 IF (ABS(F(I)) = FLP = 0.000000001) 49, 45, 49
50 DELP = F(I) / FLP
51 GO TO 46
52 DLP = DLP*XPLC
53 PLC = ABS(PLC+DLP)
C SOLVE FOR INERTIAL VELOCITY VECTORS XCLV(1), YCLV(1), ZCLV(1)
49 FLC = 1.0 - (ALC/RLC(1)*(1.0-COS(ALT(A)))*(1.0-COS(ALT(P))))
50 GLC = 1.0 - (ALC/RLC(1)*(1.0-COS(ALT(A)))*(1.0-COS(ALT(P))))
XLCV(1) = XLC(2)-FLC*YLC(1)/GLC
YLCV(1) = YLC(2)-FLC*YLC(1)/GLC
ZLCV(1) = ZLC(2)-FLC*ZLC(1)/GLC
CT = ITIME
41 PRINT 100, CT
42 PRINT 100, XLCV(1), YLCV(1), ZLCV(1)
43 FORMAT (1X, 10F12.4)
44 YLCV(1) = YLCV(1) = 11.6876, 11.6876, ZLC(1) = 11.6876, 11.6876
C SOLVE FOR CLASSICAL ELEMENTS
47 ITIME =
50 RLC(1) = SORT(1.0*2+YLC(1)*2, ZLC(1)*2, ZLC(1)*2)
APPENDIX E
GAUSSIAN POOM, POSITION AND TIME

Given \( r_1 (x_1, y_1, z_1) \), \( r_2 (x_2, y_2, z_2) \) and their corresponding universal times, \( t_1 \) and \( t_2 \), proceed as follows:

\[
\tau = ke (t_2 - t_1) \quad (95)
\]

\[
r_1 = +\sqrt{r_1 \cdot r_1} \quad (96)
\]

\[
r_2 = +\sqrt{r_2 \cdot r_2} \quad (97)
\]

\[
\cos (\nu_2 - \nu_1) = \frac{r_1 \cdot r_2}{r_1 r_2} \quad (98)
\]

\[
\sin (\nu_2 - \nu_1) = \frac{x_1 y_2 - x_2 y_1}{|x_1 y_2 - x_2 y_1|} \sqrt{1 - \cos^2 (\nu_2 - \nu_1)} \quad (99)
\]

Obtain the constants

\[
l = \frac{r_1 + r_2}{4\sqrt{r_1 r_2} \cos \left(\frac{\nu_2 - \nu_1}{2}\right)} - \frac{1}{2} \quad (100)
\]

\[
m = \frac{k \tau^2}{\left[2\sqrt{r_1 r_2} \cos \left(\frac{\nu_2 - \nu_1}{2}\right)\right]^3} \quad (101)
\]
As a first approximation, set

\[ y = 1 \]  

(102)

and continue calculating with

\[ x = \frac{m}{y^2} - 1 \]  

(103)

\[ \cos \left( \frac{E_2 - E_1}{2} \right) = 1 - 2x \]  

(104)

\[ \sin \left( \frac{E_2 - E_1}{2} \right) = \sqrt{4x (1 - x)} \]  

(105)

\[ X = \frac{(E_2 - E_1) - \sin (E_2 - E_1)}{\sin^3 \left( \frac{E_2 - E_1}{2} \right)} \]  

(106)

\[ y = 1 + X (1 + x) \]  

(107)

If \( y \) is now equal to the assumed value within some tolerance, continue with equation (108); if it is not, place the value of \( y \) from equation (107) into equation (103) and repeat equational loop (103) through (107). Continue calculating with

\[ a = \left[ \frac{\pi \sqrt{\mu}}{2y \sqrt{r_2 r_1 \cos \frac{v_2 - v_1}{2} \sin \frac{E_2 - E_1}{2}}} \right]^2 \]  

(108)
\[ f = 1 - \frac{a}{r_1} \left[ 1 - \cos (E_2 - E_1) \right] \]  \hspace{2cm} (109)

\[ g = \tau \sqrt{\frac{a^3}{\mu}} \left[ (E_2 - E_1) - \sin (E_2 - E_1) \right] \]  \hspace{2cm} (110)

\[ \dot{r}_1 = \frac{r_2 - f \cdot r_1}{g} \]  \hspace{2cm} (111)

Continue to calculate for classical elements.
GAUSSIAN FLOWCHART

START

XLC(1), YLC(1), ZLC(1), XLC(2), YLC(2), ZLC(2), T(1), T(2), XMU, XK

ECHO CHECK

ITIME = 0

DO 3 I = 1, 2

DO 19 I = 1, 25

YLCP (I+1), I

STOP

ABS [YLCP(i) - YLC(i+1)] ≤ 10^-10

T

I = 25

F

20

XLCV(1), YLCV(1), ZLCV(1)

SOLUTION FOR CLASSICAL ELEMENTS

ITIME, ALC, ELC, TE, OMEGA, QUICL, W

A

B
GAUSSIAN PRELIMINARY EQUATION DETERMINATION. YET?
POSITION AND TIME (ASEGAL, CASE 156)

DIMENSION XLC(2), YLC(2), ZLC(2), RLC(2), YLC(2), RLC(2), YLC(1),
ZLC(1), XLC(1), T(2), RLC(1)

DE 70, I = 1, 6

READ THE EQUATION SECTIONS AND THEN THE CSMAC 101 stagger

READ 101, XLC(1), YLC(1), ZLC(1), T(1), YLC(2)
READ 101, YLC(2), ZLC(2), T(2), XLC, Y

FORAT (14, 8)

PRINT 104, XLC(1), YLC(1), ZLC(1), T(1), XLC(2), YLC(2), ZLC(2), T(2)

FORMAT (14, 8)

BEGIN COMPUTATIONS

ALL METALS SYMBOL IS 1, TIME = ROUTINE

IT = 0

ST = 2000

BE = 2000

SV = 2000

FB = 2000

PT = 2000

FI

TA = X*(T(P) - T(1))

DO 3 I = 1, P

RLC(I) = RRC(T(YLC(I) + YLC(I) + ZLC(I) + T(I))

VCOS = (XLC(I) + XLC(I) + YLC(I) + ZLC(I) + T(I))

CP = XLC(I) + XLC(I) + YLC(I) + ZLC(I) + T(I)

VSIN = CP/VCOS(COM**S/VCOS(I)**S)

ANGV = ATAN(VSIN, VCOS)

DL = RLC(I) + RLC(2)/X*(SORT(RLC(I) + RLC(2)))

DM = (X**4 + X**2)/(X**2 + SORT(RLC(I) + RLC(2)))

YLC(T) = 1 + C

BEGIN GAUSSIAN ITERATION

DO 10 I = 1, P

XLC = X/(YLC(1)**2 + 1)

FCS = 4*X**2*XLC

FSIN = FSIN(4*X**2*XLC*(1 + X**2))

ANG = ATAN(FSIN, FCS)

X = (2*ANG + X)/SIN(2*ANG)**3

YLC(T) = 1 + X**2*(DL + XLC)

10 CONTINUE
PRINT 100, CT1
PRINT 102, YLCP(I+1), I
FORMAT(1X,6,16,E16.8*X***I**I)
ITIME = 0
IF(AABS(YLCP(I)-YLCP(I+1))>0.000000001) 20,0,10
CONTINUE
SOLVE FOR INERTIAL VELOCITY VECTORS X,YZT,ZFC11
A=(TAU*XCLC(XMU))/2.0*YLCP(I+1)*SRT(FLC(I)**2+LC(1))**2
COS(A**2/V**2)*SI(A**2/GE))
FLC=1.0*(A/R/LC(1))**2-COS(2.0*A**2/GE))
GLC=TAN(SORT(A**2)*XMU)/(2.0*V**2)*SI(2.0*A**2/GE))
XLCV(I)=(XLC(I)+YLCP(I+1)+FLC*XL(1))/GLC
YLCV(I)=(YLCP(I)+FLC*YL(1))/GLC
ZLCV(I)=(ZLC(I)+YLCP(I+1))/GLC
CT2=ITIME
PRINT 100, CT2
PRINT 103, XLCV(I), YLCV(I), YLCV(I), ZLCV(I)
IF(AABS(YLCP(I)-YLCP(I+1))>0.000000001) 20,0,10
SOLVE FOR CLASSICAL ELEMENTS
ITIME = 0
RLC(I)=SORT(YLCV(1)**2+YLCP(1)**2+ZLC(1)**2)
RFNT=XL(1)+YLCV(I)+ZLC(1)+ZLC(1)*ZLC(V(1))
RLCV(I)=GRT/RLC(I)
V=SORT(YLCV(I)**2+YLCV(I)**2+ZLC(1)**2)
XLC(RLC(I)+YLCV(I)+ZLC(1)+ZLC(1))
ALC=SRT(RC-I)+XLC(1)/ALC)
CSUB=(1.0)/ALC(1)/ALC)
CSUB=(*DLLC(I)**2+XLC(1)/SRT(XMU)**2)
FLC=SRT(1.0)**2+XLC(1)/SRT(XMU)**2)
CEC=(ALC-FLC(I)**2)/ALC*FLC)
XSUB=ALC*(1.0)**2+ALC)
CSSV=CSSV**2/RLC(I)
SINV=SRT(FLC(I)**2+YLCV(I)**2)/RLC(I)
X=YLCP(I)**2+ZLC(1)**2)
Y=0.000000001
Z=0.000000001
VANG=ATAN2(SINV,CSSV)
SIN=H=HX
COS=CHY=HY
OMEGA=ATAN2(SIN,HX,CSSV)
EXP=SRT(H**2+HY**2)
THETA=ATAN(0.000000001,EXP)
UNUM=YLCP(I)**2+(OMEGA)**2+COS(THETA)**2+YLC(1)**2+COS(THETA)**2+ZLC(1)**2)
DEM=YLCP(I)**2+COS(OMEGA)**2+YLC(I)**2)
U=ATAN2(UHNUM,DEM)
=*U=VANG
CT3=ITIME
PRINT 100, CT3
100 FORMAT(1X, 'MILLISEC=', I8)
PRINT 107, ALC, ELC, TE, OMEGA, OINCL, W
107 FORMAT(1X, ALE=11.5, //, ELC=16.8, //, TE=1K.8, //,
MEGA=16.8, //, OINCL=16.8, //, EN=16.8, //)
70 CONTINUE
GO TO 41
S2050 PZF
S MIN ITIME
S END *PORS
41 END
APPENDIX F
ITERATION OF TRUE ANOMALY PODM, POSITION AND TIME

Given \( r_1 (x_1, y_1, z_1) \), \( r_2 (x_2, y_2, z_2) \) and their corresponding universal times, \( t_1 \) and \( t_2 \), proceed as follows:

\[
\tau = k_e (t_2 - t_1) \tag{112}
\]

\[
r_1 = +\sqrt{r_1 \cdot r_1} \tag{113}
\]

\[
r_2 = +\sqrt{r_2 \cdot r_2} \tag{114}
\]

\[
U_1 = \frac{r_1}{r_1} \tag{115}
\]

\[
U_2 = \frac{r_2}{r_2} \tag{116}
\]

\[
\cos (\nu_2 - \nu_1) = U_1 \cdot U_2 \tag{117}
\]

\[
\sin (\nu_2 - \nu_1) = \frac{x_1 y_2 - x_2 y_1}{|x_1 y_2 - x_2 y_1|} \sqrt{1 - \cos^2 (\nu_2 - \nu_1)} \tag{118}
\]

As a first approximation, set

\[
\nu_1 = 0^\circ \tag{119}
\]
\[
v_2 = v_1 + (v_2 - v_1) \tag{120}
\]

\[
e = \frac{(r_2 - r_1)}{r_1 \cos v_1 - r_2 \cos v_2} \tag{121}
\]

If \( e < 0 \), return to equation (119) and increment \( v_1 \) by \( \Delta v_1 \), 10 degrees; if \( e > 0 \), proceed with equation (122).

\[
a = \frac{r_1 (1 + e \cos v_1)}{(1 - e^2)} \tag{122}
\]

If \( a < 0 \), return to equation (119) and increment \( v_1 \) by \( \Delta v_1 \), again 10 degrees; if \( a > 0 \), proceed with equation (123).

\[
\sin E_1 = \frac{\sqrt{1 - e^2 \sin v_1}}{1 + e \cos v_1} \tag{123}
\]

\[
\cos E_1 = \frac{\cos v_1 + e}{1 + e \cos v_1} \tag{124}
\]

\[
\sin E_2 = \frac{\sqrt{1 - e^2 \sin v_2}}{1 + e \cos v_2} \tag{125}
\]

\[
\cos E_2 = \frac{\cos v_2 + e}{1 + e \cos v_2} \tag{126}
\]

\[
M_2 - M_1 = E_2 - E_1 + e (\sin E_1 - \sin E_2) \tag{127}
\]

\[
n = k_e \sqrt{\frac{\mu}{a^3}} \tag{128}
\]
\[ F = \tau - \left( \frac{M_2 - M_1}{n} \right) k_e \]  \hspace{1cm} (129)

If the iterative function is less than a specified tolerance \( \varepsilon_1 \), that is, \( 10^{-10} \),

\[ |F| < \varepsilon_1 \]  \hspace{1cm} (130)

proceed to equation (135); if not, save the numerical value of \( F \) and increment \( v_1 \) by a small amount, \( \Delta v \), to obtain

\[ v_1 + \Delta v \]  \hspace{1cm} (131)

Repeat equational loop (120) to (129) obtain \( F(v_1 + \Delta v) \) and form

\[ F'(v_1) = \frac{F(v_1 + \Delta v) - F(v_1)}{\Delta v} \]  \hspace{1cm} (132)

Improve the value of \( v_1 \) by

\[ (v_1)_{j+1} = (v_1)_j - \frac{F}{F'} [(v_1)_j] , \quad j = 1, 2, 3, \ldots, q \]  \hspace{1cm} (133)

If

\[ |(v_1)_{j+1} - (v_1)_j| < \varepsilon_2 \]  \hspace{1cm} (134)

where \( \varepsilon_2 \) is another specified tolerance, i.e., \( 10^{-10} \), proceed to equation (135); if not, return to equation (120) with the improved value of \( v_1 \).
Continue calculating with:

\[ f = 1 - \frac{a}{r_1} \left[ 1 - \cos (E_2 - E_1) \right] \]  \hspace{1cm} (135)

\[ g = \tau - \sqrt{\frac{a^3}{\mu}} \left[ E_2 - E_1 - \sin (E_2 - E_1) \right] \]  \hspace{1cm} (136)

\[ \dot{r}_1 = \frac{r_2 - f \cdot r_1}{g} \]  \hspace{1cm} (137)

Continue by calculating for classical elements.
ITERATION OF TRUE ANOMALY FLOWCHART
ITERATION OF TRUE ANOMALY
FLOWCHART
(CONT'D)

D

I ≤ i

T

F

F

ABS

DELV < 10

F

I = 25

E

PAGE 59

STOP

ITIME, ALC, ELC, TE, OMEGA, QINCL, W

SOLUTION FOR CLASSICAL ELEMENTS

F

DELV = 0.05 VLC(1)

PAGE 59
ITERATION OF THE TRUE ANOMALY PRELIMINARY ORBIT SOLUTION: MULTIPLIERS
POSITION AND TIME (KESSEL, PAGE 215)

DIMENSION F(PS), PLC(2), UX(2), UY(2), UZ(2), DLC(2), FSIN(1), FCOS(1)
CADS(2), ANG(2), YLC(2), YLC(3), ZLC(3), XLCD(1), YLCC(1), ZLCC(1)
DO 90 N=1,6

READ THE INERTIAL POSITION VECTORS AND THEIR CORRESPONDING TIMES

READ 101, XLC(1), YLC(1), ZLC(1), T(1), XLC(2)
READ 101, YLC(2), ZLC(2), T(2), X*,Y*,Z*

101 FORMAT(5F16.8)

PRINT 104, XLC(1), YLC(1), ZLC(1), T(1), XLC(2), YLC(2), ZLC(2)

C CHAIN CHECK

C

104 FORMAT(15X,4F16.8,15X,4F16.8,15X,4F16.8,15X,4F16.8)

BEGIN COMPUTATIONS

ALL METASymbols ARE TIME SUBROUTINE

ITIME=0

LDA 205S
STA 205S
BRU 205S
S205 RS
S200 ES
S PRT=00000000
S

FIR

TA=X*(T(2)-T(1))

DP 6 J=1,2

RLC(J)=SQRT(YLC(J)**2+YLC(J)**2+ZLC(J)**2)

UX(J)=XLC(J)/RLC(J)

UY(J)=YLC(J)/RLC(J)

UZ(J)=ZLC(J)/RLC(J)

VCBS=UX(1)**2+UY(1)**2+UZ(1)**2

CGM=XLC(1)*YLC(2)**2+YLC(1)*ZLC(2)**2

VSIN=CM/ABS(CGM)**1.0-VCBS**2

ANGV=ATAN(VSIN,VCBS)

VLC(1)=CGM

BEGIN ITERATION OF TRUE ANOMALY

11 DB 35 I=1,25

12 VLC(2)=VLC(1)+ANGV

13 PLC=(RLC(2)-RLC(1))/RLC(1)*CBS(VLC(1)-RLC(2)*CBS(VLC(1))

14 IF(PLC=-0.0000000031) 17,17,15

15 ALC=(PLC(1)**2+PLC*CBS(VLC(1)))/(1.0-PLC**2)

16 IF(ALC=-0.000000001) 17,17,19
17 VCL(1) = VCL(1) + 0.1743295
18 GO TO 12
19 EST1(1) = SQR(1 + FLC*SL*SL) * SIN(VCL(1))/COS(VCL(1)) * FCLC(COS(VCL(1)) + 1) * 0 + FCLC * COS(VCL(1))
20 EST1(2) = FCLC(SQR(1 + FLC*SL*SL) * SIN(VCL(2))/COS(VCL(2)) * FCLC(COS(VCL(2)) + 1) * 0 + FCLC * COS(VCL(2))
21 ANG1 = ATAN(EST1(1), FCLC)
22 ANG2 = ATAN(EST1(2), FCLC)
23 IF* = ANG2 - ANG1 + FLC * (EST1(1) - EST1(2))
24 ETA = X * SQR(XMU/XLC**3)
25 F(I) = TAN(IF* / ETA) * X
26 CT1 = IT1
27 PRINT 100, CT1
28 PRINT 100, F(I), 1
29 FORMAT(1H3, 2F(1) = E14.8, I1**I = I**2)
30 IF(A < 0) GO TO 100
31 IF(1 = I) GO TO 30
32 FPV = F(I) - F(I-1) / DELV
33 DELV = F(I) / FPV
34 GO TO 35
35 VCL(I) = VCL(I-1) + DELV
36 WRITE FOR INITIAL VELOCITY VECTORS X, Y, Z, W, T, I, J, K
37 FLC = 1 + FLC / XLC(I) * (1 + COS(A, T, (2) - A, T, (1))
38 GLC = TAN(SQR(XLC(I) + 3 * XMU) * (A, T, (2) - A, T, (1))
39 XLC(I) = (XLC(I) - FLC * XLC(I)) / GLC
40 YLC(I) = (YLC(I) - FLC * YLC(I)) / GLC
41 ZLC(I) = (ZLC(I) - FLC * ZLC(I)) / GLC
42 CT1 = IT1
43 PRINT 100, CT2
44 PRINT 100, XCV(I), YCV(I), ZCV(I)
45 FORMAT(1H3, 2F(1) = 16.8, YCV(I) = 16.8, ZLC(I) = 16.8)
46 WRITE FOR CLASSICAL ELEMENTS
47 CT1 = 0
48 RLC(I) = SQR(XLC(I) ** 2 + YLC(I) ** 2 + ZLC(I) ** 2)
49 RL = XLC(I) * XLC(I) + YLC(I) * YLC(I) + ZLC(I) * ZLC(I)
50 RL = FLC(I) + 1
51 RL = SQR(RLC(I) ** 2 + YLC(I) ** 2 + ZLC(I) ** 2)
52 ALC = 2 * YLC(I) * ZLC(I)
53 CSULC = (1 + COS(A, L, C(I)) / ALC)
54 SULC = (1 - COS(A, L, C(I)) / ALC)
55 ELC = SQR(3) * SL**2 + CSULC**2
56 CSULC = (1 + COS(A, L, C(I)) / ALC)
57 SULC = (1 - COS(A, L, C(I)) / ALC)
58 XULC = ALC * (CSULC * SCULC)
59 CPSULC = XULC / XLC(I)
60 SULC = SQR(XULC ** 2 + XULC ** 2)
61 ETC = XULC * SULC / XLC(I)
\[ TE = T(1) = (F \cdot \text{LC} \cdot \text{SINF}) / (X \cdot \text{SORT}(X \cdot \text{MU})) \cdot \text{SORT}(\text{ALC} \cdot 3) \]
\[ HX = \text{YLC}(1) \cdot \text{ZL}(1) \cdot \text{YL}(1) \cdot \text{ZL}(1) \cdot \text{YL}(1) \]
\[ HY = (\text{XLC}(1) \cdot \text{ZL}(1) \cdot 7 \cdot \text{L}(1) \cdot \text{YL}(1)) \]
\[ HZ = \text{XLC}(1) \cdot \text{YL}(1) \cdot \text{YLC}(1) \cdot \text{ZL}(1) \cdot \text{YL}(1) \]
\[ VANGE = \text{ATAN}(\text{SINV} \cdot \text{CRS} \cdot \text{V}) \]
\[ \text{SINHX} = HX \]
\[ \text{COSHY} = HY \]
\[ \Omega \text{MEGA} = \text{ATAN}(\text{SINHX} \cdot \text{COSHY}) \]
\[ \text{EXP} = \text{SORT}(HY \cdot 2 + HY \cdot 2) \]
\[ GINCL = \text{ATAN}((\text{EXP}, 47) \]
\[ VNUM = \text{XLC}(1) \cdot \text{SIN}(\Omega \text{MEGA}) \cdot \text{COS}(\text{GINCL}) + \text{YL}(1) \cdot \text{COS}(\Omega \text{MEGA}) \cdot \text{COS}(\text{GINCL}) + \]
\[ \text{CZLC}(1) \cdot \text{SIN}(\text{GINCL}) \]
\[ \text{DEM} = \text{XLC}(1) \cdot \text{COS}(\Omega \text{MEGA}) \cdot \text{YL}(1) \cdot \text{SIN}(\Omega \text{MEGA}) \]
\[ U = \text{ATAN}(\text{VNUM} \cdot \text{DEM}) \]
\[ W = U \cdot \text{VANCE} \]
\[ \text{CTR} = \text{TIME} \]
\[ \text{PRINT} 100, \text{CTR} \]
\[ \text{FORMAT}(100, HX) \]
\[ \text{PRINT} 107, \text{ALC}, \text{ELC}, \text{TF}, \Omega \text{MEGA}, \text{GINCL}, X \]
\[ \text{FORMAT}(104, 15, 8), \text{LC}, 115, 8, \text{TF}, 115, 8, \text{TF}, 115, 8, \]
\[ \text{FORMAT}(104, 16, 8), \text{GINCL}, 114, 8, \text{TF}, 114, 8, \]
\[ \text{CONTINUE} \]
\[ \text{G9} \text{ TO } 41 \]

S2052 PZE
S MIN ITIME
S BRU #20553
41 CAD
APPENDIX G
METHOD OF GAUSS PODM, ANGLES ONLY

Given $\alpha_i$, $\delta_i$, $\phi_i$, $\lambda_{Ei}$, $H_i$, $t_i$ for $i = 1, 2, 3$, and the constants $d\phi/dt$, $f$, $a_e$, $\mu$, $k_e$, compute the following:

$$\tau_1 = k_e (t_1 - t_2)$$

$$\tau_3 = k_e (t_3 - t_2)$$

$$\tau_{13} = \tau_3 - \tau_1$$

$$A_1 = \frac{\tau_3}{\tau_{13}}$$

$$B_1 = \left(\tau_{13}^2 - \tau_3^2\right) \frac{A_1}{6}$$

$$A_3 = -\frac{\tau_1}{\tau_{13}}$$

$$B_3 = \left(\tau_{13}^2 - \tau_1^2\right) \frac{A_3}{6}$$

$$T_u = \frac{J.D. - 2415020}{36525}$$

$$\theta_{90} = 99^\circ.6909833 + 36000^\circ.7689 T_u + 0^\circ.00038708 T_u^2$$

For $i = 1, 2, 3$, compute

$$L_{xi} = \cos \delta_i \cos \alpha_i$$

$$L_{yi} = \cos \delta_i \sin \alpha_i$$
\[ L_{zi} = \sin \delta_i \]  

(147)

\[ \theta_i = \theta_0 + \frac{d\theta}{dt} (t_i - t_0) + \lambda_{E_i} \]  

(148)

\[ G_{1i} = \frac{a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \]  

(149)

\[ G_{2i} = \frac{(1 - f)^2 a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \]  

(150)

\[ X_i = -G_{1i} \cos \phi_i \cos \theta_i \]  

(151)

\[ Y_i = G_{1i} \cos \phi_i \sin \theta_i \]  

(152)

\[ Z_i = -G_{2i} \sin \phi_i \]  

(153)

Compute the following:

\[ D = L_{x1} (L_{y2}^L z_3 - L_{z2}^L y_3) - L_{x2} (L_{y1}^L z_3 \]
\[ - L_{z1}^L y_3) + L_{x3} (L_{y1}^L z_2 - L_{z1}^L y_2) \]  

(154)

\[ a_{11} = \frac{L_{y2}^L z_3 - L_{y3}^L z_2}{D} \]  

(155)
\[ a_{12} = - \frac{(L_{x2}L_{z3} - L_{x3}L_{z2})}{D} \] (156)

\[ a_{13} = \frac{L_{x2}L_{y3} - L_{x3}L_{y2}}{D} \] (157)

\[ a_{21} = - \frac{(L_{y1}L_{z3} - L_{y3}L_{z1})}{D} \] (158)

\[ a_{22} = \frac{L_{x1}L_{z3} - L_{x3}L_{z1}}{D} \] (159)

\[ a_{23} = - \frac{(L_{x1}L_{y3} - L_{x3}L_{y1})}{D} \] (160)

\[ a_{31} = \frac{L_{y1}L_{z2} - L_{y2}L_{z1}}{D} \] (161)

\[ a_{32} = - \frac{(L_{x1}L_{z2} - L_{x2}L_{z1})}{D} \] (162)

\[ a_{33} = \frac{L_{x1}L_{y2} - L_{x2}L_{y1}}{D} \] (163)
and form the vectors

\[ \mathbf{A} = \begin{bmatrix} A_1, & -1, & A_3 \end{bmatrix} \]  

(164)

\[ \mathbf{B} = \begin{bmatrix} B_1, & 0, & B_3 \end{bmatrix} \]  

(165)

\[ \mathbf{X} = \begin{bmatrix} X_1, & X_2, & X_3 \end{bmatrix} \]  

(166)

\[ \mathbf{Y} = \begin{bmatrix} Y_1, & Y_2, & Y_3 \end{bmatrix} \]  

(167)

\[ \mathbf{Z} = \begin{bmatrix} Z_1, & Z_2, & Z_3 \end{bmatrix} \]  

(168)

Evaluate the coefficients:

\[ \mathbf{A}_2^* = - (a_{21} \mathbf{A} \cdot \mathbf{X} + a_{22} \mathbf{A} \cdot \mathbf{Y} + a_{23} \mathbf{A} \cdot \mathbf{Z}) \]  

(169)

\[ \mathbf{B}_2^* = - (a_{21} \mathbf{B} \cdot \mathbf{X} + a_{22} \mathbf{B} \cdot \mathbf{Y} + a_{23} \mathbf{B} \cdot \mathbf{Z}) \]  

(170)

\[ C_\psi = -2 (X_2 Lx_2 + Y_2 Ly_2 + Z_2 Lz_2) \]  

(171)
\[ R_2^2 = x_2^2 + y_2^2 + z_2^2 \]  
\[ a = - (c \psi A_2^* + a_2^* + R_2^2) \]  
\[ b = - \mu (c \psi B_2^* + 2A_2^* B_2^*) \]  
\[ c = - \mu^2 B_2^* x_2^2 \]  

Solve

\[ r_2^8 + ar_2^6 + br_2^3 + c = 0 \]  

(173)

(174)

(175)

(176)

to obtain the applicable real root \( r_2 \), and continue calculating with

\[ u_2 = \frac{\mu}{r_2^3} \]  
\[ D_1 = A_1 + B_1 u_2 \]  
\[ D_3 = A_3 + B_3 u_2 \]  
\[ A_1^* = a_{11} A + a_{12} A \cdot Y + a_{13} A \cdot Z \]  

(177)

(178)

(179)

(180)
\[ B_1^* = a_{11} B \cdot X + a_{12} B \cdot Y + a_{13} B \cdot Z \]  \hspace{1cm} (181)

\[ A_3^* = a_{31} A \cdot X + a_{32} A \cdot Y + a_{33} A \cdot Z \]  \hspace{1cm} (182)

\[ B_3^* = a_{31} B \cdot X + a_{32} B \cdot Y + a_{33} B \cdot Z \]  \hspace{1cm} (183)

\[ \rho_1 = \frac{A_1^* + B_1^* u_2}{D_1} \]  \hspace{1cm} (184)

\[ \rho_2 = A_2^* + B_2^* u_2 \]  \hspace{1cm} (185)

\[ \rho_3 = \frac{A_3^* + B_3^* u_2}{D_3} \]  \hspace{1cm} (186)

\[ \tau_i = \rho_i L_i - R_i \]  \hspace{1cm} for \ i = 1, 2, 3 \hspace{1cm} (187)

Then, utilizing the Herrick-Gibbs formulas, calculate

\[ d_1 = \tau_3 \left( \frac{\mu}{12r_1^3} - \frac{1}{\tau_1 \tau_3} \right) \]  \hspace{1cm} (188)

\[ d_2 = (\tau_1 + \tau_3) \left( \frac{\mu}{12r_2^3} - \frac{1}{\tau_1 \tau_3} \right) \]  \hspace{1cm} (189)

\[ d_3 = -\tau_1 \left( \frac{\mu}{12r_3^3} + \frac{1}{\tau_3 \tau_1} \right) \]  \hspace{1cm} (190)
\[ \dot{r}_2 = - d_1 r_1 + d_2 r_2 + d_3 r_3 \]  \hspace{1cm} (191)

\[ r_2 = \sqrt{\dot{r}_2 \cdot \dot{r}_2} \]  \hspace{1cm} (192)

\[ \ddot{r}_2 = \frac{\dot{r}_2 \cdot \dot{r}_2}{r_2} \]  \hspace{1cm} (193)

\[ v_2 = \sqrt{\dot{v}_2 \cdot \dot{v}_2} \]  \hspace{1cm} (194)

\[ \frac{1}{a} = \frac{2}{r_2} - \frac{v_2^2}{\mu} \]  \hspace{1cm} (195)

From the \( f \) and \( g \) functions, calculate

\[ f_1 = f (v_2, r_2, \dot{r}_2, \tau_1) \]  \hspace{1cm} (196)

\[ f_3 = f (v_2, r_2, \dot{r}_2, \tau_3) \]  \hspace{1cm} (197)

\[ g_1 = g (v_2, r_2, \dot{r}_2, \tau_1) \]  \hspace{1cm} (198)

\[ g_3 = g (v_2, r_2, \dot{r}_2, \tau_3) \]  \hspace{1cm} (199)

Continue calculating with

\[ D^* = f_1 g_3 - f_3 g_1 \]  \hspace{1cm} (200)
\[ c_1 = \frac{g_3}{D^*} \]  \hspace{1cm} (201)

\[ c_2 = -1.0 \]  \hspace{1cm} (202)

\[ c_3 = -\frac{g_1}{D^*} \]  \hspace{1cm} (203)

\[ G = c_1R_1 + c_2R_2 + c_3R_3 \]  \hspace{1cm} (204)

\[ (\rho_1)_n = \frac{1}{c_1} (a_{11}G_x + a_{12}G_y + a_{13}G_z) \]  \hspace{1cm} (205)

\[ (\rho_2)_n = - (a_{21}G_x + a_{22}G_y + a_{23}G_z) \]  \hspace{1cm} (206)

\[ (\rho_3)_n = \frac{1}{c_3} (a_{31}G_x + a_{32}G_y + a_{33}G_z) \]  \hspace{1cm} (207)

The first time through, test to see if

\[ |(\rho_1)_n - \rho_1| < \varepsilon_1 \]  \hspace{1cm} (208)

\[ |(\rho_2)_n - \rho_2| < \varepsilon_2 \]  \hspace{1cm} (209)

\[ |(\rho_3)_n - \rho_3| < \varepsilon_3 \]  \hspace{1cm} (210)
where $\varepsilon_1, \varepsilon_2, \varepsilon_3$ are tolerances, i.e., $10^{-10}$. If so, proceed to equation (214); if not, return to equation (187) using $(\rho_1)_n$ and repeat equational loop (188) to (207); however, from this point on, test to see if

$$| (\rho_1)_{n+1} - (\rho_1)_n | < \varepsilon_1$$  \hspace{1cm} (211)$$

$$| (\rho_2)_{n+1} - (\rho_2)_n | < \varepsilon_2$$  \hspace{1cm} (212)$$

$$| (\rho_3)_{n+1} - (\rho_3)_n | < \varepsilon_3$$  \hspace{1cm} (213)$$

And repeat equational loop (188) to (207) until test is successful. Continue by calculating

$$r_2 = \rho_2 L_2 - R_2$$  \hspace{1cm} (214)$$

$$\ddot{r}_2 = -d_1 r_1 + d_2 r_2 + d_3 r_3$$  \hspace{1cm} (215)$$

Continue by calculating the classical elements.
METHOD OF GAUSS FLOWCHART

START

ALPHA(1), DELTA(1), YAME(1), PHI(1), H(1), T(1), FOR I = 1, 2, 3, XMU, DTHETA, FLAT, AE, XK, TJD, T(4)

ECHO CHECK

TIME = 0

DO 19 J = 1, 3

DO 47 I = 1, 25

REX(I), RLC(2), I

A

ABS [REX(I) + CLC] < 10^-10

T

PAGE 74

F

B

I = 1

T

DELTA = 0.05 RLC(2)

F

C

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ABS [REX(I) - FPR] / DELR < 10^-10

T

B

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F

44

I = 25

T

C

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F

B
METHOD OF GAUSS FLOWCHART (CONT'D)

D

ABS \( \left| \frac{P_2(I) - P(3)}{P(3)} \right| > 10^{-10} \)

F

ABS \( \left| \frac{P_1(I) - P(1)}{P(1)} \right| > 10^{-10} \)

F

ABS \( \left| \frac{P_2(I) - P(2)}{P(2)} \right| > 10^{-10} \)

F

\( I = 1, 3, 2 \)

\( P_1(I), P_2(I), P_3(I), I \)

\( P(I), P_2(I), P_3(I), I \)

\( \text{SOLUTION FOR CLASSICAL ELEMENTS} \)

\( \text{ITIME, ALC, ELC, TE, OMEGA, DIMCL, W} \)

\( \text{STOP} \)
METHOD OF GAUSS PRELIMINARY ORBIT DETERMINATION METHOD
ANGLES ONLY (ESCRBAL, PAGE 258)

DIMENSION TAU(3), A(3), B(3), YL(3), YL(3), ZL(3), THETA(3), DEL(3),
CRE(25), YLC(3), RLC(3), RLC(3), YLC(3), D(3), P(3), DLC(3),
CXLCV(3), YLVC(3), ZLVC(3), RLCV(3), V(3), PLC(3), QLC(3), F(3), FT(3),
DIMENSION GS(3), GT(3), F(3), R(3), C(3), P1(25), P2(25), P3(25),
CT(4), ALPHAT(3), DELTAT(4), PHIT(3), YAME(3), R(3)

READ ANGLE INPUT DATA

READ 100, FLAT, AP, YK, XM, DTHETA
READ 100, T(4), T(5), T(6), T(7), TJD
READ 100, ALPHA(1), ALPHA(2), ALPHA(3), DELTA(1), DELTA(2)
READ 100, DELTA(3), YAME(1), YAME(2), YAME(3), PHI(1)
READ 100, PHI(2), PHI(3), H(1), H(2), H(3)

FORMAT(EE16.8)

ECHO CHECK

PRINT 110, FLAT, AP, X, XM, DTHETA, T(4), TJD, T(1), T(2), T(3)
FORMAT(EE16.8)

1**T1**E16.8**T(1)**E16.8**T(2)**E16.8**T(3)**E16.8
1**T(1)**E16.8**T(2)**E16.8**T(3)**E16.8

PRINT 110, ALPHA(1), ALPHA(2), ALPHA(3), DELTA(1), DELTA(2), DELTA(3),
CYAME(1), CYAME(2), YAME(3)

FORMAT(EE16.8), **ALPHA(1)**E16.8**ALPHA(2)**E16.8**ALPHA(3)**E16.8
1**DELTA(1)**E16.8**DELTA(2)**E16.8**DELTA(3)**E16.8
1**YAME**E16.8**YAME**E16.8**YAME**E16.8

PRINT 110, PHI(1), PHI(2), PHI(3), H(1), H(2), H(3)

FORMAT(EE16.8), **PHI(1)**E16.8**PHI(2)**E16.8**PHI(3)**E16.8
1**H(1)**E16.8**H(2)**E16.8

BEGIN COMPUTATIONS

ALL KETA SYMBOL IS ITIME SUBROUTINE.
A(3) = TAU(1) / DTAU
B(3) = (DTAU) * TAU(1) / 2 / A(3) / 6 * 0
TUE = (TJD - 2415020.0) / 36525.0
GTHETA = 7.594193381713040 * 76.89 * TUE + 0.0038700 * TUE ** 2 / 7.57 * 2957735131
8
D0 19 J = 1, 3
XL(J) = CBS(DELTA(J)) + CBS(ALPHA(J))
YL(J) = CBS(DELTA(J)) + SIN(ALPHA(J))
ZL(J) = SIN(DELTA(J))
THETA(J) = GTHETA + DTHETA * (J(T(J) - T(4))) + YAME(J)
DEMG(J) = SORT(1, 2, 0) * FLAT = FLAT ** 2 * (SIN(PHI(J))) ** 2
G1(J) = AF / DEMG(J) + (H(J)
G2(J) = 1 + 0.0 * FLAT ** 2 * AE / DEMG(J) + (H(J)
X(J) = G1(J) * CBS(PHI(J)) * CBS(THETA(J)
Y(J) = G2(J) * CBS(PHI(J)) * SIN(THETA(J))
Z(J) = G2(J) * SIN(PHI(J))
D1 = XL(1) * YL(2) * ZL(3) - XL(2) * YL(3) - XL(3) * YL(1) - ZL(1) * YL(3) - ZL(2) * YL(1)
C + XL(3) * YL(1) * ZL(2) - ZL(1) * YL(2)
A1(1) = (XL(1) ** ZL(2) ** ZL(3) ** YL(3) ** YL(2)) / D1
A1(2) = (XL(2) ** ZL(3) ** ZL(2) ** YL(3) ** YL(2)) / D1
A1(3) = (XL(3) ** YL(3) ** ZL(3) ** YL(2) ** YL(1)) / D1
A2(1) = (YL(1) ** ZL(3) ** YL(2) ** ZL(1)) / D1
A2(2) = (YL(2) ** ZL(3) ** YL(3) ** ZL(2)) / D1
A2(3) = (YL(3) ** ZL(3) ** YL(3) ** ZL(1)) / D1
A3(1) = (YL(1) ** ZL(2) ** YL(3)) / D1
A3(2) = (XL(1) ** ZL(2) ** YL(2) ** ZL(1)) / D1
A3(3) = (XL(1) ** ZL(2) ** YL(1)) / D1
A4 = A(1) * YL(1) - X(2) * A(3) * X(3)
A5 = A(1) * YL(1) - Y(2) * A(3) * Y(3)
A6 = A(1) * Z(1) - Z(2) * A(3) * Z(3)
B1 = B(1) * X(1) + B(3) * X(3)
B2 = B(1) * Y(1) + B(3) * Y(3)
B3 = B(1) * Z(1) + B(3) * Z(3)
AS(2) = (A2(1) * AX + A2(2) * AY + A2(3) * AZ)
BS(2) = (A2(1) * AX + A2(2) * AY + A2(3) * AZ)
B1 = 0.2 * X(1) * XL(2) + Y(2) * YL(2) + Z(2) * ZL(2)
R(2) = SQRT((X(2) ** 2 + Y(2) ** 2 + Z(2) ** 2)
ALC = (C1 * AS(2) + AS(3) ** 2 + R(2) ** 2)
BLC = X**2 + Y**2 + Z**2
RLC = Y**2 + Z**2
C
C ITERATIVE LBRP FOR DETERMINING APPLICABLE REAL ROOT OF RLC(2)
C
37 DE 47 I = 1, 25
REX(I) = RLC(2) ** 3 + ALC * RLC(2) ** 6 + BLC * RLC(2) ** 3 + CLC
CT1 = TRUE
PRINT 100, CT1
PRINT 101, REX(I) ** RLC(2) ** I
102 FORMAT(1X, 15, 1X, REX(I) = $E15.4, REX(I) = $E16.3, I = I2)
ITME = 0
IF (ABS(REX(I)) - REX(I) - 0.0000000001) 48, 48, 49
49 IF (ABS(REX(I)) - 0.0000000001) 48, 48, 43
43 IF (I - 1) = 46, 46, 44
44 RR = (REX(I1) - REX(I1)) / DCLR

76
IF \( |x(x(1)|/\text{RPR} self\text{DCL} = 0.0000001 \) 48, 45, 45

```c

C

ITERATIVE LOOP FOR DETERMINING SCALAR OF THE RANGE VECTOR

```
C(2) = 1.0
C(3) = 0.1

GX = C(1) * Y(1) + C(2) * X(2) + C(3) * X(3)
GZ = C(1) * Z(1) + C(2) * Z(2) + C(3) * Z(3)

P1[I] = (1 / C(1) + A(1) * GX + A1(2) * GY + A1(3) * GZ)
P2(I) = (A2(1) * GX + A2(2) * GY + A2(3) * GZ)
P3(I) = (1 / C(3) + A3(1) * GX + A3(2) * GY + A3(3) * GZ)

CT2 = 11111

PRINT INC * CT2

FOR P1(I) = 1 TO 10, I*, P2(I), I*, P3(I), I

TIME = 0
IF (ABS(P(1) - P(1)) > 0.00000001) 90, 93, 93
IF (ABS(P(2) - P(2)) > 0.00000001) 90, 93, 93
IF (ABS(P(3) - P(3)) > 0.00000001) 90, 93, 93

GB = GB

P(1) = P1(I)
P(2) = P2(I)
P(3) = P3(I)

SOLVE FOR INERTIAL POSITION AND VELOCITY VECTORS

XLC(2) = P(2)*YLC(2) - X(2)
YLC(2) = P(2)*YLC(2) - Y(2)
ZLC(2) = P(2)*ZLC(2) - Z(2)

XLCV(2) = XLC(2) + DLC(2) + DLC(2) + DLC(2)
YLCV(2) = YLC(2) + DLC(2) + DLC(2) + DLC(2)
ZLCV(2) = ZLC(2) + DLC(2) + DLC(2) + DLC(2)

CT3 = ZLC(3)

PRINT 100, CT3
PRINT 104, XLCV(2), YLCV(2), ZLCV(2)

SOLITUDE: FOR CLASSICAL ELEMENTS

RLC(2) = SQRT(YLC(2)^2 + YLC(2)^2 + ZLC(2)^2)
RRDT = XLC(2) * XLCV(2) + YLC(2) * YLCV(2) + ZLC(2) * ZLCV(2)
RLC(2) = RRDT / RLC(2)

VE = SQRT(XLCV(2)^2 + YLCV(2)^2 + ZLCV(2)^2)

ALC = (RLC(2) * X*YU) / (2 * X*YU * VE * RLC(2))

CSUBE = (1 + RLC(2) / ALC)
SSUBE = (RLCV(2) * RLC(2)) / SQRT(X*YU * ALC)

ELC = SQRT(1 + SSUBE)^2 / CSUBE

CSE = (ALC + RLC(2)) / (ALC * ELC)

XSUB = ALC * (CSE = ELC)

CS = XS * B / RLC(2)

SINV = SQRT(RLC(2)^2 + XSUB^2) / RLC(2)
SIN = SQRT(1 + ELC^2) * SINV / (1 + ELC * SINV)
ECT = TAN(SINE * CS)

TET = (T2) / ((T2 + ELC * SINE / (X*SQRT(X*YU))) * SQRT(ALC * 3))

HX = YLC(2) * ZLCV(2) - ZLC(2) * YLCV(2)
HY=-(XLC(2)*YLXVC)-ZLC(2)*XLCV(2)
HZ=XLC(2)*YLVC(2)-YLC(2)*XLCV(2)
VANGF=ATAN2(SINV, COSF)
SINHX=SINX
COSHX=COSX
SINHY=SINY
COSHY=COSY
BMEGAF=ATAN2(SINHX, COSHY)
EXP=EXP(1)**(2+1*I)**2
BINC=ATAN(1)**(2+1*I)**2
UNV=-(XLC(2)*SIN(BMEGAF)+YLC(2)*COS(BMEGAF)+COS(SIN(BINC)+
YLC(2)*SIN(BINC)+COS(BMEGAF)+YLC(2)*COS(BMEGAF)
U=ATAN2(SIN(SINC), COS(SINC))
W=1/VANGF
CT4=ITI**4
PRINT 177, CT4
PRINT 177, 1LC, F1F, TE, BMEGAF, BINC, W
107 FORMAT(1V1.4, 1LC=|$E16.8$, ///, TE=|$E16.8$, ///,
BMEGAF=|$E16.8$, ///, SINC=|$E16.8$, ///)
100 FORMAT(1V1.4, ///, BINC=|$E16.8$, ///)
97 CF' TINLE
GO TO 169
APPENDIX H
LAPLACE PODM, ANGLES ONLY

Given $\alpha_{t_i}$, $\delta_{t_i}$, $t_i$, $\phi_i$, $\lambda_{E_i}$, $H_i$ for $i = 1, 2, 3$ and the constants $d\theta/dt$ $f$, $a_e$, $\mu$, $k$, compute the following:

\[ \tau_1 = k_e (t_1 - t_2) \]  \hspace{1cm} (216)

\[ \tau_3 = k_e (t_3 - t_2) \]  \hspace{1cm} (217)

\[ S_1 = \frac{-\tau_3}{\tau_1 (\tau_1 - \tau_3)} \]  \hspace{1cm} (218)

\[ S_2 = \frac{-(\tau_3 + \tau_1)}{\tau_1 \tau_3} \]  \hspace{1cm} (219)

\[ S_3 = \frac{-\tau_1}{\tau_3 (\tau_3 - \tau_1)} \]  \hspace{1cm} (220)

\[ S_4 = \frac{2}{\tau_1 (\tau_1 - \tau_3)} \]  \hspace{1cm} (221)

\[ S_5 = \frac{2}{\tau_1 \tau_3} \]  \hspace{1cm} (222)

\[ S_6 = \frac{2}{\tau_3 (\tau_3 - \tau_1)} \]  \hspace{1cm} (223)
For $i = 1, 2, 3$, calculate:

$$L_{xi} = \cos \delta_{ti} \cos \alpha_{ti} \quad (224)$$

$$L_{yi} = \cos \delta_{ti} \sin \alpha_{ti} \quad (225)$$

$$L_{zi} = \sin \delta_{ti} \quad (226)$$

and determine

$$L_2 = S_1L_1 + S_2L_2 + S_3L_3 \quad (227)$$

$$L_2 = S_4L_1 + S_5L_2 + S_6L_3 \quad (228)$$

For $i = 1, 2, 3$, proceed as follows:

$$Tu = \frac{J.D. - 2415020}{36525} \quad (229)$$

$$\theta_{g0} = 99^\circ6909833 + 36000^\circ7689 \, Tu + 0^\circ00038708 \, Tu^2 \quad (230)$$

$$G_{1i} = \frac{a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \quad (231)$$
Continue calculating with

\[ G_{2i} = \frac{(1 - f)^2 a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \]  

(232)

\[ \theta_i = \theta_{g0} + \frac{d\theta}{dt} (t_i - t_0) + \lambda_{E_i} \]  

(233)

\[ x_i = -G_{1i} \cos \phi_i \sin \theta_i \]  

(234)

\[ y_i = -G_{1i} \cos \phi_i \sin \theta_i \]  

(235)

\[ z_i = -G_{2i} \sin \phi_i \]  

(236)

If the observations are not from a single station, that is, \( \phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_1 \) and \( \lambda_{E1} \neq \lambda_{E2} \neq \lambda_{E3} \neq \lambda_{E1} \), continue calculating with equation (237); if the observations are from a single station, proceed to equation (239).

\[ \tilde{R}_2 = S_1R_1 + S_2R_2 + S_3R_3 \]  

(237)

\[ \tilde{R}_2 = S_4R_1 + S_5R_2 + S_6R_3 \]  

(238)

Proceed to equation (241)

\[ \tilde{R}_2 = \begin{bmatrix} -Y_2 \\ x_2 \frac{1}{k_e} \left( \frac{d\theta}{dt} \right) \\ 0 \end{bmatrix} \]  

(239)
Numerically evaluate the following determinants:

\[ \hat{\mathbf{r}_2} = \begin{bmatrix} -x_2 \\ -y_2 \\ 0 \end{bmatrix} \left( \frac{1}{k_e^2} \frac{d\theta}{dt} \right)^2 \]  

(240)

\[ \Delta = 2 \begin{bmatrix} L_{x2} \dot{L}_{x2} \ddot{L}_{x2} \\ L_{y2} \dot{L}_{y2} \ddot{L}_{y2} \\ L_{z2} \dot{L}_{z2} \ddot{L}_{z2} \end{bmatrix} \]  

(241)

\[ D_a = \begin{bmatrix} L_{x2} \dot{L}_{x2} \ddot{x}_2 \\ L_{y2} \dot{L}_{y2} \ddot{y}_2 \\ L_{z2} \dot{L}_{z2} \ddot{z}_2 \end{bmatrix} \]  

(242)

\[ D_b = \begin{bmatrix} L_{x2} \dot{L}_{x2} x_2 \\ L_{y2} \dot{L}_{y2} y_2 \\ L_{z2} \dot{L}_{z2} z_2 \end{bmatrix} \]  

(243)

\[ D_c = \begin{bmatrix} L_{x2} \ddot{x}_2 \dot{L}_{x2} \\ L_{y2} \ddot{y}_2 \dot{L}_{y2} \\ L_{z2} \ddot{z}_2 \dot{L}_{z2} \end{bmatrix} \]  

(244)

\[ D_d = \begin{bmatrix} L_{x2} x_2 \dot{L}_{x2} \\ L_{y2} y_2 \dot{L}_{y2} \\ L_{z2} z_2 \dot{L}_{z2} \end{bmatrix} \]  

(245)

83
and form:

\[ A_2^* = \frac{2D_a}{\Delta} \]  \hfill (246)

\[ B_2^* = \frac{2D_b}{\Delta} \]  \hfill (247)

\[ C_2^* = \frac{D_c}{\Delta} \]  \hfill (247)

\[ D_2^* = \frac{D_d}{\Delta} \]  \hfill (249)

\[ C_\psi = -2 \left(L_2 \cdot \frac{R_2}{R_2}\right) \]  \hfill (250)

\[ a = -\left(C_\psi A_2^* + A_2^* + R_2^2\right) \]  \hfill (251)

\[ b = -\mu \left(C_\psi B_2^* + 2A_2^* B_2^*\right) \]  \hfill (252)

\[ c = -\mu^2 B_2^* \]  \hfill (253)

Solve

\[ r_2^6 + ar_2^6 + br_2^3 + c = 0 \]  \hfill (254)
to obtain the applicable real root \( r_2 \), and continue calculating with

\[
\rho_2 = A_2^* + \frac{\mu B_2^*}{r_2^3}
\]  

(255)

\[
\dot{\rho}_2 = C_2^* + \frac{\mu D_2^*}{r_2^3}
\]  

(256)

\[
\tau_2 = \rho_2 \dot{L}_2 - \dot{R}_2
\]  

(257)

\[
\ddot{\tau}_2 = \dot{\rho}_2 \dot{L}_2 + \rho_2 \ddot{L}_2 - \ddot{R}_2
\]  

(258)

Continue by calculating for classical elements.
START

ALPHA(1), DELTA(1), T(1), PHI(1), H(1), YAME(1) FOR I = 1, 2, 3; DTHETA, FLAT, AE, XMU, XK, TJD, T(4)

ECHO CHECK

ITIME = 0

DO 12 I = 1, 3

DO 27 I = 1, 3

A

PHI(I) ≠ PHI(2)

T

F

PHI(2) ≠ PHI(3)

T

F

YAME(1) ≠ YAME(2)

T

F

YAME(3) ≠ YAME(2)

T

F

39

32

B

PAGE 87
LAPLACE FLOWCHART (CONT'D)

\[ \text{DELR} = 0.05 \ RLC(2) \]

\[ XLCV(2), YLCV(2), ELCV(2) \]

SOLUTION FOR CLASSICAL ELEMENT

\[ \text{ITIME, ALC, ELC, TE, OMEGA, OINCL, W} \]

\[ \text{STOP} \]
LAPLACE PRELIMINARY ORBIT DETERMINATION METHOD
ANGLES ONLY (ESCPSAL, PAGE 267)

DB 74 K=1,25

DIMENSION TAU(3), S(6), XL(3), YL(3), ZL(3), XLV(3), YLV(3), ZLV(3),
CXA(3), YAX(3), ZAX(3), XV(3), YV(3), ZV(3), XL(3), YL(3), ZL(3),
COEFS(3), C1(3), G2(7), THETA(3), X(3), Y(3), Z(3), R(3), AS(3), BS(3),
DIMENSION: CS(3), RS(3), F0(25), RLC(3), F1(3), PV(3), XL(3), YL(3),
CZL(3), YLCV(3), YLCV(3), ZLCV(3), RLCV(3), T(4), ALPHA(3), DELTA(3),
CYAME(3), PHI(3), H(3)

READ ANGLE INPUT DATA

READ 106, FLAT, AF, XK, XMU, DT, ETA
READ 106, T(4), T(1), T(2), T(3), TJD
READ 106, ALPHA(1), ALPHA(2), ALPHA(3), DELTA(1), DELTA(2)
READ 106, DELTA(3), YAME(1), YAME(2), YAME(3), PHI(1)
READ 106, PHI(2), PHI(3), H(1), H(2), H(3)

108

FORMAT(*F16.8)

END CHECK

PRINT 11, FLAT, AF, XK, XMU, DT, ETA, T(4), TJD, T(1), T(2), T(3)
110

FORMAT(*H=FLAT=F16.8**AF=F16.8**XK=F16.8**XMU=F16.8**DT=F16.8**ETAX=F16.8**T(4)=F16.8**TJD=F16.8**T(1)=F16.8**T(2)=F16.8**T(3)=F16.8)

PRINT 11, ALPHA(1), ALPHA(2), ALPHA(3), DELTA(1), DELTA(2), DELTA(3),
CYAME(1), YAME(2), YAME(3)

111

FORMAT(*D=ALPHA(1)=F16.8**ALPHA(2)=F16.8**ALPHA(3)=F16.8**DELTA(1)=F16.8**DELTA(2)=F16.8**DELTA(3)=F16.8)

PRINT 11, H(1), H(2), H(3)
112

FORMAT(*D=PHI(1)=F16.8**PHI(2)=F16.8**PHI(3)=F16.8)

BEGIN COMPUTATIONS

CALL SYMBOLOG (TIME)

TIME=0

LCA 1985
STA 0925
B5: 1985
S275 1985
S200 0925

PUT = 0

TAM(1)=X*(T(1)-T(2))
TAM(3)=X*(T(3)-T(2))
S(I)=TAM(3)/S(I)*(TAM(1)=TAM(3))
S(I)=S(I)*(TAM(3)+TAM(1)*TAM(3))
S(3)=S(1)*(TAM(3)-TAM(1))
```
S(4) = \sqrt{(TA(1) \times (TA(1) - TA(3)))}
S(5) = \sqrt{(TA(1) \times TA(3))}
S(6) = \sqrt{(TA(1) \times (TA(3) - TA(1)))}

X(1) = C \times S_\Delta \times T(1) + C \times S_\Delta \times S_\Delta \times T(1)
Y(1) = C \times S_\Delta \times T(1) + C \times T(1) + S_\Delta \times T(1)
Z(1) = S_\Delta \times T(1) + S_\Delta \times T(1)

XV(2) = \sqrt{(S(1) \times X(1) + S(2) \times X(2) + S(3) \times X(3))}
Y(2) = \sqrt{(S(1) \times Y(1) + S(2) \times Y(2) + S(3) \times Y(3))}
Z(2) = \sqrt{(S(1) \times Z(1) + S(2) \times Z(2) + S(3) \times Z(3))}

XY(2) = (X(2) \times DT \times \Delta T(1)) / X
YZ(2) = (Y(2) \times DT \times \Delta T(1)) / Y
ZZ(2) = (Z(2) \times DT \times \Delta T(1)) / Z
```

ITERATIVE LOOP FOR DETERMINING APPLICABLE REAL ROOT IF \( R2(0) \)

59 DO 49 I = 1, 25
RX(I) = RLC(2)**3 + RLC(2)**3 + 6*RLC(2)**3 + RLC(3)
CT = CT + 1
PRINT 100, CT
49 FORMAT (10E16.8)
R = (ABS(RF(I)) - RX(I + 1)) / DCLR
IF (ABS(RF(I)) > DCLR) GO TO 104
IF (R < 0.5) GO TO 101
IF (R > 0.5) GO TO 103
101 I = I + 1
103 DCLR = (RF(I) - RX(I + 1)) / DCLR
104 DCLR = RF(I) / DCLR
CT = CT + 1
48 FORMAT (10E16.8)
99 FORMAT (15X, 'SOLVE FOR INITIAL POSITION AND VELOCITY VECTORS')
70 P(3) = AS(3) + (YMU**4/R1C(2)**3)
P(2) = CT**2 + X**2 + \( RLC(3)**3 \)
XLC(2) = CT**2 + X**2 + \( RLC(3)**3 \)
YLC(2) = CT**2 + Y**2 + \( RLC(3)**3 \)
ZLC(2) = CT**2 + Z**2 + \( RLC(3)**3 \)
XLCV(1) = P(3) + X**2 + \( RLC(3)**3 \)
YLCV(1) = P(3) + Y**2 + \( RLC(3)**3 \)
ZLCV(1) = P(3) + Z**2 + \( RLC(3)**3 \)
CT = CT + 1
PRINT 100, CT
PRINT 104, XLCV(I), YLCV(I), ZLCV(I)
104 FORMAT (E16.8, E16.8, E16.8)
90 FORMAT (15X, 'SOLUTION FOR CLASSICAL ELEMENTS')
105 ITIME = 0
RLC(2) = CT**2 + (X**2 + Y**2 + RLC(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + ZLCV(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + RLC(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + ZLCV(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + RLC(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + ZLCV(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + RLC(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + ZLCV(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + RLC(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + ZLCV(2)**2)
RLC(2) = CT**2 + (X**2 + Y**2 + RLC(2)**2)
Given $\alpha_{t_i}$, $\delta_{t_i}$, $t_i$, $\phi_i$, $\lambda_{E_i}$, $H_i$, for $i = 1, 2, 3$, and the constants $d\theta/dt$, $f$, $a_e$, $\mu$, and $k_e$, proceed as follows:

$$\tau_1 = k_e (t_1 - t_2)$$

(259)

$$\tau_3 = k_e (t_3 - t_2)$$

(260)

$$Tu = \frac{J.D. - 2415020}{36525}$$

(261)

$$\theta_{g0} = 99.6909833 + 36000.7689 Tu + 0.00038708 Tu^2$$

(262)

For $i = 1, 2, 3$, compute:

$$L_{x_i} = \cos \delta_{t_i} \cos \alpha_{t_i}$$

(263)

$$L_{y_i} = \cos \delta_{t_i} \sin \alpha_{t_i}$$

(264)

$$L_{z_i} = \sin \delta_{t_i}$$

(265)

$$G_{1i} = \frac{a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i$$

(266)
\[
G_{2i} = \frac{(1 - f)^2 a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i
\]  
(267)

\[
\theta_i = \theta_{i0} + \frac{d\theta}{dt} (t_i - t_0) + \lambda_{Ei}
\]  
(268)

\[
X_i = -G_{1i} \cos \phi_i \cos \theta_i
\]  
(269)

\[
Y_i = -G_{1i} \cos \phi_i \sin \theta_i
\]  
(270)

\[
Z_i = -G_{2i} \sin \phi_i
\]  
(271)

\[
C_{\psi_i} = 2L_i \cdot R_i, \quad i = 1, 2, 3
\]  
(272)

As a first approximation, set

\[
r_1 = r_{1g}, \quad r_2 = r_{2g}
\]  
(273)

For near-Earth orbits, set

\[
r_{1g} = r_{2g} = 1.1 \text{ e.r.}
\]  
(274)
and compute $\rho_i$ from

$$\rho_i = \frac{1}{2} \left[ -C_{\psi_i} + \sqrt{C_{\psi_i}^2 - 4 \left( R_i^2 - r_i^2 \right)} \right]$$  \hspace{1cm} (275)

Continue calculating with

$$r_i = \rho_i L_i - R_i , \hspace{0.5cm} i = 1, 2$$  \hspace{1cm} (276)

Compute $\tilde{W}$ as

$$\tilde{W}_x = \frac{y_1 z_2 - y_2 z_1}{r_1 r_2}$$  \hspace{1cm} (277)

$$\tilde{W}_y = \frac{x_2 z_1 - x_1 z_2}{r_1 r_2}$$  \hspace{1cm} (278)

$$\tilde{W}_z = \frac{x_1 y_2 - x_2 y_1}{r_1 r_2}$$  \hspace{1cm} (279)

Continue calculating with

$$\rho_3 = \frac{R_3 \cdot \tilde{W}}{L_3 \cdot \tilde{W}}$$  \hspace{1cm} (280)

$$r_3 = \rho_3 L_3 - R_3$$  \hspace{1cm} (281)

$$r_3 = \sqrt{r_3 \cdot r_3}$$  \hspace{1cm} (282)
\[
\cos (\nu_j - \nu_k) = \frac{r_j \cdot r_k}{r_j r_k} \quad j = 2, 3, k = 1, 2
\]

If \( W_z > 0 \), calculate

\[
\sin (\nu_j - \nu_k) = \frac{x_k y_j - x_j y_k}{|x_k y_j - x_j y_k|} \sqrt{1 - \cos^2 (\nu_j - \nu_k)}
\]

(284)

If \( W_z < 0 \), calculate

\[
\sin (\nu_j - \nu_k) = -\frac{x_k y_j - x_j y_k}{|x_k y_j - x_j y_k|} \sqrt{1 - \cos^2 (\nu_j - \nu_k)}
\]

(285)

If \( \nu_3 - \nu_1 > \pi \), determine \( p \) from

\[
\begin{align*}
    c_1 &= \frac{r_2}{r_1} \frac{\sin (\nu_3 - \nu_2)}{\sin (\nu_3 - \nu_1)} \\
    c_3 &= \frac{r_2}{r_3} \frac{\sin (\nu_2 - \nu_1)}{\sin (\nu_3 - \nu_1)} \\
    p &= \frac{c_1 r_1 + c_3 r_3 - r_2}{c_1 + c_3 - 1}
\end{align*}
\]

(286)

(287)

(288)
If $\nu_3 - \nu_1 \leq \pi$, determine $p$ from

$$c_1 = \frac{r_1}{r_2} \sin \left( \nu_3 - \nu_1 \right) / \sin \left( \nu_3 - \nu_2 \right)$$  \hspace{1cm} (289)$$

$$c_3 = \frac{r_1}{r_3} \sin \left( \nu_2 - \nu_1 \right) / \sin \left( \nu_3 - \nu_2 \right)$$  \hspace{1cm} (290)$$

$$p = \frac{r_1 + c_3 r_3 - c_1 r_2}{1 + c_3 - c_1}$$  \hspace{1cm} (291)$$

Continue calculating with

$$e \cos \nu_i = \frac{p}{r_i} - 1 , \quad i = 1, 2, 3$$  \hspace{1cm} (292)$$

and for $\nu_2 - \nu_1 \neq \pi$, obtain

$$e \sin \nu_2 = \frac{\cos (\nu_2 - \nu_1)(e \cos \nu_2) + (e \cos \nu_1)}{\sin (\nu_2 - \nu_1)}$$  \hspace{1cm} (293)$$

or, if $\nu_2 - \nu_1 = \pi$, obtain

$$e \sin \nu_2 = \frac{\cos (\nu_3 - \nu_2)(e \cos \nu_2) - (e \cos \nu_3)}{\sin (\nu_3 - \nu_1)}$$  \hspace{1cm} (294)$$

Evaluate

$$e = \sqrt{(e \cos \nu_2)^2 + (e \sin \nu_2)^2}$$  \hspace{1cm} (295a)$$
\[ a = \frac{p}{1 - e^2} \]  

(295b)

For orbit determination in this paper, \( e^2 < 1 \), therefore continue calculating with

\[ n = k_e \sqrt{\frac{\mu}{a^3}} \]  

(296)

\[ S_e = \frac{r_2}{p} \sqrt{1 - e^2} e \sin \nu_2 \]  

(297)

\[ C_e = \frac{r_2}{p} (e^2 + e^2 \cos \nu_2) \]  

(298)

\[ \sin (E_3 - E_2) = \frac{r_3}{\sqrt{ap}} \sin (\nu_3 - \nu_2) - \frac{r_3}{p} \left[ 1 - \cos (\nu_3 - \nu_2) \right] S_e \]  

(299)

\[ \cos (E_3 - E_2) = 1 - \frac{r_3 r_2}{ap} \left[ 1 - \cos (\nu_3 - \nu_2) \right] \]  

(300)

\[ \sin (E_2 - E_1) = \frac{r_1}{\sqrt{ap}} \sin (\nu_2 - \nu_1) + \frac{r_1}{p} \left[ 1 - \cos (\nu_2 - \nu_1) \right] S_e \]  

(301)

\[ \cos (E_2 - E_1) = 1 - \frac{r_2 r_1}{ap} \left[ 1 - \cos (\nu_2 - \nu_1) \right] \]  

(302)

\[ M_3 - M_2 = E_3 - E_2 + 2S_e \sin^2 \left( \frac{E_3 - E_2}{2} \right) - C_e \sin (E_3 - E_2) \]  

(303)
\[ M_1 - M_2 = - (E_2 - E_1) + 2S_e \sin^2 \left( \frac{E_2 - E_1}{2} \right) + C_e \sin (E_2 - E_1) \]  
(304)

\[ F_1 = \tau_1 - k_e \left( \frac{M_1 - M_2}{n} \right) \]  
(305)

\[ F_2 = \tau_3 - k_e \left( \frac{M_3 - M_2}{n} \right) \]  
(306)

Save \( F_1, F_2, r_1 \); increment \( r_1 \) by \( \Delta r_1 \) (about 4 percent) and return to equation (275). The end result of this calculation will be \( F_1 (r_1 + \Delta r_1, r_2) \), \( F_2 (r_1 + \Delta r_1, r_2) \), so that

\[ \frac{\partial F_1}{\partial r_1} = \frac{F_1 (r_1 + \Delta r_1, r_2) - F_1 (r_1, r_2)}{\Delta r_1} \]  
(307)

\[ \frac{\partial F_2}{\partial r_1} = \frac{F_2 (r_1 + \Delta r_1, r_2) - F_2 (r_1, r_2)}{\Delta r_1} \]  
(308)

Save \( \frac{\partial F_1}{\partial r_1} \), \( \frac{\partial F_2}{\partial r_1} \); set \( r_1 \) back to the original value; increment \( r_2 \) by \( \Delta r_2 \) (about 4 percent); and return to equation (275). The end result of this calculation will be \( F_1 (r_1, r_2 + \Delta r_2) \), \( F_2 (r_1, r_2 + \Delta r_2) \), so that

\[ \frac{\partial F_1}{\partial r_2} = \frac{F_1 (r_1, r_2 + \Delta r_2) - F_1 (r_1, r_2)}{\Delta r_2} \]  
(309)
\[
\frac{\partial F_2}{\partial r_2} = \frac{F_2 (r_1, r_2 + \Delta r_2) - F_2 (r_1, r_2)}{\Delta r_2}
\]  

(310)

Continue calculating with

\[
\Delta = \left( \frac{\partial F_1}{\partial r_1} \right) F_2 + \left( \frac{\partial F_2}{\partial r_2} \right) F_1 - \left( \frac{\partial F_2}{\partial r_1} \right) F_2 - \left( \frac{\partial F_1}{\partial r_2} \right) F_1
\]  

(311)

\[
\Delta_1 = \left( \frac{\partial F_2}{\partial r_2} \right) F_1 - \left( \frac{\partial F_1}{\partial r_2} \right) F_2
\]  

(312)

\[
\Delta_2 = \left( \frac{\partial F_1}{\partial r_1} \right) F_2 - \left( \frac{\partial F_2}{\partial r_1} \right) F_1
\]  

(313)

\[
\Delta r_1 = - \frac{\Delta_1}{\Delta}
\]  

(314)

\[
\Delta r_2 = - \frac{\Delta_2}{\Delta}
\]  

(315)

Check to see if

\[|\Delta r_1| < \varepsilon\]  

(316a)

\[|\Delta r_2| < \varepsilon\]  

(316b)

where \(\varepsilon\) is a tolerance, i.e. \(10^{-10}\). If the test is not satisfied, let

\[(r_1)_{n+1} = (r_1)_n + \Delta r_1\]  

(317a)

\[(r_2)_{n+1} = (r_2)_n + \Delta r_2\]  

(317b)
and return to equation (275); if it is satisfied, continue calculating with

\[ f = 1 - \frac{a}{r_2} \left[ 1 - \cos (E_3 - E_2) \right] \]  \hspace{1cm} (318)

\[ g = r_3 \sqrt{\frac{a^3}{\mu}} \left[ (E_3 - E_2) - \sin (E_3 - E_2) \right] \]  \hspace{1cm} (319)

\[ \dot{r}_2 = \frac{r_3 - fr_2}{g} \]  \hspace{1cm} (320)

Continue by calculating for the classical elements.
DOUBLE R-ITERATION FLOWCHART

START

ALPHA(1), DELTA (1), T(1), PHI(1), YAME(1), H(1), FOR I = 1,2,3; DTHETA, FLAT, AE, XMU, XK, TJD, T(4)

ECHO

CHECK

ITIME = 0

DO 17
I = 1,3

DO 96
1, 25

DO 82
J = 1, 3

A

J \neq 1

T

F

23

J \neq 2

T

F

26

28

31

DO 35
K = 1, 2

WBZ < 0

T

46

F

B

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PAGE 102
DOUBLE R-ITERATION FLOWCHART (CONT'D)

D

\[ I = 25 \ ? \]

T

E

97

XLCV (2), YLCV (2), ZLCV (2)

SOLUTION FOR CLASSICAL ELEMENTS

ITIME, ALC, ELC, TE, OMEGA, OINCL, W

STOP

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103
DOUBLE-R ITERATION PRELIMINARY ORBIT DETERMINATION METHOD
ANGLES ONLY (ESCRA,BAL,PAGE 293)

DIMENSION TAU(3),XL(3),YL(3),ZL(3),G1(3),G2(3),X(3),Y(3),Z(3),
CTHETA(3),DCHI(3),RL(1,25),RLC(1,25),RLC(3,3),CHI(3),P(3),P(3),
CXLC(3),YLCS(3),ZLCS(3),C(3),F(3,3),DEL(3,3),POEL(3),DELR(3),
CXLC(3),YLCS(3),ZLCS(3),RLC(3,3),RLS(3)

DIMENSION T(4),ALPHA(3),DELTA(3),YAME(3),PHI(3),H(3)

READ ANGLE INPUT DATA

READ 108,FLAT,AE,XK,YK,DTHETA
READ 108,T(4),T(1),T(2),T(3),T(3)
READ 108,ALPHA(1),ALPHA(2),ALPHA(3),DELTA(1),DELTA(2)
READ 108,DELTA(3),YAME(1),YAME(2),YAME(3),PHI(1)
READ 108,PHI(2),PHI(3),H(1),H(2),H(3)

FORMAT(5F16.8)

END CHECK

PRINT 110,FLAT,AE,XK,YK,DTHETA,T(4),T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*T(4)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*T(2)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*T(1)=T(1),T(2),T(3)

PRINT 111,ALPHA(1),ALPHA(2),ALPHA(3),DELTA(1),DELTA(2),DELTA(3),
YAME(1),YAME(2),YAME(3)

FORMAT(1.2E16.8,3*12,E16.8)*ALPHA(1)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*ALPHA(2)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*ALPHA(3)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*DELTA(2)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*DELTA(3)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*DELTA(1)=T(1),T(2),T(3)

PRINT 112,PHI(1),PHI(2),PHI(3),H(1),H(2),H(3)

FORMAT(1.2E16.8,3*12,E16.8)*PHI(1)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*PHI(2)=T(1),T(2),T(3)

FORMAT(1.2E16.8,3*12,E16.8)*PHI(3)=T(1),T(2),T(3)

BEGIN: COMPUTATIONS

ALL *77 = SYSTEM TIME STAMP /PRINT/ E

ITIM=0

LDA 2005

STA 2006

BRL 2008

S205 2003

S200 2003

PET = 0.20000

EIR = 1

TAU(1)=XK(1,1)-T(2,1)

TAU(2)=YK(1,1)-T(2,1)

TAU(3)=ZK(1,1)-T(2,1)

GTHETA=30.66608*(2.00000*76.99900+3.000378.97245*20.00000)

DE 17=1

XL(1)=COS(DELTA(1))*COS(ALPHA(1))
YL(1) = choose(FIAT(1) * |i| * (A(i) * (A(i)))
ZL(1) = S1((DELT(1) * |i|))
DELTA(1) = S1((DELT(1) * |i|))
DELTA(2) = S1((DELT(1) * |i|))
DELTA(3) = S1((DELT(1) * |i|))
DELTA(4) = S1((DELT(1) * |i|))
DELTA(5) = S1((DELT(1) * |i|))
DELTA(6) = S1((DELT(1) * |i|))

C C
C C
C

ITL? ?!
FOR THE SCALAR OF THE INERTIAL POSITI
C

105
IF (ABS (DFLR (2)) > 0.00000000001) 94, 94, 95
GO TO 97
RLC1 (I+1) = ABS (RLC1 (I) + DFLR (1))
RLC2 (I+1) = ABS (RLC2 (I) + DFLR (P))
CONTINUE
C
SOLVE FOR INERTIAL VELOCITY VECTOR.
C
RLCF = RLC2 (I)
FLC = 1.0 * (ALC / RLCF) * (1.0 - CRF (ETHMT))
G LC = TAU / (XLC + YLC) * (ETHMT - SETHMT)
XLCV (P) = (XLC (3) + FLC * YLC (P)) / FLC
YLCV (P) = (YLC (3) + FLC * YLC (P)) / FLC
ZLCV (P) = (ZLC (3) + FLC * YLC (P)) / FLC
CT = ITIME
PRINT 103, CTP
PRINT 107, XLCV (P), YLCV (P), ZLCV (P)
FORMAT (179, XLCV (P), YLCV (P), ZLCV (P))

C
ITIME = 0
C
SOLUTION FOR CLASSICAL ELEMENTS
RLS (2) = SORT (XLC (P) * P + YLC (P) * P + ZLC (P) / XLC (P) * P + YLC (P) * P)
RLC (P) = RLS (2) / (XLC (P) * P + YLC (P) * P + ZLC (P) * P)
V = SORT (XLC (P) * P + YLC (P) * P + ZLC (P) * P)
ALC = (XLC (P) * P + YLC (P) * P + ZLC (P) * P) / (XLC (P) * P + YLC (P) * P + ZLC (P) * P)
CSE = (1.0 - RLS (2) / ALC)
CSS = (RSC / RLS (2)) / (XLC (P) * P + YLC (P) * P + ZLC (P) * P)
CSSC = CSE / ALC
XSEJ = ALC / (CSCC + FLC)
COSV = SORT (XLC (P) * P + YLC (P) * P + ZLC (P) * P)
SINV = SORT (1.0 + FLC * P) / (XLC (P) * P + YLC (P) * P + ZLC (P) * P)
E = ATA (P + CSE)
TEST (P) = (1.0 + FLC * P) * SINV / (1.0 + FLC * P)
H2 = YLC (P) + ZLC (P) + XLC (P) + YLC (P) + ZLC (P)
H3 = YLC (P) + ZLC (P) + XLC (P) + YLC (P) + ZLC (P)
VANG = ATA (CSCC, CSC, CSC)
SINV = Y

C
NUM = -19
DIF = ATA (CSCC, CSC, CSC) + P + 36
TEST = SORT (1.0 + FLC * P) / (XLC (P) * P + YLC (P) * P + ZLC (P) * P)
U = ATA (P + CSE)
=) = VANG
C = ITIME
PRINT 107, CTP
FORMAT (*ILL RECALL = /*)
PRINT 109, ALC, ELC, TE, WMEGA, BINCL, W
109 FORMAT(1HO, $ACL=$E16.8, $ELC=$E16.8, $TE=$E16.8, $W=$F16.8, $BINCL=$F16.8, $WMEGA=$F16.8)
119 CONTINUE
GO TO 120
S2050 PZE
S MIN ITIME
S BRU *2050S
120 END
APPENDIX J
MODIFIED LAPLACIAN PODM, MIXED DATA

Given the mixed data \( \rho_i, \alpha_i, t_i, \delta_i \) for \( i = 1, 2, 3 \). along with \( \phi_i, \lambda_{E_i}, H_i \) and the constants, \( a_e, k_e, \mu, f, \frac{d\theta}{dt} \), proceed as follows:

\[
\tau_1 = k_e (t_1 - t_2) \\
\tau_3 = k_e (t_3 - t_2) \\
S_1 = \frac{-\tau_3}{\tau_1 (\tau_1 - \tau_3)} \\
S_2 = -\frac{(\tau_3 + \tau_1)}{\tau_1 \tau_3} \\
S_3 = \frac{-\tau_1}{\tau_3 (\tau_3 - \tau_1)} \\

Tu = \frac{J.D. - 2415020}{36525} \\

\theta_0 = 9956909833 + 36000.7689 Tu + 0.00038708 Tu^2

For \( i = 1, 2, 3 \), compute

\[
\theta_i = \theta_0 + \frac{d\theta}{dt} (t_i - t_0) + \lambda_{E_i}
\]
\[ G_{1i} = \frac{ae}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \]  
(329)

\[ G_{2i} = \frac{(1-f)^2 ae}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \]  
(330)

\[ L_{xi} = \cos \delta_{ti} \cos \alpha_{ti} \]  
(331)

\[ L_{yi} = \cos \delta_{ti} \sin \alpha_{ti} \]  
(332)

\[ L_{zi} = \sin \delta_{ti} \]  
(333)

Continue calculating with

\[ \rho_2 = S_1 \rho_1 + S_2 \rho_2 + S_3 \rho_3 \]  
(334)

\[ \dot{L}_2 = S_1 \dot{L}_1 + S_2 \dot{L}_2 + S_3 \dot{L}_3 \]  
(335)

\[ X_2 = -G_{12} \cos \phi_2 \cos \theta_2 \]  
(336)

\[ Y_2 = -G_{12} \cos \phi_2 \sin \theta_2 \]  
(337)

\[ Z_2 = -G_{22} \sin \phi_2 \]  
(338)
As a first approximation, set \( r_2 = r_{2G} \), where \( r_{2G} \) is an assumed value of \( r_2 \), i.e., 1.1 e.r., and initiate the following iterative scheme:

\[
\rho_2 = \frac{A + \left( \frac{B}{r_2^3} \right)}{C + \left( \frac{D}{r_2^3} \right)}
\]  

(346)
\[ F(r_2) = \rho_2^2 + \rho_2 c_\psi + R_2^2 - r_2^2 \]  
(347)

\[ F(r_2) = \left( \frac{3}{r_2^4} \right) \left( \frac{2\rho_2 + c_\psi(D\rho_2 - B)}{C + \left( \frac{D}{r_2^3} \right)} \right) - 2r_2 \]  
(348)

and obtain a better value of \( r_2 \), that is,

\[ (r_2)_{n+1} = (r_2)_n - \frac{F[(r_2)_n]}{F'[(r_2)_n]} \quad , \quad n = 1, 2, \ldots, q \]  
(349)

If the improved value of \( r_2 \) does not vary, that is,

\[ |(r_2)_{n+1} - (r_2)_n| < \epsilon \]  
(350)

where \( \epsilon \) is a specified tolerance, i.e., \( 10^{-10} \), proceed to equation (351); if not, return to equation (346) and using the latest value of \( r_2 \), repeat equational loop (347) to (349).

Continue calculating with

\[ r_2 = \rho_2 L_2 - R_2 \]  
(351)

\[ \ddot{r}_2 = \rho_2 \dot{L}_2 + \rho_2 \ddot{L}_2 - \dot{R}_2 \]  
(352)

Continue by calculating for classical elements.
MODIFIED LAPLACIAN FLOWCHART

START

PV(1), ALPHA (1), DELTA (1), PHI (1), YAME(1), H(1), FOR I = 1, 2, 3, AE, XK, XMU, FLAT, DTHETA, TJD

ECCHO CHECK

ITIME = 0

DO 9 I = 1, 3

DO 41 I = 1, 25

RLC2(I)

A

ABS[RLC2(I) - RLC2(I-1)] < 10-10

T

42

XLCV(2), YLCV(2), ZLCV(2)

SOLUTION FOR CLASSICAL ELEMENTS

ITIME, ALC, ELC, TE, OMEGA, OINC, W

STOP

B

F

I = 25

F

T

113
**CODE 1**  

**FUNCTION**  

*TRIG*  

**RANGE TIME AND ANGLES (SCALIL, PAGE 207)  

DOUBLE N = 26  

DIMENSIONS T(N), X(N), Y(N), Z(N), T(N), T(2), T(3), T(4)  

READ 100, T(4), T(2), T(3), T(4)  

READ 100, ALPHA(1), ALPHA(2), PHI(2), PHI(3), DELTA(1), DELTA(2), DELTA(3)  

READ 100, V(1), V(2), V(3), PHI(4)  

FORMAT(315, *)  

EOF CHECK  

FORMAT (315, *)  

PRINT 1, T(4), T(2), T(3), T(4), T(2), T(3), T(4)  

FORMAT (315, *)  

READ 100, X(N), Y(N), X(N), Y(N), ETA(T, T), ETA(T, T), ETA(T, T), ETA(T, T)  

WRITE 315, T(N), X(N), Y(N), Z(N), T(N), T(N), T(N), T(N)  

C  

BEGIN CONTRACTIONS  

C  

ALL *ETA* = XYZ * IT TIME SUBROUTINE  

ITIME = 0  

LTA = REAL  

STA = REAL  

S = REAL  

S205 = REAL  

S209 = REAL  

SPO = REAL  

SPO = REAL  

EOF  

TUM = 2 * T(1) - T(1)  

TAU = 2 * T(2)  

S(1) = TUM(T(1)) - TAU(T(1)) - TAU(T(2))
SOLUTION FOR CLASSICAL ELEMENTS

IT11*E
ELS2(2) = Q((2) * XLC(2) * YLC(2) + YLC(2) * ZLC(2) * XLC(2))
ELS2* = XLC(2) * XLC(2) + YLC(2) * YLC(2) + ZLC(2) * ZLC(2)
XLC(2) = XLC(2) * YLC(2)
YLC(2) = Q((2) * YLC(2) + ZLC(2) * ZLC(2))
ZLC(2) = XLC(2) * ZLC(2)

SP05* E
S
*E: 1111
S
STOP
APPENDIX K
R-ITERATION PODM, MIXED DATA

Given the mixed data $p_i$, $a_{ti}$, $\delta_{ti}$, $t_i$, for $i = 1, 2, 3$, along with $\phi_i$, $\lambda_{Ei}$, $H_i$ and the constants $a_e$, $k_e$, $\mu$, $f$, $d\theta/dt$, proceed as follows:

\begin{align*}
\tau_1 &= k_e (t_1 - t_2) \\
\tau_3 &= k_e (t_3 - t_2) \\
S_1 &= \frac{-\tau_3}{\tau_1 (\tau_1 - \tau_3)} \\
S_2 &= -\left(\frac{\tau_3 + \tau_1}{\tau_1 \tau_3}\right) \\
S_3 &= \frac{-\tau_1}{\tau_3 (\tau_3 - \tau_1)} \\
Tu &= \frac{J \cdot D.}{36525} - \frac{2415020}{36525} \\
90 &= 99.6909833 + 36000.7689 Tu + 0.00038708 Tu^2
\end{align*}

For $i = 1, 2, 3$, compute

\begin{align*}
L_{xi} &= \cos \delta_{ti} \cos a_{ti}
\end{align*}
\[ L_{yi} = \cos \delta_{ti} \sin \alpha_{ti} \]  

\[ L_{zi} = \sin \delta_{ti} \]  

\[ \theta_i = \theta_0 + \frac{d\theta}{dt} (t_i - t_0) + \lambda_{Ei} \]  

\[ G_{1i} = \frac{ae}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \]  

\[ G_{2i} = \frac{(1 - f)^2 ae}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i \]  

\[ X_i = -G_{1i} \cos \phi_i \cos \theta_i \]  

\[ Y_i = -G_{1i} \cos \phi_i \sin \theta_i \]  

\[ Z_i = -G_{2i} \sin \phi_i \]  

\[ \dot{R}_i = \frac{1}{k_e} \begin{bmatrix} -Y_i \\ X_i \\ \frac{d\theta}{dt} \\ 0 \end{bmatrix} \]  

118
\[ C_\psi = -2(L_x x_2 + L_y y_2 + L_z z_2) \] (370)

As a first approximation, set \( r_2 = r_g \). For near-Earth orbits, set \( r_g = 1.1 \) and obtain

\[
\rho_2 = \frac{1}{2} \left\{ -C_\psi + \left[ C_\psi^2 - 4(R_2^2 - r_2^2) \right]^{1/2} \right\} \] (371)

Compute the radius vector at the central date from

\[
r_2 = \rho_2 L_2 - R_2 \] (372)

Obtain the numerical derivative

\[
\dot{L}_2 = S_1 L_1 + S_2 L_2 + S_3 L_3 \] (373)

Continue calculating with

\[
\dot{r}_2 = \dot{\rho}_2 L_2 + \rho_2 \dot{L}_2 - \dot{R}_2 \] (374)

\[
\dot{r}_2 = \frac{r_2 \cdot \dot{r}_2}{r_2} \] (375)

\[
V_2 = \sqrt{\dot{r}_2 \cdot \dot{r}_2} \] (376)

Utilize the derivatives of the \( f \) and \( g \) series to compute

\[
\dot{f}_i = \dot{f}(V_2, r_2, \dot{r}_2, \tau_i), \quad i = 1, 3 \] (377)
\[ \dot{g}_i = \dot{g}(V_2, r_2, \dot{r}_2, \tau_1), \quad i = 1, 3 \] (378)

Continue calculating with:

\[ E = \dot{f}_1 \dot{g}_3 L_1 \cdot L_2 - \dot{f}_3 \dot{g}_1 L_3 \cdot L_2 \]
\[ + \dot{g}_1 \dot{g}_3 L_2 \cdot (L_1 - L_3) \] (379)

\[ A = \{\dot{f}_1 \dot{g}_3 L_1 \cdot R_2 - \dot{f}_3 \dot{g}_1 L_3 \cdot R_2 \]
\[ + \dot{g}_1 \dot{g}_3 (L_1 - L_3) \cdot \dot{R}_2 - \dot{g}_3 L_1 \cdot \dot{R}_1 \]
\[ + \dot{g}_1 L_3 \cdot \dot{R}_3 \}/E \] (380)

\[ B = \frac{\dot{g}_3}{E} \] (381)

\[ C = -\frac{\dot{g}_1 \dot{g}_3 L_2 \cdot (L_1 - L_3)}{E} \] (382)

\[ D = -\frac{\dot{g}_1}{E} \] (383)

\[ \rho_2 = A + \dot{\rho}_1 B + \dot{\rho}_2 C + \dot{\rho}_3 D \] (384)

If

\[ |(\rho_2)_{n+1} - (\rho_2)_n| < \varepsilon \] (385)
where \( \varepsilon \) is a specified tolerance, i.e., \( 10^{-10} \), proceed to equation (386); if not, return to equation (372) with the latest value of \( \rho_2 \) obtained from equation (384) and repeat equational loop (372) to (385).

Continue calculating with

\[
\mathbf{r}_2 = \rho_2 \mathbf{l}_2 - \mathbf{R}_2 \quad \text{(386)}
\]

\[
\mathbf{r}'_2 = \rho_2 \mathbf{l}'_2 + \rho_2 \mathbf{l}'_2 - \dot{\mathbf{R}}_2 \quad \text{(387)}
\]

Continue by calculating for classical elements.
R-ITERATION FLOWCHART

START

\( PV(i), \) \( \text{ALPHA} (i) \) \( \text{DELTA} (i), \) \( T (i) \) \( \text{PHI} (i), \) \( \text{LAME} (i) \) \( H (i) \) FOR \( i = 1, 2, 3. \) \( \text{AE, XK, XMU, FLAT, DTHETA, TJD} \)

ECHO CHECK

ITIME \( \leftarrow 0 \)

DO 21
\( I \leftarrow 1, 3 \)

DO 53
\( I \leftarrow 1, 25 \)

DO 45
\( J \leftarrow 1, 3, 2 \)

A

P2 \((i+1), 1 \)

ABS \( \left[ \frac{P2 (i+1) - P2 (i)}{P2 (i)} \right] < 10^{-10} \)

T

I = 25

F

SOLUTION FOR CLASSICAL ELEMENTS

ITIME, ALC, ELC, TE, OMEGA, OINCL, W

STOP
ITERATIVE PRELIMINARY ORBIT DETERMINATION METHOD

RANGE RATE AND ANGLES (ESCALAR, PAGE 302)

DE 59 A

DIMENSION TAU(3), S(3), G1(3), XL(3), YL(3), ZL(3), THETA(2), X(2), Y(2), Z(2),
       CZ(3), CXV(3), YLV(3), XLV(3), RLC(2), R(3), PZ(2), XL(3), YLC(3), ZLC(3),
       CLXV(3), YLV(3), XLV(3), YLCV(3), ZLCV(3), FV(3), GV(3), CV(3), CLCV(3),
       CV(3), GP(3), DMG(3), T(4), ALPHA(3), DELTA(3), YAME(3), PHI(3), (3)

READ RANGE RATE AND ANGULAR INPUT DATA

READ 100, FLAT, AL, YK, YM, DT, TTA
READ 100, T(4), T(2), T(3), T(3)
READ 100, ALPHA(1), ALPHA(2), ALPH(3), DELTA(1), DELTA(2)
READ 100, DELTA(3), YL(1), YL(2), YL(3), YL(3), (3)
READ 100, PHl(2), PHl(3), PHl(3), (3)
READ 100, DT, PV, PV, PV

FORMAT(4F15.8)

FORMAT(3F15.8)

PRINT 110, FLAT, AL, X(2), X(2), X(4), TTA, T(4), T(2), T(3), T(3)
FORMAT(4F15.8)

PRINT 110, FLAT, AL, X(2), X(2), X(4), TTA, T(4), T(2), T(3), T(3)

FORMAT(4F15.8)

PRINT 110, FLAT, AL, X(2), X(2), X(4), TTA, T(4), T(2), T(3), T(3)

FORMAT(4F15.8)

PRINT 110, FLAT, AL, X(2), X(2), X(4), TTA, T(4), T(2), T(3), T(3)

FORMAT(4F15.8)

BEGIN computations

ALL MET. SYMM. IN TIME SUBPLACE

ITIME = 0

LDA = 0
STA = 0
BA = 0
S205 = 0
S200 = 0

PIT = 0

END

TAU(1) = X(2) * (T(1) - T(2))
TAU(2) = X(2) * (T(2) - T(3))
T2 = (T(3) - T(2)) / T(2)

G = TTA(4) * S200 * T2 / (S + G200 * T2)

123
\[
\begin{align*}
S(1) &= \frac{a_2}{a_1} \times S_1 \times (S_1 + S_2) \\
S(2) &= \frac{a_2}{a_1} \times S_1 \times (S_1 + S_2) \\
S(3) &= \frac{a_2}{a_1} \times S_1 \times (S_1 + S_2) \\
D(1) &= (a_1) \\
D(2) &= (a_1) \\
D(3) &= (a_1) \\
D(4) &= (a_1) \\
D(5) &= (a_1) \\
D(6) &= (a_1) \\
D(7) &= (a_1) \\
D(8) &= (a_1) \\
D(9) &= (a_1) \\
D(10) &= (a_1) \\
D(11) &= (a_1) \\
D(12) &= (a_1) \\
D(13) &= (a_1) \\
D(14) &= (a_1) \\
D(15) &= (a_1) \\
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D(98) &= (a_1) \\
D(99) &= (a_1) \\
D(100) &= (a_1) \\
D(101) &= (a_1) \\
D(102) &= (a_1) \\
D(103) &= (a_1) \\
D(104) &= (a_1) \\
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D(106) &= (a_1) \\
D(107) &= (a_1) \\
D(108) &= (a_1) \\
D(109) &= (a_1) \\
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D(111) &= (a_1) \\
D(112) &= (a_1) \\
D(113) &= (a_1) \\
D(114) &= (a_1) \\
D(115) &= (a_1) \\
D(116) &= (a_1) \\
D(117) &= (a_1) \\
D(118) &= (a_1) \\
D(119) &= (a_1) \\
D(120) &= (a_1) \\
D(121) &= (a_1) \\
D(122) &= (a_1) \\
D(123) &= (a_1) \\
D(124) &= (a_1) \\
\end{align*}
\]
Given the mixed data $\rho_j, \dot{\rho}_j, t_j, j = 1, 2, \ldots, q$, for a set of observing stations with coordinates $\phi_i, \lambda_{E1}, H_i, i = 1, 2, 3$, and constants $a_e, f, \frac{d\phi}{dt}$, proceed as follows. Reduce the range and range-rate data to a common simultaneous time such that $\rho_i, \dot{\rho}_i, i = 1, 2, 3$, are available for an arbitrary modified time $\tau_0$ and compute

\[
Tu = \frac{J.D. - 2415020}{36525}
\]

(388)

\[
\theta_{g0} = 99°6909833 + 36000°7689 Tu + 0°000038708 Tu^2
\]

(389)

For $i = 1, 2, 3$, compute

\[
G_{1i} = \frac{a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i
\]

(390)

\[
G_{2i} = \frac{(1 - f)^2 a_e}{\sqrt{1 - (2f - f^2) \sin^2 \phi_i}} + H_i
\]

(391)

\[
\theta_i = \theta_{g0} + \frac{d\phi}{dt} (t_i - t_0) + \lambda_{E1}
\]

(392)

\[
X_i = - G_{1i} \cos \phi_i \cos \theta_i
\]

(393)

\[
Y_i = - G_{1i} \cos \phi_i \sin \theta_i
\]

(394)
\[ Z_i = -G_{2i} \sin \phi_i \]  
(395)

\[ R_i = R \cdot R_i \]  
(396)

\[ \xi_{21} = \frac{1}{2} \left[ \rho_2^2 - \rho_1^2 - (R_2^2 - R_1^2) \right] \]  
(397)

\[ \xi_{31} = \frac{1}{2} \left[ \rho_3^2 - \rho_1^2 - (R_3^2 - R_1^2) \right] \]  
(398)

\[ \Delta_1 = (Z_3 - Z_1)(Y_2 - Y_1) - (Z_2 - Z_1)(Y_3 - Y_1) \]  
(399)

\[ A = \frac{(X_2 - X_1)(Y_3 - Y_1) - (X_3 - X_1)(Y_2 - Y_1)}{\Delta_1} \]  
(400)

\[ B = \frac{\xi_{31} (Y_2 - Y_1) - \xi_{21} (Y_3 - Y_1)}{\Delta_1} \]  
(401)

\[ \Delta_2 = (Y_3 - Y_1)(Z_2 - Z_1) - (Y_2 - Y_1)(Z_3 - Z_1) \]  
(402)

\[ C = \frac{(X_2 - X_1)(Z_3 - Z_1) - (X_3 - X_1)(Z_2 - Z_1)}{\Delta_2} \]  
(403)

\[ D = \frac{\xi_{31} (Z_2 - Z_1) - \xi_{21} (Z_3 - Z_1)}{\Delta_2} \]  
(404)
\[ \varepsilon_1 = A^2 + C^2 + 1 \]  
(405)

\[ \varepsilon_2 = 2(AB + CD + X_1 + CY_1 + AZ_1) \]  
(406)

\[ \varepsilon_3 = B^2 + D^2 + 2DY_1 + 2BZ_1 + R_1^2 - \rho_1^2 \]  
(407)

\[ x_{0j} = \frac{\varepsilon_2 \pm \sqrt{\varepsilon_2^2 - 4\varepsilon_1\varepsilon_3}}{2\varepsilon_1} \]  
(408)

\[ y_{0j} = Cx_{0j} + D \]  
(409)

\[ z_{0j} = Ax_{0j} + B \]  
(410)

\[ r_{0j}^2 = r_{0j} \cdot r_{0j} \]  
(411)

Reject the \( r_{0j} \) that does not satisfy

\[ \rho_1^2 = r_{0j}^2 + 2r_{0j} \cdot R_1 + R_1^2 \]  
(412)

and continue calculating for \( i = 1, 2, 3 \), with

\[ \dot{R}_i = \frac{1}{k_e} \begin{bmatrix} -y_i \\ x_i \frac{d\theta}{dt} \\ z_i \end{bmatrix} \]  
(413)
\[ E_i = r_i^0 + R_i \]  
(414)

\[ E_i = \rho_i \dot{\rho}_i - \dot{R}_i \cdot \rho_i \]  
(415)

Invert the matrix
\[
M_s = \begin{bmatrix}
\rho_{x1} & \rho_{y1} & \rho_{z1} \\
\rho_{x2} & \rho_{y2} & \rho_{z2} \\
\rho_{x3} & \rho_{y3} & \rho_{z3}
\end{bmatrix}
\]  
(416)

and obtain
\[
\begin{bmatrix}
\dot{x}_0 \\
\dot{y}_0 \\
\dot{z}_0
\end{bmatrix}
= \left[M_s\right]^{-1}
\begin{bmatrix}
E_1 \\
E_2 \\
E_3
\end{bmatrix}
\]  
(417)

Continue by calculating for classical elements.
TRILATERATION FLOWCHART

START

P(1), PV(1), T(1),
PHI(1), YAME(1),
H(1), FOR I = 1, 2, 3,
AE, FLAT, DTHETA,
TJD, XMU, XK, T(4)

ECHO CHECK

ITIME = 0

DO 11
J = 1, 3

DO 31
J = 1, 2

RLDR (J),
PRLCR (J),
J

A

ABS [RLDR (1)-
PRLCR (1)]
> 10^-5

T

F

39

35

42

DO 49
I = 1, 3

XLCY (2),
YLCV (2),
ZLCV (2)

SOLUTION FOR CLASSICAL ELEMENTS

A

B

PAGE 132

131
TRILATERATION FLOWCHART (CONT'D)

\[ B \]

TIME, ALC, ELC, TB, OMEGA, OINCL, W

STOP
TRILATERATION PRELIMINARY ORBIT DETERMINATION METHOD
RANGE AND RATE (EQUATION PAGE 312)

\[ 2 \leq n \leq 19 \]


CPTP(3), XLC(3), YLC(3), ZLC(3), XLC(3), YLC(3), ZLC(3), XLC(3), YLC(3), ZLC(3)


READ RANGE AND RATE INPUT DATA

READ 105, FLAT, AD, DX, D, THTA
READ 102, T(4), T(3), T(3), T(3), T(3), T(3), T(3), T(3)

READ 106, P(1), P(2), P(3), P(4), P(5), P(6), P(7), P(8), P(9), P(10)

READ 107, P(1), P(2), P(3), P(4), P(5), P(6), P(7), P(8)

FOR IAT = 1 TO 10

FORMAT 158, T(3), T(3), T(3), T(3)

FORMAT 158, FLAT = E1, E1, E1, E1, E1, E1, E1, E1

FORMAT 158, THTA = THTA

FORMAT 158, P(1), P(2), P(3), P(4), P(5), P(6), P(7), P(8), P(9), P(10)

FORMAT 158, P(1), P(2), P(3), P(4), P(5), P(6), P(7), P(8), P(9), P(10)

FOR I = 1 TO 10

FORMAT 158, P(1), P(2), P(3), P(4), P(5), P(6), P(7), P(8), P(9), P(10)

FORMAT 158, P(1), P(2), P(3), P(4), P(5), P(6), P(7), P(8), P(9), P(10)

FORMAT 158, P(1), P(2), P(3), P(4), P(5), P(6), P(7), P(8), P(9), P(10)

C

BEFORE CONTINUING

ALL INPUTS ARE Valid TIME OF OCCURRENCE

110 IT = 1

120 LTA = 0

125 STA = 0

127 BRM = 0

129 S205 = 1

130 S200 = 1

135 X = 0

P0 = 0

137 T = T0

138 THTA = THTA

139 IT = IT + 1

140 IF (IT > 10) THEN

141 STOP

142 END
\[ \Theta(j) = \Theta(0) + \Theta(1) + \Theta(2) \]
\[ X(j) = G(0) \times (C(0) \times \Theta(j)) \times (\Theta(0) \times \Theta(1)) \]
\[ Y(j) = G(0) \times (C(0) \times \Theta(0)) \times (\Theta(0) \times \Theta(1)) \]
\[ Z(j) = \Theta(0) \times \Theta(1) \]

11
\[ R(j) = s \times (X(j) - Y(j)) \times (Z(j) - X(j)) \]
\[ D(j) = s \times (X(j) + Y(j)) \times (Z(j) - X(j)) \]
\[ D(j) = s \times (Y(j) + Z(j)) \times (Z(j) - X(j)) \]

26
\[ \text{If } \text{eq(1), print a, print b, print c} \]
\[ \text{Print a, print b, print c} \]

31
\[ \text{Print a, print b, print c} \]

32
\[ \text{If eq(1), print a, print b, print c} \]

35
\[ X(2) = \text{abs}(X(1)) \]
\[ Y(2) = \text{abs}(Y(1)) \]

38
\[ X(2) = \text{abs}(X(1)) \]

39
\[ X(2) = \text{abs}(X(1)) \]

42
\[ X(1) = \text{abs}(X(1)) \]
\[ Y(1) = \text{abs}(Y(1)) \]
\[ Z(1) = \text{abs}(Z(1)) \]

49
\[ X(1) = \text{abs}(X(1)) \]
\[ Y(1) = \text{abs}(Y(1)) \]
\[ Z(1) = \text{abs}(Z(1)) \]

134
SOLVE FOR RIGHT LAGRANGE VECTORS

\text{XLC}(P) = \text{YLC}(P) \times (1 + \text{COS}(P)) * \text{ZLC}(P) \\
\text{YLC}(P) = \text{YLC}(P) \times (1 + \text{COS}(P)) * \text{ZLC}(P) \\
\text{ZLC}(P) = \text{YLC}(P) \times (1 + \text{COS}(P)) * \text{ZLC}(P)

\text{COST}=\text{SIN} \times \text{COS}
\text{SIN}=\text{SIN} \times \text{COS}
\text{COS}=\text{SIN} \times \text{COS}
DE^2 = XLC(2) * COS(1 - MEGA) + YLC(2) * SIN(OMEGA)
Y = ATAN(XLC(2), YLC(2))
K = 2 * YLC(2)
C7 = INT
PRINT 100, C7
FORMAT ('I7, A10, 1E6, 1E6, 1E6, 1E6, 1E6, 1E6)
107 FORMAT (2I7, 1E4, 1E6, 1E6, 1E6, 1E6, 1E6, 1E6)
100 FORMAT (' 11111111111')
50 CONTINUE
50 STOP
STOP
Appendix M
Herrick-Gibbs PODM, Mixed Data

Given the mixed data $p_i, \alpha_{ti}, \delta_{ti}$, for some $t_i$ with $i = 1, 2, 3$ along with station data $\phi_i, \lambda_{Ei}, H_i$ and the constants $a_e, K_e, \mu, f, \frac{d\phi}{dt}$, proceed as follows:

\[
Tu = \frac{JD - 2415020}{36525} \quad (418)
\]

\[
\theta_0 = 99^\circ.6909833 + 36000^\circ.7689 Tu + 0^\circ.00038708 Tu^2 \quad (419)
\]

For $i = 1, 2, 3$ compute

\[
L_{xi} = \cos \delta_{ti} \cos \alpha_{ti} \quad (420)
\]

\[
L_{yi} = \cos \delta_{ti} \sin \alpha_{ti} \quad (421)
\]

\[
L_{zi} = \sin \alpha_{ti} \quad (422)
\]

\[
G_{1i} = \frac{a_e}{1 - (2f - f^2) \sin^2 \phi_i} + H_i \quad (423)
\]

\[
G_{2i} = \frac{(1 - f)^2 a_e}{1 - (2f - f^2) \sin^2 \phi_i} + H_i \quad (424)
\]
\[ \theta_i = \theta_0 + \frac{d\theta}{dt} (t_i - t_0) + \lambda_{\xi i} \]  

(425)

\[ X_i = -G_{1i} \cos \phi_i \cos \theta_i \]  

(426)

\[ Y_i = -G_{1i} \cos \phi_i \sin \theta_i \]  

(427)

\[ Z_i = -G_{2i} \sin \phi_i \]  

(428)

\[ r_i = \rho_i L_i - R_i \]  

(429)

From the observation times, one may compute the respective modified times, that is

\[ \tau_{ij} = K_e (t_j - t_i) \]  

(430)

with \( j = 1, 2, 3 \) and \( i = 2 \)

\[ G^{-1}_1 \equiv \frac{\tau_{23}}{\tau_{12} \tau_{13}} \]  

(431)

\[ G^{-1}_3 \equiv \frac{\tau_{12}}{\tau_{23} \tau_{13}} \]  

(432)

\[ G^{-2} \equiv G^{-1}_1 - G^{-1}_3 \]  

(433)
with \( T_{13} \equiv T_3 - T_1 \) \hspace{1cm} (434)

Continue by computing

\[
H^{-1}_1 \equiv \frac{\mu}{12} \frac{T_{23}}{12} \hspace{1cm} (435)
\]

\[
H^{-3}_3 \equiv \frac{\mu}{12} \frac{T_{12}}{12} \hspace{1cm} (436)
\]

\[
H^{-2} \equiv H^{-1}_1 - H^{-3}_3 \hspace{1cm} (437)
\]

and form the coefficients

\[
d_i = g^{-1}_i + \frac{H^{-1}_i}{r_1^3} \text{ for } i = 1, 2, 3 \hspace{1cm} (438)
\]

\[
\hat{r}_2 = -d_1 r_1 + d_2 r_2 + d_3 r_3 \hspace{1cm} (439)
\]

Continue by calculating for the classical elements.
HERRICK-GIBBS FLOWCHART

START

P(1), H(1), PHI(1)
YAME(1), DELTA(1)
ALPHA(1), T(I), FOR
I = 1,2,3, AE, FLAT,
DTHETA, TJD, XMU,
XK, T(4)

ECOCH

CHECK

I TIME = 0

DO 14
I = 1,3

A

DO 24
I = 1,3

XLCV(2)
YLCV(2)
ZLCV(2)

SOLUTION FOR
CLASSICAL
ELEMENTS

I TIME, ALC
ELC, TE,
OMEGA,
OINCL, W

STOP

140
YL(I) = \cos(\Delta(I)) \times \sin(\alpha(I)) \\
ZL(I) = \sin(\Delta(I)) \\
\Delta(I) = \text{SORT}(1) = 2, \times FLAT = FLAT**2 \times (\sin(\phi(I)))**2 \\
\alpha(I) = \text{AF}(\Delta(I)) + H(I) \\
g(I) = (1, 2, \times FLAT)**2 \times AF(\Delta(I)) + H(I) \\
\Theta(I) = \text{THETA}(I) + \text{THETA}(T(I) = T(4)) + \text{YANG}(I) \\
X(I) = g(I) \times \cos(\theta(I)) \times \cos(\Theta(I)) \\
Y(I) = g(I) \times \sin(\Theta(I)) \times \sin(\Theta(I)) \\
Z(I) = g(I) \times \sin(\Theta(I)) \\
XLC(I) = X(I) \times YLC(I) - X(I) \\
YLC(I) = \sin(I) \times Y(I) - Y(I) \\
ZLC(I) = \cos(I) \times Z(I) - Z(I) \\
RLC(I) = \cos(T) \times YLC(I) + \sin(T)*ZLC(I)**2 + ZLC(I)**2 \\
DT3 = \text{XX}(T - T(1)) \\
DT1 = \text{XX}(T - T(3)) \\
DT1 = \text{XX}(T - T(3)) \\
GR(1) = \text{DT3} / (\text{DT2} + \text{DT1}) \\
GB(3) = \text{DT1} / (\text{DT2} + \text{DT1}) \\
GR(1) = \text{GR}(1) \times \text{GR}(3) \\
HR(1) = \text{HR}(1) / \text{HR}(3) \\
HR(3) = \text{HR}(3) / \text{HR}(3) \\
D(I) = \text{GR}(1) \times \text{GR}(1) / \text{RLC(I)}**2 \\
XLCV(I) = \sin(I) \times XLC(I) + \sin(I) \times YLC(I) + \sin(I) \times ZLC(I) \\
YLCV(I) = \cos(I) \times XLC(I) + \cos(I) \times YLC(I) + \cos(I) \times ZLC(I) \\
ZLCV(I) = \sin(I) \times XLC(I) + \sin(I) \times YLC(I) + \sin(I) \times ZLC(I) \\
CT = \text{IT} \\
\text{PRINT} 1 \text{C}, \text{CT} \\
\text{PRINT 92, XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)} \\
\text{FORMAT} (10) \times \text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)} \\
\text{FORMAT} (10) \times \text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)} \\
\text{SOUT} = \text{FOR} \times \text{CLASSICAL ELEMENTS} \\
\text{IT} = \text{SOUT} \\
\text{RLCV(I)} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{RLCV(I)} = \text{SORT}(\text{XLC(V), YLC(I), ZLC(I)**2}) \\
\text{RLCV(I)} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)**2}) \\
\text{ALC} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2) \\
\text{CSPE} = \text{SORT}(\text{XLCV(I)}, \text{YLCV(I)}, \text{ZLCV(I)}**2)
## APPENDIX N
**OSO-III ORBITAL PARAMETERS**
*Epoch 67Y 10M 27D OOH OOM*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semimajor Axis</td>
<td>006931.15 km or 004306.81 mi</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0.00216</td>
</tr>
<tr>
<td>Inclination</td>
<td>032.863°</td>
</tr>
<tr>
<td>Mean Anomaly</td>
<td>351.947°</td>
</tr>
<tr>
<td>Argument of Perigee</td>
<td>226.399°</td>
</tr>
<tr>
<td>RA of Ascending Node</td>
<td>187.347°</td>
</tr>
<tr>
<td>Anomalistic Period</td>
<td>0095.70901 min</td>
</tr>
<tr>
<td>Height of Perigee</td>
<td>000537.76 km or 000334.15 mi</td>
</tr>
<tr>
<td>Height of Apogee</td>
<td>000567.76 km or 000352.79 mi</td>
</tr>
<tr>
<td>Velocity at Perigee</td>
<td>027360 km/hr or 017001 mi/hr</td>
</tr>
<tr>
<td>Velocity at Apogee</td>
<td>027242 km/hr or 016928 mi/hr</td>
</tr>
<tr>
<td>Geocentric Latitude of Perigee</td>
<td>-23.138°</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Semimajor Axis</td>
<td>011129.48 km or 006915.5 mi</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0.24115°</td>
</tr>
<tr>
<td>Inclination</td>
<td>046.323°</td>
</tr>
<tr>
<td>Mean Anomaly</td>
<td>291.027°</td>
</tr>
<tr>
<td>Argument of Perigee</td>
<td>248.553°</td>
</tr>
<tr>
<td>RA of Ascending Node</td>
<td>161.988°</td>
</tr>
<tr>
<td>Anomalous Period</td>
<td>0194.74113 min</td>
</tr>
<tr>
<td>Height of Perigee</td>
<td>002067.24 km or 001284.52 mi</td>
</tr>
<tr>
<td>Height of Apogee</td>
<td>007434.94 km or 004619.85 mi</td>
</tr>
<tr>
<td>Velocity at Perigee</td>
<td>027554 km/hr or 017121 mi/hr</td>
</tr>
<tr>
<td>Velocity at Apogee</td>
<td>016847 km/hr or 010468 mi/hr</td>
</tr>
<tr>
<td>Geocentric Latitude of Perigee</td>
<td>-42.311°</td>
</tr>
</tbody>
</table>
### APPENDIX P

#### STATION COORDINATES

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude ($\phi$)</th>
<th>Longitude ($\lambda$)</th>
<th>Height (H)</th>
<th>e.r. ($10^{-7}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Degrees</td>
<td>Radians</td>
<td>Degrees</td>
<td>Radians</td>
</tr>
<tr>
<td>Fort Myers</td>
<td>26° 32' 53.78 0.46335476</td>
<td>278° 08' 04.60 4.8543647</td>
<td>9</td>
<td>14.110639</td>
</tr>
<tr>
<td>Newfoundland</td>
<td>47° 44' 28.94 0.83324413</td>
<td>307° 16' 46.71 5.3630414</td>
<td>112</td>
<td>175.59907</td>
</tr>
<tr>
<td>Quito</td>
<td>00° 37' 20.55 0.01086249</td>
<td>281° 25' 15.62 4.9117231</td>
<td>3,578</td>
<td>5609.7632</td>
</tr>
<tr>
<td>Lima</td>
<td>-11° 46' 34.86 -0.20553608</td>
<td>282° 50' 59.14 4.9366596</td>
<td>516</td>
<td>809.00999</td>
</tr>
<tr>
<td>Santiago</td>
<td>-33° 08' 56.23 -0.57855837</td>
<td>289° 19' 52.88 5.0497847</td>
<td>681</td>
<td>1067.7050</td>
</tr>
<tr>
<td>Winkfield</td>
<td>51° 26' 45.43 0.89790126</td>
<td>359° 18' 13.57 6.2710337</td>
<td>87</td>
<td>136.40285</td>
</tr>
<tr>
<td>Johannesburg</td>
<td>-25° 53' 00.98 -0.45175414</td>
<td>27° 42' 28.49 0.48359432</td>
<td>1,565</td>
<td>2453.6834</td>
</tr>
<tr>
<td>Madagascar</td>
<td>-19° 00' 25.21 -0.33173478</td>
<td>47° 18' 00.46 0.82554296</td>
<td>1,361</td>
<td>2133.8422</td>
</tr>
<tr>
<td>Orroral</td>
<td>-35° 37' 37.51 -0.62180996</td>
<td>148° 57' 10.71 2.5997184</td>
<td>947</td>
<td>1484.7528</td>
</tr>
</tbody>
</table>
APPENDIX Q
RANGE, RANGE RATE, AND ANGULAR DATA COMPUTATIONAL ALGORITHM AND
COMPUTER PROGRAM LISTING

Given $r (x, y, z)$ and $\dot{r} (\dot{x}, \dot{y}, \dot{z})$ at a time $t$ with constants $\phi, H, \lambda_E, \frac{d\phi}{dt}, k_e, \mu, t_g, a_e, f$, proceed as follows:

$$J.D. = \frac{2415020}{36525}$$

$$\theta_g = 99^\circ 6909833 + 36000^\circ 7689Tu + 0^\circ 00038708Tu^2$$

$$\theta = \theta_g + \frac{d\theta}{dt} (t - t_g) - (2\pi - \lambda_E)$$

$$G_1 = \frac{ae}{\sqrt{1 - (2f - f^2)\sin^2 \phi}} + H$$

$$G_2 = \frac{(1 - f)^2 a_e}{\sqrt{1 - (2f - f^2)\sin^2 \phi}} + H$$

$$X = -G_1 \cos \phi \cos \theta$$

$$Y = -G_1 \cos \phi \sin \theta$$

$$Z = -G_2 \sin \phi$$

$$\dot{X} = -\frac{d\theta}{dt} Y$$

147
\[ \dot{Y} = \frac{d\theta}{dt} x \quad (448) \]

\[ \dot{z} = 0.0 \quad (449) \]

\[ \rho = r + R \quad (450) \]

\[ \rho = \sqrt{\rho \cdot \rho} \quad (451) \]

\[ \dot{\rho} = \dot{r} + \dot{R} \quad (452) \]

\[ \dot{\rho} = \frac{\dot{\rho} \cdot \rho}{\rho} \quad (453) \]

\[ r_p = \sqrt{x^2 + y^2} \quad (454) \]

\[ r = \sqrt{x^2 + y^2 + z^2} \quad (455) \]

\[ \cos \delta = \frac{r_p}{r} \quad (456) \]

\[ \sin \delta = \frac{z}{r} \quad (457) \]

\[ \cos \alpha = \frac{x}{r_p} \quad (458) \]

\[ \sin \alpha = \frac{y}{r_p} \quad (459) \]
APPENDIX R

SOLUTION FOR CLASSICAL ELEMENTS

Given $r_1 (x_1, y_1, z_1)$ or $r_2 (x_2, y_2, z_2)$ and the velocity $\mathbf{r}_1 (x_1', y_1', z_1')$ or $\mathbf{r}_2 (x_2', y_2', z_2')$, proceed as follows:

$$r_1 = \sqrt{\mathbf{r}_1 \cdot \mathbf{r}_1}$$

(460)

$$r_1 \mathbf{r}_1 = x_1 x' + y_1 y' + z_1 z'$$

(461)

$$\mathbf{r}_1 = \frac{\mathbf{r}_1 \cdot \mathbf{r}_1}{r_1}$$

(462)

$$v = \sqrt{\mathbf{r}_1 \cdot \mathbf{r}_1}$$

(463)

Semimajor axis, $a$,

$$a = \frac{r_1 \mu}{2\mu - V^2 r_1}$$

(464)

$$c_e = 1 - \frac{r_1}{a}$$

(465)

$$s_e = \frac{r_1 r_1}{\sqrt{\mu a}}$$

(466)

Eccentricity, $e$,

$$e = \sqrt{s_e^2 + c_e^2}$$

(467)
\[
\cos E = \frac{a - r_1}{a_e} \tag{468}
\]
\[
x_w = a (\cos E - e) \tag{469}
\]
\[
\cos v = \frac{x_w}{r_1} \tag{470}
\]
\[
\sin v = \frac{\sqrt{r_1^2 - x_w^2}}{r_1} \tag{471}
\]
\[
\sin E = \sqrt{1 - e^2} \left( \frac{\sin v}{1 + e \cos v} \right) \tag{472}
\]

Time of perifocal passage, \(T\)
\[
T = t_1 - \frac{(E - e \sin E)}{k_e \sqrt{\mu a^3}} \tag{473}
\]
\[
h_x = y_1 \dot{z}_1 - z_1 \dot{y}_1 \tag{474}
\]
\[
h_y = - (x_1 \dot{z}_1 - z_1 \dot{x}_1) \tag{475}
\]
\[
h_z = x_1 \dot{y}_1 - y_1 \dot{x}_1 \tag{476}
\]

Longitude of ascending node, \(\Omega\)
\[
\tan \Omega = \frac{h_x}{h_y} \tag{477}
\]
Orbit inclination, $i$

$$\tan i = \frac{\sqrt{h_x^2 + h_y^2}}{h_z}$$

(478)

$$\tan u = \frac{-x_1 \sin \Omega \cos i + y_1 \cos \Omega \cos i + z_1 \sin i}{x_1 \cos \Omega + y_1 \sin \Omega}$$

(479)

Augment of perigee, $\omega$

$$\omega = u - v$$

(480)
### APPENDIX S
FLOWCHART SYMBOL DEFINITIONS

<table>
<thead>
<tr>
<th>Symbol Shape</th>
<th>Definition</th>
<th>Information Inside Symbol</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>circle</td>
<td>Start/stop statement</td>
<td>Start or stop</td>
<td>START</td>
</tr>
<tr>
<td>rectangle</td>
<td>Card input statement</td>
<td>Input items</td>
<td>XLC (1), YLC (1), ZLC (1)</td>
</tr>
<tr>
<td>trapezoid</td>
<td>Printer output statement</td>
<td>Output items</td>
<td>F (I), 1</td>
</tr>
<tr>
<td>rectangle</td>
<td>Assignment statement</td>
<td>One or more statements</td>
<td>DELV = 0.05 VLC (1)</td>
</tr>
<tr>
<td>trapezoid</td>
<td>DO statement</td>
<td>Repetition parameters</td>
<td>DO 31</td>
</tr>
<tr>
<td>diamond</td>
<td>Decision or IF statements</td>
<td>True and false conditions</td>
<td>1 = 25</td>
</tr>
</tbody>
</table>

153
<table>
<thead>
<tr>
<th>Symbol Shape</th>
<th>Definition</th>
<th>Information Inside Symbol</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unconditional transfer or GO TO statement</td>
<td>Numerical statement</td>
<td><img src="image" alt="Example" /></td>
</tr>
<tr>
<td></td>
<td>Off-page connector label</td>
<td>Alphabetical letter</td>
<td><img src="image" alt="Example" /></td>
</tr>
<tr>
<td></td>
<td>On-page connector label</td>
<td>Alphabetical letter</td>
<td><img src="image" alt="Example" /></td>
</tr>
</tbody>
</table>
## APPENDIX T
### ASSUMED VALUES OF GEOPHYSICAL CONSTANTS

<table>
<thead>
<tr>
<th>Constant</th>
<th>Symbol</th>
<th>Assumed Value</th>
<th>FORTRAN Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flatness coefficient</td>
<td>$f$</td>
<td>$0.33528919 \times 10^{-2}$</td>
<td>FLAT</td>
</tr>
<tr>
<td>Canonical unit of length</td>
<td>CUL</td>
<td>$0.63781660 \times 10^7$ meters</td>
<td>-</td>
</tr>
<tr>
<td>Earth radius</td>
<td>e.r.</td>
<td>$0.10000000 \times 10$ CUL</td>
<td>AE</td>
</tr>
<tr>
<td>Gravitational constant of Earth</td>
<td>$k_e$</td>
<td>$0.74366728 \times 10^{-1} \left( \frac{\text{e.r.}^3}{\text{min.}^2} \right)$</td>
<td>XK</td>
</tr>
<tr>
<td>Sum of masses</td>
<td>$\mu$</td>
<td>$0.10000000 \times 10$</td>
<td>XMU</td>
</tr>
<tr>
<td>Rotation of Earth</td>
<td>$\frac{d\theta}{dt}$</td>
<td>$0.43752691 \times 10^{-2} \left( \text{radians/min.} \right)$</td>
<td>DTHETA</td>
</tr>
<tr>
<td>Julian Date</td>
<td>J.D.</td>
<td>$0.24397835 \times 10^7$</td>
<td>TJD</td>
</tr>
<tr>
<td>OSO-III EPOCH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RELAY-II EPOCH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canonical unit of time</td>
<td>CUT</td>
<td>$0.13446874 \times 10^2$ min.</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 2. Results of Lambert-Euler PODM for OSO-III Orbit
Figure 3. Results of Lambert-Euler PODM for Relay-II Orbit
Figure 4. Results of F and G Series PODM for OSO-III Orbit
Figure 5. Results of F and G Series PODM for Relay-II Orbit
Figure 6. Results of Iteration of Semiparameter PODM for OSO-III Orbit
Figure 7. Results of Iteration of Semiparameter PODM for Relay-II Orbit
Figure 8. Results of Gaussian PODM for OSO-III Orbit
Figure 9. Results of Gaussian PODM for Relay-II Orbit
Figure 10. Results of Iteration of True Anomaly PODM for OSO-III Orbit
Figure 11. Results of Iteration of True Anomaly PODM for Relay-II Orbit
Figure 12. Elliptical Orbit
### Table 1. OSO-III Position and Velocity Orbit Data*

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Position Vector (Canonical Units of Length)</th>
<th>Time from Epoch (Minutes)</th>
<th>Resultant Velocity Vector (Canonical Unit of Length Per Canonical Unit of Time)</th>
<th>Change in True Anomaly from Data Point 1 (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X: 0.63397379 E00, Y: 0.87714911 E00, Z: -0.57285980 E-01</td>
<td>T: 0.42900000 E03</td>
<td>X DOT: -0.67128213 E00, Y DOT: 0.45237915 E00, Z DOT: -0.51983933 E00</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>X: 0.58274812 E00, Y: 0.90885977 E00, Z: -0.95773336 E-01</td>
<td>T: 0.43000000 E03</td>
<td>X DOT: -0.70685743 E00, Y DOT: 0.40013314 E00, Z DOT: -0.51534094 E00</td>
<td>3.8</td>
</tr>
<tr>
<td>3</td>
<td>X: 0.47289180 E00, Y: 0.96034300 E00, Z: -0.17136390 E00</td>
<td>T: 0.43200000 E03</td>
<td>X DOT: -0.76862972 E00, Y DOT: 0.29068616 E00, Z DOT: -0.49963709 E00</td>
<td>11.4</td>
</tr>
<tr>
<td>4</td>
<td>X: 0.29327509 E00, Y: 0.10061443 E01, Z: -0.27810196 E00</td>
<td>T: 0.43500000 E03</td>
<td>X DOT: -0.83592404 E00, Y DOT: 0.11781151 E00, Z DOT: -0.45992297 E00</td>
<td>22.8</td>
</tr>
<tr>
<td>5</td>
<td>X: -0.92932753 E-01, Y: 0.97992039 E00, Z: -0.45733638 E00</td>
<td>T: 0.44100000 E03</td>
<td>X DOT: -0.87135390 E00, Y DOT: 0.23048489 E00, Z DOT: -0.32909258 E00</td>
<td>45.6</td>
</tr>
<tr>
<td>6</td>
<td>X: -0.46473516 E00, Y: 0.80228180 E00, Z: -0.56523331 E00</td>
<td>T: 0.44700000 E03</td>
<td>X DOT: -0.77289578 E00, Y DOT: 0.54884506 E00, Z DOT: -0.14805021 E00</td>
<td>68.4</td>
</tr>
<tr>
<td>7</td>
<td>X: -0.76519048 E00, Y: 0.50282255 E00, Z: 0.58621929 E00</td>
<td>T: 0.45300000 E03</td>
<td>X DOT: -0.55646495 E00, Y DOT: -0.77864062 E00, Z DOT: 0.55149247 E-01</td>
<td>91.2</td>
</tr>
<tr>
<td>8</td>
<td>X: -0.94868622 E00, Y: 0.12595263 E00, Z: -0.51737727 E00</td>
<td>T: 0.45900000 E03</td>
<td>X DOT: -0.25549497 E00, Y DOT: -0.88905191 E00, Z DOT: 0.24948641 E00</td>
<td>114.0</td>
</tr>
<tr>
<td>9</td>
<td>X: -0.98742402 E00, Y: -0.27017428 E00, Z: -0.3635944 E00</td>
<td>T: 0.46500000 E03</td>
<td>X DOT: 0.84194416 E-01, Y DOT: -0.85372645 E00, Z DOT: 0.40546748 E00</td>
<td>136.8</td>
</tr>
<tr>
<td>10</td>
<td>X: -0.62955513 E00, Y: -0.88498102 E00, Z: 0.65285980 E-01</td>
<td>T: 0.47700000 E03</td>
<td>X DOT: 0.67560492 E00, Y DOT: -0.44112696 E00, Z DOT: 0.51698187 E00</td>
<td>180.0</td>
</tr>
<tr>
<td>11</td>
<td>X: 0.76766608 E00, Y: -0.49328024 E00, Z: 0.58396071 E00</td>
<td>T: 0.50100000 E03</td>
<td>X DOT: 0.55145966 E00, Y DOT: 0.7682607 E00, Z DOT: -0.62654770 E-01</td>
<td>270.0</td>
</tr>
<tr>
<td>12</td>
<td>X: 0.61361294 E00, Y: 0.89000851 E00, Z: -0.77740201 E-01</td>
<td>T: 0.52500000 E03</td>
<td>X DOT: -0.68743522 E00, Y DOT: 0.42989298 E00, Z DOT: -0.51773733 E00</td>
<td>360.0</td>
</tr>
</tbody>
</table>

*From reference 3.
### Table 2. Relay-II Position and Velocity Orbit Data*

**Epoch** 67Y 11M 13D 00H 00M 00S

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Position Vector (Canonical Units of Length)</th>
<th>Time From Epoch (Minutes)</th>
<th>Resultant Velocity Vector (Canonical Unit of Length Per Canonical Unit of Time)</th>
<th>Change in True Anomaly from Data Point 1 (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>X</strong></td>
<td><strong>Y</strong></td>
<td><strong>Z</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-0.62705086 E00</td>
<td>0.13026303 E01</td>
<td>-0.2678816 E00</td>
<td>-0.58071281 E00</td>
</tr>
<tr>
<td>2</td>
<td>-0.67640560 E00</td>
<td>0.13001240 E01</td>
<td>-0.22446287 E00</td>
<td>0.56641873 E00</td>
</tr>
<tr>
<td>3</td>
<td>-0.72456249 E00</td>
<td>0.12954130 E01</td>
<td>-0.19069118 E00</td>
<td>-0.48674037 E01</td>
</tr>
<tr>
<td>4</td>
<td>-0.81727365 E00</td>
<td>0.12796195 E00</td>
<td>-0.92290918 E-01</td>
<td>-0.63983417 E00</td>
</tr>
<tr>
<td>5</td>
<td>-0.90499037 E00</td>
<td>0.12244558 E01</td>
<td>0.85668977 E-01</td>
<td>-0.77927626 E00</td>
</tr>
<tr>
<td>6</td>
<td>-0.12598173 E01</td>
<td>0.10352957 E01</td>
<td>0.43259412 E00</td>
<td>-0.53391142 E00</td>
</tr>
<tr>
<td>7</td>
<td>-0.14338367 E01</td>
<td>0.76920152 E00</td>
<td>0.74830809 E00</td>
<td>-0.37896294 E00</td>
</tr>
<tr>
<td>8</td>
<td>-0.15105151 E01</td>
<td>0.53075523 E00</td>
<td>0.95602583 E00</td>
<td>-0.22604802 E00</td>
</tr>
<tr>
<td>9</td>
<td>-0.15435262 E01</td>
<td>0.33061169 E01</td>
<td>0.11069735 E01</td>
<td>-0.49460571 E00</td>
</tr>
<tr>
<td>10</td>
<td>-0.15282029 E01</td>
<td>0.11262472 E-01</td>
<td>0.30383234 E01</td>
<td>-0.56593395 E00</td>
</tr>
<tr>
<td>11</td>
<td>0.89934644 E-01</td>
<td>-0.17919032 E01</td>
<td>0.10225903 E01</td>
<td>-0.57869376 E00</td>
</tr>
<tr>
<td>12</td>
<td>0.10671941 E01</td>
<td>-0.13527369 E01</td>
<td>0.76826469 E-01</td>
<td>-0.75270923 E01</td>
</tr>
<tr>
<td>13</td>
<td>-0.64038080 E00</td>
<td>0.13030522 E01</td>
<td>-0.15192970 E00</td>
<td>-0.37661014 E00</td>
</tr>
</tbody>
</table>

*From reference 3.
Table 3. Results of Lambert-Euler PODM for OSO-III Orbit

<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $\bar{r}_1 \rightarrow \bar{r}_2$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot (CUL/CUT)</th>
<th>Iterations Required to Obtain an Epsilon ($\epsilon$) of $&lt;$10^-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
<td>-0.67081054 EO</td>
<td>0.45235122 EO</td>
<td>-0.51959007 EO</td>
<td>7</td>
</tr>
<tr>
<td>11.4</td>
<td>-0.67103078 EO</td>
<td>0.45243688 EO</td>
<td>-0.51971812 EO</td>
<td>7</td>
</tr>
<tr>
<td>22.8</td>
<td>-0.67130422 EO</td>
<td>0.45244467 EO</td>
<td>-0.51981342 EO</td>
<td>7</td>
</tr>
<tr>
<td>45.6</td>
<td>-0.67165405 EO</td>
<td>0.45226798 EO</td>
<td>-0.51976476 EO</td>
<td>8</td>
</tr>
<tr>
<td>68.4</td>
<td>-0.67164899 EO</td>
<td>0.45215526 EO</td>
<td>-0.51947102 EO</td>
<td>7</td>
</tr>
<tr>
<td>91.2</td>
<td>-0.67080666 EO</td>
<td>0.47883872 EO</td>
<td>-0.52650669 EO</td>
<td>8</td>
</tr>
<tr>
<td>114.0</td>
<td>-0.67166326 EO</td>
<td>0.45243605 EO</td>
<td>-0.51859662 EO</td>
<td>7</td>
</tr>
<tr>
<td>136.8</td>
<td>-0.67198271 EO</td>
<td>0.45278865 EO</td>
<td>-0.51775009 EO</td>
<td>7</td>
</tr>
<tr>
<td>180.0</td>
<td>Computer halted after second iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>270.0</td>
<td>0.65513605 EO</td>
<td>-0.39298239 EO</td>
<td>0.48590209 EO</td>
<td>I=25*</td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted after six iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Did not converge.
Table 4. Results of Lambert-Euler PODM for Relay-II Orbit

<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $r_1 \to r_2$, i.e., $\nu_2 - \nu_1$ (Degrees)</th>
<th>Computed X Dot</th>
<th>Computed Y Dot</th>
<th>Computed Z Dot</th>
<th>Iterations Required to Obtain an Epsilon ($\epsilon$) of $\leq 10^{-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>-0.67100717 E0</td>
<td>-0.18597544 E-01</td>
<td>0.58100110 E0</td>
<td>15</td>
</tr>
<tr>
<td>5.0</td>
<td>-0.67073406 E0</td>
<td>-0.18589597 E-01</td>
<td>0.58076722 E0</td>
<td>9</td>
</tr>
<tr>
<td>10.0</td>
<td>-0.67072314 E0</td>
<td>-0.18613539 E-01</td>
<td>0.58077790 E0</td>
<td>15</td>
</tr>
<tr>
<td>21.0</td>
<td>-0.67063993 E0</td>
<td>-0.18632342 E-01</td>
<td>0.58072454 E0</td>
<td>10</td>
</tr>
<tr>
<td>40.0</td>
<td>-0.67060216 E0</td>
<td>-0.18680951 E-01</td>
<td>0.58071562 E0</td>
<td>9</td>
</tr>
<tr>
<td>60.0</td>
<td>-0.67058860 E0</td>
<td>-0.18723884 E-01</td>
<td>0.58070555 E0</td>
<td>8</td>
</tr>
<tr>
<td>72.0</td>
<td>-0.67057670 E0</td>
<td>-0.18726358 E-01</td>
<td>0.58066965 E0</td>
<td>14</td>
</tr>
<tr>
<td>85.0</td>
<td>-0.67057675 E0</td>
<td>-0.18730622 E-01</td>
<td>0.58064458 E0</td>
<td>14</td>
</tr>
<tr>
<td>105.00</td>
<td>-0.67058715 E0</td>
<td>-0.18733006 E-01</td>
<td>0.58060167 E0</td>
<td>8</td>
</tr>
<tr>
<td>237.0</td>
<td>Computer halted after two iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290.0</td>
<td>Computer halted after two iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted after fifteen iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Results of F and G Series PODM for OSO-III Orbit

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference</th>
<th>Computed X Dot</th>
<th>Reference Orbit X Dot</th>
<th>Computed Y Dot</th>
<th>Reference Orbit Y Dot</th>
<th>Computed Z Dot</th>
<th>Reference Orbit Z Dot</th>
<th>Iterations Required to Obtain an Epsilon (ε) of ≤10⁻¹⁰</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Degrees)</td>
<td>i.e., ( \nu_2 - \nu_1 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.8</td>
<td></td>
<td>-0.67081054 E0</td>
<td>0.45235122 E0</td>
<td>-0.51959007 E0</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.4</td>
<td></td>
<td>-0.67103078 E0</td>
<td>0.45243689 E0</td>
<td>-0.51971812 E0</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.8</td>
<td></td>
<td>-0.67130428 E0</td>
<td>0.45244469 E0</td>
<td>-0.51981347 E0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45.6</td>
<td></td>
<td>-0.67165853 E0</td>
<td>0.45226850 E0</td>
<td>-0.51976718 E0</td>
<td>10</td>
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</tr>
<tr>
<td>68.4</td>
<td></td>
<td>0.45123977 E0</td>
<td>-0.51913683 E0</td>
<td>0.33426901 E0</td>
<td>I=25*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>91.2</td>
<td></td>
<td>0.23846019 E1</td>
<td>0.70582817 E0</td>
<td>-0.23591702 E1</td>
<td>I=25*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>114.0</td>
<td>Computer halted after six iterations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>136.8</td>
<td>Computer halted after three iterations.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>180.0</td>
<td>Computer halted after one iteration.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>270.0</td>
<td>Computer halted after one iteration.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted after two iterations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Did not converge.
### Table 6. Results of F and G Series PODM for Relay-II Orbit

<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $r_1 + r_2$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot is -0.67069755 E0 (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot is -0.18565986 E-01 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot is 0.58071281 E0 (CUL/CUT)</th>
<th>Iterations Required to Obtain an Epsilon ($\epsilon$) of $&lt; 10^{-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>-0.67100717 E0</td>
<td>-0.18597544 E-01</td>
<td>0.58100110 E0</td>
<td>3</td>
</tr>
<tr>
<td>5.0</td>
<td>-0.67073406 E0</td>
<td>-0.18589597 E-01</td>
<td>0.58076722 E0</td>
<td>3</td>
</tr>
<tr>
<td>10.0</td>
<td>-0.67072313 E0</td>
<td>-0.18613540 E-01</td>
<td>0.58077789 E0</td>
<td>4</td>
</tr>
<tr>
<td>21.0</td>
<td>-0.67063956 E0</td>
<td>-0.18632358 E-01</td>
<td>0.58072423 E0</td>
<td>5</td>
</tr>
<tr>
<td>40.0</td>
<td>-0.67058782 E0</td>
<td>-0.18673756 E-01</td>
<td>0.58069903 E0</td>
<td>8</td>
</tr>
<tr>
<td>60.0</td>
<td>-0.67050862 E0</td>
<td>-0.18611443 E-01</td>
<td>0.58056860 E0</td>
<td>13</td>
</tr>
<tr>
<td>72.0</td>
<td>-0.67043325 E0</td>
<td>-0.18305457 E-01</td>
<td>0.58028936 E0</td>
<td>17</td>
</tr>
<tr>
<td>85.0</td>
<td>-0.19824139 E-01</td>
<td>0.57848394 E0</td>
<td>0.53834986 E0</td>
<td>I=25*</td>
</tr>
<tr>
<td>105.0</td>
<td>-0.24107564 E-01</td>
<td>0.57356778 E0</td>
<td>0.43500250 E0</td>
<td>I=25*</td>
</tr>
<tr>
<td>237.0</td>
<td>Computer halted after four iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290.0</td>
<td>Computer halted after one iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted after one iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Did not converge.
### Table 7. Results of Iteration of Semiparameter PODM for OSO-III Orbit

<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $\vec{r}_1 - \vec{r}_2$ i.e., $\nu_2 - \nu_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot is -0.67128213 E0 (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot is 0.45237915 E0 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot is -0.51983933 E0 (CUL/CUT)</th>
<th>Iterations Required to Obtain an Epsilon ($\epsilon$) of $&lt; 10^{-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
<td>-0.67081054 E0</td>
<td>0.45235122 E0</td>
<td>-0.51959007 E0</td>
<td>14</td>
</tr>
<tr>
<td>11.4</td>
<td>-0.67103078 E0</td>
<td>0.45243688 E0</td>
<td>-0.51971812 E0</td>
<td>20</td>
</tr>
<tr>
<td>22.8</td>
<td>-0.67130422 E0</td>
<td>0.45244466 E0</td>
<td>-0.51981342 E0</td>
<td>10</td>
</tr>
<tr>
<td>45.6</td>
<td>-0.67165405 E0</td>
<td>0.45226799 E0</td>
<td>-0.51976476 E0</td>
<td>16</td>
</tr>
<tr>
<td>68.4</td>
<td>-0.67164899 E0</td>
<td>0.45215526 E0</td>
<td>-0.51947102 E0</td>
<td>7</td>
</tr>
<tr>
<td>91.2</td>
<td>-0.67080666 E0</td>
<td>0.47883870 E0</td>
<td>0.52650669 E0</td>
<td>8</td>
</tr>
<tr>
<td>114.0</td>
<td>-0.67166326 E0</td>
<td>0.45243607 E0</td>
<td>-0.51859662 E0</td>
<td>9</td>
</tr>
<tr>
<td>136.8</td>
<td>-0.67198271 E0</td>
<td>0.45278865 E0</td>
<td>-0.51775009 E0</td>
<td>8</td>
</tr>
<tr>
<td>180.0</td>
<td>Computer halted after one iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>270.0</td>
<td>Computer halted after two iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted after two iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8. Results of Iteration of Semiparameter PODM for Relay-II Orbit

<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $r_1 + r_2$ i.e., $\nu_2 - \nu_1$ (Degrees)</th>
<th>Computed X Dot</th>
<th>Computed Y Dot</th>
<th>Computed Z Dot</th>
<th>Iterations Required to Obtain an Epsilon ($\epsilon$) of $&lt;10^{-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>-0.67100717 E0</td>
<td>-0.18597543 E-01</td>
<td>0.58100110 E0</td>
<td>15</td>
</tr>
<tr>
<td>5.0</td>
<td>-0.67073406 E0</td>
<td>-0.18589597 E-01</td>
<td>0.58076722 E0</td>
<td>9</td>
</tr>
<tr>
<td>10.0</td>
<td>-0.67072314 E0</td>
<td>-0.18613537 E-01</td>
<td>0.5807790 E0</td>
<td>8</td>
</tr>
<tr>
<td>21.0</td>
<td>-0.67063993 E0</td>
<td>-0.18632343 E-01</td>
<td>0.58072454 E0</td>
<td>9</td>
</tr>
<tr>
<td>40.0</td>
<td>-0.67060216 E0</td>
<td>-0.18680947 E-01</td>
<td>0.58071562 E0</td>
<td>7</td>
</tr>
<tr>
<td>60.0</td>
<td>-0.67058860 E0</td>
<td>-0.18723889 E-01</td>
<td>0.58070555 E0</td>
<td>11</td>
</tr>
<tr>
<td>72.0</td>
<td>-0.67057669 E0</td>
<td>-0.18726365 E-01</td>
<td>0.58066965 E0</td>
<td>11</td>
</tr>
<tr>
<td>85.0</td>
<td>-0.67057675 E0</td>
<td>-0.18730629 E-01</td>
<td>0.58064458 E0</td>
<td>8</td>
</tr>
<tr>
<td>105.0</td>
<td>-0.67058717 E0</td>
<td>-0.18732987 E-01</td>
<td>0.58060167 E0</td>
<td>10</td>
</tr>
<tr>
<td>237.0</td>
<td>Computer halted after five iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290.0</td>
<td>Computer halted after two iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted after two iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>True Anomaly Angular Difference of $r_1 + r_2$, i.e., $\nu_2 - \nu_1$ (Degrees)</td>
<td>Computed $X$ Dot</td>
<td>Reference Orbit $X$ Dot is -0.67128213 E0 (CUL/CUT)</td>
<td>Computed $Y$ Dot</td>
<td>Reference Orbit $Y$ Dot is 0.45237915 E0 (CUL/CUT)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3.8</td>
<td>-0.67081054 E0</td>
<td>0.45235122 E0</td>
<td>-0.51959007 E0</td>
<td>4</td>
</tr>
<tr>
<td>11.4</td>
<td>-0.67103078 E0</td>
<td>0.45243688 E0</td>
<td>-0.51971812 E0</td>
<td>6</td>
</tr>
<tr>
<td>22.8</td>
<td>-0.67130423 E0</td>
<td>0.45244466 E0</td>
<td>-0.51981342 E0</td>
<td>8</td>
</tr>
<tr>
<td>45.6</td>
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<td>-0.37633925 EO1</td>
<td>0.11297649 E01</td>
<td>I=25*</td>
</tr>
<tr>
<td>68.4</td>
<td>-0.79344996 E0</td>
<td>-0.83165543 E-02</td>
<td>-0.38585390 E0</td>
<td>I=25*</td>
</tr>
<tr>
<td>91.2</td>
<td>Computer halted during first iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>114.0</td>
<td>Computer halted during first iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>136.8</td>
<td>Computer halted during first iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>180.0</td>
<td>Computer halted during first iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>270.0</td>
<td>Computer halted during first iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted during first iteration.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Did not converge.
<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $\tilde{r}_1 \rightarrow \tilde{r}_2$, i.e., $\nu_2 - \nu_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot is -0.67069755 EO (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot is -0.18566596 E-01 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot is 0.58071281 EO (CUL/CUT)</th>
<th>Iterations Required to Obtain an Epsilon ((\varepsilon)) of &lt;10^-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>-0.67100717 E0</td>
<td>-0.18597544 E-01</td>
<td>0.58100110 E0</td>
<td>3</td>
</tr>
<tr>
<td>5.0</td>
<td>-0.67073406 E0</td>
<td>-0.18589598 E-01</td>
<td>0.58076722 E0</td>
<td>4</td>
</tr>
<tr>
<td>10.0</td>
<td>-0.67072314 E0</td>
<td>-0.18613541 E-01</td>
<td>0.58077790 E0</td>
<td>6</td>
</tr>
<tr>
<td>21.0</td>
<td>-0.67063993 E0</td>
<td>-0.18632347 E-01</td>
<td>0.58072454 E0</td>
<td>8</td>
</tr>
<tr>
<td>40.0</td>
<td>-0.67060215 E0</td>
<td>-0.18680959 E-01</td>
<td>0.58071562 E0</td>
<td>15</td>
</tr>
<tr>
<td>60.0</td>
<td>0.18744650 E-01</td>
<td>-0.38893012 E-01</td>
<td>0.79794763 E-02</td>
<td>I=25*</td>
</tr>
<tr>
<td>72.0</td>
<td>0.29766430 E-01</td>
<td>-0.61606750 E-01</td>
<td>0.12576050 E-01</td>
<td>I=25*</td>
</tr>
<tr>
<td>85.0</td>
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<td>-0.79439075 E-01</td>
<td>0.16103859 E-01</td>
<td>I=25*</td>
</tr>
<tr>
<td>105.0</td>
<td></td>
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<td></td>
<td>Computer halted after first iteration.</td>
</tr>
<tr>
<td>237.0</td>
<td></td>
<td></td>
<td></td>
<td>Computer halted during first iteration.</td>
</tr>
<tr>
<td>290.0</td>
<td></td>
<td></td>
<td></td>
<td>Computer halted during first iteration.</td>
</tr>
<tr>
<td>360.0</td>
<td></td>
<td></td>
<td></td>
<td>Computer halted during first iteration.</td>
</tr>
</tbody>
</table>

* Did not converge.
<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $r_1 \rightarrow r_2$</th>
<th>Computed X Dot Reference Orbit X Dot is -0.67128213 E0 (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot is 0.45237915 E0 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot is -0.51983933 E0 (CUL/CUT)</th>
<th>Iterations Required to Obtain an Epsilon ($\epsilon$) of $\leq 10^{-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
<td>-0.67081054 E0</td>
<td>0.45235122 E0</td>
<td>-0.51959007 E0</td>
<td>15</td>
</tr>
<tr>
<td>11.4</td>
<td>-0.67103078 E0</td>
<td>0.45243688 E0</td>
<td>-0.51971812 E0</td>
<td>12</td>
</tr>
<tr>
<td>22.8</td>
<td>-0.67130422 E0</td>
<td>0.45244467 E0</td>
<td>-0.51981342 E0</td>
<td>10</td>
</tr>
<tr>
<td>45.6</td>
<td>-0.67165404 E0</td>
<td>0.45226800 E0</td>
<td>-0.51976476 E0</td>
<td>10</td>
</tr>
<tr>
<td>68.4</td>
<td>-0.67164899 E0</td>
<td>0.45215526 E0</td>
<td>-0.51947102 E0</td>
<td>8</td>
</tr>
<tr>
<td>91.2</td>
<td>-0.67744460 E0</td>
<td>0.50667361 E0</td>
<td>0.53936484 E0</td>
<td>$I=25^*$</td>
</tr>
<tr>
<td>114.0</td>
<td>-0.67166326 E0</td>
<td>0.45243607 E0</td>
<td>-0.51859662 E0</td>
<td>8</td>
</tr>
<tr>
<td>136.8</td>
<td>-0.67198271 E0</td>
<td>0.45278862 E0</td>
<td>-0.51775008 E0</td>
<td>7</td>
</tr>
<tr>
<td>180.0</td>
<td>-0.17226110 E00</td>
<td>0.11138352 E01</td>
<td>-0.19506859 E01</td>
<td>$I=25^*$</td>
</tr>
<tr>
<td>270.0</td>
<td>0.12672460 E0</td>
<td>-0.85052773 E-01</td>
<td>0.97780343 E-01</td>
<td>$I=25^*$</td>
</tr>
<tr>
<td>360.0</td>
<td>Computer halted after six iterations.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Did not converge.
Table 12. Results of Iteration of True Anomaly PODM for Relay-II Orbit

<table>
<thead>
<tr>
<th>True Anomaly Angular Difference of $\vec{r}_1 \rightarrow \vec{r}_2$ i.e., $v_2 - v_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot is -0.67069755 E0 (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot is -0.18565986 E-01 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot is 0.58071281 E0 (CUL/CUT)</th>
<th>Iterations Required to Obtain an Epsilon ($\epsilon$) of $\leq 10^{-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>-0.67100717 E0</td>
<td>-0.18597543 E-01</td>
<td>0.58100110 E0</td>
<td>14</td>
</tr>
<tr>
<td>5.0</td>
<td>-0.67073406 E0</td>
<td>-0.18589597 E-01</td>
<td>0.58076722 E0</td>
<td>19</td>
</tr>
<tr>
<td>10.0</td>
<td>-0.67072314 E0</td>
<td>-0.18613537 E-01</td>
<td>0.58077790 E0</td>
<td>13</td>
</tr>
<tr>
<td>21.0</td>
<td>-0.67063993 E0</td>
<td>-0.18632342 E-01</td>
<td>0.58072454 E0</td>
<td>14</td>
</tr>
<tr>
<td>40.0</td>
<td>-0.6706216 E0</td>
<td>-0.18680947 E-01</td>
<td>0.58071562 E0</td>
<td>12</td>
</tr>
<tr>
<td>60.0</td>
<td>-0.67058860 E0</td>
<td>-0.18723889 E-01</td>
<td>0.58070555 E0</td>
<td>10</td>
</tr>
<tr>
<td>72.0</td>
<td>-0.67057669 E0</td>
<td>-0.18726361 E-01</td>
<td>0.58066965 E0</td>
<td>I=25*</td>
</tr>
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Table 13. Position and Time PODM Classical Orbital Element Comparisons - Semimajor Axis

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No data indicates program failed in computing these values.
### Table 16. Position and Time PODM Classical Orbital Element Comparisons - Orbital Inclination

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No data indicates program failed in computing these values.
Table 17. Position and Time PODM Classical Orbital Element Comparisons - Nominal Argument of Perigee

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<th>True Anomaly Angular Difference of $\vec{t}_1 \rightarrow \vec{t}_2$ i.e., $\nu_2 - \nu_1$ (Degrees)</th>
<th>Nominal Argument of Perigee from Reference Orbit (Radians)</th>
<th>Gaussian PODM</th>
<th>F and G Series PODM</th>
<th>Iteration of True Anomaly PODM</th>
<th>Iteration of Semiparameter PODM</th>
<th>Lambert-Euler PODM</th>
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No data indicates program failed in computing these values.
Table 18. Computer Core Requirements

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<tr>
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<td>Herrick-Gibbs</td>
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<td>Computation for Range, Range Rate, and Angle Data</td>
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<td>PODM</td>
<td>Total Time for Program with One Iteration (Milliseconds)</td>
</tr>
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<td>------</td>
<td>--------------------------------------------------------</td>
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<td>F and G Series</td>
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(1) Method of Gauss has two iteration loops
### Table 20. Ease of Convergence

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<th>Combined Average</th>
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<td>Lambert-Euler</td>
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<td>11</td>
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### Table 21. Best Overall Results for Radius Vector Spread

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<th>Range of Radius Vector Spread</th>
<th>PODM</th>
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<td>$0^\circ &lt; \nu &lt; 45^\circ$</td>
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<td>$45^\circ &lt; \nu &lt; 140^\circ$</td>
<td>Gaussian</td>
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<td>Lambert-Euler</td>
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<td></td>
<td>Iteration of True Anomaly</td>
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### Table 22. Order of Selection for Optimum PODM

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<th>PODM</th>
<th>Computation Time</th>
<th>Ease of Convergence</th>
<th>Best Overall Accuracy</th>
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### Table 23. OSO-III Range/Range Rate and Angular Data
(Topocentric Coordinate System)
Epoch 67Y 10M 20D 00H 00M 00S

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<tr>
<th>Data Point</th>
<th>Range $\rho$ (CUL)</th>
<th>Range Rate $\delta$ (CUL/CUT)</th>
<th>Declination $\delta$ (Radians)</th>
<th>Right Ascension $\alpha$ (Radians)</th>
<th>Time from Epoch (Minutes)</th>
<th>Station Name</th>
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Table 23. OSO-III Range/Range Rate and Angular Data  
(Topocentric Coordinate System)  
Epoch 67Y 10M 20D 00H 00M 00S (Cont'd)

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<th>Range ( \rho ) (CUL)</th>
<th>Range Rate ( \dot{\rho} ) (CUL/CUT)</th>
<th>Declination ( \delta ) (Radians)</th>
<th>Right Ascension ( \alpha ) (Radians)</th>
<th>Time from Epoch (Minutes)</th>
<th>Station Name</th>
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Table 24. Relay-II Range/Range Rate and Angular Data  
(Topocentric Coordinate System)  
Epoch 67Y 11M 13D 00H 00M 00S

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Table 24. Relay-II Range/Range Rate and Angular Data  
(Topocentric Coordinate System)  
Epoch 67Y 11M 13D 00H 00M 00S (Cont'd)  

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Table 25. OSO-III Data Points and Stations Used for PODMs Requiring Angular and Mixed Data Inputs

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Table 25. OSO-III Data Points and Stations Used for PODMs Requiring Angular and Mixed Data Inputs (Cont'd)

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Table 26. Relay-II Data Points and Stations Used for PODMs Requiring Angular and Mixed Data Inputs

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<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Lima</td>
<td>Ft. Myers</td>
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<td>Ft. Myers</td>
<td>Ft. Myers</td>
<td>6</td>
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<td>Ft. Myers</td>
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<td>Ft. Myers</td>
<td>Ft. Myers</td>
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Table 26. Relay-II Data Points and Stations Used for PODMs Requiring Angular and Mixed Data Inputs (Cont'd)

<table>
<thead>
<tr>
<th>Data Points Used</th>
<th>Station for Three-Station Inputs</th>
<th>Station for Single-Station Input</th>
<th>Three Stations with Input Resolved to Single Time Input</th>
</tr>
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<tbody>
<tr>
<td>6</td>
<td>Quito</td>
<td>Ft. Myers</td>
<td>10 Ft. Myers</td>
</tr>
<tr>
<td>9</td>
<td>Ft. Myers</td>
<td>Ft. Myers</td>
<td>10 Newfoundland</td>
</tr>
<tr>
<td>10</td>
<td>Newfoundland</td>
<td>Ft. Myers</td>
<td>10 Winkfield</td>
</tr>
<tr>
<td>1</td>
<td>Santiago</td>
<td>Quito</td>
<td>13 Santiago</td>
</tr>
<tr>
<td>2</td>
<td>Lima</td>
<td>Quito</td>
<td>13 Lima</td>
</tr>
<tr>
<td>13</td>
<td>Quito</td>
<td>Quito</td>
<td>13 Quito</td>
</tr>
<tr>
<td>1</td>
<td>Santiago</td>
<td>Quito</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>Lima</td>
<td>Quito</td>
<td>N/A</td>
</tr>
<tr>
<td>13</td>
<td>Quito</td>
<td>Quito</td>
<td>N/A</td>
</tr>
<tr>
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<td>Santiago</td>
<td>Quito</td>
<td>N/A</td>
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<tr>
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<td>Lima</td>
<td>Quito</td>
<td>N/A</td>
</tr>
<tr>
<td>13</td>
<td>Quito</td>
<td>Quito</td>
<td>N/A</td>
</tr>
<tr>
<td>True Anomaly</td>
<td>Angular Difference ( \vec{r}_1 - \vec{r}_2 ) (Degrees)</td>
<td>Computed X Dot Reference Orbit X Dot at ( T_2 ) (CUL/CUT)</td>
<td>Computed Y Dot Reference Orbit Y Dot at ( T_2 ) (CUL/CUT)</td>
</tr>
<tr>
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<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>3.8</td>
<td>11.4</td>
<td>-0.70791722 E0</td>
<td>0.39743942 E0</td>
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<tr>
<td>3.8</td>
<td>22.8</td>
<td>-0.70667326 E0</td>
<td>0.39969767 E0</td>
</tr>
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<td>3.8</td>
<td>45.6</td>
<td>-0.70657644 E0</td>
<td>0.39983035 E0</td>
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<td>11.4</td>
<td>45.6</td>
<td>-0.76769882 E0</td>
<td>0.29034934 E0</td>
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<td>22.8</td>
<td>45.6</td>
<td>-0.83775843 E0</td>
<td>0.11826982 E0</td>
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<tr>
<td>(2) 22.8</td>
<td>45.6</td>
<td>NO DATA</td>
<td>NO DATA</td>
</tr>
<tr>
<td>22.8</td>
<td>68.4</td>
<td>-0.11614366 E1</td>
<td>-0.16762643 E1</td>
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<tr>
<td>(3) 22.8</td>
<td>111.6</td>
<td>NO DATA</td>
<td>NO DATA</td>
</tr>
<tr>
<td>45.0</td>
<td>68.4</td>
<td>-0.25517320</td>
<td>-0.88735304 E0</td>
</tr>
<tr>
<td>68.4</td>
<td>111.6</td>
<td>0.65269027 E-1</td>
<td>-0.69242933 E0</td>
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Table 27. Results of Method of Gauss PODM for OSO-III (Cont'd)

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Computed X Dot</th>
<th>Computed Y Dot</th>
<th>Computed Z Dot</th>
<th>Number of Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular $\hat{r}_1 + \hat{r}_2$, i.e., $v_2 - v_1$ (Degrees)</td>
<td>Difference $\hat{r}_3 - \hat{r}_1$, i.e., $v_3 - v_1$ (Degrees)</td>
<td>Reference Orbit X Dot at $T_2$ (CUL/CUT)</td>
<td>Reference Orbit Y Dot at $T_2$ (CUL/CUT)</td>
<td>Reference Orbit Z Dot at $T_2$ (CUL/CUT)</td>
</tr>
<tr>
<td>(4) 3.8</td>
<td>360.0</td>
<td>NO DATA</td>
<td>NO DATA</td>
<td>NO DATA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.70685743 E0</td>
<td>0.40013314 E0</td>
<td>-0.51534094 E0</td>
</tr>
<tr>
<td>(5) 45.6</td>
<td>360.0</td>
<td>NO DATA</td>
<td>NO DATA</td>
<td>NO DATA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.87135390 E0</td>
<td>-0.23408489 E0</td>
<td>-0.32909258 E0</td>
</tr>
</tbody>
</table>

(1) Method of Gauss has two iteration loops (1/2)
(2) Computer halted after third iteration of second loop
(3) Computer halted after fifth iteration of second loop
(4) Computer halted after third iteration of second loop
(5) Computer halted after sixth iteration of second loop
Table 28. Results of Method of Gauss PODM for Relay-II

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $r_1 \rightarrow r_2$ (Degrees)</th>
<th>Computed X Dot of Reference Orbit X Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot of Reference Orbit Y Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot of Reference Orbit Z Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>5.0</td>
<td>-0.65573896 E0 0.58465493 E0</td>
<td>-0.48529845 E-1 0.58641873 E0</td>
<td>25/6</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>10.0</td>
<td>-0.6557567 E0 0.58613153 E0</td>
<td>-0.47736815 E-1 0.58641873 E0</td>
<td>25/7</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>21.0</td>
<td>-0.6558460 E0 0.58649359 E0</td>
<td>-0.47958021 E-1 0.58641873 E0</td>
<td>24/7</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>21.0</td>
<td>-0.63987321 E0 0.59110496 E0</td>
<td>-0.77623212 E-1 0.59099381 E0</td>
<td>15/7</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>21.0</td>
<td>-0.60642894 E0 0.59706499 E0</td>
<td>-0.13341274 E0 0.59694559 E0</td>
<td>25/5</td>
<td></td>
</tr>
<tr>
<td>20.0</td>
<td>32.0</td>
<td>-0.22620569 E0 0.49575304 E0</td>
<td>-0.49453221 E0 0.49560149 E0</td>
<td>25/8</td>
<td></td>
</tr>
<tr>
<td>20.0</td>
<td>45.0</td>
<td>-0.22630405 E0 0.49582764 E0</td>
<td>-0.49457044 E0 0.49560149 E0</td>
<td>25/9</td>
<td></td>
</tr>
<tr>
<td>20.0</td>
<td>65.0</td>
<td>-0.22658515 E0 0.49613260 E0</td>
<td>-0.49480670 E0 0.49560149 E0</td>
<td>25/25</td>
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</tr>
<tr>
<td>32.0</td>
<td>45.0</td>
<td>-0.11872069 E0 0.43382895 E0</td>
<td>-0.54240256 E0 0.43373466 E0</td>
<td>22/9</td>
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</tr>
<tr>
<td>(2) 45.0</td>
<td>65.0</td>
<td>NO DATA            NO DATA</td>
<td>-0.56593395 E0 0.37767977 E0</td>
<td>25/5</td>
<td></td>
</tr>
<tr>
<td>(3) 2.5</td>
<td>360.0</td>
<td>NO DATA            NO DATA</td>
<td>-0.58641873 E0</td>
<td>6/3</td>
<td></td>
</tr>
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Table 28. Results of Method of Gauss PODM for Relay-II (Cont'd)

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $\hat{r}_1 + \hat{r}_2$ i.e., $\nu_2 - \nu_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) 21.0</td>
<td>360.0</td>
<td>NO DATA -0.53391142 EO</td>
<td>NO DATA -0.23461233 EO</td>
<td>NO DATA 0.59733711 EO</td>
<td>14/3</td>
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<tr>
<td>(5) 60.0</td>
<td>360.0</td>
<td>NO DATA -0.22604802 EO</td>
<td>NO DATA -0.49460573 EO</td>
<td>NO DATA 0.49560149 EO</td>
<td>25/3</td>
</tr>
</tbody>
</table>

(1) Method of Gauss has two iteration loops (1/2)
(2) Computer halted after fifth iteration of second loop
(3) Computer halted after third iteration of second loop
(4) Computer halted after third iteration of second loop
(5) Computer halted after third iteration of second loop
Table 29. Results of Laplace PODM for OSO-III

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $r_1 - r_2$, i.e., $\hat{v}_2 - \hat{v}_1$ (Degrees)</th>
<th>Computed X Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
<td>11.4</td>
<td>-0.62214854 E0</td>
<td>-0.42083550 E1</td>
<td>-0.18298844 E2</td>
<td>25</td>
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<tr>
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<td></td>
<td>-0.70685743 E0</td>
<td>0.40013314 E0</td>
<td>-0.51534094 E0</td>
<td></td>
</tr>
<tr>
<td>3.8</td>
<td>22.8</td>
<td>-0.12509150 E1</td>
<td>0.81876243 E0</td>
<td>0.26324664 E1</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.70685743 E0</td>
<td>0.40013314 E0</td>
<td>-0.51534094 E0</td>
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</tr>
<tr>
<td>3.8</td>
<td>45.6</td>
<td>0.62338167 E0</td>
<td>-0.97365651 E0</td>
<td>-0.91009868 E1</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.70685743 E0</td>
<td>0.40013314 E0</td>
<td>-0.51534094 E0</td>
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<tr>
<td>11.4</td>
<td>45.6</td>
<td>-0.17521341 E1</td>
<td>0.10642148 E1</td>
<td>0.36921444 E0</td>
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<td>-0.76862972 E0</td>
<td>0.29068616 E0</td>
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<td>22.8</td>
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<td>0.19952538 E0</td>
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<td>0.11781151 E0</td>
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<td>-0.17955487 E1</td>
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<td>-0.77864062 E0</td>
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<td>-0.73672249 E0</td>
<td>0.23126402 E1</td>
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<td>-0.77864062 E0</td>
<td>0.55149247 E-1</td>
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<tr>
<td>22.8</td>
<td>111.6</td>
<td>0.25079742 E1</td>
<td>-0.11870974 E0</td>
<td>0.45458931 E1</td>
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<td>-0.55646495 E0</td>
<td>-0.77864062 E0</td>
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<td>-0.25549497 E0</td>
<td>-0.88905191 E0</td>
<td>0.24948641 E0</td>
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</table>
Table 29. Results of Laplace PODM for OSO-III (Cont'd)

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $r_1 \to r_2$ (Degrees)</th>
<th>Difference $r_3 \to r_1$ (Degrees)</th>
<th>Computed X Dot of Reference Orbit at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot of Reference Orbit at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot of Reference Orbit at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
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<tbody>
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<td>68.4</td>
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<td></td>
<td>0.95421127 E-1</td>
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<td>0.33948553 E0</td>
<td>-0.56191323 E0</td>
<td>18</td>
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<tr>
<td>True Anomaly</td>
<td>Angular Difference $\Delta r = r_3 - r_1$ (Degrees)</td>
<td>Computed X Dot at T2 Reference Orbit (CUL/CUT)</td>
<td>Computed Y Dot at T2 Reference Orbit (CUL/CUT)</td>
<td>Computed Z Dot at T2 Reference Orbit (CUL/CUT)</td>
<td>Number of Iterations</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
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<td>0.58641873 E0</td>
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<td>-0.18628955 E1</td>
<td>0.36820326 E1</td>
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<tr>
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<td>-0.48674037 E-1</td>
<td>0.58641873 E0</td>
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<td>-0.23647739 E5</td>
<td>0.36046111 E5</td>
<td>25</td>
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<td>-0.65562172 E0</td>
<td>-0.48674037 E-1</td>
<td>0.58641873 E0</td>
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<tr>
<td>5.0</td>
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<td>-0.48696044 E0</td>
<td>-0.18666574 E1</td>
<td>0.35635083 E1</td>
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<td>-0.77927626 E-1</td>
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<td>-0.60637538 E0</td>
<td>-0.13383906 E2</td>
<td>0.59694559 E0</td>
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<td>-0.43433233 E0</td>
<td>0.69450731 E0</td>
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<td>-0.49460573 E0</td>
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<td>-0.22604802 E0</td>
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<td>0.49560149 E0</td>
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<td>-0.11873926 E0</td>
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<td>0.37767977 E0</td>
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Table 30. Results of Laplace PODM for Relay-II (Cont'd)

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular $\Delta \zeta$ $\zeta_{1} \rightarrow \zeta_{2}$ (degrees)</th>
<th>Difference $\Delta \zeta$ $\zeta_{3} \rightarrow \zeta_{1}$ (degrees)</th>
<th>Computed $X$ Dot</th>
<th>Computed $Y$ Dot</th>
<th>Computed $Z$ Dot</th>
<th>Number of Iterations</th>
</tr>
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<td>-0.48674037 E-1</td>
<td>0.58641873 E0</td>
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</tr>
<tr>
<td>21.0</td>
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<td>-0.49460573 E0</td>
<td>0.49560149 E0</td>
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Table 31. Results of Double R-Iteration PODM for OSO-III

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $\bar{\mu}_2 - \bar{\mu}_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit $\bar{X}_2$ at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit $\bar{Y}_2$ at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit $\bar{Z}_2$ at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
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Table 31. Results of Double R-Iteration PODM for OSO-III (Cont'd)

<table>
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<tr>
<th>True Anomaly</th>
<th>Angular Difference</th>
<th>Computed X Dot</th>
<th>Computed Y Dot</th>
<th>Computed Z Dot</th>
<th>Number of Iterations</th>
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<tr>
<td></td>
<td>$\tilde{r}_1 + \tilde{r}_2$</td>
<td>$\tilde{r}_3 + \tilde{r}_1$</td>
<td>$\dot{X}$ at $T_2$</td>
<td>$\dot{Y}$ at $T_2$</td>
<td>$\dot{Z}$ at $T_2$</td>
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<tr>
<td></td>
<td>(Degrees)</td>
<td>(Degrees)</td>
<td>(CUL/CUT)</td>
<td>(CUL/CUT)</td>
<td>(CUL/CUT)</td>
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<td>-0.23084489 E0</td>
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(1) Computer halted after twenty-fifth iteration
(2) Computer halted after twenty-fifth iteration
(3) Computer halted after twenty-fifth iteration
Table 32. Results of Double R-Iteration PODM for Relay-II

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $\vec{r}_1 \rightarrow \vec{r}_2$ i.e., $\nu_2 \rightarrow \nu_1$ (Degrees)</th>
<th>Angular Difference $\vec{r}_3 \rightarrow \vec{r}_1$ i.e., $\nu_3 \rightarrow \nu_1$ (Degrees)</th>
<th>Computed X Dot at $T_2$ Reference Orbit (CUL/CUT)</th>
<th>Computed Y Dot at $T_2$ Reference Orbit (CUL/CUT)</th>
<th>Computed Z Dot at $T_2$ Reference Orbit (CUL/CUT)</th>
<th>Number of Iterations</th>
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<td>2.5</td>
<td>1.0</td>
<td>2.5</td>
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<td>NO DATA</td>
<td>-0.48674037 E-1</td>
<td>NO DATA</td>
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<td>2.5</td>
<td>1.0</td>
<td>-0.22604802 E0</td>
<td>-0.49460573 E0</td>
<td>0.49560149 E0</td>
<td>25</td>
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<td>-0.56593395 E0</td>
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Table 32. Results of Double R-Iteration PODM for Relay-II (Cont'd)

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular $\hat{\pi}_1 + \hat{\pi}_2$ i.e., $v_2 - v_1$ (Degrees)</th>
<th>Difference $\hat{\pi}_3 - \hat{\pi}_1$ i.e., $v_3 - v_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-0.34564548E0</td>
<td>0.22778349E-1</td>
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<td>NO DATA</td>
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<td>-0.12068895E-1</td>
<td>0.49560149E0</td>
<td>25</td>
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</tbody>
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(1) Computer halted after twenty-fifth iteration
(2) Computer halted after twenty-fifth iteration
(3) Computer halted after twenty-fifth iteration
(4) Computer halted after twenty-fifth iteration
(5) Computer halted after twenty-fifth iteration
(6) Computer halted after twenty-fifth iteration
(7) Computer halted after twenty-fifth iteration
Table 33. Results of Modified Laplacian PODM for OSO-III

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $\vec{r}_1 - \vec{r}_2$ i.e., $v_2 - v_1$ (Degrees)</th>
<th>Angular Difference $\vec{r}_3 - \vec{r}_1$ i.e., $v_3 - v_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at T2 (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at T2 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at T2 (CUL/CUT)</th>
<th>Number of Iterations</th>
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<tbody>
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Table 33. Results of Modified Laplacian PODM for OSO-III (Cont'd)

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<th>Angular Difference ( \bar{r}_1 \to \bar{r}_2 ) (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at T2 (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at T2 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at T2 (CUL/CUT)</th>
<th>Number of Iterations</th>
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<td>True Anomaly</td>
<td>Angular Difference $\vec{r}_1 - \vec{r}_2$ (Degrees)</td>
<td>Computed X Dot $\vec{r}_3 - \vec{r}_1$ (CUL/CUT)</td>
<td>Computed Y Dot $\vec{r}_3 - \vec{r}_1$ (CUL/CUT)</td>
<td>Computed Z Dot $\vec{r}_3 - \vec{r}_1$ (CUL/CUT)</td>
<td>Number of Iterations</td>
</tr>
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<td>-------------</td>
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<td>True Anomaly</td>
<td>Angular Difference (\tilde{\varphi}_1 \rightarrow \tilde{\varphi}_2) (Degrees)</td>
<td>Difference (\tilde{\varphi}_3 \rightarrow \tilde{\varphi}_1) (Degrees)</td>
<td>Computed X Dot Reference Orbit X Dot at (T_2) (CUL/CUT)</td>
<td>Computed Y Dot Reference Orbit Y Dot at (T_2) (CUL/CUT)</td>
<td>Computed Z Dot Reference Orbit Z Dot at (T_2) (CUL/CUT)</td>
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<td>-0.49460573 E0</td>
<td>0.49560149 E0</td>
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Table 35. Results of R-Iteration PODM for OSO-III

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference $\overline{\varphi}_1 + \overline{\varphi}_2$ (Degrees)</th>
<th>Computed $X$ Dot at $T_2$ (CUL/CUT)</th>
<th>Computed $Y$ Dot at $T_2$ (CUL/CUT)</th>
<th>Computed $Z$ Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
</tr>
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<td>22.8</td>
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<td>0.43304281 E-3</td>
<td>-0.13491177 E0</td>
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Table 35. Results of R-Iteration PODM for OSO-III (Cont'd)

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<th>Angular Difference $\hat{\varphi}_1 \rightarrow \hat{\varphi}_2$ (Degrees)</th>
<th>Difference $\hat{\varphi}_3 \rightarrow \hat{\varphi}_1$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
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<td></td>
<td>0.10841023 E1 E0</td>
<td>-0.14663795 E0 E0</td>
<td>0.15214168 E0 E0</td>
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<td></td>
<td></td>
<td>-0.70685743 E0 E0</td>
<td>0.40013314 E0 E0</td>
<td>-0.51534094 E0 E0</td>
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<tr>
<td>45.6</td>
<td>360.0</td>
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<td>0.26869148 E1 E0</td>
<td>0.61834314 E0 E0</td>
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<td>-0.87135390 E0 E0</td>
<td>-0.23408489 E0 E0</td>
<td>-0.32909258 E0 E0</td>
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(1) Computer halt prior to iteration loop
Table 36. Results of R-Iteration PODM for Relay-II

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular ( \vec{r}_1 + \vec{r}_2 ) i.e., ( \nu_2 - \nu_1 ) (Degrees)</th>
<th>Difference ( \vec{r}_3 + \vec{r}_1 ) i.e., ( \nu_3 - \nu_1 ) (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at T_2 (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at T_2 (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at T_2 (CUL/CUT)</th>
<th>Number of Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>5.0</td>
<td>-0.65536606 E0</td>
<td>-0.49981041 E-1</td>
<td>0.58661809 E0</td>
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<tr>
<td>2.5</td>
<td>10.0</td>
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<td>-0.52202059 E-1</td>
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<tr>
<td>2.5</td>
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<td>-0.54280921 E-1</td>
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<td>-0.86952051 E-1</td>
<td>0.58974413 E0</td>
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### Table 36. Results of R-Iteration PODM for Relay-II (Cont'd)

<table>
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<th>True Anomaly</th>
<th>Angular Difference $\Delta \bar{r}_1$ (Degrees) $\bar{r}_2$ i.e., $v_2 - v_1$</th>
<th>Computed X Dot Reference Orbit X Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
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<tbody>
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<td>-0.48674037 E-1</td>
<td>0.58641873 E0</td>
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<td>-0.23461233 E0</td>
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<td>-0.22604802 E0</td>
<td>-0.49460573 E0</td>
<td>0.49560149 E0</td>
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Table 37. Results of Herrick-Gibbs PODM for OSO-III

<table>
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<tr>
<th>True Anomaly</th>
<th>Angular Difference $\frac{r_1 - r_2}{i.e., v_2 - v_1}$ (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at $T_2$ (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at $T_2$ (CUL/CUT)</th>
<th>Number of Iterations</th>
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<tbody>
<tr>
<td>3.8</td>
<td>11.4</td>
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<td>0.40020864 E0</td>
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Table 37. Results of Herrick-Gibbs PODM for OSO-III (Cont'd)

<table>
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<tr>
<th>True Anomaly</th>
<th>Angular ( \vec{r}_1 \rightarrow \vec{r}_2 ) i.e., ( \nu_2 - \nu_1 ) (Degrees)</th>
<th>Difference ( \vec{r}_3 \rightarrow \vec{r}_1 ) i.e., ( \nu_3 - \nu_1 ) (Degrees)</th>
<th>Computed X Dot Reference Orbit X Dot at ( T_2 ) (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit Y Dot at ( T_2 ) (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit Z Dot at ( T_2 ) (CUL/CUT)</th>
<th>Number of Iterations</th>
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### Table 38. Results of Herrick-Gibbs PODM for Relay-II

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<th>Angular Difference i.e., ( v_3 - v_1 ) (Degrées)</th>
<th>Computed X Dot at T2 (CUL/CUT)</th>
<th>Computed Y Dot at T2 (CUL/CUT)</th>
<th>Computed Z Dot at T2 (CUL/CUT)</th>
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<td>32.0</td>
<td>45.0</td>
<td>-0.11888973 E-1</td>
<td>-0.54230026 E-1</td>
<td>0.43388195 E-1</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.11873926 E-1</td>
<td>-0.54226741 E-1</td>
<td>0.43373466 E-1</td>
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</tr>
<tr>
<td>45.0</td>
<td>65.0</td>
<td>-0.36077449 E-1</td>
<td>-0.56616147 E-1</td>
<td>0.37820133 E-1</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.36527838 E-1</td>
<td>-0.56593395 E-1</td>
<td>0.37767977 E-1</td>
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</tr>
</tbody>
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Table 38. Results of Herrick-Gibbs PODM for Relay-II (Cont'd)

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Angular Difference</th>
<th>Computed X Dot Reference Orbit (CUL/CUT)</th>
<th>Computed Y Dot Reference Orbit (CUL/CUT)</th>
<th>Computed Z Dot Reference Orbit (CUL/CUT)</th>
<th>Number of Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>360.0</td>
<td>-0.67240405 E0</td>
<td>-0.46594379 E-1</td>
<td>0.59939317 E0</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.65562172 E0</td>
<td>-0.48674037 E-1</td>
<td>0.58641873 E0</td>
<td></td>
</tr>
<tr>
<td>21.0</td>
<td>360.0</td>
<td>-0.64066348 E0</td>
<td>-0.23290743 E0</td>
<td>0.68697493 E0</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.53391142 E0</td>
<td>-0.23461233 E0</td>
<td>0.59733711 E0</td>
<td></td>
</tr>
<tr>
<td>60.0</td>
<td>360.0</td>
<td>-0.43829390 E0</td>
<td>-0.50943763 E0</td>
<td>0.68517316 E0</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.22604802 E0</td>
<td>-0.49460573 E0</td>
<td>0.49560149 E0</td>
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(1) No iteration loop exists
Table 39. Computation Results from Trilateration PODM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OSO-III</th>
<th>RELAY-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computed X-Dot</td>
<td>-0.77396768 E0</td>
<td>-0.65232511 E-1</td>
</tr>
<tr>
<td>Reference Orbit X-Dot</td>
<td>-0.77269578 E0</td>
<td>-0.35627838 E-1</td>
</tr>
<tr>
<td>Computed Y-Dot</td>
<td>-0.53944807 E0</td>
<td>-0.58262553 E0</td>
</tr>
<tr>
<td>Reference Orbit Y-Dot</td>
<td>-0.54884506 E0</td>
<td>-0.56593395 E0</td>
</tr>
<tr>
<td>Computed Z-Dot</td>
<td>-0.13339736 E0</td>
<td>0.36304436 E0</td>
</tr>
<tr>
<td>Reference Orbit Z-Dot</td>
<td>-0.14805021 E0</td>
<td>0.37767977 E0</td>
</tr>
<tr>
<td>Computed Semimajor Axis</td>
<td>0.10715168 E1</td>
<td>0.17798733 E1</td>
</tr>
<tr>
<td>Reference Orbit Semimajor Axis</td>
<td>0.10866609 E1</td>
<td>0.17448736 E1</td>
</tr>
<tr>
<td>Computed Eccentricity</td>
<td>0.13944822 E-1</td>
<td>0.24677798 E0</td>
</tr>
<tr>
<td>Reference Orbit Eccentricity</td>
<td>0.21640595 E-2</td>
<td>0.24114781 E0</td>
</tr>
<tr>
<td>Computed Longitude of Ascending Node</td>
<td>-0.23098294 E1</td>
<td>0.21387843 E1</td>
</tr>
<tr>
<td>Reference Orbit Longitude of Ascending Node</td>
<td>-0.22460589 E1</td>
<td>0.22064792 E1</td>
</tr>
<tr>
<td>Computed Orbit Inclination</td>
<td>0.56873906 E0</td>
<td>0.77806829 E0</td>
</tr>
<tr>
<td>Reference Orbit Orbit Inclination</td>
<td>0.57356194 E0</td>
<td>0.80848228 E0</td>
</tr>
<tr>
<td>Computed Argument of Perigee</td>
<td>-0.48379221 E1</td>
<td>-0.11822875 E1</td>
</tr>
<tr>
<td>Reference Orbit Argument of Perigee</td>
<td>-0.34856807 E1</td>
<td>-0.13234053 E1</td>
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Table 40. Angles Only and Mixed Data PODM Classical Orbital Element Comparisons - Semimajor Axis

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Method of Gauss (Angles Only)</th>
<th>Laplace (Angles Only)</th>
<th>Double-R Iteration (Angles Only)</th>
<th>Modified Laplacian (Mixed Data)</th>
<th>R-Iteration (Mixed Data)</th>
<th>Herrick-Gibbs (Mixed Data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{t}_1) + ( \bar{t}_2) (\bar{t}_3) - (\bar{t}_1) (Degrees)</td>
<td>(\bar{t}_1) + (\bar{t}_3) (\bar{t}_3) - (\bar{t}_1) (Degrees)</td>
<td>(Angles Only)</td>
<td>(Angles Only)</td>
<td>(Mixed Data)</td>
<td>(Mixed Data)</td>
<td>(Mixed Data)</td>
</tr>
<tr>
<td>3.8</td>
<td>11.4</td>
<td>1.0933545</td>
<td>No Data</td>
<td>0.55680724</td>
<td>1.4565199</td>
<td>1.2706987</td>
</tr>
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<td>22.8</td>
<td>1.0870821</td>
<td>No Data</td>
<td>0.76012870</td>
<td>1.6411056</td>
<td>1.5309293</td>
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<td>45.6</td>
<td>1.0862247</td>
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<td>0.77258918</td>
<td>1.6740630</td>
<td>2.0096861</td>
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<td>45.6</td>
<td>1.0849989</td>
<td>No Data</td>
<td>3.4145947</td>
<td>3.2250124</td>
<td>1.6797845</td>
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<tr>
<td>22.8</td>
<td>68.4</td>
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<td>No Data</td>
<td>0.9742429</td>
<td>No Data</td>
<td>No Data</td>
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<td>111.6</td>
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<td>No Data</td>
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<td>No Data</td>
<td>1.0992819</td>
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<td>111.6</td>
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<td>No Data</td>
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<td>1.6703803</td>
<td>1.0261115</td>
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<td>No Data</td>
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<td>No Data</td>
<td>No Data</td>
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</table>

Nominal semimajor axis from reference orbit (Earth Radii)
1.0866609 for OSO-III

Nominal semimajor axis from reference orbit (Earth Radii)
1.7448736 for RELAY-II
Table 41. Angles Only and Mixed Data PODM Classical Orbital Element Comparisons - Eccentricity

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Method of Gauss (Angles Only)</th>
<th>Laplace (Angles Only)</th>
<th>Double-R Iteration (Angles Only)</th>
<th>Modified Laplacian (Mixed Data)</th>
<th>R-Iteration (Mixed Data)</th>
<th>Herrick-Gibbs (Mixed Data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau \rightarrow \bar{r}$</td>
<td>i.e., $\psi_2 - \psi_1$ (Degrees)</td>
<td>$\bar{r} \rightarrow \bar{r}$</td>
<td>$\psi_3 - \psi_1$ (Degrees)</td>
<td>$\phi$ (Degrees)</td>
<td>$\dot{\phi}$ (Degrees)</td>
<td>$\dot{\psi}_2$ (Degrees)</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>0.26042608</td>
<td>0.16855448</td>
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<td>22.8</td>
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<td>No Data</td>
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<td>0.35348243</td>
<td>0.31165306</td>
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<td>45.6</td>
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<td>0.37236123</td>
<td>0.47077550</td>
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<td>0.9688166</td>
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</tr>
<tr>
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<td>0.62995502</td>
<td>0.0059085738</td>
<td>0.67259723</td>
<td>No Data</td>
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<tr>
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<td>68.4</td>
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<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
</tr>
<tr>
<td>22.8</td>
<td>111.6</td>
<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
</tr>
<tr>
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<td>0.0054796699</td>
<td>No Data</td>
<td>0.92855803</td>
<td>0.37632616</td>
<td>0.37632616</td>
</tr>
<tr>
<td>68.4</td>
<td>111.6</td>
<td>0.33483581</td>
<td>0.65056730</td>
<td>0.97721692</td>
<td>0.97721692</td>
<td>0.29548092</td>
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<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
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<tr>
<td>45.6</td>
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<td>0.65056730</td>
<td>0.97721692</td>
<td>0.97721692</td>
<td>No Data</td>
</tr>
</tbody>
</table>

Nominal eccentricity from reference orbit
0.0021640595 for OSO-III

| 2.5 | 5.0 | 0.23998301 | 0.42608590 | No Data | No Data | 0.24135718 | 0.24112274 |
| 2.5 | 10.0 | 0.24170341 | No Data | No Data | No Data | 0.24305787 | 0.24150217 |
| 2.5 | 21.0 | 0.24191983 | No Data | 0.54264214 | No Data | 0.24721999 | 0.24161043 |
| 5.0 | 21.0 | 0.24134923 | No Data | No Data | No Data | 0.25052518 | 0.24107510 |
| 10.0 | 21.0 | 0.24138999 | No Data | No Data | No Data | 0.24819047 | 0.24096335 |
| 20.0 | 32.0 | 0.24083358 | 0.29548092 | 0.12926246 | 0.75155324 | 0.44973306 | 0.24069890 |
| 20.0 | 45.0 | 0.24088657 | 0.12926246 | 0.54264214 | 0.75155324 | 0.44973306 | 0.24080103 |
| 20.0 | 65.0 | 0.24095068 | 0.94594361 | 0.85163884 | 0.42517904 | 0.86390255 | 0.24071615 |
| 32.0 | 45.0 | 0.24043689 | 0.37710462 | No Data | No Data | 0.37710462 | 0.52988183 |
| 45.0 | 65.0 | No Data | No Data | No Data | No Data | 0.98400947 | 0.28042783 |
| 2.5 | 360.0 | No Data | No Data | No Data | No Data | 0.98400947 | 0.032882344 |
| 21.0 | 360.0 | No Data | No Data | No Data | No Data | 0.98400947 | 0.032882344 |
| 60.0 | 360.0 | No Data | No Data | No Data | No Data | 0.98400947 | 0.032882344 |

Nominal eccentricity from reference orbit
0.24114781 for RELAY-II
Table 42. Angles Only and Mixed Data PODM Classical Orbital Element Comparisons -
Longitude of Ascending Node

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Method of Gauss (Angles Only)</th>
<th>Laplace (Angles Only)</th>
<th>Double-R Iteration (Angles Only)</th>
<th>Modified Laplacian (Mixed Data)</th>
<th>R-Iteration (Mixed Data)</th>
<th>Herrick-Gibbs (Mixed Data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{r}_1 + \tilde{r}_2$</td>
<td>$\tilde{r}_1 + \tilde{r}_3$</td>
<td>$\tilde{v}_1 - \tilde{v}_1$</td>
<td>$\tilde{v}_3 - \tilde{v}_1$</td>
<td>(Degrees)</td>
<td>(Degrees)</td>
<td>(Degrees)</td>
</tr>
<tr>
<td>i.e., $\dot{v}_2 - \dot{v}_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal longitude of ascending node from reference orbit</td>
<td>Nominal 1 on i titude of ascending node from reference orbit</td>
<td>2.2460589 (radians) for OSO-III</td>
<td>2.2064792 (radians) for RELAY-II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>11.4</td>
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<td>-2.2666136</td>
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<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
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<tr>
<td>22.8</td>
<td>111.6</td>
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<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
<td>No Data</td>
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<tr>
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<td>No Data</td>
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<td>No Data</td>
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<tr>
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<td>-2.2781742</td>
<td>2.1237891</td>
<td>2.2786043</td>
</tr>
</tbody>
</table>

Nominal longitude of ascending node from reference orbit
-2.2460589 (radians) for OSO-III
2.2064792 (radians) for RELAY-II
Table 43. Angles Only and Mixed Data PODM Classical Orbital Element Comparisons - Argument of Perigee

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Method of Gauss (Angles Only)</th>
<th>Laplace (Angles Only)</th>
<th>Double-R Iteration (Angles Only)</th>
<th>Modified Laplacian (Mixed Data)</th>
<th>R-Iteration (Mixed Data)</th>
<th>Herrick-Gibbs (Mixed Data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_1 + r_2$</td>
<td>$r_1 + r_3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i.e., $v_2 - v_1$ (Degrees)</td>
<td>$v_3 - v_1$ (Degrees)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal argument of perigee from reference orbit -3.4856807 (radians) for OSO-III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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<td>-3.3619857</td>
<td>-3.6361456</td>
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</tr>
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Table 44. Angles Only and Mixed Data PODM Classical Orbital Element Comparisons - Orbit Inclination

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<tr>
<th>True Anomaly</th>
<th>Method of Gauss (Angles Only)</th>
<th>Laplace (Angles Only)</th>
<th>Double-R Iteration (Angles Only)</th>
<th>Modified Laplacian (Mixed Data)</th>
<th>R-Iteration (Mixed Data)</th>
<th>Herrick-Gibbs (Mixed Data)</th>
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<tbody>
<tr>
<td>$\mathbf{r}_1 \rightarrow \mathbf{r}_2$ i.e., $v_2 - v_1$ (Degrees)</td>
<td>$\mathbf{r}_1 \rightarrow \mathbf{r}_3$ $v_3 - v_1$ (Degrees)</td>
<td>Gauss (Angles Only)</td>
<td>Laplace (Angles Only)</td>
<td>Double-R Iteration (Angles Only)</td>
<td>Modified Laplacian (Mixed Data)</td>
<td>R-Iteration (Mixed Data)</td>
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Nominal orbital inclination from reference orbit:
0.57356194 (radians) for OSO-III

<table>
<thead>
<tr>
<th>True Anomaly</th>
<th>Method of Gauss (Angles Only)</th>
<th>Laplace (Angles Only)</th>
<th>Double-R Iteration (Angles Only)</th>
<th>Modified Laplacian (Mixed Data)</th>
<th>R-Iteration (Mixed Data)</th>
<th>Herrick-Gibbs (Mixed Data)</th>
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No data indicates program failed in computing these values.
Table 45. Average Number of Iterations Using Both OSO-III and Relay-II Orbit Results

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<th>PODM</th>
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<td>Double R-Iteration</td>
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<td>Modified Laplacian</td>
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<td>25</td>
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<tr>
<td>R-Iteration</td>
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<tr>
<td>Herrick-Gibbs</td>
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<td>18</td>
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<td>Trilateration</td>
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*Two Iteration loops

Table 46. Best Overall Results for Radius Vector Spread to 360°

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<th>Radius Vector Spread</th>
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<td>65° &lt; v &lt; 360°</td>
<td>Herrick-Gibbs</td>
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<td>30° &lt; v &lt; 65°</td>
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<td>Double R-Iteration</td>
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<td>Laplace</td>
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Table 47. Considerations for Selecting Optimum PODM

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<th>PODM</th>
<th>Computation Time</th>
<th>Ease of Convergence</th>
<th>Best Overall Accuracy</th>
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REFERENCES


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—National Aeronautics and Space Act of 1958

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