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DEVELOPMENT OF FINITE ELEMENT MODELS FOR THE EARTH'S GRAVITY FI--ETC(U)
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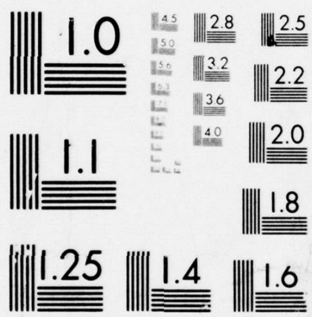
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University of Virginia

Charlottesville, Virginia 22901

DEVELOPMENT OF FINITE ELEMENT MODELS FOR THE EARTH'S GRAVITY FIELD

PHASE II: FINE STRUCTURE DISTURBANCE GRAVITY REPRESENTATIONS

Submitted to:

Computer Science Laboratory
U. S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

March 1977

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Final Report

DEVELOPMENT OF FINITE ELEMENT MODELS FOR THE EARTH'S GRAVITY FIELD

PHASE II: FINE STRUCTURE DISTURBANCE GRAVITY REPRESENTATIONS

Contract No. DAAG 53-76-C-0067

Submitted to:

Computer Science Laboratory
Code 82000
U. S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

Submitted by:

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Associate Professor

John T. Saunders
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Report No. UVA/525023/ESS77/104

March 1977

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1.0 SUMMARY

This research and development effort has obtained the following results:

- Software suitable for the construction of finite element gravity disturbance fields has been developed.
- Software suitable for calculation of the gravity disturbance model within finite element fields has been developed.
- Example finite element gravity disturbance fields have been developed and tested.

2.0 PREFACE

This report constitutes the final report of Phase II of Contract No. DAAG-53-76-C-0067 performed by the University of Virginia for the U. S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia, under the sponsorship of the Defense Mapping Agency. The Phase II effort is concerned with representing local fine structure gravity by locally valid (finite element) gravity functions. The Phase I effort, documented in Reference (1), deals with replacing globally valid gravity representations (such as spherical harmonic series) by an equivalent family of locally valid gravity functions. The Phase I effort yielded a macro gravity model suitable for high speed satellite orbit integration. The Phase II effort (documented herein) yielded fine structure gravity representations for efficient disturbance acceleration calculation (to use, for example, in inertial guidance equations).

The authors appreciate the technical inputs of Mr. L. A. Gambino (technical monitor), Dr. R. W. Ballew, Mr. H. W. Howard, and Mr. B. L. Decker.

3.0 INTRODUCTION

The finite element concept may be considered as an extension to three dimensions of one dimensional piecewise approximation techniques. Some quantity that is functionally related in a "complicated" fashion to position over a "large" interval may be replaced for much "smaller" intervals of position with much "less complicated" approximating functions. Thus the complicated function, which will normally be "more expensive" to evaluate, will have been replaced by a set of locally valid functions which will normally be "less expensive" to evaluate.

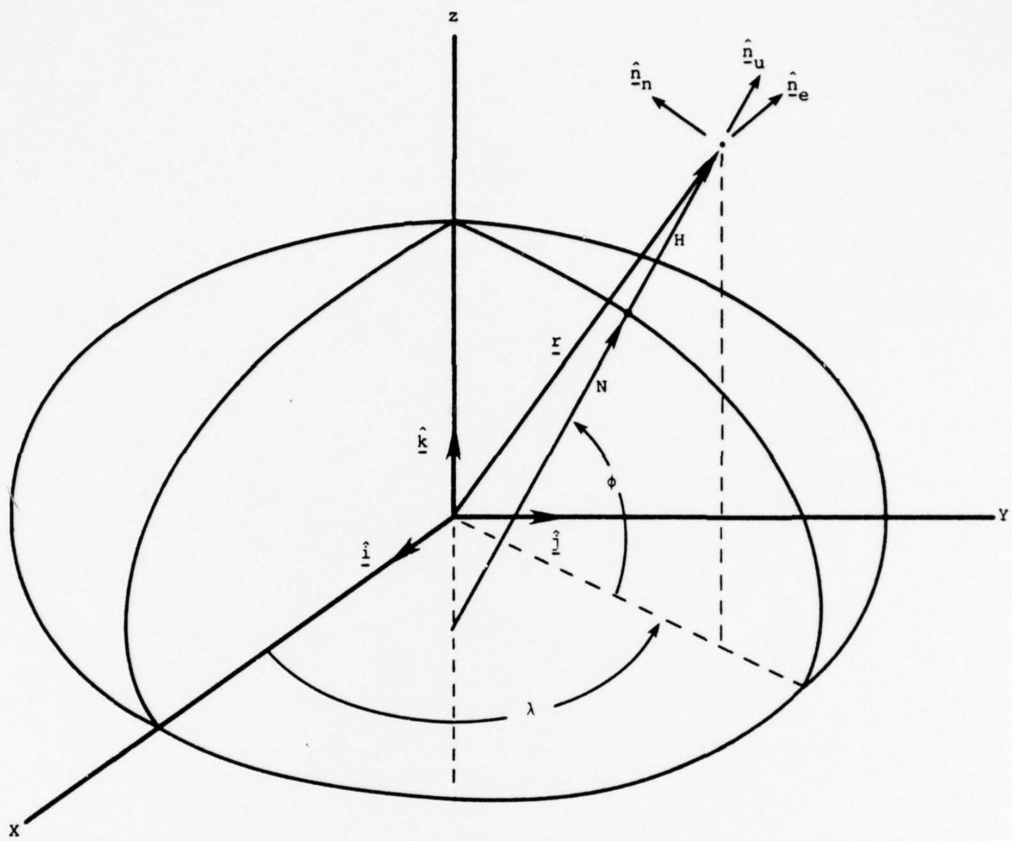
The idea may easily be extended to three dimensions. A quantity which is functionally related to position over some large region may be replaced by a set of approximations which are valid only in small volumes of the large region, but which are easier (faster computationally) to evaluate. The finite element concept may be applied to any of a variety of modeling problems; this investigation centered specifically on fine structure gravity modeling.

Previously, earth-fixed spherical coordinate based finite element fields have been successfully used to replace globally valid spherical harmonic representations of the geopotential and its derivatives. But because the model used to simulate gravity disturbance data (Model 310) consists of a set of point masses placed in relation to the Geodetic Reference Surface of 1967, geodetic coordinates (H, λ, ϕ - see Figure 1) were used in the finite element modeling process.

Finite element fields may be defined with geodetic coordinates as shown in Figure 2. The region to be modeled is defined by a set of maximum bounds (H_{max}, λ_{max}, ϕ_{max}) and a set of minimum bounds (H_{min}, λ_{min}, ϕ_{min}). The region is then divided into a set of smaller volumes, or finite element cells, where each cell has dimensions H_{cell}, λ_{cell}, ϕ_{cell}. Thus the 300 km × 10° × 10° region above the reference ellipsoid,

altitude 0 - 300 km,
longitude 70°E - 80°E, and
latitude 25°S - 35°S,

could be modeled by one hundred (100) cells each 300 km × 1° × 1° or four (4) cells each 300 km × 5° × 5° or one cell 300 km × 10° × 10°, etc.



$$\begin{Bmatrix} \hat{\underline{i}} \\ \hat{\underline{j}} \\ \hat{\underline{k}} \end{Bmatrix} = \text{earth-fixed unit vectors}$$

$$\begin{Bmatrix} \hat{\underline{n}}_u \\ \hat{\underline{n}}_e \\ \hat{\underline{n}}_n \end{Bmatrix} = \text{instantaneous up, east, and north unit vectors.}$$

$$\begin{Bmatrix} \hat{\underline{n}}_u \\ \hat{\underline{n}}_e \\ \hat{\underline{n}}_n \end{Bmatrix} = \begin{bmatrix} \cos\phi\cos\lambda & \cos\phi\sin\lambda & \sin\phi \\ -\sin\lambda & \cos\lambda & 0 \\ -\sin\phi\cos\lambda & -\sin\phi\sin\lambda & \cos\phi \end{bmatrix} \begin{Bmatrix} \hat{\underline{i}} \\ \hat{\underline{j}} \\ \hat{\underline{k}} \end{Bmatrix}$$

Figure 1 Earth-Fixed Rectangular and Geodetic Coordinate Systems.

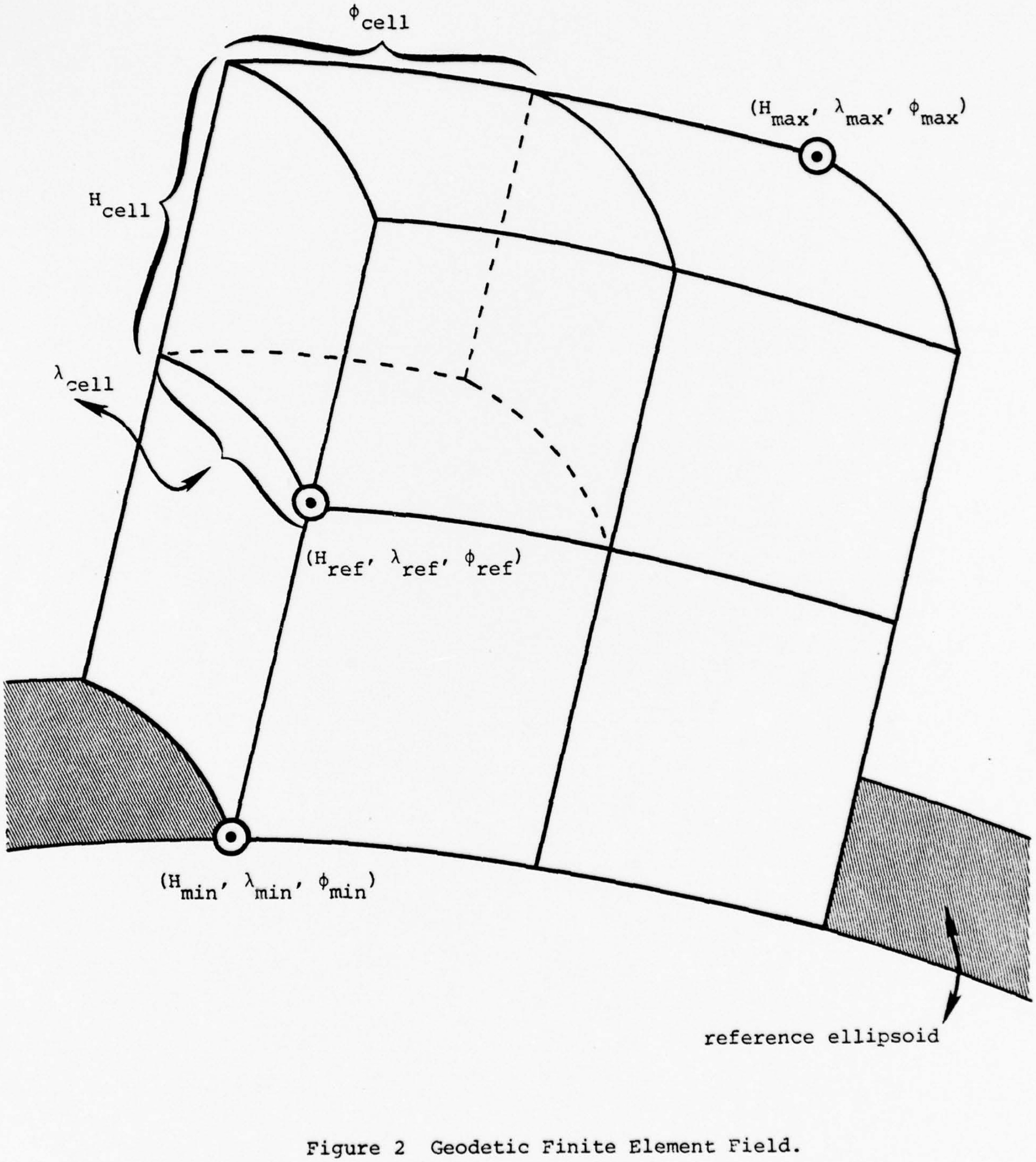


Figure 2 Geodetic Finite Element Field.

The approximation valid in any one cell is generated independentally of the approximation for any other cell. A set of gravity disturbance "observations" are produced for each cell directly from Model 310 and then approximated for only that cell in a least squares fitting process. The approximating models thus generated are then stored on a high speed rotating mass storage device for later use in the computation of the approximate gravity disturbance in any finite element cell of the region modeled.

4.0 FINITE ELEMENT FORMULATION

Define the gravity disturbance, $\delta\underline{g}$:

$$\underline{g}_{actual} = \underline{g}_{reference} + \delta\underline{g} \tag{1}$$

$$\delta\underline{g} = \begin{Bmatrix} \delta g_{up} \\ \delta g_{east} \\ \delta g_{north} \end{Bmatrix} = \underline{g}_{actual} - \underline{g}_{reference} \tag{2}$$

Now, replace the components of $\delta\underline{g}$ with locally valid Chebyshev polynomial approximations, $\delta\underline{G}$, of the form,

$$\delta\underline{G} = \begin{Bmatrix} G_{up} \\ G_{east} \\ G_{north} \end{Bmatrix} \approx \sum_{n=0}^{N} \sum_{i=0}^{n} \sum_{j=0}^{n-i} \begin{Bmatrix} C_{up_{ijk}} \\ C_{east_{ijk}} \\ C_{north_{ijk}} \end{Bmatrix} T_i(X_1) T_j(X_2) T_k(X_3) \tag{3}$$

where,

N = NORDER = the highest order Chebyshev polynomials,

$k = n - i - j$

$$X_1 = (H - H_{ref})/H_{cell}$$
$$X_2 = (\lambda - \lambda_{ref})/\lambda_{cell} \tag{4}$$
$$X_3 = (\phi - \phi_{ref})/\phi_{cell}$$

$T_n(X)$ = shifted Chebyshev polynomials, and

$C_{up_{ijk}}$, $C_{east_{ijk}}$, and $C_{north_{ijk}}$ are constant coefficients determined via least square fits so that $\sum_{i=1}^{m} (\delta G_{up} - \delta g_{up})_i^2$, $\sum_{i=1}^{m} (\delta G_{east} - \delta g_{east})_i^2$, and $\sum_{i=1}^{m} (\delta G_{north} - \delta g_{north})_i^2$ are minimized for some local volume of space (i.e. the cell being modeled).

Chebyshev polynomials, $t_n(X)$, of order n may be generated:

n	$t_n(X)$
0	1
1	X
2	$2X^2 - 1$

For $n \geq 2$, a recursion may be used:

$$t_n(X) = 2X\, t_{n-1}(X) - t_{n-2}(X), \qquad -1 \leq X \leq 1 \tag{5}$$

Shifted Chebyshev polynomials, $T_n(\bar{X})$ may be computed by substituting

$$X = 2\bar{X} - 1$$

so that,

$$T_n(\bar{X}) = t_n(X) = t_n(2\bar{X} - 1), \qquad 0 \leq \bar{X} \leq 1 \tag{6}$$

To generate shifted Chebyshev polynomials a set of X's with values between 0 and 1 are needed. The difference between some point (H,λ,ϕ) in a cell and a reference point $(H_{ref},\lambda_{ref},\phi_{ref})$ (the "lowermost corner" of the cell) is divided by the cell's dimensions, H_{cell}, λ_{cell}, ϕ_{cell}, as in (4) to obtain a set of non-dimensional coordinates, X_1, X_2, X_3, for each cell. The non-dimensional coordinates may then be used to generate the shifted Chebyshev polynomials.

To determine the three sets of constant coefficients, C_{up}, C_{east}, and C_{north}, for each cell, formulate and solve the linear least squares problems,

$$\begin{aligned} ||\delta G_{up} - \delta g_{up}|| &= ||AC_{up} - \delta g_{up}|| = \min. \\ ||\delta G_{east} - \delta g_{east}|| &= ||AC_{east} - \delta g_{east}|| = \min. \\ ||\delta G_{north} - \delta g_{north}|| &= ||AC_{north} - \delta g_{north}|| = \min. \end{aligned} \tag{7}$$

where the coefficient matrix, A, has the form,

$$A = \begin{bmatrix} 1 & T_1(X_{3_1}) & T_1(X_{2_1}) & T_1(X_{1_1}) & T_2(X_{3_1}) & T_1(X_{3_1})T_1(X_{2_1}) \cdots \\ 1 & T_1(X_{3_2}) & T_1(X_{2_2}) & T_1(X_{1_2}) & T_2(X_{3_2}) & T_1(X_{3_2})T_1(X_{2_2}) \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \quad \ddots \\ 1 & T_1(X_{3_m}) & T_1(X_{2_m}) & T_1(X_{1_m}) & T_2(X_{3_m}) & T_1(X_{3_m})T_1(X_{2_m}) \cdots \end{bmatrix} \tag{8}$$

and the three coefficient vectors, C_{up}, C_{east}, and C_{north}, have the form

$$C_{up} = \begin{Bmatrix} C_{up_{000}} \\ C_{up_{001}} \\ C_{up_{010}} \\ C_{up_{100}} \\ C_{up_{002}} \\ C_{up_{011}} \\ \vdots \\ C_{up_{N00}} \end{Bmatrix}, \quad C_{east} = \begin{Bmatrix} C_{east_{000}} \\ C_{east_{001}} \\ C_{east_{010}} \\ C_{east_{100}} \\ C_{east_{002}} \\ C_{east_{011}} \\ \vdots \\ C_{east_{N00}} \end{Bmatrix}, \quad C_{north} = \begin{Bmatrix} C_{north_{000}} \\ C_{north_{001}} \\ C_{north_{010}} \\ C_{north_{100}} \\ C_{north_{002}} \\ C_{north_{011}} \\ \vdots \\ C_{north_{N00}} \end{Bmatrix} \tag{9}$$

where

N = NORDER,

and the three sets of gravity disturbance observations, δg_{up}, δg_{east}, and δg_{north}, are

$$\delta g_{up} = \begin{Bmatrix} \delta g_{up}(X_{1_1}, X_{2_1}, X_{3_1}) \\ \delta g_{up}(X_{1_2}, X_{2_2}, X_{3_2}) \\ \delta g_{up}(X_{1_3}, X_{2_3}, X_{3_3}) \\ \vdots \\ \delta g_{up}(X_{1_m}, X_{2_m}, X_{3_m}) \end{Bmatrix} \quad \delta g_{east} = \begin{Bmatrix} \delta g_{east}(X_{1_1}, X_{2_1}, X_{3_1}) \\ \delta g_{east}(X_{1_2}, X_{2_2}, X_{3_2}) \\ \delta g_{east}(X_{1_3}, X_{2_3}, X_{3_3}) \\ \vdots \\ \delta g_{east}(X_{1_m}, X_{2_m}, X_{3_m}) \end{Bmatrix}$$

$$\delta g_{north} = \begin{Bmatrix} \delta g_{north}(X_{1_1}, X_{2_1}, X_{3_1}) \\ \delta g_{north}(X_{1_2}, X_{2_2}, X_{3_2}) \\ \delta g_{north}(X_{1_3}, X_{2_3}, X_{3_3}) \\ \vdots \\ \delta g_{north}(X_{1_m}, X_{2_m}, X_{3_m}) \end{Bmatrix} \tag{10}$$

where $\{(X_{1_i}, X_{2_i}, X_{3_i}),\ i = 1, 2, \ldots, m\}$ = a specified set of (H_i, λ_i, ϕ_i) coordinates - usually a uniform observation grid in any one cell. The gravity disturbance observations are determined directly from Model 310 evaluations on the observation grid in each cell.

4.1 Discussion

Certain aspects of the process by which finite element fields are created may be capitalized on under special circumstances. When it is known beforehand that uniformly gridded gravity disturbance observations will be available, only one least squares matrix (A matrix) need be generated. This is true because the set of non-dimensional coordinates, $\{(X_{1_i}, X_{2_i}, X_{3_i}),\ i = 1, 2, \ldots, m\}$ of one cell's observation grid will be the same as every other cell's non-dimensional observation grid coordinates when the observation grid pattern is set for all cells. If the same number of observations are made in each cell and the positions of the observations points are the same relative to the reference point (H_{ref}, λ_{ref}, ϕ_{ref}) in each cell, then all cells will have the same A matrix. The A matrix, after all, consists only of products of Chebyshev polynomials, which are functions only of the non-dimensional coordinates of the observation points.

This all means that only one A-matrix need be generated for the first cell of a finite element field; but the gravity observations must be generated for each cell. A reduction of the A-matrix to upper triangular form may be performed for the least squares fitting process, after which each set of observations may be similarly reduced and then back-substituted to produce a set of coefficients for each cell. The A-matrix, again, needs to be reduced only once.

It should be noted that this method of finite element field generation does not rely on Model 310 or any other particular gravity disturbance model. Model 310 could be replaced by any other process that is capable of producing the gravity disturbance observations at the observation grid points of each cell.

Once a finite element field has been created, the Chebyshev polynomial gravity disturbance approximation $\delta \underline{G}$ may be computed by evaluating (3).

The subscripts ijk always follow the same pattern for a given NORDER. This means that a "current coefficient number", ℓ, may be attached to each group of subscripts ijk <u>and</u> that the total number of coefficients, NC, necessary to model any one component of the gravity disturbance in one cell will be constant for a given NORDER. Table 1 shows these relationships for various NORDER's.

Since we can precompute and save the subscripts, ijk, in the appropriate pattern such that they are functions of only the current coefficient number, ℓ, (3) can be written,

$$\delta \underline{G} = \begin{Bmatrix} \delta G_{up} \\ \delta G_{east} \\ \delta G_{north} \end{Bmatrix} = \sum_{\ell=1}^{NC} \begin{Bmatrix} C_{up_\ell} \\ C_{east_\ell} \\ C_{north_\ell} \end{Bmatrix} T_i({}_1) T_j(X_2) T_k(X_3) \qquad (11)$$

where,

NC = the total number of coefficients for one component of the gravity disturbance, as above

ijk = precomputed and saved as functions of ℓ

X_1, X_2, X_3 = functions of H, λ, ϕ and the constants H_{ref}, λ_{ref}, ϕ_{ref}, H_{cell}, λ_{cell}, ϕ_{cell} as in (4) above. The total number of summations in (11) is the same as in (3) but the amount of bookkeeping has been cut down tremendously by doing business in this fashion. Computational savings of up to 50% were obtained by using (11) in lieu of (3) for evaluation purposes. Table 1 was also used in the generation of the A matrix, but the saving here is not as significant due to the previously discussed fact that the A matrix is only generated once.

NORDER	ijk	ℓ	NC
0	0 0 0	1	1
1	0 0 1	2	
	0 1 0	3	
	1 0 0	4	4
2	0 0 2	5	
	0 1 1	6	
	0 2 0	7	
	1 0 1	8	
	1 1 0	9	
	2 0 0	10	10
3	0 0 3	11	
	0 1 2	12	
	⋮ ⋮ ⋮	⋮	
	3 0 0	20	20
⋮	⋮ ⋮ ⋮	⋮	⋮
N	0 0 N	·	
	0 1 N-1	·	
	⋮ ⋮ ⋮	⋮	
	N 0 0	NC	$\sum_{n=1}^{N+1}\left(\sum_{m=1}^{n} m\right)$

Table 1 Subscript Patterns for Various NORDER's.

5.0 DISCUSSION OF SOFTWARE

A variety of FORTRAN programs and subroutines were written during the course of this research effort. The creation of finite element gravity disturbance fields may be accomplished by the execution of PROGRAM LOCALG followed by the execution of PROGRAM FINEG. Once a finite element field has been generated, the gravity disturbance approximation may be calculated at any point in the finite element field by SUBROUTINE FINITE. To calculate the gravity disturbance from the mass points of Model 310, SUBROUTINE PTMASS was written. SUBROUTINE PTMASS was used both to produce observations for the least squares fitting process and to produce observations to test against for error analyses of finite element fields. Because SUBROUTINE PTMASS required the precomputed products of each point mass and the gravitational constant and the earth-fixed Cartesian coordinates of each point mass of Model 310, another small program, PROGRAM MASPOS, was written to calculate and store these quantities.

PROGRAM LOCALG requires input from the user which defines the finite element field to be generated. It writes the coefficient matrix (A matrix) and a set of gravity disturbance observations for each cell of the finite element field onto a magnetic tape (TAPE 3 - this may be any sequential mass storage device) for later use by PROGRAM FINEG. PROGRAM LOCALG is the first part of the local gravity disturbance modeling process. Figure 3 shows the logic flow for PROGRAM LOCALG.

The second part of the local gravity disturbance modeling process - the reduction of the A matrix and the calculation of the fine structure gravity model coefficients (9) - is accomplished by PROGRAM FINEG. PROGRAM FINEG reads the A matrix and observation from the magnetic tape (really, sequential file) created by PROGRAM LOCALG. PROGRAM FINEG reduces the A matrix and calculates each cell's model coefficients in a least squares reduction. The model coefficients are written onto a random access file (preferably a high speed disk file but any high speed mass storage random access file could be used). The logic flow for PROGRAM FINEG is shown in Figure 4.

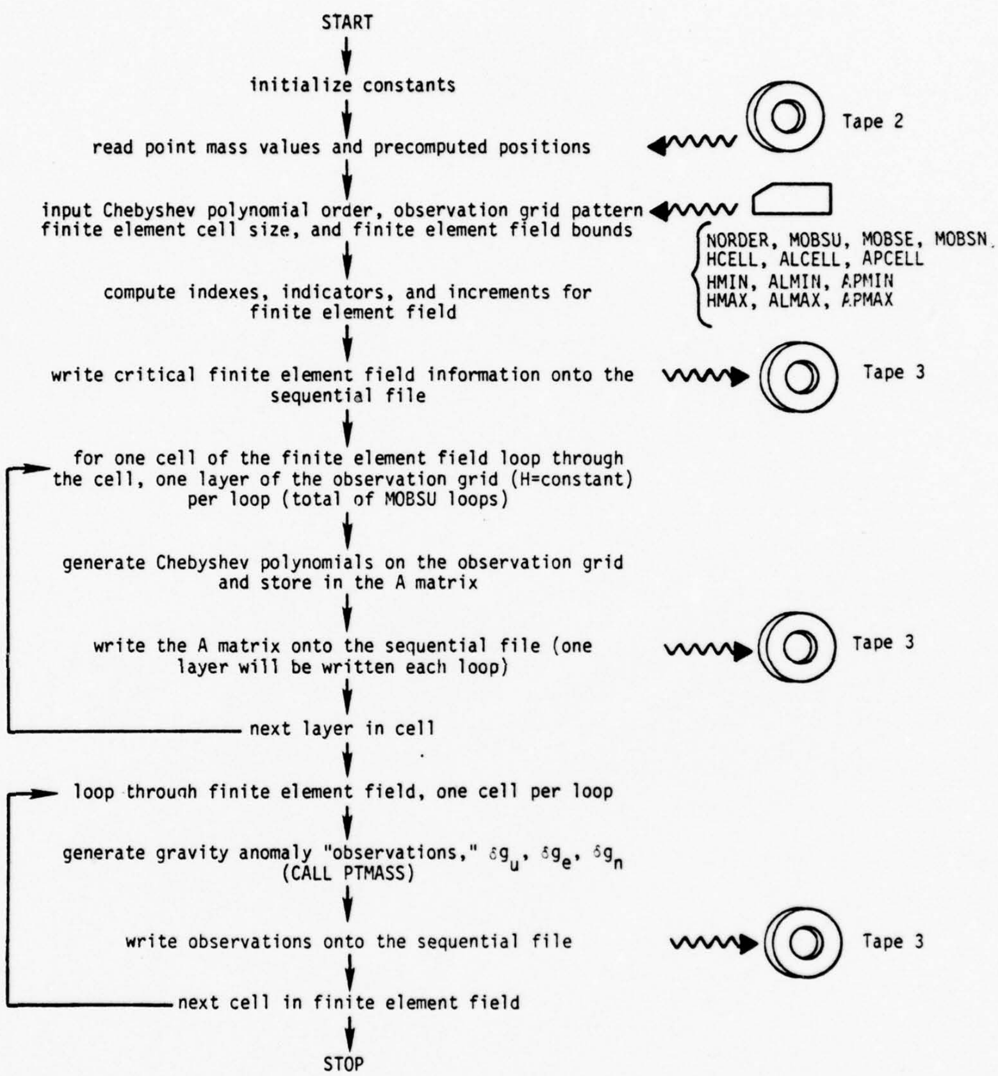


Figure 3 PROGRAM LOCALG Logic Flow.

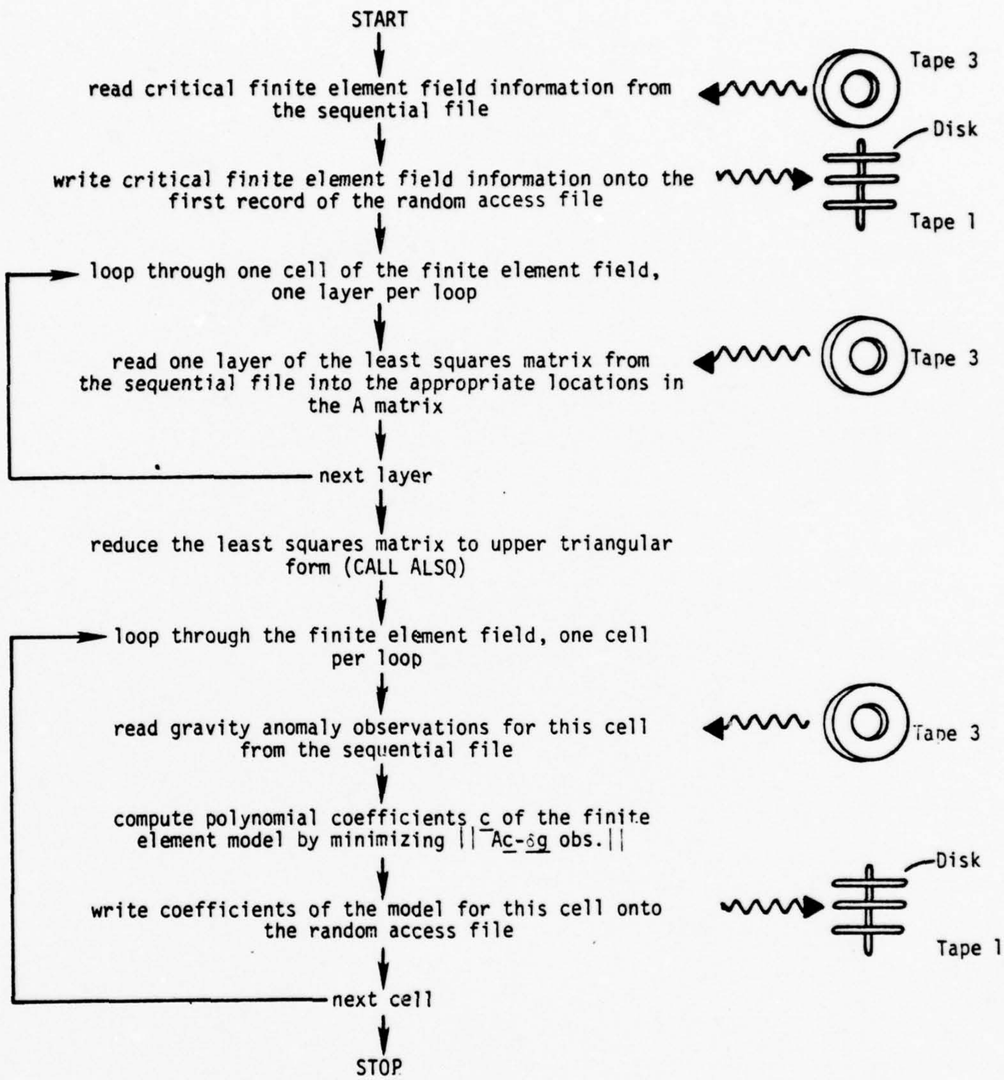


Figure 4 PROGRAM FINEG Logic Flow.

SUBROUTINE FINITE evaluates (11) above at some point (H,λ,ϕ). Using the sets of finite element coefficients previously generated by PROGRAM FINEG, SUBROUTINE FINITE returns an evaluation of the gravity disturbance approximation (11) at the specified point. The logic flow for SUBROUTINE FINITE is shown in Figure 5.

Gravity disturbance observations were produced for this study by SUBROUTINE PTMASS, which uses the 1080 point masses of Model 310 and (12) below to compute the gravity anomaly, $\delta\underline{g}$, at some point P(x,y,z):

$$\delta\underline{g} = \begin{Bmatrix} \delta g_x \\ \delta g_y \\ \delta g_z \end{Bmatrix} = \sum_{i=1}^{1080} \frac{km_i}{d_i^{\,3}} \underline{d}_i \qquad (12)$$

where

$k = 6.67 \times 10^{-14}\ m^3/(g \cdot sec^2)$ = the gravitational constant

$m_i = 1 \times 10^{19}$, 0, or $1 \times 10^{19}g$

$$\underline{d}_i = \begin{Bmatrix} d_{x_i} \\ d_{y_i} \\ d_{z_i} \end{Bmatrix} = \begin{Bmatrix} x - x_i \\ y - y_i \\ z - z_i \end{Bmatrix} \qquad (13)$$

$$d_i = \sqrt{d_{x_i}^{\,2} + d_{y_i}^{\,2} + d_{z_i}^{\,2}}$$

To minimize the execution time of SUBROUTINE PTMASS, PROGRAM MASPOS was written to compute and save the products of the gravitational constant and each of the 1080 point masses (14) and the earth-fixed x,y,z coordinates of each of the 1080 point masses (15):

$$(km)_i,\ i = 1, 2, \ldots, 1080 \qquad (14)$$

$$x_i,\ y_i,\ z_i,\ i = 1, 2, \ldots, 1080 \qquad (15)$$

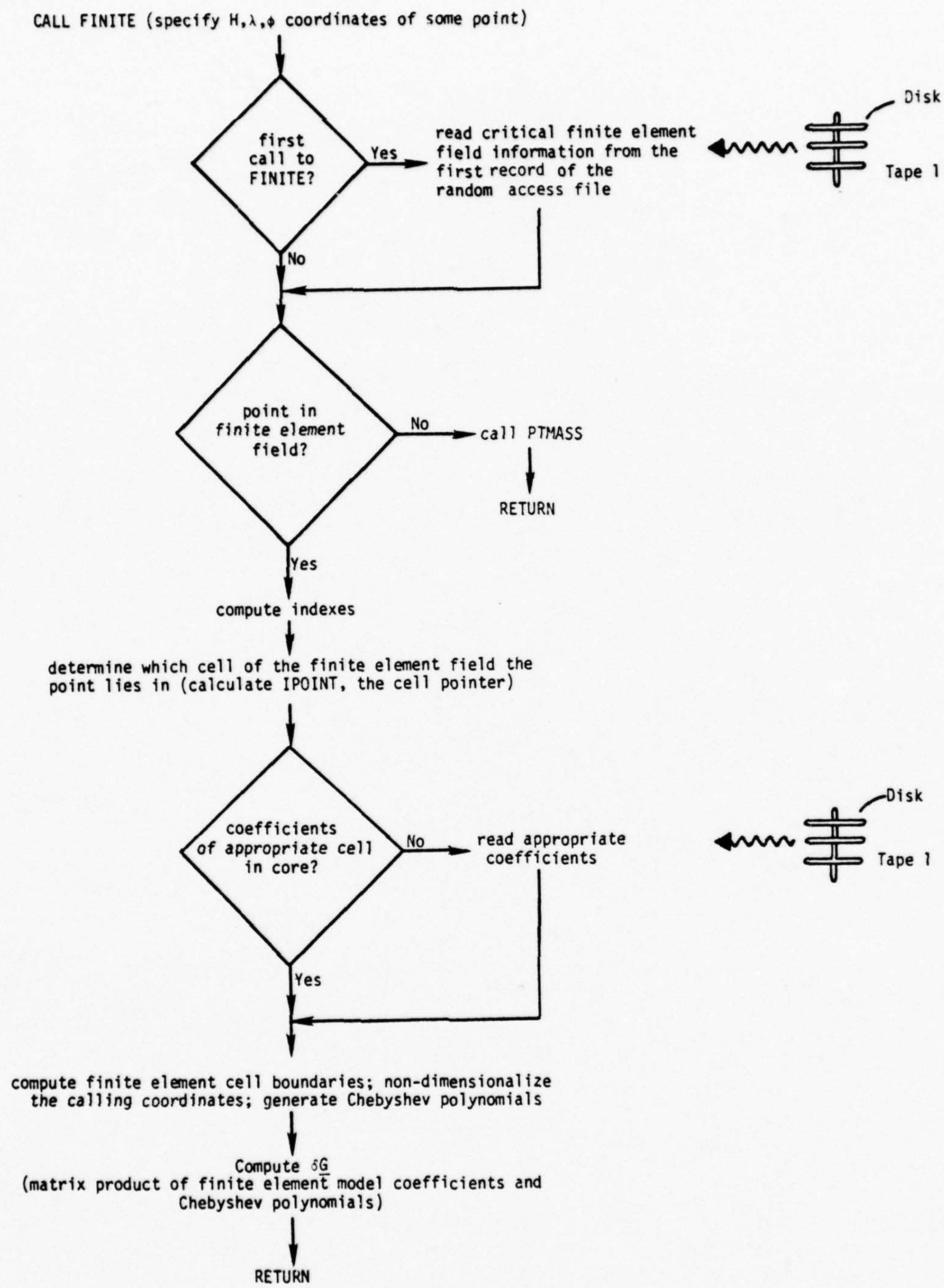


Figure 5 SUBROUTINE FINITE Logic Flow.

6.0 TRADEOFF STUDIES

Several tradeoff studies were conducted on the UVA CDC Cyber 172. The central processor execution times of SUBROUTINE FINITE were compared to SUBROUTINE PTMASS (Model 310). Although it is really a price that is paid only once and a priori in the laboratory, the central processor execution times necessary to create finite element fields were examined. Consideration was given to the tradeoff: total number of finite element coefficients versus NORDER versus cell size, for finite element models of a given region. Lastly, error analyses for a variety of NORDER's and cell sizes were conducted; specifically, the maximum absolute error versus NORDER versus cell size tradeoff was examined.

Figure 6 shows the execution time test results for SUBROUTINE FINITE and SUBROUTINE PTMASS. SUBROUTINE PTMASS has a nearly constant run time. The run time for SUBROUTINE FINITE, however, depends on NORDER, the Chebyshev polynomial order, and on whether or not a random access call is needed. A random access call is needed anytime the set of coefficients currently in core is not the set for the cell in which the calling coordinates lie; that is, the previous calling coordinates were in a different finite element cell than the current calling coordinates.

Observe that the random access time is approximately constant (0.7 ms) regardless of NORDER. This is true because most of the random access time is spent in finding the address of the *first* coefficient on the rotating mass storage device. The read time for one cell's set of coefficients (even NORDER = 6 has only 252 total coefficients for one cell) will be very small compared to the first word address find time. The execution time ratios show that even for the worst cases SUBROUTINE FINITE will be at least 20-50 times faster than an explicit point mass disturbance acceleration model (e.g., SUBROUTINE PTMASS).

A certain price must be paid to generate finite element fields. Execution times involved in running PROGRAM LOCALG and PROGRAM FINEG are shown in Figure 7 for the UVA CDC Cyber 172. The total price for running both programs is also shown. The generation and reduction of the A matrix is a one-time price for any one finite element field. The price

SUBROUTINE PTMASS: 123.2 ms

SUBROUTINE FINITE:

NORDER	Execution Times (ms) No Random Access	Random Access
3	1.7	2.4
4	2.6	3.3
5	3.8	4.5
6	5.4	6.1

$$\frac{\text{(SUBROUTINE FINITE Execution Time)}}{\text{(SUBROUTINE PTMASS Execution Time)}} = \text{(computational speed advantage)}$$

NORDER	No Random Access	Random Access
3	1/72.5	1/51.3
4	1/47.4	1/37.3
5	1/32.4	1/27.4
6	1/22.8	1/20.2

Figure 6 SUBROUTINE FINITE vs. SUBROUTINE PTMASS Central Processor Execution Time Comparison.

	NORDER			
	3	4	5	6
PROGRAM LOCALG				
time to generate A matrix (sec.)	.2	.3	.7	1.4
time to generate observations per cell (sec.)	7.9	15.4	26.6	42.3
PROGRAM FINEG				
time to reduce A matrix (sec.)	.4	2.0	8.7	30.4
time to calculate coefficients per cell (sec.)	.2	.7	1.9	4.3
TOTAL PRICES				
A matrix and reduction (pay once) (sec.)	.6	2.3	9.4	31.8
observations and coefficients per cell (sec.)	8.1	16.1	28.5	46.6

Given: H_{cell} = constant = 300 km

Figure 7 Central Processor Times to Create Finite Element Fields.

per cell must be multiplied by the total number of cells in the finite element field and added to the price to generate and reduce the A matrix. Note that *over 90%* of the price paid per cell is just the generation of the gravity observations via SUBROUTINE PTMASS.

The total numbers of coefficients needed for various finite element field models of the 35°×40° region covered by Model 310 are shown in Figure 8. Figure 8 assumes that H_{cell} will be constant at 300 km and that 300 km will be the maximum altitude to be modeled. For a given cell size, it shows how many finite element cells would be needed to model the region and how many total coefficients would be needed for various NORDER's to model the region. Based upon error analyses conducted on a small volume near the center of the 35°×40° region, expected maximum error bounds were determined for certain cell sizes and NORDER's. The upper solid and dashed underline indicates an expected maximum absolute error of 1.5 mgals and the lower solid and dashed underline indicates an expected maximum absolute error of 3.0 mgals. Solid underlines in both cases indicate that the expected maximum absolute error was verified for small test volumes while dashes indicate the apparent trend.

In order to study the maximum absolute error as functions of NORDER and cell size, it was decided to consider the maximum absolute error as a function of cell size only for fixed NORDER's (see Figure 9) and to consider absolute error as a function of NORDER for fixed cell sizes (see Figure 10). For all cases, cell altitude (H_{cell}) was fixed at 300 km.

Figure 9 shows that the maximum absolute error varies approximately as the square of the cell dimension in λ or ϕ. For constant cell altitude and for small λ_{cell} and ϕ, the volume will vary approximately as the square of λ_{cell} or ϕ_{cell}, if $\lambda_{cell} = \phi_{cell}$. Hence the maximum absolute error is really proportional to cell volume. Figure 10 shows that the maximum absolute error varies approximately inversely as the square of NORDER. As the number of coefficients per cell varies approximately as the square of NORDER, the maximum absolute error may be considered to vary nearly inversely with the number of coefficients per cell.

Cell Size ($\lambda_{cell} \times \phi_{cell}$)	No. of Cells	NORDER 3	NORDER 4	NORDER 5	NORDER 6
1.0°×1.0°	35×40 = 1400	84,000	147,000	235,200	352,800
1.25°×1.25°	28×32 = 896	53,760	94,080	150,528	225,792
1.5°×1.5°	24×27 = 648	38,880	68,040	108,864	163,296 *
1.75°×1.75°	20×23 = 460	27,600	48,300	77,280	115,920
2.0°×2.0°	18×20 = 360	21,600	37,800	60,480	90,720 †
2.25°×2.25°	16×18 = 288	17,280	30,240	48,384	72,576
2.5°×2.5°	14×16 = 224	13,440	23,520	37,632	56,448
2.75°×2.75°	13×15 = 195	11,700	20,475	32,760	49,140
3.0°×3.0°	12×14 = 168	10,080	17,640	28,224	42,336

Given: H_{cell} = constant = 300 km

* - Finite element fields above this line are expected to have $|error|_{max} \leq 1.5$ mgals.

† - Finite element fields above this line are expected to have $|error|_{max} \leq 3.0$ mgals.

Figure 8 Total Number of Coefficients vs. NORDER vs. Cell Size For a 300 km × 35° × 40° Finite Element Field.

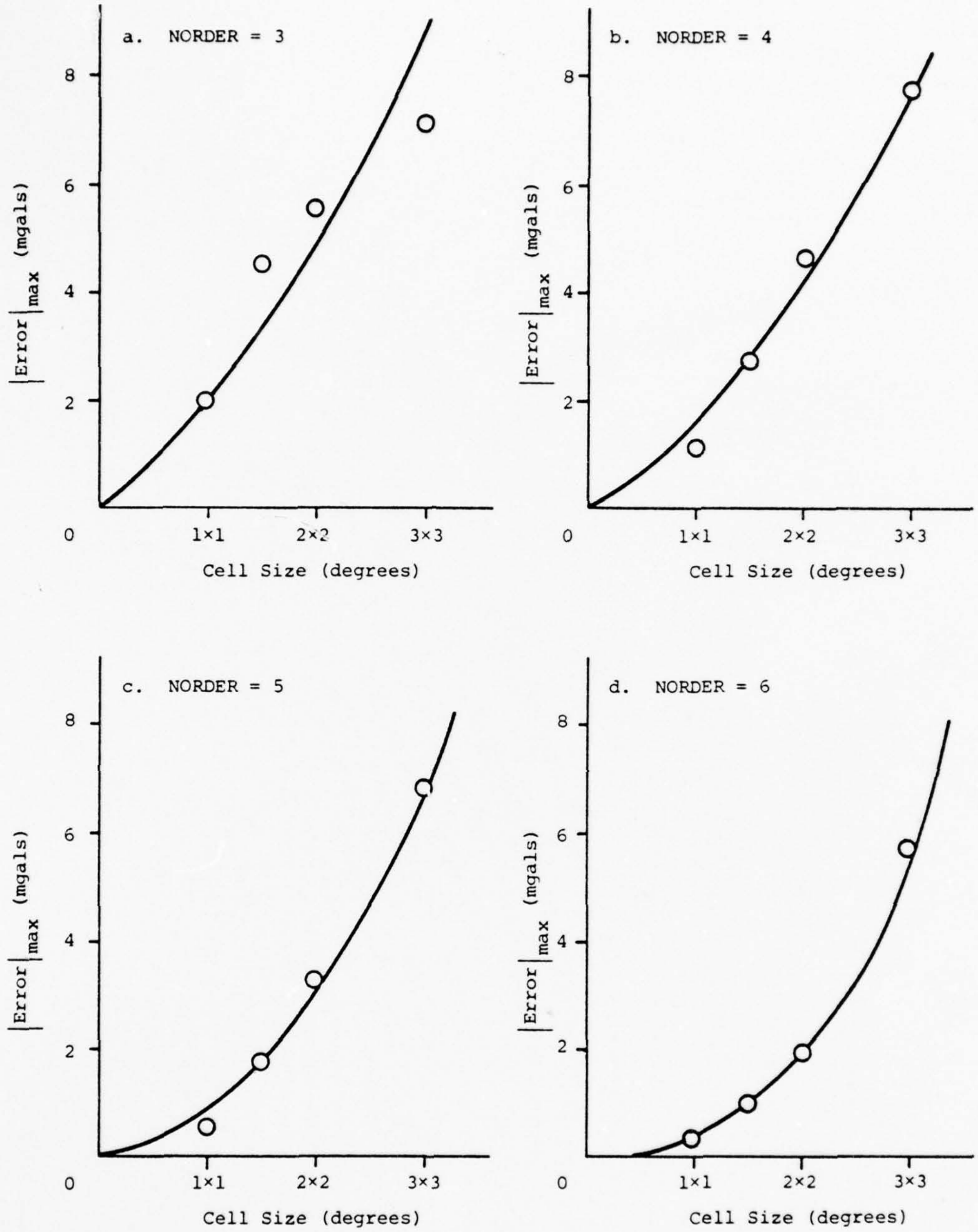


Figure 9 Maximum Absolute Error versus Cell Size for Fixed NORDER's.

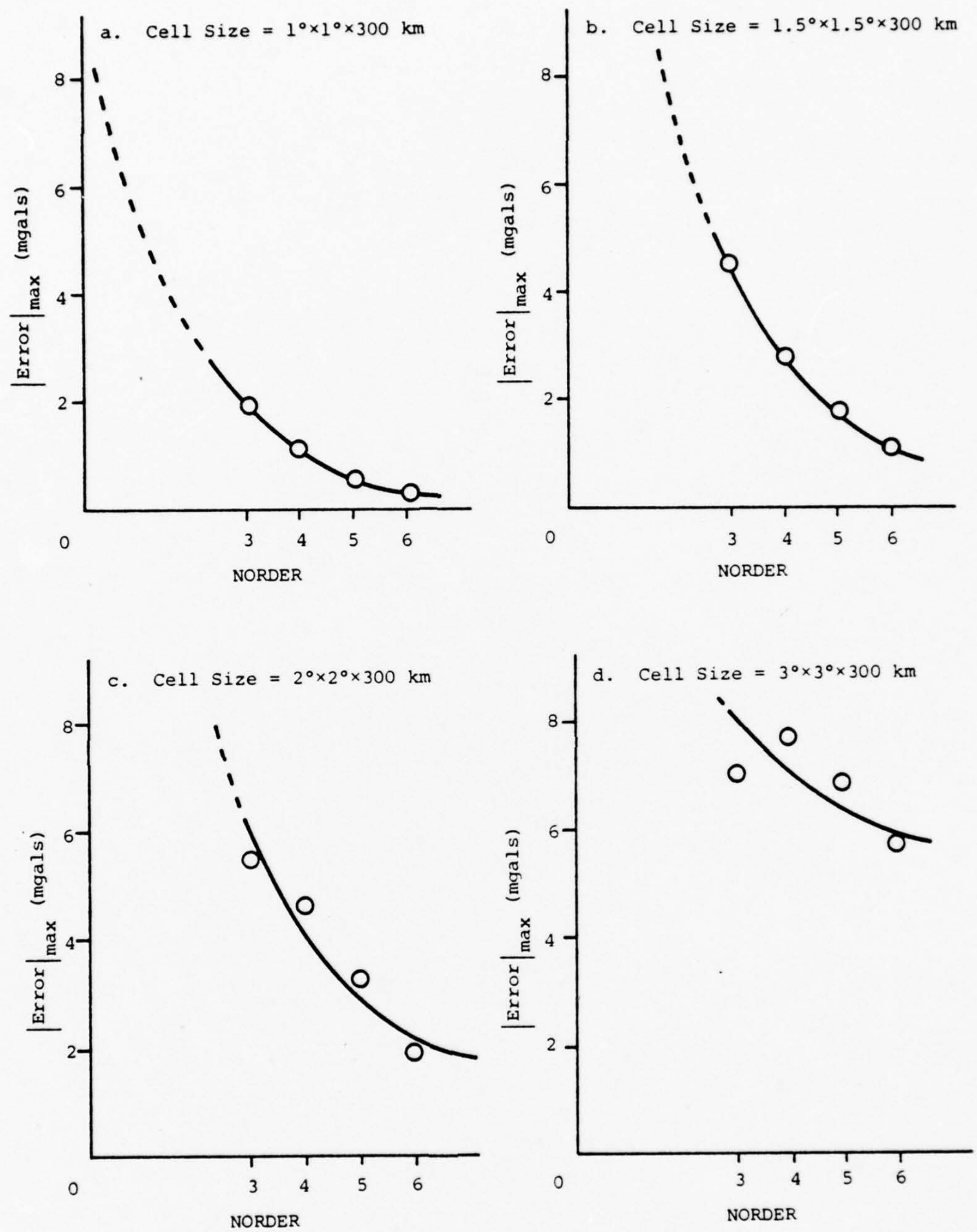


Figure 10 Maximum Absolute Error versus NORDER
for Fixed Cell Sizes.

7.0 EXAMPLE FINITE ELEMENT GRAVITY MODELS

Based upon the tradeoff studies conducted as described above, two example finite element gravity fields were generated. The 300 km × 10° × 10° region with altitude 0 to 300 km, longitude 70°E to 80°E, and latitude 25°S to 35°S was modeled. A finite element field with NORDER = 3 and with one hundred 300 km × 1° × 1° cells was generated as was a finite element field with NORDER = 5 and the same size and number of cells. An error analysis was conducted on both fields. The finite element model was compared on a point by point basis with Model 310 at sample points "away from the fit points" for altitudes of 1 m, 150 km, and 299 km. The error mean, the RMS error, and the maximum absolute error were determined for the three sets of sample points for both finite element fields and are shown in Figure 11 and Figure 12.

	δg_{up} (mgals)	δg_{east} (mgals)	δg_{north} (mgals)
H = 1 m			
$\overline{\text{error}}$	-.005	-.001	.004
RMS error	.963	.645	.727
$\lvert\text{error}\rvert_{max}$	2.717	2.074	2.236
H = 150 km			
$\overline{\text{error}}$	-.023	.003	.009
RMS error	.352	.224	.270
$\lvert\text{error}\rvert_{max}$	1.149	.701	1.039
H = 299 km			
$\overline{\text{error}}$	.018	-.006	-.007
RMS error	.424	.277	.322
$\lvert\text{error}\rvert_{max}$	1.130	.771	1.002

Figure 11 NORDER = 3 Example Finite Element Gravity Disturbance Field.

	δg_{up} (mgals)	δg_{east} (mgals)	δg_{north} (mgals)
H = 1 m			
$\overline{\text{error}}$	-.004	.001	.002
RMS error	.224	.150	.167
$\lvert\text{error}\rvert_{max}$	.918	.637	.581
H = 150 km			
$\overline{\text{error}}$	.007	-.002	-.004
RMS error	.071	.044	.055
$\lvert\text{error}\rvert_{max}$	.216	.157	.215
H = 299 km			
$\overline{\text{error}}$	-.002	.001	.001
RMS error	.101	.067	.077
$\lvert\text{error}\rvert_{max}$	.329	.254	.249

Figure 12 NORDER = 5 Example Finite Element Gravity Disturbance Field.

8.0 CONCLUSIONS

This effort has demonstrated that:

- Finite element fields are suitable for modeling the gravity disturbance.
- Finite element fields are computationally attractive for modeling the gravity disturbance.

9.0 REFERENCES

1. Junkins, J. L., "Development of Finite Element Models for the Earth's Gravity Field, Phase I: Macro Gravity Model for Satellite Orbit Integration," University of Virginia, RLES Report No. UVA/525023/ESS77/103, February 1977.

APPENDIX - SOFTWARE

A.0 FORTRAN IV programs have been developed which create finite element gravity disturbance fields and which evaluate the gravity disturbance within these fields via the methods discussed in this report. Descriptions of these routines and their attendant subroutines are provided here, together with listings of all routines and example executions.

Three major routines were developed - PROGRAM LOCALG, PROGRAM FINEG, and SUBROUTINE FINITE - to create finite element gravity disturbance fields and to evaluate the gravity disturbance within these fields. Two additional routines were developed to provide simulated gravity disturbance data - PROGRAM MASPOS, which, for the 1080 mass points of Model 310, computes and stores the products of each mass point and the gravitational constant together with the geocentric rectangular coordinates of each mass point, and SUBROUTINE PTMASS, which evaluates the gravity disturbance as simulated by Model 310.

A.1.1 PROGRAM LOCALG generates the A matrix (8) for a "typical" finite element cell and a set of gravity disturbance observations (10) for each cell of a finite element gravity disturbance field. The gravity disturbance observations are evaluations of SUBROUTINE PTMASS on the uniform observation grid in each cell. The user defines a finite element gravity disturbance field by providing the following items as inputs to PROGRAM LOCALG:

1. The integral order of the locally valid Chebyshev polynomial approximating functions, NORDER, ($0 \leq$ NORDER ≤ 6).
2. The observation grid pattern (same for all cells) to include the number of observations in the up, eastern and northern directions, MOBSU, MOBSE, MOBSN. The total number of observations (MOBSU × MOBSE × MOBSN) should be at least three times the number of coefficients, NC (see Table 1), in the approximating model (3). Furthermore, the number of observations in each direction should be equal (MOBSU = MOBSE = MOBSN). A good rule of thumb is that for all NORDER's between 3 and 6 inclusive, the number of observations in each direction should be one more than NORDER (MOBSU = MOBSE = MOBSN = NORDER + 1).

The maximum number of observations allowed by the program is 343 (a 7×7×7 observation grid). Non-uniform sample grids (e.g. 5×7×7, 6×5×4, etc.) produce unpredictable results - often an unacceptable fit.

3. The size of each finite element cell in H,λ,φ must be specified, HCELL, ALCELL, APCELL. HCELL is cell size in H (meters), (HCELL ≤ [HMAX - HMIN]). ALCELL is cell size in λ (degrees), (ALCELL ≤ [ALMAX - ALMIN]). APCELL is cell size in φ (degrees), (APCELL ≤ [APMAX - APMIN]).

4. The minimum and maximum H,λ,φ boundaries of the finite element field, HMIN, ALMIN, APMIN, HMAX, ALMAX, and APMAX. HMIN and HMAX are heights (H) above the reference ellipsoid in meters, (HMIN ≥ 0 and HMAX > HMIN). ALMIN and ALMAX are geodetic longitudes (λ) in degrees, (-180° ≤ ALMIN < ALMAX ≤ 180°). APMIN and APMAX are geodetic latitudes (φ) in degrees, (-90°≤ APMIN < APMAX ≤ 90°).

These thirteen items are input on four data cards. NORDER, MOBSU, MOBSE, and MOBSN are input in (4I10) format on the first card. The remaining three cards must have a (3E20.14) format, with the finite element field delimiters, HCELL, ALCELL, and APCELL on the second card, HMIN, ALMIN, and APMIN on the third card, and HMAX, ALMAX, and APMAX on the last card.

Because gravity disturbance observations are generated within PROGRAM LOCALG by SUBROUTINE PTMASS, PROGRAM LOCALG also requires as input the precomputed products of the gravitational constant and each of the mass points of Model 310 and the precomputed rectangular coordinates of each mass point. These quantities should have previously been stored sequentially via an unformatted write on TAPE 2. PROGRAM LOCALG accesses these quantities with an unformatted read of TAPE 2.

PROGRAM LOCALG produces as output an unformatted sequential file, TAPE 3, which contains the A matrix for a typical finite element cell and a set of gravity disturbance observations for each cell of the user specified finite element field. This file is properly formatted for later use by PROGRAM FINEG. PROGRAM LOCALG requires two supporting subroutines - SUBROUTINE CHEBY and SUBROUTINE PTMASS.

A.1.2 SUBROUTINE CHEBY (X, N, TA) returns Chebyshev polynomials in array TA, evaluated at a specified value, X, through the specified order, N. TA(1) = T_0(X), TA(2) = T_1(X), TA(3) = T_2(X), etc. TA is a seven element array; hence the specified order is bounded, $0 \leq N \leq 6$

A.1.3 SUBROUTINE PTMASS produces gravity disturbance "observations", δg_{up}, δg_{east}, and δg_{north}, from (10) to be used by PROGRAM LOCALG and PROGRAM FINEG for fitting purposes and to be used to test as data against SUBROUTINE FINITE. SUBROUTINE PTMASS produces the gravity disturbance data by using the 1080 point masses of Model 310. SUBROUTINE PTMASS requires that COMMON /MASPOS/ be filled with the precomputed products of the gravitational constant and each point mass and the geocentric rectangular coordinates of each point mass. SUBROUTINE PTMASS interfaces with the calling program via COMMON /XYZ/ through which the rectangular coordinates, x, y, z, of the calling point are received and the components of the gravity disturbance δg_x, δg_y, and δg_z (DELGX, DELGY, DELGZ) are transmitted. The rectangular components of the gravity disturbance must be transformed to geodetic components δg_{up}, δg_{east}, and δg_{north}, outside SUBROUTINE PTMASS (i.e., in the calling routine).

A.2.1 PROGRAM FINEG generates sets of locally valid coefficients C_{up}, C_{east}, and C_{north} (9) for each cell of a finite element field which was previously specified by inputs to PROGRAM LOCALG. The only input required by PROGRAM FINEG is the unformatted sequential file, TAPE 3, previously produced by PROGRAM LOCALG. PROGRAM FINEG produces as output a random access file, TAPE 1, which contains, in effect, a finite element gravity disturbance field. The first record of the random access file contains certain important information about the finite element field (NORDER, boundaries, etc.). In addition to the first record, the random access file consists of one record of coefficients (9) for each cell of the finite element field. Thus the number of records in the random access file will be equal to the number of cells in the finite element field plus 1. PROGRAM FINEG requires one supporting subroutine - SUBROUTINE ALSQ.

A.2.2 SUBROUTINE ALSQ (A,Y,B,R2,NN,MM,NA) solves the linear least squares problem, $||AB - Y||$ = minimum. SUBROUTINE ALSQ requires as input the coefficient matrix, A, the observation vector which is to be fit, Y, the number of rows used in the A matrix, NN, the number of columns used in the A matrix, MM, and the first dimension of the A matrix, NA. NA must be equal to one plus the maximum number of rows in the A matrix (NA = NN_{max} + 1). SUBROUTINE ALSQ returns B, the coefficients of the fit and R2, the sum of the squares of the residuals.

A.3.1 PROGRAM FINTES is a simple error analysis routine. It compares the gravity disturbance as approximated by SUBROUTINE FINITE with the gravity disturbance as evaluated by SUBROUTINE PTMASS (Model 310). Residuals are printed for each point of a user specified grid, along with the mean of the residuals, the root mean square of the residuals, and the maximum absolute value of the residuals, for each component of the gravity disturbance. The following items are required as input to specify the sample grid:

1. The number of samples in each direction, ISTEPH, ISTEPL, and ISTEPP, (ISTEPH > 0, ISTEPL > 0, and ISTEPP > 0). The total number of sample points on the grid will be the product of these three numbers.

2. The minimum sample grid coordinate values ("the lower corner"), HMIN (meters), ALMIN (degrees), and APMIN (degrees) and the maximum sample grid coordinate values ("the upper corner"), HMAX (meters), ALMAX (degrees), and APMAX (degrees), ($0 \leq$ HMIN $\leq$ HMAX, $-180° \leq$ ALMIN $\leq$ ALMAX $\leq 180°$, $-90° \leq$ APMIN $\leq$ APMAX $\leq 90°$).

These nine items are input on three data cards. ISTEPH, ISTEPL, and ISTEPP are input on the first data card in a (3I5) format. HMIN, ALMIN, and APMIN are input on the second card in (F10.0, 2F10.2) format and HMAX, ALMAX, and APMAX are input on the third card in the same format. PROGRAM FINTES requires three supporting subroutines - SUBROUTINE FINITE, SUBROUTINE CHEBY (see discussion of this routine above), and SUBROUTINE PTMASS (also discussed above).

Because PROGRAM FINTES uses SUBROUTINE PTMASS, it also requires as input the unformatted sequential file, TAPE 2, containing the precomputed products of the gravitational constant and each point mass of Model 310 and the precomputed rectangular coordinates of each point mass.

4.3.2 SUBROUTINE FINITE directly replaces Model 310 in applications involving the gravity disturbance $\delta \underline{g}$. Given the geodetic coordinates, H, ALAM, and APHI (H, λ, ϕ), of a specified point, SUBROUTINE FINITE returns the geodetic components, GU, GE, and GN (δG_{up}, δG_{east}, δG_{north}) of the gravity disturbance approximation, $\underline{\delta G}$ (3). SUBROUTINE FINITE determines which set of finite element coefficients to use at the specified point, reads them into core, and computes $\underline{\delta G}$. SUBROUTINE FINITE requires SUBROUTINE CHEBY (described previously) to produce Chebyshev polynomials at the specified point. Whenever the specified point does not lie within the bounds of the finite element field currently accessed, SUBROUTINE FINITE calls SUBROUTINE PTMASS, writes an error message, and sets the error flag ISITIN to zero.

Prior to the first call to SUBROUTINE FINITE, the random access file, Tape 1, must be made available to the calling program, and two flags, IFLAG and ISITIN, must be set to zero and included in a COMMON in both the calling program and SUBROUTINE FINITE. This could be COMMON /HLP/ if necessary (COMMON /HLP/ is the vehicle by which SUBROUTINE FINITE receives the calling coordinates and returns the components of $\underline{\delta G}$), although COMMON /IMARK/ was used.

The requirements of CDC FORTRAN dictated that the CDC utility subroutines, OPENMS, WRITMS, READMS, and CLOSMS, be used to access the random access file. Furthermore, these CDC utility routines require that the user establish an index array (IMARK, in this case) for the random access file. If an index array is required by a particular version of FORTRAN, the index array, IMARK, should be included in a COMMON in both the calling program and SUBROUTINE FINITE.

A.4 PROGRAM MASPOS creates an unformatted sequential file, TAPE 2, which contains the precomputed products of the gravitational constant and each point mass of Model 310 and the precomputed geocentric rectangular coordinates of each point mass. PROGRAM MASPOS requires as input coded information about Model 310 in the form of 30 cards. Each card represents 36 mass points in a grid row of equal latitude where the mass points are 50 longitude minutes apart. The mass points should be listed on each card by increasing longitude and the cards should be arranged in order of decreasing latitude. PROGRAM MASPOS reads only the coded multiplication factors for each of the 36 mass points of the grid row, where the coded factors indicate the mass of the respective mass points, 1 = $-1.\times10^{19}$ grams, 2 - 0. grams, and 3 = $+1.\times10^{19}$ grams. The coded factors are located in columns 25-60 of each data card. All other data card columns are ignored (for information only, columns 1-9 indicate south latitude in arc minutes of the grid row and columns 10-18 indicate east longitude in arc minutes of the west-most mass point in the row).

SOFTWARE LISTINGS

PROGRAM LOCALG AND SUPPORTING SUBROUTINES

```
      PROGRAM LOCALG(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE2,TAPE3)
C-----------------------------------------------------------------------
C
C     LOCAL GRAVITY MODEL COEFFICIENT DETERMINATION PROGRAM, FIRST PART
C
C                   BY
C              DR. JOHN L. JUNKINS
C                   AND
C              JOHN T. SAUNDERS
C
C              DEPARTMENT OF ENGINEERING SCIENCE AND SYSTEMS
C              SCHOOL OF ENGINEERING AND APPLIED SCIENCE
C              UNIVERSITY OF VIRGINIA
C              CHARLOTTESVILLE,VA  22901
C
C-----------------------------------------------------------------------
C
C     A PROGRAM WHICH CREATES A SEQUENTIAL FILE CONTAINING THE LEAST
C   SQUARES MATRIX (A MATRIX) AND A SET OF GRAVITY OBSERVATIONS FOR A
C   FINITE ELEMENT FIELD MODEL OF A USER SPECIFIED REGION.
C
C-----------------------------------------------------------------------
      COMMON  /XYZ/X,Y,Z,GX,GY,GZ
      COMMON  /MASPOS/PMVALS(1080),POSITS(1080,3)
      DIMENSION  TX(7),TY(7),TZ(7),A(49,84)
      DIMENSION  DELGU(343),DELGE(343),DELGN(343)
      DIMENSION  IX(84),IY(84),IZ(84)
      DATA  RA/6378160./
      DATA  RB/6356774.504/
      DATA  MAXOBS,MAXC/343,84/
      DATA  IX(1),IX(2),IX(3),IX(4),IX(5),IX(6),IX(7),IX(8),IX(9),
     +IX(10),IX(11),IX(12),IX(13),IX(14),IX(15),IX(16),IX(17),IX(18),
     +IX(19),IX(20),IX(21),IX(22),IX(23),IX(24),IX(25),IX(26),IX(27),
     +IX(28),IX(29),IX(30),IX(31),IX(32),IX(33),IX(34),IX(35),IX(36),
     +IX(37),IX(38),IX(39),IX(40),IX(41),IX(42),IX(43),IX(44),IX(45),
     +IX(46),IX(47),IX(48),IX(49),IX(50),IX(51),IX(52),IX(53),IX(54),
```

```
+IX(55),IX(56),IX(57),IX(58),IX(59),IX(60),IX(61),IX(62),IX(63),
+IX(64),IX(65),IX(66),IX(67),IX(68),IX(69),IX(70),IX(71),IX(72),
+IX(73),IX(74),IX(75),IX(76),IX(77),IX(78),IX(79),IX(80),IX(81),
+IX(82),IX(83),IX(84)/
+1,1,1,2,1,1,1,2,2,3,1,1,1,1,2,2,2,3,3,4,1,1,1,1,1,2,2,2,2,3,
+3,3,4,4,5,1,1,1,1,1,1,2,2,2,2,2,3,3,3,3,4,4,4,5,5,6,1,1,1,1,
+1,1,1,2,2,2,2,2,2,3,3,3,3,3,4,4,4,4,5,5,5,6,6,7/
 DATA  IY(1),IY(2),IY(3),IY(4),IY(5),IY(6),IY(7),IY(8),IY(9),
+IY(10),IY(11),IY(12),IY(13),IY(14),IY(15),IY(16),IY(17),IY(18),
+IY(19),IY(20),IY(21),IY(22),IY(23),IY(24),IY(25),IY(26),IY(27),
+IY(28),IY(29),IY(30),IY(31),IY(32),IY(33),IY(34),IY(35),IY(36),
+IY(37),IY(38),IY(39),IY(40),IY(41),IY(42),IY(43),IY(44),IY(45),
+IY(46),IY(47),IY(48),IY(49),IY(50),IY(51),IY(52),IY(53),IY(54),
+IY(55),IY(56),IY(57),IY(58),IY(59),IY(60),IY(61),IY(62),IY(63),
+IY(64),IY(65),IY(66),IY(67),IY(68),IY(69),IY(70),IY(71),IY(72),
+IY(73),IY(74),IY(75),IY(76),IY(77),IY(78),IY(79),IY(80),IY(81),
+IY(82),IY(83),IY(84)/
+1,1,2,1,1,2,3,1,2,1,1,2,3,4,1,2,3,1,2,1,1,2,3,4,5,1,2,3,4,1,
+2,3,1,2,1,1,2,3,4,5,6,1,2,3,4,5,1,2,3,4,1,2,3,1,2,1,1,2,3,4,
+5,6,7,1,2,3,4,5,6,1,2,3,4,5,1,2,3,4,1,2,3,1,2,1/
 DATA  IZ(1),IZ(2),IZ(3),IZ(4),IZ(5),IZ(6),IZ(7),IZ(8),IZ(9),
+IZ(10),IZ(11),IZ(12),IZ(13),IZ(14),IZ(15),IZ(16),IZ(17),IZ(18),
+IZ(19),IZ(20),IZ(21),IZ(22),IZ(23),IZ(24),IZ(25),IZ(26),IZ(27),
+IZ(28),IZ(29),IZ(30),IZ(31),IZ(32),IZ(33),IZ(34),IZ(35),IZ(36),
+IZ(37),IZ(38),IZ(39),IZ(40),IZ(41),IZ(42),IZ(43),IZ(44),IZ(45),
+IZ(46),IZ(47),IZ(48),IZ(49),IZ(50),IZ(51),IZ(52),IZ(53),IZ(54),
+IZ(55),IZ(56),IZ(57),IZ(58),IZ(59),IZ(60),IZ(61),IZ(62),IZ(63),
+IZ(64),IZ(65),IZ(66),IZ(67),IZ(68),IZ(69),IZ(70),IZ(71),IZ(72),
+IZ(73),IZ(74),IZ(75),IZ(76),IZ(77),IZ(78),IZ(79),IZ(80),IZ(81),
+IZ(82),IZ(83),IZ(84)/
+1,2,1,1,3,2,1,2,1,1,4,3,2,1,3,2,1,2,1,1,5,4,3,2,1,4,3,2,1,3,
+2,1,2,1,1,6,5,4,3,2,1,5,4,3,2,1,4,3,2,1,3,2,1,2,1,1,7,6,5,4,
+3,2,1,6,5,4,3,2,1,5,4,3,2,1,4,3,2,1,3,2,1,2,1,1/
1 FORMAT(8I10)
2 FORMAT(4E20.14)
3 FORMAT(1H1)
```

```
    4 FORMAT(1X,12I10)
    5 FORMAT(1X,6E20.12)
C
C  TERMINOLOGY
C
C  P--SOME POINT IN SPACE
C
C  VARIABLES
C
C  X,Y,Z--EARTH-FIXED RECTANGULAR COORDINATES
C  H,ALAM,APHI--GEODETIC COORDINATES
C  R--MAG. OF VECTOR FROM ORIGIN TO P
C  RN--EAST-WEST RADIUS OF CURVATURE
C  H--HEIGHT ABOVE REF. ELLIPSOID ALONG NORMAL TO P
C  ALAM--ANGLE LAMBDA, GEODETIC/GEOCENTRIC LONGITUDE (RADIANS) OF P
C  APHI--ANGLE PHI, GEODETIC LATITUDE (RADIANS) OF P
C
C  INPUTS
C
C  NORDER--ORDER OF CHEBYSHEV POLYNOMIALS DESIRED
C  MOBSU,MOBSE,MOBSN--OBSERVATION GRID PATTERN FOR ONE CELL
C  HCELL,ALCELL,APCELL--CELL SIZE IN H,LAMBDA,PHI
C  HMIN,ALMIN,APMIN--MINIMUM BOUNDS OF FINITE ELMENT FIELD DESIRED
C  HMAX,ALMAX,APMAX--MAXIMUM BOUNDS OF FINITE ELEMENT FIELD DESIRED
C
C
C  SET CONSTANTS
C
      PI=ACOS(-1.)
      DEGRAD=PI/180.
      A2=RA*RA
      B2=RB*RB
      READ(2)  PMVALS,POSITS
C
C  READ CHEBYSHEV POLYNOMIALS ORDER, GRID PATTERN, CELL SIZE, AND FINITE
C  ELEMENT FIELD BOUNDS
```

```
C
      READ(5,1) NORDER,MOBSU,MOBSE,MOBSN
      IF (EOF(5) .NE. 0.)  GOTO 500
      READ(5,2) HCELL,ALCELL,APCELL
      IF (EOF(5) .NE. 0.)  GOTO 500
      READ(5,2) HMIN,ALMIN,APMIN
      IF (EOF(5) .NE. 0.)  GOTO 500
      READ(5,2) HMAX,ALMAX,APMAX
      IF (EOF(5) .NE. 0.)  GOTO 500
C
      MOBS=MOBSU*MOBSE*MOBSN
      RMU=MOBSU
      RME=MOBSE
      RMN=MOBSN
      RMUM1=RMU-1
      RMEM1=RME-1
      RMNM1=RMN-1
C
C  COMPUTE THE NUMBER OF COLUMNS IN THE A MATRIX
C
      NP1=NORDER+1
      NC=0
      N=0
      DO 100 IC=1,NP1
      N=N+IC
      NC=NC+N
  100 CONTINUE
      NC2=2*NC
      NC3=3*NC
      WRITE(6,3)
      WRITE(6,4) NORDER,NC
      WRITE(6,4) MOBSU,MOBSE,MOBSN,MOBS
      WRITE(6,5) HCELL,ALCELL,APCELL
      WRITE(6,5) HMIN,ALMIN,APMIN
      WRITE(6,5) HMAX,ALMAX,APMAX
C
```

```
C  CONVERT ANGLES FROM DEGREES TO RADIANS
C
      ALCELL=ALCELL*DEGRAD
      APCELL=APCELL*DEGRAD
      ALMIN=ALMIN*DEGRAD
      APMIN=APMIN*DEGRAD
      ALMAX=ALMAX*DEGRAD
      APMAX=APMAX*DEGRAD
C
C  COMPUTE THE NUMBER OF CELLS IN UP, EASTERN, AND NORTHERN DIRECTIONS
C  AND TOTAL NUMBER OF CELLS IN FINITE ELEMENT FIELD
C
      RNH=(HMAX-HMIN)/HCELL + .999
      RNL=(ALMAX-ALMIN)/ALCELL + .999
      RNP=(APMAX-APMIN)/APCELL + .999
      NH=RNH
      NLAM=RNL
      NPHI=RNP
      NCELLS=NH*NLAM*NPHI
      PNCELL=NCELLS
C
C  COMPUTE THE INCREMENT SIZE WITHIN EACH CELL.
C
      DH=HCELL/RMUM1
      DLAM=ALCELL/RMEM1
      DPHI=APCELL/RMNM1
C
C  WRITE FIELD DATA ONTO FIRST RECORD OF SEQUENTIAL FILE
C
      WRITE(3) HMIN,HMAX,HCELL,ALMIN,ALMAX,ALCELL,APMIN,APMAX,APCELL,NH,
     +NLAM,NPHI,NORDER,NC,NC2,NC3,MOBSU,MOBSE,MOBSN,MOBS,NCELLS
C
C  GENERATE THE CHEBYCHEV POLYNOMIALS FOR A TYPICAL CELL.
C
      H=HMIN-DH
      DO 200  IH=1,MOBSU
```

```
      MJ=0
      H=H+DH
      X1=(H-HMIN)/HCELL
      CALL  CHEBY(X1,NORDER,TX)
      ALAM=ALMIN-DLAM
      DO 150 IL=1,MOBSE
      ALAM=ALAM+DLAM
      X2=(ALAM-ALMIN)/ALCELL
      CALL  CHEBY(X2,NORDER,TY)
      APHI=APMIN-DPHI
      DO 150  IP=1,MOBSN
      APHI=APHI+DPHI
      X3=(APHI-APMIN)/APCELL
      CALL  CHEBY(X3,NORDER,TZ)
      MJ=MJ+1
C
C  FILL THE A MATRIX
C
      DO 150  II=1,NC
      NX=IX(II)
      NY=IY(II)
      NZ=IZ(II)
      A(MJ,II)=TX(NX)*TY(NY)*TZ(NZ)
  150 CONTINUE
C
C  WRITE ONE LAYER OF THE A MATRIX ONTO THE SEQUENTIAL FILE
C
      WRITE(3)  ((A(I,J),I=1,MJ),J=1,NC)
  200 CONTINUE
C
C  GENERATE DATA FOR EACH CELL.
C
      HMCELL=HMIN-HCELL
      DO 300  IHC=1,NH
      HMCELL=HMCELL+HCELL
      ALMCEL=ALMIN-ALCELL
```

```
      DO 300  ILC=1,NLAM
      ALMCEL=ALMCEL+ALCELL
      APMCEL=APMIN-APCELL
      DO 300  IPC=1,NPHI
      APMCEL=APMCEL+APCELL
      MJ=0
C
      H=HMCELL-DH
      DO 250  IH=1,MOBSU
      H=H+DH
      ALAM=ALMCEL-DLAM
      DO 250  IL=1,MOBSE
      ALAM=ALAM+DLAM
      APHI=APMCEL-DPHI
      DO 250  IP=1,MOBSN
      APHI=APHI+DPHI
      MJ=MJ+1
C
C  TRANSFORM TO X,Y,Z COORDINATES
C
      COSL=COS(ALAM)
      SINL=SIN(ALAM)
      COSP=COS(APHI)
      SINP=SIN(APHI)
C
      RN=SORT(A2*COSP*COSP + B2*SINP*SINP)
      ZN=B2/RN
      RN=A2/RN
      Y=(RN+H)*COSP
      X=Y*COSL
      X=Y*COSL
      Y=Y*SINL
      Z=(ZN+H)*SINP
C
      CALL PTMASS
C
```

```
C   DIRECTION COSINE MATRIX FOR 3-2 ROTATION (LAMBDA,-PHI) FROM X,Y,Z, TO
C   UP,EAST,NORTH
C
C   C11=COSP*COSL
C   C12=COSP*SINL
C   C13=SINP
C   C21=-SINL
C   C22=COSL
C   C23=0
C   C31=-SINP*COSL
C   C32=-SINP*SINL
C   C33=COSP
C
       GU=COSP*COSL*GX + COSP*SINL*GY + SINP*GZ
       GE=-SINL*GX + COSL*GY
       GN=-SINP*COSL*GX - SINP*SINL*GY + COSP*GZ
       DELGU(MJ)=GU
       DELGE(MJ)=GE
       DELGN(MJ)=GN
   250 CONTINUE
C
C   WRITE THE THREE OBSERVATION ARRAYS ONTO THE SEQUENTIAL FILE
C
       WRITE(3)  (DELGU(I),I=1,MOBS)
       WRITE(3)  (DELGE(I),I=1,MOBS)
       WRITE(3)  (DELGN(I),I=1,MOBS)
   300 CONTINUE
   500 STOP
       END
```

```
      SUBROUTINE CHEBY(X,N,TA)
      DIMENSION  TA(7)
C
C  S/R CHEBY RETURNS CHEBYCHEV POLYNOMIALS THROUGH ORDER N,
C  EVALUATED AT X, IN VECTOR TA
C
      IF (N .GT. 0 .AND. N .LT. 7) GOTO 10
      WRITE(6,5)   N
    5 FORMAT(24H0ILLEGAL NORDER, NORDER=,I6)
      STOP
   10 CONTINUE
      XBAR=2.*X-1.
C
C  XBAR=2X-1  MAPS  (0 .LE. X .LE. 1)  INTO  (-1 .LE. XBAR .LE. 1)
C
      TA(1)=1.
      TA(2)=XBAR
      NP1=N+1
      DO 20 I=3,NP1
   20 TA(I)=2.*XBAR*TA(I-1)-TA(I-2)
      RETURN
      END
```

```
      SUBROUTINE PTMASS
      COMMON  /XYZ/X,Y,Z,DELGX,DELGY,DELGZ
      COMMON  /MASPOS/PMVALS(1080),POSITS(1080,3)
C
C   GIVEN THE RECTANGULAR COORDINATES, X, Y, Z, OF A POINT, THIS ROUTINE
C   RETURNS THE COMPONENTS OF THE GRAVITY DISTURBANCE, DELGX, DELGY, AND
C   DELGZ, USING USING THE POINT MASSES OF MASS MODEL 310.
C
C   PMVALS CONTAINS THE PRECOMPUTED PRODUCTS OF THE GRAVITATIONAL
C   CONSTANT (6.67E-14) AND THE 1080 POINT MASSES (-1.E19, 0., OR +1.E19)
C   POSITS CONTAINS THE PRECOMPUTED EARTH-FIXED X, Y, Z COORDINATES OF
C   THE 1080 POINT MASSES.
C
C   TERMINOLOGY
C
C   X,Y,Z--EARTH-FIXED RECTANGULAR COORDINATES OF POINT AT WHICH GRAVITY
C   DISTURBANCE IS TO BE EVALUATED
C   XI,YI,ZI--EARTH-FIXED RECTANGULAR COORDINATES OF THE ITH POINT MASS
C   POSITS(I,1)=XI
C   POSITS(I,2)=YI
C   POSITS(I,3)=ZI
C   DELGX,DELGY,DELGZ--EARTH-FIXED RECTANGULAR COMPONENTS OF THE GRAVITY
C   DISTURBANCE
C
      DELGX=0.
      DELGY=0.
      DELGZ=0.
C
      DO 20 I=1,1080
      IF (PMVALS(I)) 10,20,10
   10 CONTINUE
      DX=POSITS(I,1)-X
      DY=POSITS(I,2)-Y
      DZ=POSITS(I,3)-Z
      DISTSQ=DX*DX+DY*DY+DZ*DZ
      DIST=SQRT(DISTSQ)
```

```
      TEMP=FMVALS(I)/DIST/DISTSQ
C
      DELGX=DELGX+(DX*TEMP)
      DELGY=DELGY+(DY*TEMP)
      DELGZ=DELGZ+(DZ*TEMP)
C
   20 CONTINUE
C
      RETURN
      END
```

PROGRAM FINEG AND SUPPORTING SUBROUTINES

```
      PROGRAM FINEG(OUTPUT,TAPE6=OUTPUT,TAPE1,TAPE3)
C-----------------------------------------------------------------------
C
C     LOCAL GRAVITY MODEL COEFFICIENT DETERMINATION PROGRAM, SECOND PART
C
C                 BY
C             DR. JOHN L. JUNKINS
C                 AND
C             JOHN T. SAUNDERS
C
C             DEPARTMENT OF ENGINEERING SCIENCE AND SYSTEMS
C             SCHOOL OF ENGINEERING AND APPLIED SCIENCE
C             UNIVERSITY OF VIRGINIA
C             CHARLOTTESVILLE,VA  22901
C
C-----------------------------------------------------------------------
C
C     A PROGRAM WHICH CREATES ONE RANDOM ACCESS FILE CONTAINING THE
C   COEFFICIENTS FOR A FINITE ELEMENT GRAVITY REPRESENTATION OF A USER
C   SPECIFIED REGION.  THIS PROGRAM RELIES ON PROGRAM LOCALG TO SUPPLY
C   THE LEAST SQUARES MATRIX (A MATRIX) AND LOCAL GRAVITY OBSERVATIONS.
C
C-----------------------------------------------------------------------
      COMMON  /FLDATA/HMIN,HMAX,HCELL,ALMIN,ALMAX,ALCELL,APMIN,APMAX,
     +APCELL,NH,NLAM,NPHI,NORDER,NC,NC2,NC3
      DIMENSION  A(344,85),DELG(343)
      DIMENSION  CU(84),CE(84),CN(84),C(252)
      DIMENSION  IMARK(1402)
      DATA  MAXOB1/344/
C
    6 FORMAT(1X,10E12.4)
    7 FORMAT(1H0,10X,18HALSO CALLED, TIME=,F10.4)
    8 FORMAT(1H0,10X,16HCOEFFICIENTS FOR,I5,25H CELLS COMPUTED, DELTAT=
     +,F10.4,14H AVERAGE TIME=,F10.4)
      XXX=SECOND(CP)
C
```

```
      READ(3) HMIN,HMAX,HCELL,ALMIN,ALMAX,ALCELL,APMIN,APMAX,APCELL,NH,
     +NLAM,NPHI,NORDER,NC,NC2,NC3,MOBSU,MOBSE,MOBSN,MOBS,NCELLS
      CALL OPENMS(1,IMARK,1402,0)
      CALL WRITMS(1,HMIN,16,1)
C
      NLAYER=MOBSE*MOBSN
      PNCELL=NCELLS
      ISTOP=0
C
C  READ THE LEAST SQUARES MATRIX FROM THE SEQUENTIAL FILE
C
      DO 10  IH=1,MOBSU
      ISTART=ISTOP+1
      ISTOP=ISTART+NLAYER-1
      READ(3) ((A(I,J),I=ISTART,ISTOP),J=1,NC)
   10 CONTINUE
C
C  REDUCE THE LEAST SQUARES MATRIX TO UPPER TRIANGULAR FORM
C
      CALL ALSQ(A,DELG,CU,SUMSQ,MOBS,NC,MAXOB1)
      XXY=SECOND(CP)
      TIME=XXY-XXX
      WRITE(6,7)  TIME
C
C  FOR EACH CELL, READ ONE SET OF GRAVITY OBSERVATIONS AND
C  COMPUTE THE COEFFICIENT ARRAY FOR EACH COMPONENT OF GRAVITY
C
      IPOINT=1
      DO 40  ID=1,NCELLS
      READ(3)  (DELG(I),I=1,MOBS)
      CALL ALSQ1(A,DELG,CU,SUMSQ,MOBS,NC,MAXOB1)
C
      READ(3)  (DELG(I),I=1,MOBS)
      CALL ALSQ1(A,DELG,CE,SUMSQ,MOBS,NC,MAXOB1)
C
      READ(3)  (DELG(I),I=1,MOBS)
```

```
      CALL  A_SQ1(A,DELG,CN,SUMSQ,MOBS,NC,MAXOB1)
C
C   STORE THE THREE COEFFICIENT ARRAYS IN ONE ARRAY,C
C
      DO 30  IC=1,NC
      IPNC=IC+NC
      IPNC2=IPNC+NC
      C(IC)=CU(IC)
      C(IPNC)=CE(IC)
      C(IPNC2)=CN(IC)
   30 CONTINUE
C
C   WRITE C ONTO RANDOM ACCESS FILE
C
      IPOINT=IPOINT+1
      CALL  WRITMS(1,C,NC3,IPOINT)
C
C   AS A CHECK ONLY, READ C FROM RANDOM ACCESS FILE AND PRINT IT
C
      CALL  READMS(1,C,NC3,IPOINT)
      WRITE(6,6)
      WRITE(6,6)   (C(J),J=1,NC3)
   40 CONTINUE
      XXY=SECOND(CP)
      TIME=XXX-XXY
      TAV=TIME/RNCELL
      WRITE(6,8) NCELLS,TIME,TAV
   50 CALL  CLOSMS(1)
      STOP
      END
```

```
      SUBROUTINE ALSQ(A,Y,B,R2,NN,MM,NA)
C
C     ALSQ IS A FORTRAN IV SUBROUTINE TO SOLVE THE LINEAR LEAST SQUARES
C     PROBLEM NORM(AB - Y) = MIN.  ITS CALLING SEQUENCE IS
C          CALL ALSQ(A,Y,B,R2,N,M,NA)
C     WHERE
C          A   IS AN ARRAY CONTAINING THE LEAST SQUARES MATRIX.
C              UPON RETURN THE (M+1)-TH COLUMN CONTAINS THE
C              APPROXIMATING VECTOR AB.
C          Y   IS THE VECTOR TO BE FIT.
C          B   CONTAINS UPON RETURN THE COEFFICIENTS OF THE FIT.
C          R2  CONTAINS UPON RETURN THE RESIDUAL SUM OF SQUARES.
C          N   IS THE NUMBER OF ROWS IN THE LEAST SQUARES MATRIX.
C          M   IS THE NUMBER OF COLUMNS IN THE LEAST SQUARES MATRIX.
C          NA  IS THE FIRST DIMENSION OF THE ARRAY A.
C
      DIMENSION A(NA,1),Y(1),B(1)
      N=NN
      N1=N+1
      M=MM
      M1=M+1
      MM1=M-1
C
C      REDUCE THE LEAST SQUARES MATRIX TO UPPER TRIANGULAR FORM
C
      DO 60 L=1,M
      SS=0.
      DO 10 I=L,N
   10 SS=SS+A(I,L)**2
      S2=SS
      S=SQRT(S2)
      IF(A(L,L).LT.0.) S=-S
      D=S2 + S*A(L,L)
      A(L,L)=A(L,L) + S
      IF(L.EQ.M) GO TO 50
      L1=L+1
```

```
      DO 30 J=L1,M
      PP=0.
      DO 20 I=L,N
   20 PP=PP + A(I,L)*A(I,J)
   30 A(N1,J)=PP/D
      DO 40 J=L1,M
      DO 40 I=L,N
   40 A(I,J)=A(I,J) - A(I,L)*A(N1,J)
   50 A(N1,L)=-S
   60 CONTINUE
      RETURN
C
C     REDUCE THE VECTOR Y
C
      ENTRY ALSQ1
   70 DO 80 I=1,N
   80 A(I,M1)=Y(I)
      DO 100 L=1,M
      PP=0.
      DO 90 I=L,N
   90 PP = PP +A(I,L)*A(I,M1)
      D=PP/(-A(L,L)*A(N1,L))
      DO 100 I=L,N
  100 A(I,M1)= A(I,M1) - D*A(I,L)
C
C     CALCULATE THE COEFFICIENT VECTOR B
C
      B(M)=A(M,M1)/A(N1,M)
      IF(M.EQ.1) GO TO 130
      DO 120 LL=1,MM1
      L=M-LL
      L1=L+1
      PP=A(L,M1)
      DO 110 I=L1,M
  110 PP=PP-A(L,I)*B(I)
  120 B(L)=PP/A(N1,L)
```

```
C
C CALCULATE R2
C
  130 SS=0.
      MP1=M+1
      DO 140 I=MP1,N
      SS=SS+A(I,M1)**2
  140 A(I,M1)=0.
      R2=SS
      WRITE(6,901) R2
  901 FORMAT(1H0,10X,24HRESIDUAL SUM OF SQUARES=,E20.12)
C
C     PERFORM THE BACK CALCULATIONS
C
      DO 170 LL=1,M
      L=M-LL+1
      PP=0.
      DO 150 I=L,N
  150 PP=PP+A(I,L)*A(I,M1)
      D=PP/(-A(L,L)*A(N1,L))
      DO 160 I=L,N
  160 A(I,M1)=A(I,M1)-D*A(I,L)
  170 CONTINJE
      RETURN
      END
```

EXAMPLE EXECUTION OF PROGRAM LOCALG AND

PROGRAM FINEG

```
 3          20
 4           4           4           64
 .300000000000E+06   .100000000000E+01   .100000000000E+01
0.                   .750000000000E+02  -.300000000000E+02
 .300000000000E+06   .760000000000E+02  -.290000000000E+02

      ALSQ CALLED, TIME=      .3680

      RESIDUAL SUM OF SQUARES=    .395503006059E-08

      RESIDUAL SUM OF SQUARES=    .171144648150E-08

      RESIDUAL SUM OF SQUARES=    .171171873427E-08

-.3353E-04  -.5628E-05  -.2398E-04   .2731E-04   .6475E-05  -.1682E-05   .4872E-06   .7849E-05   .2939E-04  -.8509E-05
-.6083E-06   .2199E-05  -.3804E-05  -.3778E-07  -.1040E-04   .3329E-05  -.1112E-05  -.1842E-05  -.1073E-04   .2475E-05
 .4658E-04  -.1087E-06   .1808E-05  -.5524E-04  -.1790E-05   .5418E-05  -.2378E-05  -.8368E-06  -.9636E-06   .1816E-04
 .1493E-06   .2636E-05  -.1023E-05   .1908E-06   .2598E-05  -.1008E-04   .3084E-05   .1114E-05  -.4758E-06  -.4376E-05
 .1044E-04  -.2165E-04   .6955E-06  -.1520E-04  -.9120E-07  -.5273E-05   .1441E-05   .2708E-04  -.2063E-05   .6402E-05
 .1764E-05   .5068E-06   .1999E-05  -.1864E-06  -.4536E-06   .7314E-05  -.2657E-05  -.1232E-04   .1729E-05  -.1596E-05

      COEFFICIENTS FOR    1 CELLS COMPUTED, DELTAT=      .2340 AVERAGE TIME=     .2340
```

PROGRAM FINTES, SUBROUTINE FINITE, AND

SUPPORTING SUBROUTINES

```
      PROGRAM FINTES(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2)
      COMMON  /HLP/H,ALAM,APHI,GU,GE,GN
      COMMON  /XYZ/X,Y,Z,GX,GY,GZ
      COMMON  /IMARK/IFLAG,ISITIN,IMARK(1402)
      COMMON  /FLDATA/REA(9),INT(7)
      COMMON  /MASPOS/PMVALS(1080),POSITS(1080,3)
      DATA   A/6378160./
      DATA   B/6356774.504/
    1 FORMAT(16I5)
    2 FORMAT(F10.0,7F10.2)
    3 FORMAT(1H1)
    4 FORMAT(1X,12I10)
    5 FORMAT(1X,F10.0,7F10.2)
    6 FORMAT(1H0,4X,1HH,8X,6HLAMBDA,5X,3HPHI,7X,5HERRGU,5X,5HERRGE,5X
     +5HERRGN,5X,4HPMGU,6X,4HPMGE,6X,4HPMGN,6X,4HFIGU,6X,4HFIGE,6X,
     +4HFIGN)
    7 FORMAT(4X,4H(KM),1X,2(5X,5H(DEG)),2X,9(3X,7H(MGALS)))
    8 FORMAT(2X,9(1H-),11(2X,8(1H-)))
    9 FORMAT(1H0,10X,22HFINITE TIME/EXECUTION=,F9.4)
   10 FORMAT(1H0,10X,22HPTMASS TIME/EXECUTION=,F9.4)
   11 FORMAT(1X,-3PF10.3,2(0PF10.4),9(1X,5PF9.4))
   12 FORMAT(///,1X,5HMEANS,25X,3(1X,5PF9.4))
   13 FORMAT(1X,19HSTANDARD DEVIATIONS,11X,3(1X,5PF9.4))
   14 FORMAT(1X,26HABS. VALUES OF MAX. ERRORS,4X,3(1X,5PF9.4))
   15 FORMAT(46H0*****    NEGATIVE OR ZERO NO. OF STEPS    *****)
      CALL  OPENMS(1,IMARK,1402,0)
      CALL  READMS(1,REA,16,1)
      READ(2) PMVALS,POSITS
      PI=ACOS(-1.)
      DEGRAD=PI/180.
      A2=A*A
      B2=B*B
      IFLAG=0
      ISITIN=0
   20 READ(5,1) ISTEPH,ISTEPL,ISTEPP
      IF (EOF(5) .NE. 0.)  GOTO 40
```

```
      READ(5,2) HMIN,ALMIN,APMIN
      IF (EOF(5) .NE. 0.)  GOTO 40
      READ(5,2) HMAX,ALMAX,APMAX
      IF (EOF(5) .NE. 0.)  GOTO 40
      WRITE(6,3)
      WRITE(6,4) ISTEPH,ISTEPL,ISTEPP
      WRITE(6,5) HMIN,ALMIN,APMIN
      WRITE(6,5) HMAX,ALMAX,APMAX
      IHM1=ISTEPH-1
      ILM1=ISTEPL-1
      IPM1=ISTEPP-1
      IF (IHM1)  21,22,23
   21 WRITE(6,15)
      GOTO 40
   22 DH=0.
      GOTO 24
   23 RHM1=IHM1
      DH=(HMAX-HMIN)/RHM1
   24 IF (ILM1)  21,25,26
   25 DLAM=0.
      GOTO 27
   26 RLM1=ILM1
      DLAM=(ALMAX-ALMIN)/RLM1
   27 IF (IPM1)  21,28,29
   28 DPHI=0.
      GOTO 30
   29 RPM1=IPM1
      DPHI=(APMAX-APMIN)/RPM1
   30 WRITE(6,6)
      WRITE(6,7)
      WRITE(6,8)
      FTIME=0.
      PTIME=0.
      EGU=0.
      EGF=0.
      EGN=0.
```

```
SDEGU=0.
SDEGE=0.
SDEGN=0.
EGUMAX=0.
EGEMAX=0.
EGNMAX=0.
H=HMIN-DH
DO 35  I=1,ISTEPH
H=H+DH
AL=ALMIN-DLAM
DO 35  J=1,ISTEPL
AL=AL+DLAM
ALAM=AL*DEGRAD
AP=APMIN-DPHI
DO 35  K=1,ISTEPP
AP=AP+DPHI
APHI=AP*DEGRAD
COSL=COS(ALAM)
SINL=SIN(ALAM)
COSP=COS(APHI)
SINP=SIN(APHI)
RN=SQRT(A2*COSP*COSP + B2*SINP*SINP)
ZN=B2/RN
RN=A2/RN
Y=(RN+H)*COSP
X=Y*COSL
Y=Y*SINL
Z=(ZN+H)*SINP
TBEF=SECOND(CP)
CALL FINITE
TAFT=SECOND(CP)
FTIME=FTIME+TAFT-TBEF
GUF=GU
GEF=GE
GNF=GN
TBEF=SECOND(CP)
```

```
      CALL  FTMASS
      TAFT=SECOND(CP)
      PTIME=PTIME+TAFT-TREF
      GU=COSP*COSL*GX + COSP*SINL*GY + SINP*GZ
      GE=-SINL*GX + COSL*GY
      GN=-SINP*COSL*GX - SINP*SINL*GY + COSP*GZ
      ERRGU=GU-GUF
      ERRGE=GE-GEF
      ERRGN=GN-GNF
      WRITE(6,11) H,AL,AP,ERRGU,ERRGE,ERRGN,GU,GE,GN,GUF,GFF,GNF
      AERRGU=ABS(ERRGU)
      AERRGE=ABS(ERRGE)
      AERRGN=ABS(ERRGN)
      IF(AERRGU.GT.EGUMAX)  EGUMAX=AERRGU
      IF(AERRGE.GT.EGEMAX)  EGEMAX=AERRGE
      IF(AERRGN.GT.EGNMAX)  EGNMAX=AERRGN
      EGU=EGU+ERRGU
      EGE=EGE+ERRGE
      EGN=EGN+ERRGN
      SDEGU=SDEGU+ERRGU*ERRGU
      SDEGE=SDEGE+ERRGE*ERRGE
      SDEGN=SDEGN+ERRGN*ERRGN
   35 CONTINUE
      IPTS=ISTEPH*ISTEPL*ISTEPP
      RIPTS=IPTS
      RIPTM1=RIPTS-1.
      EGU=EGU/RIPTS
      EGE=EGE/RIPTS
      EGN=EGN/RIPTS
      SDEGU=SQRT(SDEGU/RIPTM1)
      SDEGE=SQRT(SDEGE/RIPTM1)
      SDEGN=SQRT(SDEGN/RIPTM1)
      WRITE(6,12) EGU,EGE,EGN
      WRITE(6,13) SDEGU,SDEGE,SDEGN
      WRITE(6,14) EGUMAX,EGEMAX,EGNMAX
      FTIME=FTIME/RIPTS
```

```
      PTIME=PTIME/RIPTS
      WRITE(6,9)  FTIME
      WRITE(6,10)  PTIME
      GOTO 20
   40 CONTINJE
      CALL CLOSMS(1)
      STOP
      END
```

```
      SUBROUTINE FINITE
C-----------------------------------------------------------------------
C
C     FINITE ELEMENT GRAVITY FIELD GRAVITY EVALUATION SUBROUTINE
C
C                BY
C          DR. JOHN L. JUNKINS
C                AND
C          JOHN T. SAUNDERS
C
C          DEPARTMENT OF ENGINEERING SCIENCE AND SYSTEMS
C          SCHOOL OF ENGINEERING AND APPLIED SCIENCE
C          UNIVERSITY OF VIRGINIA
C          CHARLOTTESVILLE,VA  22901
C
C-----------------------------------------------------------------------
C
C     A SUBROUTINE WHICH EVALUATES THE GRAVITY ANOMALY, DELTA G, FROM
C  ANY ONE RANDOM ACCESS FILE CREATED BY PROGRAMS LOCALG AND FINEG.
C
C-----------------------------------------------------------------------
      COMMON  /HLP/H,ALAM,APHI,GU,GE,GN
      COMMON  /XYZ/X,Y,Z,GX,GY,GZ
      COMMON  /IMARK/IFLAG,ISITIN,IMARK(1402)
      COMMON  /FLDATA/HMIN,HMAX,HCELL,ALMIN,ALMAX,ALCELL,APMIN,APMAX,
     +APCELL,NH,NLAM,NPHT,NORDER,NC,NC2,NC3
      DIMENSION  TX(7),TY(7),TZ(7),C(252)
      DIMENSION  IX(84),IY(84),IZ(84)
      DATA  IX(1),IX(2),IX(3),IX(4),IX(5),IX(6),IX(7),IX(8),IX(9),
     +IX(10),IX(11),IX(12),IX(13),IX(14),IX(15),IX(16),IX(17),IX(18),
     +IX(19),IX(20),IX(21),IX(22),IX(23),IX(24),IX(25),IX(26),IX(27),
     +IX(28),IX(29),IX(30),IX(31),IX(32),IX(33),IX(34),IX(35),IX(36),
     +IX(37),IX(38),IX(39),IX(40),IX(41),IX(42),IX(43),IX(44),IX(45),
     +IX(46),IX(47),IX(48),IX(49),IX(50),IX(51),IX(52),IX(53),IX(54),
     +IX(55),IX(56),IX(57),IX(58),IX(59),IX(60),IX(61),IX(62),IX(63),
     +IX(64),IX(65),IX(66),IX(67),IX(68),IX(69),IX(70),IX(71),IX(72),
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     +IX(73),IX(74),IX(75),IX(76),IX(77),IX(78),IX(79),IX(80),IX(81),
     +IX(82),IX(83),IX(84)/
     +1,1,1,2,1,1,1,2,2,3,1,1,1,1,2,2,2,3,3,4,1,1,1,1,1,2,2,2,2,3,
     +3,3,4,4,5,1,1,1,1,1,1,2,2,2,2,2,3,3,3,3,4,4,4,5,5,6,1,1,1,1,
     +1,1,1,2,2,2,2,2,2,3,3,3,3,3,4,4,4,4,5,5,5,6,6,7/
      DATA  IY(1),IY(2),IY(3),IY(4),IY(5),IY(6),IY(7),IY(8),IY(9),
     +IY(10),IY(11),IY(12),IY(13),IY(14),IY(15),IY(16),IY(17),IY(18),
     +IY(19),IY(20),IY(21),IY(22),IY(23),IY(24),IY(25),IY(26),IY(27),
     +IY(28),IY(29),IY(30),IY(31),IY(32),IY(33),IY(34),IY(35),IY(36),
     +IY(37),IY(38),IY(39),IY(40),IY(41),IY(42),IY(43),IY(44),IY(45),
     +IY(46),IY(47),IY(48),IY(49),IY(50),IY(51),IY(52),IY(53),IY(54),
     +IY(55),IY(56),IY(57),IY(58),IY(59),IY(60),IY(61),IY(62),IY(63),
     +IY(64),IY(65),IY(66),IY(67),IY(68),IY(69),IY(70),IY(71),IY(72),
     +IY(73),IY(74),IY(75),IY(76),IY(77),IY(78),IY(79),IY(80),IY(81),
     +IY(82),IY(83),IY(84)/
     +1,1,2,1,1,2,3,1,2,1,1,2,3,4,1,2,3,1,2,1,1,2,3,4,5,1,2,3,4,1,
     +2,3,1,2,1,1,2,3,4,5,6,1,2,3,4,5,1,2,3,4,1,2,3,1,2,1,1,2,3,4,
     +5,6,7,1,2,3,4,5,6,1,2,3,4,5,1,2,3,4,1,2,3,1,2,1/
      DATA  IZ(1),IZ(2),IZ(3),IZ(4),IZ(5),IZ(6),IZ(7),IZ(8),IZ(9),
     +IZ(10),IZ(11),IZ(12),IZ(13),IZ(14),IZ(15),IZ(16),IZ(17),IZ(18),
     +IZ(19),IZ(20),IZ(21),IZ(22),IZ(23),IZ(24),IZ(25),IZ(26),IZ(27),
     +IZ(28),IZ(29),IZ(30),IZ(31),IZ(32),IZ(33),IZ(34),IZ(35),IZ(36),
     +IZ(37),IZ(38),IZ(39),IZ(40),IZ(41),IZ(42),IZ(43),IZ(44),IZ(45),
     +IZ(46),IZ(47),IZ(48),IZ(49),IZ(50),IZ(51),IZ(52),IZ(53),IZ(54),
     +IZ(55),IZ(56),IZ(57),IZ(58),IZ(59),IZ(60),IZ(61),IZ(62),IZ(63),
     +IZ(64),IZ(65),IZ(66),IZ(67),IZ(68),IZ(69),IZ(70),IZ(71),IZ(72),
     +IZ(73),IZ(74),IZ(75),IZ(76),IZ(77),IZ(78),IZ(79),IZ(80),IZ(81),
     +IZ(82),IZ(83),IZ(84)/
     +1,2,1,1,3,2,1,2,1,1,4,3,2,1,3,2,1,2,1,1,5,4,3,2,1,4,3,2,1,3,
     +2,1,2,1,1,6,5,4,3,2,1,5,4,3,2,1,4,3,2,1,3,2,1,2,1,1,7,6,5,4,
     +3,2,1,6,5,4,3,2,1,5,4,3,2,1,4,3,2,1,3,2,1,2,1,1/
C
C  COMPARE COORDINATES TO REGION BOUNDARIES.  IF POINT IS OUTSIDE FINITE
C  ELEMENT FIELD, PRINT ERROR MESSAGE AND CALL GRAV
C
  100 IF(H.LT.HMIN.OR.H.GT.HMAX.OR.ALAM.LT.ALMIN.OR.ALAM.GT.ALMAX.OR.
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```
     +APHI.LT.APMIN.OR.APHI.GT.APMAX)   GOTO 400
      ISITIN=1
C
C  COMPUTE VARIOUS INDEXES TO HELP FIND THE RIGHT CELL IN THE REGION
C
      I=INT((H-HMIN)/HCELL+1.)
      J=INT((ALAM-ALMIN)/ALCELL+1.)
      K=INT((APHI-APMIN)/APCELL+1.)
      IF(H .EQ. HMAX)  I=I-1
      IF(ALAM .EQ. ALMAX)   J=J-1
      IF(APHI .EQ. APMAX)   K=K-1
      RI=I
      RJ=J
      RK=K
C
C  COMPUTE IPOINT, THE POINTER FOR THE SET OF COEFFICIENTS AT THESE
C  COORDINATES
C
      IPOINT=(I-1)*NPHI*NLAM + (J-1)*NPHI + K + 1
      IF (IPOINT .EQ. IFLAG)   GOTO 200
C
C  READ A NEW SET OF COEFFICIENTS ONLY IF PROPER SET IS NOT IN CORE
C
      CALL READMS(1,C,NC3,IPOINT)
      IFLAG=IPOINT
C
C  FIND THE MINIMUM CELL BOUNDARY COORDINATES
C
  200 HMCELL=HMIN + (RI-1.)*HCELL
      ALMCEL=ALMIN + (RJ-1.)*ALCELL
      APMCEL=APMIN + (RK-1.)*APCELL
C
C  NON DIMENSIONALIZE THE CALLING COORDINATES
C
      X1=(H-HMCELL)/HCELL
      X2=(ALAM-ALMCEL)/ALCELL
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```
      X3=(APHI-APMCFL)/APCFLL
C
C   GENERATE CHEBYCHEV POLYNOMIALS AT NON-DIMENSIONALIZED COORDINATES
C
      CALL  CHEBY(X1,NORDER,TX)
      CALL  CHEBY(X2,NORDER,TY)
      CALL  CHEBY(X3,NORDER,TZ)
C
C   EVALUATE DELTA G-UP, DELTA G-EAST, AND DELTA G-NORTH
C
      GU=0.
      GE=0.
      GN=0.
C
      DO 300  II=1,NC
      NX=IX(II)
      NY=IY(II)
      NZ=IZ(II)
      AAA=TX(NX)*TY(NY)*TZ(NZ)
      IIPNC=II+NC
      IIPNC2=II+NC2
      GU=GU + AAA*C(II)
      GE=GE + AAA*C(IIPNC)
      GN=GN + AAA*C(IIPNC2)
  300 CONTINUE
      RETURN
  400 CONTINUE
      CALL  PTMASS
      COSL=COS(ALAM)
      SINL=SIN(ALAM)
      COSP=COS(APHI)
      SINP=SIN(APHI)
      GU=COSP*COSL*GX + COSP*SINL*GY + SINP*GZ
      GE=-SINL*GX + COSL*GY
      GN=-SINP*COSL*GX - SINP*SINL*GY + COSP*GZ
      WRITE(6,1)
```

```
    1 FORMAT(49H POINT NOT IN FINITE ELEMENT FIELD, PTMASS CALLED)
      ISITIN=0
      RETURN
      END
```

```
      SUBROUTINE CHEBY(X,N,TA)
      DIMENSION  TA(7)
C
C  S/R CHEBY RETURNS CHEBYCHEV POLYNOMIALS THROUGH ORDER N,
C  EVALUATED AT X, IN VECTOR TA
C
      IF (N .GT. 0 .AND. N .LT. 7) GOTO 10
      WRITE(6,5)  N
    5 FORMAT(24H0ILLEGAL NORDER, NORDER=,I6)
      STOP
   10 CONTINUE
      XBAR=2.*X-1.
C
C  XBAR=2X-1  MAPS  (0 .LE. X .LE. 1)  INTO  (-1 .LE. XBAR .LE. 1)
C
      TA(1)=1.
      TA(2)=XBAR
      NP1=N+1
      DO 20 I=3,NF1
   20 TA(I)=2.*XBAR*TA(I-1)-TA(I-2)
      RETURN
      END
```

```
      SUBROUTINE PTMASS
      COMMON  /XYZ/X,Y,Z,DELGX,DELGY,DELGZ
      COMMON  /MASPOS/PMVALS(1080),POSITS(1080,3)
C
C  GIVEN THE RECTANGULAR COORDINATES, X, Y, Z, OF A POINT, THIS ROUTINE
C  RETURNS THE COMPONENTS OF THE GRAVITY DISTURBANCE, DELGX, DELGY, AND
C  DELGZ, USING USING THE POINT MASSES OF MASS MODEL 310.
C
C  PMVALS CONTAINS THE PRECOMPUTED PRODUCTS OF THE GRAVITATIONAL
C  CONSTANT (6.67E-14) AND THE 1080 POINT MASSES (-1.E19, 0., OR +1.E19)
C  POSITS CONTAINS THE PRECOMPUTED EARTH-FIXED X, Y, Z COORDINATES OF
C  THE 1080 POINT MASSES.
C
C  TERMINOLOGY
C
C  X,Y,Z--EARTH-FIXED RECTANGULAR COORDINATES OF POINT AT WHICH GRAVITY
C  DISTURBANCE IS TO BE EVALUATED
C  XI,YI,ZI--EARTH-FIXED RECTANGULAR COORDINATES OF THE ITH POINT MASS
C  POSITS(I,1)=XI
C  POSITS(I,2)=YI
C  POSITS(I,3)=ZI
C  DELGX,DELGY,DELGZ--EARTH-FIXED RECTANGULAR COMPONENTS OF THE GRAVITY
C  DISTURBANCE
C
      DELGX=0.
      DELGY=0.
      DELGZ=0.
C
      DO 20 I=1,1080
      IF (PMVALS(I)) 10,20,10
   10 CONTINUE
      DX=POSITS(I,1)-X
      DY=POSITS(I,2)-Y
      DZ=POSITS(I,3)-Z
      DISTSQ=DX*DX+DY*DY+DZ*DZ
      DIST=SQRT(DISTSQ)
```

```
      TEMP=PMVALS(I)/DIST/DISTSQ
C
      DELGX=DELGX+(DX*TEMP)
      DELGY=DELGY+(DY*TEMP)
      DELGZ=DELGZ+(DZ*TEMP)
C
   20 CONTINUE
C
      RETURN
      END
```

EXAMPLE EXECUTION OF PROGRAM FINTES

4	5	5
1.	75.10	-29.90
270001.	75.90	-29.10

H (KM)	LAMBDA (DEG)	PHI (DEG)	ERRGU (MGALS)	ERRGE (MGALS)	ERRGN (MGALS)	PMGU (MGALS)	PMGE (MGALS)	PMGN (MGALS)	FIGJ (MGALS)	FIGE (MGALS)	FIGN (MGALS)
.001	75.1000	-29.9000	.3926	.6070	.0101	-.2254	13.4039	7.2174	-.6180	12.7969	7.2073
.001	75.1000	-29.7000	.1973	1.2721	.2630	-2.4032	14.2677	5.5622	-2.6005	12.9956	5.2993
.001	75.1000	-29.5000	.0682	1.2426	.0803	-3.4537	13.9983	3.1978	-3.5219	12.7557	3.1175
.001	75.1000	-29.3000	.2074	.2284	-.0141	-3.2682	12.3283	.9189	-3.4757	12.0999	.9330
.001	75.1000	-29.1000	.2308	-1.1554	.1823	-2.3244	9.8959	-.8010	-2.5552	11.0513	-.9833
.001	75.3000	-29.9000	-.5029	.5100	.6726	-3.9483	13.3893	8.2169	-3.4454	12.8793	7.5444
.001	75.3000	-29.7000	-1.3583	.9714	.6481	-6.8048	14.2355	5.9868	-5.4465	13.2641	5.3387
.001	75.3000	-29.5000	-1.3807	.9485	-.3658	-7.7109	14.2262	2.5065	-6.3302	13.2777	2.8723
.001	75.3000	-29.3000	-.1347	.2777	-1.1041	-6.3246	13.2207	-.6880	-6.1899	12.9430	.4161
.001	75.3000	-29.1000	1.4081	-.6031	-.8758	-3.7109	11.6797	-2.6347	-5.1190	12.2829	-1.7589
.001	75.5000	-29.9000	-.6758	-.2521	1.0552	-6.6458	12.3832	9.1252	-5.9699	12.6353	8.0700
.001	75.5000	-29.7000	-1.9041	-.0015	.8739	-9.9911	13.1784	6.4918	-8.0870	13.1799	5.6178
.001	75.5000	-29.5000	-1.9483	.1538	-.5455	-10.9786	13.5747	2.3725	-9.0303	13.4209	2.9180
.001	75.5000	-29.3000	-.3298	.2135	-1.5657	-9.2231	13.5945	-1.3243	-8.8933	13.3810	.2414
.001	75.5000	-29.1000	1.7049	.3277	-1.2725	-6.0645	13.4109	-3.4136	-7.7695	13.0832	-2.1412
.001	75.7000	-29.9000	-.0625	-.7436	1.1791	-8.2598	11.3505	9.9346	-8.1973	12.0940	8.7555
.001	75.7000	-29.7000	-1.4471	-.6305	.9925	-11.9748	12.1419	7.1006	-10.5277	12.7724	6.1081
.001	75.7000	-29.5000	-1.6698	-.3568	-.4023	-13.2978	12.8577	2.8237	-11.6280	13.2145	3.2260
.001	75.7000	-29.3000	-.3933	.1874	-1.3257	-11.9850	13.6306	-.9457	-11.5918	13.4432	.3800
.001	75.7000	-29.1000	1.1065	.9989	-.9157	-9.4059	14.4804	-3.0745	-10.5123	13.4815	-2.1588
.001	75.9000	-29.9000	.7690	-.5360	1.0738	-9.3644	10.7489	10.6460	-10.1334	11.2850	9.5723
.001	75.9000	-29.7000	-.7843	-.6542	.9792	-13.5587	11.4166	7.7600	-12.7745	12.0708	6.7808
.001	75.9000	-29.5000	-1.2499	-.5286	-.2092	-15.3791	12.1592	3.5584	-14.1292	12.6878	3.7676
.001	75.9000	-29.3000	-.5020	-.0380	-.8373	-14.7931	13.1210	-.0337	-14.2911	13.1590	.8035
.001	75.9000	-29.1000	.0848	.8059	-.2601	-13.2686	14.3131	-2.1007	-13.3534	13.5072	-1.8405
90.001	75.1000	-29.9000	-.2144	-.6369	-.2868	-.8264	4.8236	2.2272	-.6120	5.4605	2.5140
90.001	75.1000	-29.7000	.3979	-.6991	-.1668	-1.3491	4.9092	1.8026	-1.7470	5.6083	1.9694
90.001	75.1000	-29.5000	.4577	-.5036	.1362	-1.7627	4.9135	1.2699	-2.2205	5.4171	1.1337
90.001	75.1000	-29.3000	.0841	-.0829	.3918	-2.0416	4.8269	.6697	-2.1257	4.9098	.2778
90.001	75.1000	-29.1000	-.6288	.5457	.3683	-2.1851	4.6552	.0410	-1.5563	4.1095	-.3273
90.001	75.3000	-29.9000	.2709	-.3897	-.3664	-1.7416	5.1780	2.3316	-2.0125	5.5677	2.6980
90.001	75.3000	-29.7000	.8369	-.5570	-.0780	-2.2972	5.2477	1.8480	-3.1341	5.8047	1.9260
90.001	75.3000	-29.5000	.8174	-.5238	.3666	-2.7204	5.2464	1.2425	-3.5378	5.7703	.8758
90.001	75.3000	-29.3000	.3353	-.3210	.7492	-2.9818	5.1663	.5677	-3.3171	5.4873	-.1815
90.001	75.3000	-29.1000	-.5213	.0332	.8495	-3.0867	5.0119	-.1255	-2.5653	4.9787	-.9751
90.001	75.5000	-29.9000	.4595	-.0672	-.5508	-2.6932	5.3997	2.4176	-3.1527	5.4669	2.9685
90.001	75.5000	-29.7000	1.0753	-.3162	-.1359	-3.2831	5.4508	1.8843	-4.3583	5.7670	2.0202
90.001	75.5000	-29.5000	1.0667	-.4173	.4114	-3.7231	5.4457	1.2183	-4.7897	5.8631	.8069
90.001	75.5000	-29.3000	.5597	-.4005	.8814	-3.9806	5.3776	.4806	-4.5404	5.7781	-.4007
90.001	75.5000	-29.1000	-.3611	-.2882	1.0622	-4.0648	5.2469	-.2695	-3.7037	5.5350	-1.3316
90.001	75.7000	-29.9000	.3927	.3077	-.8187	-3.6459	5.4949	2.4781	-4.0386	5.1873	3.2968
90.001	75.7000	-29.7000	1.1570	-.0069	-.3161	-4.2686	5.5174	1.9074	-5.4256	5.5243	2.2236
90.001	75.7000	-29.5000	1.2497	-.2235	.2981	-4.7323	5.5012	1.1962	-5.9820	5.7247	.8981
90.001	75.7000	-29.3000	.7997	-.3718	.8178	-5.0017	5.4399	.4092	-5.8014	5.8116	-.4086
90.001	75.7000	-29.1000	-.1085	-.4795	1.0350	-5.0856	5.3284	-.3907	-4.9772	5.8079	-1.4256
90.001	75.9000	-29.9000	.0967	.7177	-1.1536	-4.5792	5.4759	2.5009	-4.6758	4.7582	3.6545
90.001	75.9000	-29.7000	1.1164	.3488	-.6008	-5.2252	5.4547	1.9065	-6.3415	5.1059	2.5073
90.001	75.9000	-29.5000	1.4078	.0285	.0459	-5.7127	5.4131	1.1669	-7.1205	5.3846	1.1210
90.001	75.9000	-29.3000	1.1025	-.2721	.5786	-6.0035	5.3451	.3450	-7.1060	5.6171	-.2337
90.001	75.9000	-29.1000	.2897	-.5865	.7885	-6.1019	5.2401	-.4972	-6.3916	5.8265	-1.2856
180.001	75.1000	-29.9000	.2171	-.1652	.3293	-1.0209	2.0133	.8436	-1.2380	2.1785	.5143
180.001	75.1000	-29.7000	.4270	-.3015	-.0036	-1.2046	2.0379	.6200	-1.6316	2.3394	.6236
180.001	75.1000	-29.5000	.4079	-.2316	-.0612	-1.3552	2.0296	.3632	-1.7631	2.2611	.4244
180.001	75.1000	-29.3000	.2607	.0212	-.1098	-1.4653	1.9878	.0777	-1.7260	1.9666	.1875

180.001	75.1000	-29.1000	.0842	.4347	-.4147	-1.5296	1.9134	-.2306	-1.6138	1.4787	.1841
180.001	75.3000	-29.9000	.3892	-.1058	.2339	-1.4406	2.1773	.8786	-1.8298	2.2831	.6448
180.001	75.3000	-29.7000	.5502	-.2427	.0311	-1.6278	2.1938	.6280	-2.1781	2.4365	.5969
180.001	75.3000	-29.5000	.4304	-.2381	.0898	-1.7775	2.1801	.3432	-2.2079	2.4182	.2534
180.001	75.3000	-29.3000	.1314	-.1152	.1444	-1.8815	2.1359	.0297	-2.0129	2.2511	-.1146
180.001	75.3000	-29.1000	-.2479	.1038	-.0691	-1.9342	2.0619	-.3055	-1.6863	1.9581	-.2364
180.001	75.5000	-29.9000	.3219	-.0025	.1456	-1.8823	2.2956	.9053	-2.2042	2.2981	.7598
180.001	75.5000	-29.7000	.5334	-.1148	.0240	-2.0710	2.3030	.6299	-2.6044	2.4177	.6058
180.001	75.5000	-29.5000	.4116	-.1501	.1504	-2.2184	2.2831	.3197	-2.6300	2.4332	.1694
180.001	75.5000	-29.3000	.0585	-.1315	.2597	-2.3158	2.2358	-.0191	-2.3743	2.3673	-.2788
180.001	75.5000	-29.1000	-.4265	-.0813	.0888	-2.3574	2.1618	-.3788	-1.9309	2.2431	-.4676
180.001	75.7000	-29.9000	.0297	.1111	.0921	-2.3370	2.3637	.9227	-2.3668	2.2527	.8306
180.001	75.7000	-29.7000	.3915	.0486	.0030	-2.5249	2.3610	.6248	-2.9164	2.3125	.6218
180.001	75.7000	-29.5000	.3665	-.0015	.1485	-2.6686	2.3340	.2920	-3.0351	2.3355	.1435
180.001	75.7000	-29.3000	.0575	-.0618	.2641	-2.7588	2.2829	-.0694	-2.8162	2.3447	-.3335
180.001	75.7000	-29.1000	-.4360	-.1549	.0872	-2.7893	2.2082	-.4511	-2.3533	2.3631	-.5383
180.001	75.9000	-29.9000	-.4722	.2027	.1011	-2.7956	2.3790	.9297	-2.3234	2.1763	.8286
180.001	75.9000	-29.7000	.1401	.2153	-.0043	-2.9798	2.3653	.6118	-3.1199	2.1500	.6162
180.001	75.9000	-29.5000	.3114	.1759	.1119	-3.1176	2.3303	.2591	-3.4291	2.1544	.1472
180.001	75.9000	-29.3000	.1449	.0621	.1855	-3.1995	2.2746	-.1221	-3.3444	2.2125	-.3076
180.001	75.9000	-29.1000	-.2594	-.1488	-.0459	-3.2187	2.1984	-.5230	-2.9593	2.3472	-.4771
270.001	75.1000	-29.9000	.2685	.0189	-.0472	-.9443	.7014	.3334	-1.2128	.6825	.3806
270.001	75.1000	-29.7000	-.0437	-.1999	-.2382	-1.0147	.7209	.1960	-.9711	.9207	.4342
270.001	75.1000	-29.5000	-.2008	-.2964	-.1164	-1.0677	.7231	.0455	-.8668	1.0195	.1619
270.001	75.1000	-29.3000	-.1068	-.2930	.0489	-1.1002	.7087	-.1165	-.9935	1.0018	-.1654
270.001	75.1000	-29.1000	.3346	-.2116	-.0108	-1.1099	.6789	-.2876	-1.4445	.8905	-.2768
270.001	75.3000	-29.9000	.4701	.0258	-.1990	-1.1442	.7828	.3582	-1.6143	.7570	.5572
270.001	75.3000	-29.7000	.0806	-.0909	-.3179	-1.2146	.8000	.2059	-1.2953	.8910	.5239
270.001	75.3000	-29.5000	-.2078	-.1521	-.1366	-1.2652	.8008	.0410	-1.0574	.9529	.1776
270.001	75.3000	-29.3000	-.2990	-.1800	.0760	-1.2931	.7859	-.1348	-.9941	.9659	-.2108
270.001	75.3000	-29.1000	-.0969	-.1964	.0516	-1.2957	.7563	-.3187	-1.1989	.9527	-.3703
270.001	75.5000	-29.9000	.4865	-.0167	-.2356	-1.3545	.8437	.3806	-1.8410	.8604	.6163
270.001	75.5000	-29.7000	.1179	-.0055	-.3329	-1.4241	.8583	.2142	-1.5420	.8638	.5471
270.001	75.5000	-29.5000	-.2039	-.0054	-.1424	-1.4717	.8574	.0355	-1.2679	.8628	.1780
270.001	75.5000	-29.3000	-.3826	-.0385	.0671	-1.4946	.8417	-.1532	-1.1120	.8802	-.2202
270.001	75.5000	-29.1000	-.3223	-.1266	.0275	-1.4902	.8124	-.3491	-1.1679	.9390	-.3766
270.001	75.7000	-29.9000	.3272	-.1396	-.1287	-1.5715	.8822	.4004	-1.8987	1.0218	.5291
270.001	75.7000	-29.7000	.0778	.0254	-.2548	-1.6394	.8940	.2206	-1.7171	.8686	.4753
270.001	75.7000	-29.5000	-.1794	.1129	-.1055	-1.6835	.8912	.0291	-1.5041	.7783	.1345
270.001	75.7000	-29.3000	-.3479	.1006	.0506	-1.7010	.8747	-.1717	-1.3531	.7740	-.2224
270.001	75.7000	-29.1000	-.3319	-.0331	-.0544	-1.6894	.8455	-.3788	-1.3575	.8786	-.3244
270.001	75.9000	-29.9000	.0021	-.3735	.1502	-1.7910	.8972	.4173	-1.7931	1.2707	.2671
270.001	75.9000	-29.7000	-.0300	-.0286	-.0551	-1.8564	.9060	.2248	-1.8264	.9346	.2799
270.001	75.9000	-29.5000	-.1245	.1723	.0028	-1.8964	.9012	.0214	-1.7719	.7289	.0186
270.001	75.9000	-29.3000	-.1850	.2071	.0553	-1.9081	.8838	-.1905	-1.7231	.6767	-.2458
270.001	75.9000	-29.1000	-.1157	.0541	-.1655	-1.8892	.8549	-.4078	-1.7735	.8009	-.2423

MEANS	.0678	-.0446	.0239
STANDARD DEVIATIONS	.6723	.4173	.5345
ABS. VALUES OF MAX. ERRORS	1.9483	1.2721	1.5657

FINITE TIME/EXECUTION= .0018

PTMASS TIME/EXECUTION= .1229

PROGRAM MASPOS

```
      PROGRAM MASPOS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE2)
      DIMENSION  MASSES(1080),PMVALS(1080),POSITS(1080,3)
C
      DATA  A,B/6378160.,6356774.504/
      DATA  BIGG/6.67E-14/
C
  901 FORMAT(1H1,3X,9HMASSES(I),18X,1HX,19X,1HY,19X,1HZ)
  902 FORMAT(1X,4(3X,17(1H-)))
  903 FORMAT(24X,36I1,20X)
  904 FORMAT(1X,I6,4X,3(1PE20.10))
  905 FORMAT(1X,4(1PE20.10))
C
      PI=ACOS(-1.)
      RADMIN=10800./PI
      ISTART=-35
      DO 10 I=1,30
      ISTART=ISTART+36
      ISTOP=ISTART+35
      READ(5,903) (MASSES(K),K=ISTART,ISTOP)
   10 CONTINUE
C
      A2=A*A
      B2=B*B
      RHI=-80000.
      IPT=0
      PHIM=-875.
      DO 20 I=1,30
      PHIM=PHIM-50.
      PHI=PHIM/RADMIN
      SINP=SIN(PHI)
      COSP=COS(PHI)
C
      RNI=A2/SQRT(A2*COSP*COSP+B2*SINP*SINP)
C
      ALAMBM=3575.
      DO 20 J=1,36
```

```
      ALAMBM=ALAMBM+50.
      ALAMB=ALAMBM/RADMIN
      SINL=SIN(ALAMB)
      COSL=COS(ALAMB)
C
      IPT=IPT+1
      TEMP=(RNI+RHI)*COSP
      POSITS(IPT,1)=TEMP*COSL
      POSITS(IPT,2)=TEMP*SINL
      POSITS(IPT,3)=(B2*RNI/A2+RHI)*SINP
   20 CONTINUE
C
      DO 30 I=1,1080
      MI=MASSES(I)-2
      RMI=MI
      PMVALS(I)=RMI*BIGG*1.E19
   30 CONTINUE
C
      WRITE(2) PMVALS,POSITS
C
      IPT=0
      DO 40  I=1,20
      WRITE(6,901)
      WRITE(6,902)
      DO 40  J=1,54
      IPT=IPT+1
      WRITE(6,905) PMVALS(IPT),POSITS(IPT,1),POSITS(IPT,2),POSITS(IPT,3)
   40 CONTINUE
C
      STOP
      END
```

INPUT DATA CARDS FOR PROGRAM MASPOS

925	3625	333333121133111331133321113111111313
975	3625	311131131131221111311111131131111131
1025	3625	111313111133113131311111321113333333
1075	3625	313331333311133313123233113111113111
1125	3625	111333313313113133111333333231111133
1175	3625	131111233113333333332333333333333333
1225	3625	131323131113313211333311331111312333
1275	3625	113111233111313131133131113111332111
1325	3625	133131131111233113311133311331313311
1375	3625	111131131111131132331133312313313311
1425	3625	133331333332123131121331321311113131
1475	3625	333323333333232133112311333333111333
1525	3625	312313333313311131111331133131113133
1575	3625	231111311131131131111111311131333131
1625	3625	113112111133323131333311331313133333
1675	3625	313313333311333331231322111113111133
1725	3625	133333331313331113133333331312333111
1775	3625	332111111113321131332311323313111131
1825	3625	113133131333111131213231333311311113
1875	3625	323331113311133311313331333331111311
1925	3625	133133331111312311313333111333113111
1975	3625	111113132133133131133111313313313333
2025	3625	131331133311332111112333211213331113
2075	3625	11312333211333333121111111111333333
2125	3625	31113332313333311311111131311123133
2175	3625	111311131311311331331311111311233331
2225	3625	223111331333331333333311131111131133
2275	3625	311313331333331331331311311231111133
2325	3625	311233111312113111111231333332312111
2375	3625	333323111111212113333233333333231331

EXAMPLE EXECUTION OF PROGRAM MASPOS

MASSES(I)	X	Y	Z
6.6700000000E+05	2.9981705034E+06	5.2813109998E+06	-1.6633286355E+06
6.6700000000E+05	2.9210425461E+06	5.3243574906E+06	-1.6633286355E+06
6.6700000000E+05	2.8432966826E+06	5.3662776874E+06	-1.6633286355E+06
6.6700000000E+05	2.7649493592E+06	5.4070627225E+06	-1.6633286355E+06
6.6700000000E+05	2.6860171490E+06	5.4467039684E+06	-1.6633286355E+06
6.6700000000E+05	2.6065167490E+06	5.4851930395E+06	-1.6633286355E+06
-6.6700000000E+05	2.5264649766E+06	5.5225217940E+06	-1.6633286355E+06
0.	2.4458787655E+06	5.5586823356E+06	-1.6633286355E+06
-6.6700000000E+05	2.3647751627E+06	5.5936670149E+06	-1.6633286355E+06
-6.6700000000E+05	2.2831713244E+06	5.6274684315E+06	-1.6633286355E+06
6.6700000000E+05	2.2010845129E+06	5.6600794350E+06	-1.6633286355E+06
6.6700000000E+05	2.1185320924E+06	5.6914931272E+06	-1.6633286355E+06
-6.6700000000E+05	2.0355315258E+06	5.7217028629E+06	-1.6633286355E+06
-6.6700000000E+05	1.9521003708E+06	5.7507022516E+06	-1.6633286355E+06
-6.6700000000E+05	1.8682562759E+06	5.7784851589E+06	-1.6633286355E+06
6.6700000000E+05	1.7840169773E+06	5.8050457077E+06	-1.6633286355E+06
6.6700000000E+05	1.6994002946E+06	5.8303782795E+06	-1.6633286355E+06
-6.6700000000E+05	1.6144241274E+06	5.8544775156E+06	-1.6633286355E+06
-6.6700000000E+05	1.5291064510E+06	5.8773383181E+06	-1.6633286355E+06
6.6700000000E+05	1.4434653134E+06	5.8989558511E+06	-1.6633286355E+06
6.6700000000E+05	1.3575188307E+06	5.9193255417E+06	-1.6633286355E+06
6.6700000000E+05	1.2712851837E+06	5.9384430809E+06	-1.6633286355E+06
0.	1.1847826140E+06	5.9563044248E+06	-1.6633286355E+06
-6.6700000000E+05	1.0980294199E+06	5.9729057951E+06	-1.6633286355E+06
-6.6700000000E+05	1.0110439528E+06	5.9882436798E+06	-1.6633286355E+06
-6.6700000000E+05	9.2384461348E+05	6.0023148346E+06	-1.6633286355E+06
6.6700000000E+05	8.3644984759E+05	6.0151162829E+06	-1.6633286355E+06
-6.6700000000E+05	7.4887814232E+05	6.0266453166E+06	-1.6633286355E+06
-6.6700000000E+05	6.6114802226E+05	6.0368994970E+06	-1.6633286355E+06
-6.6700000000E+05	5.7327804549E+05	6.0458766549E+06	-1.6633286355E+06
-6.6700000000E+05	4.8528679969E+05	6.0535748914E+06	-1.6633286355E+06
-6.6700000000E+05	3.9719289820E+05	6.0599925780E+06	-1.6633286355E+06
-6.6700000000E+05	3.0901497605E+05	6.0651283571E+06	-1.6633286355E+06
6.6700000000E+05	2.2077168606E+05	6.0689811424E+06	-1.6633286355E+06
-6.6700000000E+05	1.3248169488E+05	6.0715501187E+06	-1.6633286355E+06
6.6700000000E+05	4.4163679031E+04	6.0728347428E+06	-1.6633286355E+06
6.6700000000E+05	2.9859062221E+06	5.2597073305E+06	-1.7509242636E+06
-6.6700000000E+05	2.9090937635E+06	5.3025777359E+06	-1.7509242636E+06
-6.6700000000E+05	2.8316659263E+06	5.3443264544E+06	-1.7509242636E+06
-6.6700000000E+05	2.7536390895E+06	5.3849446547E+06	-1.7509242636E+06
6.6700000000E+05	2.6750297585E+06	5.4244237446E+06	-1.7509242636E+06
-6.6700000000E+05	2.5958545620E+06	5.4627553728E+06	-1.7509242636E+06
-6.6700000000E+05	2.5161302484E+06	5.4999314307E+06	-1.7509242636E+06
6.6700000000E+05	2.4358736824E+06	5.5359440544E+06	-1.7509242636E+06
-6.6700000000E+05	2.3551018410E+06	5.5707856258E+06	-1.7509242636E+06
-6.6700000000E+05	2.2738318104E+06	5.6044487747E+06	-1.7509242636E+06
6.6700000000E+05	2.1920807822E+06	5.6369263800E+06	-1.7509242636E+06
-6.6700000000E+05	2.1098660497E+06	5.6682115717E+06	-1.7509242636E+06
0.	2.0272050043E+06	5.6982977318E+06	-1.7509242636E+06
0.	1.9441151317E+06	5.7271784960E+06	-1.7509242636E+06
-6.6700000000E+05	1.8606140085E+06	5.7548477548E+06	-1.7509242636E+06
-6.6700000000E+05	1.7767192982E+06	5.7812996554E+06	-1.7509242636E+06
-6.6700000000E+05	1.6924487476E+06	5.8065286021E+06	-1.7509242636E+06
-6.6700000000E+05	1.6078201828E+06	5.8305292581E+06	-1.7509242636E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	1.5228515060E+06	5.8532965464E+06	-1.7509242636E+06
-6.6700000000E+05	1.4375606910E+06	5.8748256510E+06	-1.7509242636E+06
-6.6700000000E+05	1.3519657800E+06	5.8951120176E+06	-1.7509242636E+06
-6.6700000000E+05	1.2660848794E+06	5.9141513549E+06	-1.7509242636E+06
-6.6700000000E+05	1.1799361560E+06	5.9319396354E+06	-1.7509242636E+06
-6.6700000000E+05	1.0935378335E+06	5.9484730962E+06	-1.7509242636E+06
-6.6700000000E+05	1.0069081882E+06	5.9637482400E+06	-1.7509242636E+06
6.6700000000E+05	9.2006554547E+05	5.9777618355E+06	-1.7509242636E+06
-6.6700000000E+05	8.3302827559E+05	5.9905109183E+06	-1.7509242636E+06
-6.6700000000E+05	7.4581479012E+05	6.0019927915E+06	-1.7509242636E+06
6.6700000000E+05	6.5844353786E+05	6.0122050262E+06	-1.7509242636E+06
-6.6700000000E+05	5.7093300100E+05	6.0211454623E+06	-1.7509242636E+06
-6.6700000000E+05	4.8330169116E+05	6.0288122085E+06	-1.7509242636E+06
-6.6700000000E+05	3.9556814556E+05	6.0352036430E+06	-1.7509242636E+06
-6.6700000000E+05	3.0775092299E+05	6.0403184137E+06	-1.7509242636E+06
-6.6700000000E+05	2.1986859997E+05	6.0441554388E+06	-1.7509242636E+06
6.6700000000E+05	1.3193976680E+05	6.0467139066E+06	-1.7509242636E+06
-6.6700000000E+05	4.3983023600E+04	6.0479932757E+06	-1.7509242636E+06
-6.6700000000E+05	2.9730132619E+06	5.2369962364E+06	-1.8381562613E+06
-6.6700000000E+05	2.8965324748E+06	5.2796815300E+06	-1.8381562613E+06
-6.6700000000E+05	2.8194389663E+06	5.3212499801E+06	-1.8381562613E+06
6.6700000000E+05	2.7417490446E+06	5.3616927935E+06	-1.8381562613E+06
-6.6700000000E+05	2.6634791438E+06	5.4010014151E+06	-1.8381562613E+06
6.6700000000E+05	2.5846458210E+06	5.4391675296E+06	-1.8381562613E+06
-6.6700000000E+05	2.5052657521E+06	5.4761830637E+06	-1.8381562613E+06
-6.6700000000E+05	2.4253557290E+06	5.5120401870E+06	-1.8381562613E+06
-6.6700000000E+05	2.3449326555E+06	5.5467313146E+06	-1.8381562613E+06
-6.6700000000E+05	2.2640135439E+06	5.5802491081E+06	-1.8381562613E+06
6.6700000000E+05	2.1826155117E+06	5.6125864772E+06	-1.8381562613E+06
6.6700000000E+05	2.1007557773E+06	5.6437365813E+06	-1.8381562613E+06
-6.6700000000E+05	2.0184516572E+06	5.6736928312E+06	-1.8381562613E+06
-6.6700000000E+05	1.9357205616E+06	5.7024488900E+06	-1.8381562613E+06
6.6700000000E+05	1.8525799912E+06	5.7299986747E+06	-1.8381562613E+06
-6.6700000000E+05	1.7690475331E+06	5.7563363575E+06	-1.8381562613E+06
6.6700000000E+05	1.6851408575E+06	5.7814563672E+06	-1.8381562613E+06
-6.6700000000E+05	1.6006777137E+06	5.8053533898E+06	-1.8381562613E+06
6.6700000000E+05	1.5162759265E+06	5.8280223704E+06	-1.8381562613E+06
-6.6700000000E+05	1.4313533920E+06	5.8494585136E+06	-1.8381562613E+06
-6.6700000000E+05	1.3461280746E+06	5.8696572849E+06	-1.8381562613E+06
-6.6700000000E+05	1.2606180024E+06	5.8886144115E+06	-1.8381562613E+06
-6.6700000000E+05	1.1748412640E+06	5.9063258833E+06	-1.8381562613E+06
-6.6700000000E+05	1.0888160041E+06	5.9227879537E+06	-1.8381562613E+06
6.6700000000E+05	1.0025604203E+06	5.9379971404E+06	-1.8381562613E+06
0.	9.1609275880E+05	5.9519502260E+06	-1.8381562613E+06
-6.6700000000E+05	8.2943131052E+05	5.9646442590E+06	-1.8381562613E+06
-6.6700000000E+05	7.4259440753E+05	5.9760765542E+06	-1.8381562613E+06
-6.6700000000E+05	6.5560041899E+05	5.9862446931E+06	-1.8381562613E+06
6.6700000000E+05	5.6846774726E+05	5.9951465250E+06	-1.8381562613E+06
6.6700000000E+05	4.8121482406E+05	6.0027801666E+06	-1.8381562613E+06
6.6700000000E+05	3.9386010653E+05	6.0091440033E+06	-1.8381562613E+06
6.6700000000E+05	3.0642207335E+05	6.0142366888E+06	-1.8381562613E+06
6.6700000000E+05	2.1891922082E+05	6.0180571458E+06	-1.8381562613E+06
6.6700000000E+05	1.3137005897E+05	6.0206045662E+06	-1.8381562613E+06
6.6700000000E+05	4.3793107598E+04	6.0218784112E+06	-1.8381562613E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	2.9594942018E+06	5.2131822603E+06	-1.9250064288E+06
-6.6700000000E+05	2.8833611926E+06	5.2556734528E+06	-1.9250064288E+06
6.6700000000E+05	2.8066182482E+06	5.2970528804E+06	-1.9250064288E+06
6.6700000000E+05	2.7292816027E+06	5.3373117899E+06	-1.9250064288E+06
6.6700000000E+05	2.6513676154E+06	5.3764416650E+06	-1.9250064288E+06
-6.6700000000E+05	2.5728927681E+06	5.4144342284E+06	-1.9250064288E+06
6.6700000000E+05	2.4938736609E+06	5.4512814432E+06	-1.9250064288E+06
6.6700000000E+05	2.4143270093E+06	5.4869755149E+06	-1.9250064288E+06
6.6700000000E+05	2.3342696403E+06	5.5215088930E+06	-1.9250064288E+06
6.6700000000E+05	2.2537184889E+06	5.5548742724E+06	-1.9250064288E+06
-6.6700000000E+05	2.1726905945E+06	5.5870645951E+06	-1.9250064288E+06
-6.6700000000E+05	2.0912030976E+06	5.6180730517E+06	-1.9250064288E+06
-6.6700000000E+05	2.0092732356E+06	5.6478930827E+06	-1.9250064288E+06
6.6700000000E+05	1.9269183397E+06	5.6765183802E+06	-1.9250064288E+06
6.6700000000E+05	1.8441558309E+06	5.7039428890E+06	-1.9250064288E+06
6.6700000000E+05	1.7610032165E+06	5.7301608076E+06	-1.9250064288E+06
-6.6700000000E+05	1.6774780863E+06	5.7551665900E+06	-1.9250064288E+06
6.6700000000E+05	1.5935981088E+06	5.7789549468E+06	-1.9250064288E+06
-6.6700000000E+05	1.5093810277E+06	5.8015208456E+06	-1.9250064288E+06
0.	1.4248446580E+06	5.8228595131E+06	-1.9250064288E+06
6.6700000000E+05	1.3400068821E+06	5.8429664354E+06	-1.9250064288E+06
0.	1.2548856464E+06	5.8618373590E+06	-1.9250064288E+06
6.6700000000E+05	1.1694989569E+06	5.8794682922E+06	-1.9250064288E+06
6.6700000000E+05	1.0838648762E+06	5.8958555053E+06	-1.9250064288E+06
-6.6700000000E+05	9.9800151886E+05	5.9109955318E+06	-1.9250064288E+06
-6.6700000000E+05	9.1192704813E+05	5.9248851692E+06	-1.9250064288E+06
6.6700000000E+05	8.2565967186E+05	5.9375214792E+06	-1.9250064288E+06
-6.6700000000E+05	7.3921763873E+05	5.9489017887E+06	-1.9250064288E+06
-6.6700000000E+05	6.5261923435E+05	5.9590236905E+06	-1.9250064288E+06
-6.6700000000E+05	5.6588277742E+05	5.9678850434E+06	-1.9250064288E+06
-6.6700000000E+05	4.7902661582E+05	5.9754839729E+06	-1.9250064288E+06
-6.6700000000E+05	3.9206912278E+05	5.9818188716E+06	-1.9250064288E+06
6.6700000000E+05	3.0502869294E+05	5.9868883993E+06	-1.9250064288E+06
-6.6700000000E+05	2.1792373851E+05	5.9906914837E+06	-1.9250064288E+06
-6.6700000000E+05	1.3077268534E+05	5.9932273204E+06	-1.9250064288E+06
-6.6700000000E+05	4.3593969013E+04	5.9944953728E+06	-1.9250064288E+06
-6.6700000000E+05	2.9453517479E+06	5.1882701689E+06	-2.0114566337E+06
-6.6700000000E+05	2.8695825534E+06	5.2305583099E+06	-2.0114566337E+06
-6.6700000000E+05	2.7932063384E+06	5.2717399988E+06	-2.0114566337E+06
6.6700000000E+05	2.7162392594E+06	5.3118065242E+06	-2.0114566337E+06
6.6700000000E+05	2.6386975976E+06	5.3507494104E+06	-2.0114566337E+06
6.6700000000E+05	2.5605977558E+06	5.3885604197E+06	-2.0114566337E+06
6.6700000000E+05	2.4819562551E+06	5.4252315538E+06	-2.0114566337E+06
-6.6700000000E+05	2.4027897309E+06	5.4607550552E+06	-2.0114566337E+06
6.6700000000E+05	2.3231149299E+06	5.4951234096E+06	-2.0114566337E+06
6.6700000000E+05	2.2429487060E+06	5.5283293468E+06	-2.0114566337E+06
-6.6700000000E+05	2.1623080175E+06	5.5603658425E+06	-2.0114566337E+06
6.6700000000E+05	2.0812099226E+06	5.5912261198E+06	-2.0114566337E+06
-6.6700000000E+05	1.9996715766E+06	5.6209036507E+06	-2.0114566337E+06
-6.6700000000E+05	1.9177102278E+06	5.6493921573E+06	-2.0114566337E+06
6.6700000000E+05	1.8353432139E+06	5.6766856132E+06	-2.0114566337E+06
-6.6700000000E+05	1.7525879587E+06	5.7027782450E+06	-2.0114566337E+06
6.6700000000E+05	1.6694619677E+06	5.7276645330E+06	-2.0114566337E+06
6.6700000000E+05	1.5859828252E+06	5.7513392130E+06	-2.0114566337E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	1.5021681899E+06	5.7737972768E+06	-2.0114566337E+06
-6.6700000000E+05	1.4190357918E+06	5.7950339738E+06	-2.0114566337E+06
-6.6700000000E+05	1.3336034279E+06	5.8150448116E+06	-2.0114566337E+06
6.6700000000E+05	1.2488889587E+06	5.8338255573E+06	-2.0114566337E+06
6.6700000000E+05	1.1639103043E+06	5.8513722380E+06	-2.0114566337E+06
6.6700000000E+05	1.0786854408E+06	5.8676811420E+06	-2.0114566337E+06
6.6700000000E+05	9.9323239632E+05	5.8827488193E+06	-2.0114566337E+06
6.6700000000E+05	9.0756924731E+05	5.8965720826E+06	-2.0114566337E+06
6.6700000000E+05	8.2171411459E+05	5.9091480078E+06	-2.0114566337E+06
6.6700000000E+05	7.3568515964E+05	5.9204739346E+06	-2.0114566337E+06
0.	6.4950058069E+05	5.9305474671E+06	-2.0114566337E+06
6.6700000000E+05	5.6317860888E+05	5.9393664745E+06	-2.0114566337E+06
-6.6700000000E+05	4.7673750444E+05	5.9469290912E+06	-2.0114566337E+06
-6.6700000000E+05	3.9019555279E+05	5.9532337175E+06	-2.0114566337E+06
-6.6700000000E+05	3.0357106068E+05	5.9582790196E+06	-2.0114566337E+06
-6.6700000000E+05	2.1688235231E+05	5.9620639304E+06	-2.0114566337E+06
6.6700000000E+05	1.3014776549E+05	5.9645876491E+06	-2.0114566337E+06
6.6700000000E+05	4.3385647707E+04	5.9658496419E+06	-2.0114566337E+06
-6.6700000000E+05	2.9305887331E+06	5.1622649526E+06	-2.0974888147E+06
6.6700000000E+05	2.8551993172E+06	5.2043411324E+06	-2.0974888147E+06
-6.6700000000E+05	2.7792059235E+06	5.2453164059E+06	-2.0974888147E+06
-6.6700000000E+05	2.7026246273E+06	5.2851821054E+06	-2.0974888147E+06
-6.6700000000E+05	2.6254716283E+06	5.3239297978E+06	-2.0974888147E+06
-6.6700000000E+05	2.5477632471E+06	5.3615512867E+06	-2.0974888147E+06
0.	2.4695159220E+06	5.3980386136E+06	-2.0974888147E+06
6.6700000000E+05	2.3907462049E+06	5.4333840603E+06	-2.0974888147E+06
6.6700000000E+05	2.3114707586E+06	5.4675801499E+06	-2.0974888147E+06
-6.6700000000E+05	2.2317063527E+06	5.5006196486E+06	-2.0974888147E+06
-6.6700000000E+05	2.1514698602E+06	5.5324955674E+06	-2.0974888147E+06
6.6700000000E+05	2.0707782541E+06	5.5632011635E+06	-2.0974888147E+06
6.6700000000E+05	1.9896486036E+06	5.5927299414E+06	-2.0974888147E+06
6.6700000000E+05	1.9080980704E+06	5.6210756548E+06	-2.0974888147E+06
6.6700000000E+05	1.8261439055E+06	5.6482323075E+06	-2.0974888147E+06
6.6700000000E+05	1.7438034452E+06	5.6741941549E+06	-2.0974888147E+06
6.6700000000E+05	1.6610941074E+06	5.6989557051E+06	-2.0974888147E+06
6.6700000000E+05	1.5780333882E+06	5.7225117203E+06	-2.0974888147E+06
6.6700000000E+05	1.4946388579E+06	5.7448572173E+06	-2.0974888147E+06
6.6700000000E+05	1.4109281574E+06	5.7659874694E+06	-2.0974888147E+06
6.6700000000E+05	1.3269189947E+06	5.7858980068E+06	-2.0974888147E+06
0.	1.2426291406E+06	5.8045846175E+06	-2.0974888147E+06
6.6700000000E+05	1.1580764255E+06	5.8220433488E+06	-2.0974888147E+06
6.6700000000E+05	1.0732787354E+06	5.8382705075E+06	-2.0974888147E+06
6.6700000000E+05	9.8825400806E+05	5.8532626610E+06	-2.0974888147E+06
6.6700000000E+05	9.0302022926E+05	5.8670166378E+06	-2.0974888147E+06
6.6700000000E+05	8.1759542905E+05	5.8795295286E+06	-2.0974888147E+06
6.6700000000E+05	7.3199767786E+05	5.8907986863E+06	-2.0974888147E+06
6.6700000000E+05	6.4624508269E+05	5.9008217272E+06	-2.0974888147E+06
6.6700000000E+05	5.6035578334E+05	5.9095965310E+06	-2.0974888147E+06
6.6700000000E+05	4.7434794848E+05	5.9171212415E+06	-2.0974888147E+06
6.6700000000E+05	3.8823977188E+05	5.9233942670E+06	-2.0974888147E+06
6.6700000000E+05	3.0204946854E+05	5.9284142805E+06	-2.0974888147E+06
6.6700000000E+05	2.1579527082E+05	5.9321802201E+06	-2.0974888147E+06
6.6700000000E+05	1.2949542459E+05	5.9346912892E+06	-2.0974888147E+06
6.6700000000E+05	4.3168185408E+04	5.9359469565E+06	-2.0974888147E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	2.9152081168E+06	5.1351718244E+06	-2.1830849847E+06
6.6700000000E+05	2.8402143674E+06	5.1770271756E+06	-2.1830849847E+06
-6.6700000000E+05	2.7646198100E+06	5.2177873985E+06	-2.1830849847E+06
6.6700000000E+05	2.6884404356E+06	5.2574438707E+06	-2.1830849847E+06
0.	2.6116923589E+06	5.2959882036E+06	-2.1830849847E+06
6.6700000000E+05	2.5343918148E+06	5.3334122435E+06	-2.1830849847E+06
-6.6700000000E+05	2.4565551553E+06	5.3697080739E+06	-2.1830849847E+06
6.6700000000E+05	2.3781988456E+06	5.4048680170E+06	-2.1830849847E+06
-6.6700000000E+05	2.2993394608E+06	5.4388846351E+06	-2.1830849847E+06
-6.6700000000E+05	2.2199936826E+06	5.4717507325E+06	-2.1830849847E+06
-6.6700000000E+05	2.1401782955E+06	5.5034593569E+06	-2.1830849847E+06
6.6700000000E+05	2.0599101834E+06	5.5340038007E+06	-2.1830849847E+06
6.6700000000E+05	1.9792063258E+06	5.5633776027E+06	-2.1830849847E+06
-6.6700000000E+05	1.8980837945E+06	5.5915745492E+06	-2.1830849847E+06
6.6700000000E+05	1.8165597499E+06	5.6185886756E+06	-2.1830849847E+06
0.	1.7346514372E+06	5.6444142673E+06	-2.1830849847E+06
-6.6700000000E+05	1.6523761830E+06	5.6690458615E+06	-2.1830849847E+06
-6.6700000000E+05	1.5697513916E+06	5.6924782475E+06	-2.1830849847E+06
6.6700000000E+05	1.4867945410E+06	5.7147064686E+06	-2.1830849847E+06
6.6700000000E+05	1.4035231796E+06	5.7357258228E+06	-2.1830849847E+06
6.6700000000E+05	1.3199549224E+06	5.7555318636E+06	-2.1830849847E+06
6.6700000000E+05	1.2361074469E+06	5.7741204014E+06	-2.1830849847E+06
-6.6700000000E+05	1.1519984901E+06	5.7914875040E+06	-2.1830849847E+06
-6.6700000000E+05	1.0676458439E+06	5.8076294976E+06	-2.1830849847E+06
6.6700000000E+05	9.8306735204E+05	5.8225429677E+06	-2.1830849847E+06
6.6700000000E+05	8.9828090591E+05	5.8362247596E+06	-2.1830849847E+06
-6.6700000000E+05	8.1330440089E+05	5.8486719789E+06	-2.1830849847E+06
-6.6700000000E+05	7.2815593259E+05	5.8598819926E+06	-2.1830849847E+06
-6.6700000000E+05	6.4285339299E+05	5.8698524296E+06	-2.1830849847E+06
-6.6700000000E+05	5.5741486666E+05	5.8785811806E+06	-2.1830849847E+06
6.6700000000E+05	4.7185842694E+05	5.8860663991E+06	-2.1830849847E+06
-6.6700000000E+05	3.8620217210E+05	5.8923065019E+06	-2.1830849847E+06
0.	3.0046422155E+05	5.8973001688E+06	-2.1830849847E+06
6.6700000000E+05	2.1466271195E+05	5.9010463437E+06	-2.1830849847E+06
6.6700000000E+05	1.2881579343E+05	5.9035442339E+06	-2.1830849847E+06
6.6700000000E+05	4.2941625712E+04	5.9047933111E+06	-2.1830849847E+06
-6.6700000000E+05	2.8992129847E+06	5.1069962197E+06	-2.2682272345E+06
-6.6700000000E+05	2.8246307102E+06	5.1486219195E+06	-2.2682272345E+06
6.6700000000E+05	2.7494509243E+06	5.1891584996E+06	-2.2682272345E+06
-6.6700000000E+05	2.6736895300E+06	5.2285973851E+06	-2.2682272345E+06
-6.6700000000E+05	2.5973625538E+06	5.2669302333E+06	-2.2682272345E+06
-6.6700000000E+05	2.5204861415E+06	5.3041489354E+06	-2.2682272345E+06
0.	2.4430765553E+06	5.3402456183E+06	-2.2682272345E+06
6.6700000000E+05	2.3651501701E+06	5.3752126462E+06	-2.2682272345E+06
6.6700000000E+05	2.2867234701E+06	5.4090426223E+06	-2.2682272345E+06
-6.6700000000E+05	2.2078130455E+06	5.4417283904E+06	-2.2682272345E+06
-6.6700000000E+05	2.1284355886E+06	5.4732630362E+06	-2.2682272345E+06
-6.6700000000E+05	2.0486078907E+06	5.5036398891E+06	-2.2682272345E+06
6.6700000000E+05	1.9683468381E+06	5.5328525232E+06	-2.2682272345E+06
-6.6700000000E+05	1.8876694090E+06	5.5608947590E+06	-2.2682272345E+06
6.6700000000E+05	1.8065926697E+06	5.5877606646E+06	-2.2682272345E+06
-6.6700000000E+05	1.7251337706E+06	5.6134445568E+06	-2.2682272345E+06
6.6700000000E+05	1.6433099434E+06	5.6379410026E+06	-2.2682272345E+06
-6.6700000000E+05	1.5611384968E+06	5.6612448200E+06	-2.2682272345E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	1.4786368130E+06	5.6833510796E+06	-2.2682272345E+06
6.6700000000E+05	1.3958223440E+06	5.7042551050E+06	-2.2682272345E+06
6.6700000000E+05	1.3127126081E+06	5.7239524742E+06	-2.2682272345E+06
-6.6700000000E+05	1.2293251861E+06	5.7424390206E+06	-2.2682272345E+06
6.6700000000E+05	1.1456777173E+06	5.7597108336E+06	-2.2682272345E+06
-6.6700000000E+05	1.0617878963E+06	5.7757642596E+06	-2.2682272345E+06
-6.6700000000E+05	9.7767346883E+05	5.7905959026E+06	-2.2682272345E+06
-6.6700000000E+05	8.9335222805E+05	5.8042026253E+06	-2.2682272345E+06
6.6700000000E+05	8.0884201097E+05	5.8165815493E+06	-2.2682272345E+06
-6.6700000000E+05	7.2416069457E+05	5.8277300561E+06	-2.2682272345E+06
-6.6700000000E+05	6.3932619202E+05	5.8376457874E+06	-2.2682272345E+06
-6.6700000000E+05	5.5435644886E+05	5.8463266455E+06	-2.2682272345E+06
6.6700000000E+05	4.6926943928E+05	5.8537707943E+06	-2.2682272345E+06
6.6700000000E+05	3.8408316224E+05	5.8599766589E+06	-2.2682272345E+06
0.	2.9881563774E+05	5.8649429267E+06	-2.2682272345E+06
-6.6700000000E+05	2.1348490293E+05	5.8686685470E+06	-2.2682272345E+06
-6.6700000000E+05	1.2810900834E+05	5.8711527319E+06	-2.2682272345E+06
-6.6700000000E+05	4.2706014069E+04	5.8723949556E+06	-2.2682272345E+06
-6.6700000000E+05	2.8826065484E+06	5.0777437957E+06	-2.3528977357E+06
6.6700000000E+05	2.8084514746E+06	5.1191310671E+06	-2.3528977357E+06
6.6700000000E+05	2.7337023118E+06	5.1594354573E+06	-2.3528977357E+06
-6.6700000000E+05	2.6583748722E+06	5.1986484404E+06	-2.3528977357E+06
6.6700000000E+05	2.5824850901E+06	5.2367617214E+06	-2.3528977357E+06
-6.6700000000E+05	2.5060490192E+06	5.2737672381E+06	-2.3528977357E+06
-6.6700000000E+05	2.4290828282E+06	5.3096571623E+06	-2.3528977357E+06
6.6700000000E+05	2.3516027985E+06	5.3444239022E+06	-2.3528977357E+06
-6.6700000000E+05	2.2736253198E+06	5.3780601032E+06	-2.3528977357E+06
-6.6700000000E+05	2.1951668871E+06	5.4105586501E+06	-2.3528977357E+06
-6.6700000000E+05	2.1162440973E+06	5.4419126682E+06	-2.3528977357E+06
-6.6700000000E+05	2.0368736453E+06	5.4721155252E+06	-2.3528977357E+06
0.	1.9570723210E+06	5.5011608319E+06	-2.3528977357E+06
6.6700000000E+05	1.8768570051E+06	5.5290424442E+06	-2.3528977357E+06
6.6700000000E+05	1.7962446662E+06	5.5557544643E+06	-2.3528977357E+06
-6.6700000000E+05	1.7152523565E+06	5.5812912414E+06	-2.3528977357E+06
-6.6700000000E+05	1.6338972090E+06	5.6056473737E+06	-2.3528977357E+06
6.6700000000E+05	1.5521964332E+06	5.6288177090E+06	-2.3528977357E+06
6.6700000000E+05	1.4701673117E+06	5.6507973458E+06	-2.3528977357E+06
-6.6700000000E+05	1.3878271967E+06	5.6715816348E+06	-2.3528977357E+06
-6.6700000000E+05	1.3051935061E+06	5.6911661792E+06	-2.3528977357E+06
-6.6700000000E+05	1.2222837198E+06	5.7095468363E+06	-2.3528977357E+06
6.6700000000E+05	1.1391153764E+06	5.7267197179E+06	-2.3528977357E+06
6.6700000000E+05	1.0557060689E+06	5.7426811912E+06	-2.3528977357E+06
6.6700000000E+05	9.7207344142E+05	5.7574278799E+06	-2.3528977357E+06
-6.6700000000E+05	8.8823518527E+05	5.7709566645E+06	-2.3528977357E+06
-6.6700000000E+05	8.0420903526E+05	5.7832646832E+06	-2.3528977357E+06
6.6700000000E+05	7.2001276598E+05	5.7943493323E+06	-2.3528977357E+06
6.6700000000E+05	6.3566418797E+05	5.8042082671E+06	-2.3528977357E+06
-6.6700000000E+05	5.5118114401E+05	5.8128394021E+06	-2.3528977357E+06
6.6700000000E+05	4.6658150531E+05	5.8202409114E+06	-2.3528977357E+06
-6.6700000000E+05	3.8188316776E+05	5.8264112294E+06	-2.3528977357E+06
6.6700000000E+05	2.9710404812E+05	5.8313490508E+06	-2.3528977357E+06
6.6700000000E+05	2.1226208023E+05	5.8350533311E+06	-2.3528977357E+06
-6.6700000000E+05	1.2737521124E+05	5.8375232868E+06	-2.3528977357E+06
-6.6700000000E+05	4.2461397786E+04	5.8387583952E+06	-2.3528977357E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	2.8653921450E+06	5.0474204307E+06	-2.4370787448E+06
-6.6700000000E+05	2.7916799118E+06	5.0885605449E+06	-2.4370787448E+06
-6.6700000000E+05	2.7173771374E+06	5.1286242445E+06	-2.4370787448E+06
-6.6700000000E+05	2.6424995396E+06	5.1676030548E+06	-2.4370787448E+06
6.6700000000E+05	2.5670629576E+06	5.2054887302E+06	-2.4370787448E+06
-6.6700000000E+05	2.4910833490E+06	5.2422732567E+06	-2.4370787448E+06
-6.6700000000E+05	2.4145767862E+06	5.2779488528E+06	-2.4370787448E+06
6.6700000000E+05	2.3375594531E+06	5.3125079720E+06	-2.4370787448E+06
-6.6700000000E+05	2.2600476417E+06	5.3459433037E+06	-2.4370787448E+06
-6.6700000000E+05	2.1820577486E+06	5.3782477751E+06	-2.4370787448E+06
-6.6700000000E+05	2.1036062714E+06	5.4094145528E+06	-2.4370787448E+06
-6.6700000000E+05	2.0247098054E+06	5.4394370437E+06	-2.4370787448E+06
-6.6700000000E+05	1.9453850401E+06	5.4683088972E+06	-2.4370787448E+06
6.6700000000E+05	1.8656487555E+06	5.4960240056E+06	-2.4370787448E+06
-6.6700000000E+05	1.7855178188E+06	5.5225765063E+06	-2.4370787448E+06
-6.6700000000E+05	1.7050091805E+06	5.5479607824E+06	-2.4370787448E+06
6.6700000000E+05	1.6241398712E+06	5.5721714643E+06	-2.4370787448E+06
0.	1.5429269976E+06	5.5952034305E+06	-2.4370787448E+06
6.6700000000E+05	1.4613877392E+06	5.6170518090E+06	-2.4370787448E+06
6.6700000000E+05	1.3795393444E+06	5.6377119779E+06	-2.4370787448E+06
-6.6700000000E+05	1.2973991272E+06	5.6571795670E+06	-2.4370787448E+06
-6.6700000000E+05	1.2149844631E+06	5.6754504582E+06	-2.4370787448E+06
6.6700000000E+05	1.1323127860E+06	5.6925207864E+06	-2.4370787448E+06
6.6700000000E+05	1.0494015837E+06	5.7083869407E+06	-2.4370787448E+06
6.6700000000E+05	9.6626839514E+05	5.7230455649E+06	-2.4370787448E+06
-6.6700000000E+05	8.8293080584E+05	5.7364935580E+06	-2.4370787448E+06
0.	7.9940644476E+05	5.7487280754E+06	-2.4370787448E+06
6.6700000000E+05	7.1571298033E+05	5.7597465290E+06	-2.4370787448E+06
-6.6700000000E+05	6.3186811673E+05	5.7695465881E+06	-2.4370787448E+06
6.6700000000E+05	5.4788959018E+05	5.7781261795E+06	-2.4370787448E+06
6.6700000000E+05	4.6379516519E+05	5.7854834883E+06	-2.4370787448E+06
-6.6700000000E+05	3.7960263075E+05	5.7916169583E+06	-2.4370787448E+06
6.6700000000E+05	2.9532979663E+05	5.7965252919E+06	-2.4370787448E+06
6.6700000000E+05	2.1099448958E+05	5.8002074510E+06	-2.4370787448E+06
-6.6700000000E+05	1.2661454958E+05	5.8026626565E+06	-2.4370787448E+06
-6.6700000000E+05	4.2207826020E+04	5.8038903891E+06	-2.4370787448E+06
-6.6700000000E+05	2.8475732365E+06	5.0160322234E+06	-2.5207526061E+06
6.6700000000E+05	2.7743193949E+06	5.0569165011E+06	-2.5207526061E+06
6.6700000000E+05	2.7004786844E+06	5.0967310581E+06	-2.5207526061E+06
6.6700000000E+05	2.6260667252E+06	5.1354674723E+06	-2.5207526061E+06
6.6700000000E+05	2.5510992578E+06	5.1731175494E+06	-2.5207526061E+06
-6.6700000000E+05	2.4755921408E+06	5.2096733253E+06	-2.5207526061E+06
6.6700000000E+05	2.3995613465E+06	5.2451270669E+06	-2.5207526061E+06
6.6700000000E+05	2.3230229583E+06	5.2794712745E+06	-2.5207526061E+06
6.6700000000E+05	2.2459931668E+06	5.3126986832E+06	-2.5207526061E+06
6.6700000000E+05	2.1684882665E+06	5.3448022640E+06	-2.5207526061E+06
6.6700000000E+05	2.0905246526E+06	5.3757752260E+06	-2.5207526061E+06
0.	2.0121188172E+06	5.4056110172E+06	-2.5207526061E+06
-6.6700000000E+05	1.9332873459E+06	5.4343033263E+06	-2.5207526061E+06
0.	1.8540469144E+06	5.4618460838E+06	-2.5207526061E+06
6.6700000000E+05	1.7744142850E+06	5.4882334634E+06	-2.5207526061E+06
-6.6700000000E+05	1.6944063028E+06	5.5134598833E+06	-2.5207526061E+06
6.6700000000E+05	1.6140398925E+06	5.5375200071E+06	-2.5207526061E+06
-6.6700000000E+05	1.5333320544E+06	5.5604087453E+06	-2.5207526061E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	1.4522998611E+06	5.5821212560E+06	-2.5207526061E+06
0.	1.3709604539E+06	5.6026529464E+06	-2.5207526061E+06
-6.6700000000E+05	1.2893310391E+06	5.6219994731E+06	-2.5207526061E+06
6.6700000000E+05	1.2074288841E+06	5.6401567437E+06	-2.5207526061E+06
6.6700000000E+05	1.1252713142E+06	5.6571209173E+06	-2.5207526061E+06
-6.6700000000E+05	1.0428757088E+06	5.6728884054E+06	-2.5207526061E+06
6.6700000000E+05	9.6025949750E+05	5.6874558725E+06	-2.5207526061E+06
0.	8.7744015660E+05	5.7008202371E+06	-2.5207526061E+06
-6.6700000000E+05	7.9443520539E+05	5.7129786721E+06	-2.5207526061E+06
6.6700000000E+05	7.1126220241E+05	5.7239286057E+06	-2.5207526061E+06
-6.6700000000E+05	6.2793874177E+05	5.7336677215E+06	-2.5207526061E+06
-6.6700000000E+05	5.4448244939E+05	5.7421939593E+06	-2.5207526061E+06
-6.6700000000E+05	4.6091097930E+05	5.7495055155E+06	-2.5207526061E+06
-6.6700000000E+05	3.7724200986E+05	5.7556008435E+06	-2.5207526061E+06
6.6700000000E+05	2.9349324011E+05	5.7604786539E+06	-2.5207526061E+06
-6.6700000000E+05	2.0968238593E+05	5.7641379148E+06	-2.5207526061E+06
6.6700000000E+05	1.2582717635E+05	5.7665778522E+06	-2.5207526061E+06
-6.6700000000E+05	4.1945349769E+04	5.7677979499E+06	-2.5207526061E+06
6.6700000000E+05	2.8291534100E+06	4.9835854923E+06	-2.6039017553E+06
6.6700000000E+05	2.7563734186E+06	5.0242053057E+06	-2.6039017553E+06
6.6700000000E+05	2.6830103545E+06	5.0637623181E+06	-2.6039017553E+06
6.6700000000E+05	2.6090797368E+06	5.1022481617E+06	-2.6039017553E+06
0.	2.5345972044E+06	5.1396546954E+06	-2.6039017553E+06
6.6700000000E+05	2.4595785131E+06	5.1759740063E+06	-2.6039017553E+06
6.6700000000E+05	2.3840395320E+06	5.2111984117E+06	-2.6039017553E+06
6.6700000000E+05	2.3079962404E+06	5.2453204602E+06	-2.6039017553E+06
6.6700000000E+05	2.2314647242E+06	5.2783329339E+06	-2.6039017553E+06
6.6700000000E+05	2.1544611725E+06	5.3102288494E+06	-2.6039017553E+06
6.6700000000E+05	2.0770018744E+06	5.3410014595E+06	-2.6039017553E+06
6.6700000000E+05	1.9991032153E+06	5.3706442547E+06	-2.6039017553E+06
0.	1.9207816737E+06	5.3991509646E+06	-2.6039017553E+06
6.6700000000E+05	1.8420538172E+06	5.4265155589E+06	-2.6039017553E+06
0.	1.7629362999E+06	5.4527322490E+06	-2.6039017553E+06
-6.6700000000E+05	1.6834458577E+06	5.4777954891E+06	-2.6039017553E+06
6.6700000000E+05	1.6035993060E+06	5.5016999775E+06	-2.6039017553E+06
6.6700000000E+05	1.5234135350E+06	5.5244406574E+06	-2.6039017553E+06
-6.6700000000E+05	1.4429055070E+06	5.5460127185E+06	-2.6039017553E+06
-6.6700000000E+05	1.3620922523E+06	5.5664115975E+06	-2.6039017553E+06
0.	1.2809908658E+06	5.5856329792E+06	-2.6039017553E+06
6.6700000000E+05	1.1996185035E+06	5.6036727976E+06	-2.6039017553E+06
-6.6700000000E+05	1.1179923786E+06	5.6205272366E+06	-2.6039017553E+06
-6.6700000000E+05	1.0361297578E+06	5.6361927310E+06	-2.6039017553E+06
6.6700000000E+05	9.5404795811E+05	5.6506659669E+06	-2.6039017553E+06
6.6700000000E+05	8.7176434281E+05	5.6639438827E+06	-2.6039017553E+06
6.6700000000E+05	7.8929631784E+05	5.6760236697E+06	-2.6039017553E+06
6.6700000000E+05	7.0666132817E+05	5.6869027725E+06	-2.6039017553E+06
6.6700000000E+05	6.2387685409E+05	5.6965788898E+06	-2.6039017553E+06
6.6700000000E+05	5.4096040750E+05	5.7050499747E+06	-2.6039017553E+06
-6.6700000000E+05	4.5792952823E+05	5.7123142354E+06	-2.6039017553E+06
-6.6700000000E+05	3.7480178031E+05	5.7183701351E+06	-2.6039017553E+06
-6.6700000000E+05	2.9159474827E+05	5.7232163928E+06	-2.6039017553E+06
6.6700000000E+05	2.0832603340E+05	5.7268519834E+06	-2.6039017553E+06
6.6700000000E+05	1.2501325005E+05	5.7292761378E+06	-2.6039017553E+06
6.6700000000E+05	4.1674021869E+04	5.7304883433E+06	-2.6039017553E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	2.8101363768E+06	4.9500867748E+06	-2.6865087231E+06
-6.6700000000E+05	2.7378455987E+06	4.9904335495E+06	-2.6865087231E+06
0.	2.6649756672E+06	5.0297246671E+06	-2.6865087231E+06
6.6700000000E+05	2.5915419971E+06	5.0679518162E+06	-2.6865087231E+06
-6.6700000000E+05	2.5175601222E+06	5.1051069103E+06	-2.6865087231E+06
6.6700000000E+05	2.4430456923E+06	5.1411820897E+06	-2.6865087231E+06
6.6700000000E+05	2.3680144700E+06	5.1761697233E+06	-2.6865087231E+06
6.6700000000E+05	2.2924823269E+06	5.2100624099E+06	-2.6865087231E+06
6.6700000000E+05	2.2164652411E+06	5.2428529799E+06	-2.6865087231E+06
6.6700000000E+05	2.1399792927E+06	5.2745344971E+06	-2.6865087231E+06
-6.6700000000E+05	2.0630406613E+06	5.3051002596E+06	-2.6865087231E+06
6.6700000000E+05	1.9856656222E+06	5.3345438015E+06	-2.6865087231E+06
6.6700000000E+05	1.9078705432E+06	5.3628588947E+06	-2.6865087231E+06
-6.6700000000E+05	1.8296718805E+06	5.3900395494E+06	-2.6865087231E+06
-6.6700000000E+05	1.7510861761E+06	5.4160800158E+06	-2.6865087231E+06
-6.6700000000E+05	1.6721300536E+06	5.4409747856E+06	-2.6865087231E+06
6.6700000000E+05	1.5928202152E+06	5.4647185926E+06	-2.6865087231E+06
-6.6700000000E+05	1.5131734378E+06	5.4873064140E+06	-2.6865087231E+06
-6.6700000000E+05	1.4332065695E+06	5.5087334718E+06	-2.6865087231E+06
-6.6700000000E+05	1.3529365262E+06	5.5289952333E+06	-2.6865087231E+06
-6.6700000000E+05	1.2723802879E+06	5.5480874125E+06	-2.6865087231E+06
6.6700000000E+05	1.1915548952E+06	5.5660059707E+06	-2.6865087231E+06
6.6700000000E+05	1.1104774456E+06	5.5827471174E+06	-2.6865087231E+06
-6.6700000000E+05	1.0291650899E+06	5.5983073113E+06	-2.6865087231E+06
-6.6700000000E+05	9.4763502849E+05	5.6126832609E+06	-2.6865087231E+06
6.6700000000E+05	8.6590450806E+05	5.6258719250E+06	-2.6865087231E+06
6.6700000000E+05	7.8399081753E+05	5.6378705139E+06	-2.6865087231E+06
-6.6700000000E+05	7.0191128461E+05	5.6486764895E+06	-2.6865087231E+06
6.6700000000E+05	6.1968327207E+05	5.6582875657E+06	-2.6865087231E+06
-6.6700000000E+05	5.3732417413E+05	5.6667017096E+06	-2.6865087231E+06
-6.6700000000E+05	4.5485141270E+05	5.6739171413E+06	-2.6865087231E+06
-6.6700000000E+05	3.7228243375E+05	5.6799323344E+06	-2.6865087231E+06
6.6700000000E+05	2.8963470362E+05	5.6847460165E+06	-2.6865087231E+06
-6.6700000000E+05	2.0692570527E+05	5.6883571694E+06	-2.6865087231E+06
6.6700000000E+05	1.2417293466E+05	5.6907650291E+06	-2.6865087231E+06
6.6700000000E+05	4.1393896990E+04	5.6919690863E+06	-2.6865087231E+06
0.	2.7905259720E+06	4.9155428266E+06	-2.7685561384E+06
6.6700000000E+05	2.7187396717E+06	4.9556080433E+06	-2.7685561384E+06
-6.6700000000E+05	2.6463782597E+06	4.9946249697E+06	-2.7685561384E+06
-6.6700000000E+05	2.5734570430E+06	5.0325853524E+06	-2.7685561384E+06
-6.6700000000E+05	2.4999914471E+06	5.0694811614E+06	-2.7685561384E+06
-6.6700000000E+05	2.4259970127E+06	5.1053045919E+06	-2.7685561384E+06
6.6700000000E+05	2.3514893922E+06	5.1400480659E+06	-2.7685561384E+06
-6.6700000000E+05	2.2764843467E+06	5.1737042340E+06	-2.7685561384E+06
-6.6700000000E+05	2.2009977424E+06	5.2062659766E+06	-2.7685561384E+06
-6.6700000000E+05	2.1250455476E+06	5.2377264058E+06	-2.7685561384E+06
6.6700000000E+05	2.0486438289E+06	5.2680788665E+06	-2.7685561384E+06
-6.6700000000E+05	1.9718087479E+06	5.2973169381E+06	-2.7685561384E+06
-6.6700000000E+05	1.8945565581E+06	5.3254344357E+06	-2.7685561384E+06
6.6700000000E+05	1.8169036012E+06	5.3524254115E+06	-2.7685561384E+06
-6.6700000000E+05	1.7388663034E+06	5.3782841558E+06	-2.7685561384E+06
-6.6700000000E+05	1.6604611726E+06	5.4030051986E+06	-2.7685561384E+06
6.6700000000E+05	1.5817047942E+06	5.4265833105E+06	-2.7685561384E+06
-6.6700000000E+05	1.5026138280E+06	5.4490135038E+06	-2.7685561384E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	1.4232050048E+06	5.4702910339E+06	-2.7685561384E+06
-6.6700000000E+05	1.3434951222E+06	5.4904113997E+06	-2.7685561384E+06
-6.6700000000E+05	1.2635010418E+06	5.5093703450E+06	-2.7685561384E+06
-6.6700000000E+05	1.1832396853E+06	5.5271638594E+06	-2.7685561384E+06
-6.6700000000E+05	1.1027280303E+06	5.5437881788E+06	-2.7685561384E+06
-6.6700000000E+05	1.0219831096E+06	5.5592397866E+06	-2.7685561384E+06
6.6700000000E+05	9.4102200194E+05	5.5735154143E+06	-2.7685561384E+06
-6.6700000000E+05	8.5986183411E+05	5.5866120420E+06	-2.7685561384E+06
-6.6700000000E+05	7.7851977442E+05	5.5985268993E+06	-2.7685561384E+06
-6.6700000000E+05	6.9701302966E+05	5.6092574658E+06	-2.7685561384E+06
6.6700000000E+05	6.1535884145E+05	5.6188014716E+06	-2.7685561384E+06
-6.6700000000E+05	5.3357448261E+05	5.6271568978E+06	-2.7685561384E+06
6.6700000000E+05	4.5167725347E+05	5.6343219769E+06	-2.7685561384E+06
6.6700000000E+05	3.6968447827E+05	5.6402951933E+06	-2.7685561384E+06
6.6700000000E+05	2.8761350144E+05	5.6450752834E+06	-2.7685561384E+06
-6.6700000000E+05	2.0548168396E+05	5.6486612360E+06	-2.7685561384E+06
6.6700000000E+05	1.2330639967E+05	5.6510522925E+06	-2.7685561384E+06
-6.6700000000E+05	4.1105031623E+04	5.6522479473E+06	-2.7685561384E+06
-6.6700000000E+05	2.7703261544E+06	4.8799606211E+06	-2.8500267322E+06
-6.6700000000E+05	2.6990594945E+06	4.9197358171E+06	-2.8500267322E+06
6.6700000000E+05	2.6272218860E+06	4.9584703111E+06	-2.8500267322E+06
-6.6700000000E+05	2.5548285251E+06	4.9961559095E+06	-2.8500267322E+06
-6.6700000000E+05	2.4818947256E+06	5.0327846403E+06	-2.8500267322E+06
0.	2.4084359156E+06	5.0683487552E+06	-2.8500267322E+06
-6.6700000000E+05	2.3344676345E+06	5.1028407312E+06	-2.8500267322E+06
-6.6700000000E+05	2.2600055290E+06	5.1362532719E+06	-2.8500267322E+06
-6.6700000000E+05	2.1850653507E+06	5.1685793094E+06	-2.8500267322E+06
-6.6700000000E+05	2.1096629520E+06	5.1998120056E+06	-2.8500267322E+06
6.6700000000E+05	2.0338142834E+06	5.2299447535E+06	-2.8500267322E+06
6.6700000000E+05	1.9575353896E+06	5.2589711791E+06	-2.8500267322E+06
6.6700000000E+05	1.8808424063E+06	5.2868851423E+06	-2.8500267322E+06
0.	1.8037515568E+06	5.3136807381E+06	-2.8500267322E+06
6.6700000000E+05	1.7262791486E+06	5.3393522983E+06	-2.8500267322E+06
-6.6700000000E+05	1.6484415701E+06	5.3638943926E+06	-2.8500267322E+06
6.6700000000E+05	1.5702552865E+06	5.3873018293E+06	-2.8500267322E+06
-6.6700000000E+05	1.4917368372E+06	5.4095696569E+06	-2.8500267322E+06
6.6700000000E+05	1.4129028317E+06	5.4306931650E+06	-2.8500267322E+06
6.6700000000E+05	1.3337699461E+06	5.4506678853E+06	-2.8500267322E+06
6.6700000000E+05	1.2543549200E+06	5.4694895922E+06	-2.8500267322E+06
6.6700000000E+05	1.1746745524E+06	5.4871543044E+06	-2.8500267322E+06
-6.6700000000E+05	1.0947456987E+06	5.5036582851E+06	-2.8500267322E+06
-6.6700000000E+05	1.0145852668E+06	5.5189980432E+06	-2.8500267322E+06
6.6700000000E+05	9.3421021339E+05	5.5331703337E+06	-2.8500267322E+06
6.6700000000E+05	8.5363754075E+05	5.5461721587E+06	-2.8500267322E+06
-6.6700000000E+05	7.7288429292E+05	5.5580007678E+06	-2.8500267322E+06
6.6700000000E+05	6.9196755212E+05	5.5686536588E+06	-2.8500267322E+06
-6.6700000000E+05	6.1090443518E+05	5.5781285783E+06	-2.8500267322E+06
6.6700000000E+05	5.2971208986E+05	5.5864235219E+06	-2.8500267322E+06
-6.6700000000E+05	4.4840769130E+05	5.5935367351E+06	-2.8500267322E+06
6.6700000000E+05	3.6700843829E+05	5.5994667131E+06	-2.8500267322E+06
6.6700000000E+05	2.8553154974E+05	5.6042122014E+06	-2.8500267322E+06
6.6700000000E+05	2.0399426094E+05	5.6077721963E+06	-2.8500267322E+06
6.6700000000E+05	1.2241381999E+05	5.6101459447E+06	-2.8500267322E+06
6.6700000000E+05	4.0807484081E+04	5.6113329445E+06	-2.8500267322E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	2.7495410054E+06	4.8433473478E+06	-2.9309033404E+06
-6.6700000000E+05	2.6788090436E+06	4.8828241192E+06	-2.9309033404E+06
6.6700000000E+05	2.6075104169E+06	4.9212679969E+06	-2.9309033404E+06
6.6700000000E+05	2.5356602075E+06	4.9586708485E+06	-2.9309033404E+06
-6.6700000000E+05	2.4632736143E+06	4.9950247620E+06	-2.9309033404E+06
6.6700000000E+05	2.3903659497E+06	5.0303220472E+06	-2.9309033404E+06
6.6700000000E+05	2.3169526363E+06	5.0645552374E+06	-2.9309033404E+06
6.6700000000E+05	2.2430492036E+06	5.0977170912E+06	-2.9309033404E+06
6.6700000000E+05	2.1686712850E+06	5.1298005935E+06	-2.9309033404E+06
6.6700000000E+05	2.0938346140E+06	5.1607989576E+06	-2.9309033404E+06
-6.6700000000E+05	2.0185550213E+06	5.1907056261E+06	-2.9309033404E+06
-6.6700000000E+05	1.9428484313E+06	5.2195142729E+06	-2.9309033404E+06
6.6700000000E+05	1.8667308586E+06	5.2472188036E+06	-2.9309033404E+06
6.6700000000E+05	1.7902184048E+06	5.2738133580E+06	-2.9309033404E+06
6.6700000000E+05	1.7133272551E+06	5.2992923101E+06	-2.9309033404E+06
6.6700000000E+05	1.6360736748E+06	5.3236502704E+06	-2.9309033404E+06
6.6700000000E+05	1.5584740058E+06	5.3468820863E+06	-2.9309033404E+06
-6.6700000000E+05	1.4805446632E+06	5.3689828433E+06	-2.9309033404E+06
0.	1.4023021319E+06	5.3899478664E+06	-2.9309033404E+06
6.6700000000E+05	1.3237629630E+06	5.4097727207E+06	-2.9309033404E+06
-6.6700000000E+05	1.2449437703E+06	5.4284532125E+06	-2.9309033404E+06
6.6700000000E+05	1.1658612271E+06	5.4459853902E+06	-2.9309033404E+06
0.	1.0865320621E+06	5.4623655452E+06	-2.9309033404E+06
0.	1.0069730563E+06	5.4775902124E+06	-2.9309033404E+06
-6.6700000000E+05	9.2720103924E+05	5.4916561713E+06	-2.9309033404E+06
-6.6700000000E+05	8.4723288568E+05	5.5045604465E+06	-2.9309033404E+06
-6.6700000000E+05	7.6708551174E+05	5.5163003081E+06	-2.9309033404E+06
-6.6700000000E+05	6.8677587148E+05	5.5268732728E+06	-2.9309033404E+06
-6.6700000000E+05	6.0632095331E+05	5.5362771041E+06	-2.9309033404E+06
6.6700000000E+05	5.2573777634E+05	5.5445098126E+06	-2.9309033404E+06
-6.6700000000E+05	4.4504338682E+05	5.5515696569E+06	-2.9309033404E+06
-6.6700000000E+05	3.6425485455E+05	5.5574551435E+06	-2.9309033404E+06
-6.6700000000E+05	2.8338926920E+05	5.5621650275E+06	-2.9309033404E+06
-6.6700000000E+05	2.0246373678E+05	5.5656983126E+06	-2.9309033404E+06
6.6700000000E+05	1.2149537597E+05	5.5680542513E+06	-2.9309033404E+06
6.6700000000E+05	4.0501314486E+04	5.5692323452E+06	-2.9309033404E+06
-6.6700000000E+05	2.7281747291E+06	4.8057104123E+06	-3.0111689081E+06
6.6700000000E+05	2.6579924150E+06	4.8448804156E+06	-3.0111689081E+06
6.6700000000E+05	2.5872478393E+06	4.8830255516E+06	-3.0111689081E+06
6.6700000000E+05	2.5159559673E+06	4.9201377512E+06	-3.0111689081E+06
6.6700000000E+05	2.4441318796E+06	4.9562091637E+06	-3.0111689081E+06
6.6700000000E+05	2.3717907696E+06	4.9912321590E+06	-3.0111689081E+06
6.6700000000E+05	2.2989479402E+06	5.0251993282E+06	-3.0111689081E+06
6.6700000000E+05	2.2256188002E+06	5.0581034861E+06	-3.0111689081E+06
-6.6700000000E+05	2.1518188614E+06	5.0899376722E+06	-3.0111689081E+06
6.6700000000E+05	2.0775637351E+06	5.1206951526E+06	-3.0111689081E+06
-6.6700000000E+05	2.0028691290E+06	5.1503694209E+06	-3.0111689081E+06
6.6700000000E+05	1.9277508436E+06	5.1789541999E+06	-3.0111689081E+06
6.6700000000E+05	1.8522247693E+06	5.2064434428E+06	-3.0111689081E+06
6.6700000000E+05	1.7763068825E+06	5.2328313348E+06	-3.0111689081E+06
-6.6700000000E+05	1.7000132426E+06	5.2581122938E+06	-3.0111689081E+06
-6.6700000000E+05	1.6233599884E+06	5.2822809720E+06	-3.0111689081E+06
-6.6700000000E+05	1.5463633350E+06	5.3053322569E+06	-3.0111689081E+06
6.6700000000E+05	1.4690395697E+06	5.3272612722E+06	-3.0111689081E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	1.3914050495E+06	5.3480633792E+06	-3.0111689081E+06
6.6700000000E+05	1.3134761969E+06	5.3677341774E+06	-3.0111689081E+06
6.6700000000E+05	1.2352694965E+06	5.3862695059E+06	-3.0111689081E+06
6.6700000000E+05	1.1568014921E+06	5.4036654437E+06	-3.0111689081E+06
6.6700000000E+05	1.0780887822E+06	5.4199183109E+06	-3.0111689081E+06
6.6700000000E+05	9.9914801766E+05	5.4350246695E+06	-3.0111689081E+06
6.6700000000E+05	9.1999589718E+05	5.4489813239E+06	-3.0111689081E+06
6.6700000000E+05	8.4064916430E+05	5.4617853219E+06	-3.0111689081E+06
-6.6700000000E+05	7.6112460374E+05	5.4734339548E+06	-3.0111689081E+06
6.6700000000E+05	6.8143903782E+05	5.4839247585E+06	-3.0111689081E+06
-6.6700000000E+05	6.0160932291E+05	5.4932555140E+06	-3.0111689081E+06
0.	5.2165234588E+05	5.5014242474E+06	-3.0111689081E+06
6.6700000000E+05	4.4158502053E+05	5.5084292307E+06	-3.0111689081E+06
6.6700000000E+05	3.6142428398E+05	5.5142689821E+06	-3.0111689081E+06
6.6700000000E+05	2.8118709313E+05	5.5189422662E+06	-3.0111689081E+06
-6.6700000000E+05	2.0089042105E+05	5.5224480947E+06	-3.0111689081E+06
-6.6700000000E+05	1.2055125338E+05	5.5247857257E+06	-3.0111689081E+06
-6.6700000000E+05	4.0186584765E+04	5.5259546648E+06	-3.0111689081E+06
6.6700000000E+05	2.7062316516E+06	4.7670574349E+06	-3.0908064923E+06
6.6700000000E+05	2.6366138233E+06	4.8059123886E+06	-3.0908064923E+06
0.	2.5664382558E+06	4.8437507181E+06	-3.0908064923E+06
-6.6700000000E+05	2.4957197939E+06	4.8805644192E+06	-3.0908064923E+06
-6.6700000000E+05	2.4244733970E+06	4.9163457046E+06	-3.0908064923E+06
-6.6700000000E+05	2.3527141364E+06	4.9510870051E+06	-3.0908064923E+06
-6.6700000000E+05	2.2804571917E+06	4.9847809718E+06	-3.0908064923E+06
-6.6700000000E+05	2.2077178478E+06	5.0174204771E+06	-3.0908064923E+06
-6.6700000000E+05	2.1345114919E+06	5.0489986166E+06	-3.0908064923E+06
-6.6700000000E+05	2.0608536096E+06	5.0795087104E+06	-3.0908064923E+06
-6.6700000000E+05	1.9867597823E+06	5.1089443046E+06	-3.0908064923E+06
6.6700000000E+05	1.9122456834E+06	5.1372991723E+06	-3.0908064923E+06
6.6700000000E+05	1.8373270755E+06	5.1645673156E+06	-3.0908064923E+06
0.	1.7620198065E+06	5.1907429662E+06	-3.0908064923E+06
-6.6700000000E+05	1.6863398067E+06	5.2158205870E+06	-3.0908064923E+06
-6.6700000000E+05	1.6103030850E+06	5.2397948733E+06	-3.0908064923E+06
6.6700000000E+05	1.5339257260E+06	5.2626607535E+06	-3.0908064923E+06
-6.6700000000E+05	1.4572238862E+06	5.2844133908E+06	-3.0908064923E+06
6.6700000000E+05	1.3802137909E+06	5.3050481837E+06	-3.0908064923E+06
6.6700000000E+05	1.3029117306E+06	5.3245607670E+06	-3.0908064923E+06
0.	1.2253340573E+06	5.3429470134E+06	-3.0908064923E+06
6.6700000000E+05	1.1474971815E+06	5.3602030333E+06	-3.0908064923E+06
-6.6700000000E+05	1.0694175687E+06	5.3763251765E+06	-3.0908064923E+06
-6.6700000000E+05	9.9111173532E+05	5.3913100326E+06	-3.0908064923E+06
6.6700000000E+05	9.1259624602E+05	5.4051544318E+06	-3.0908064923E+06
0.	8.3388770962E+05	5.4178554454E+06	-3.0908064923E+06
6.6700000000E+05	7.5500277584E+05	5.4294103868E+06	-3.0908064923E+06
6.6700000000E+05	6.7595813168E+05	5.4398168116E+06	-3.0908064923E+06
-6.6700000000E+05	5.9677049794E+05	5.4490725186E+06	-3.0908064923E+06
6.6700000000E+05	5.1745662566E+05	5.4571755497E+06	-3.0908064923E+06
-6.6700000000E+05	4.3803329261E+05	5.4641241910E+06	-3.0908064923E+06
-6.6700000000E+05	3.5851729969E+05	5.4699169724E+06	-3.0908064923E+06
-6.6700000000E+05	2.7892546739E+05	5.4745526688E+06	-3.0908064923E+06
-6.6700000000E+05	1.9927463228E+05	5.4780302993E+06	-3.0908064923E+06
6.6700000000E+05	1.1958164338E+05	5.4803491285E+06	-3.0908064923E+06
-6.6700000000E+05	3.9863358641E+04	5.4815086657E+06	-3.0908064923E+06

AD-A038 468 VIRGINIA UNIV CHARLOTTESVILLE DEPT OF ENGINEERING SC--ETC F/G 8/5
DEVELOPMENT OF FINITE ELEMENT MODELS FOR THE EARTH'S GRAVITY FI--ETC(U)
FEB 77 J L JUNKINS, J T SAUNDERS DAAG53-76-C-0067

UNCLASSIFIED UVA/525023/ESS77/104 ETL-0097 NL

2 OF 2
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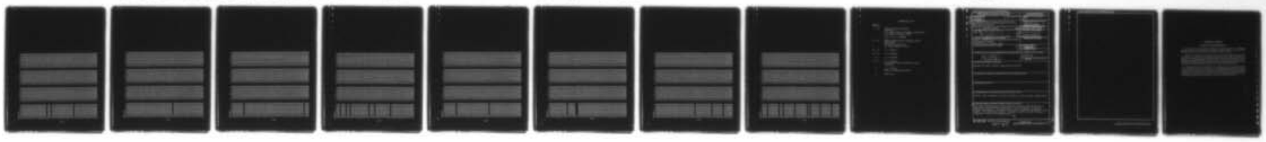

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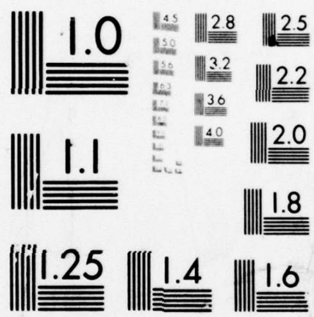

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MASSES(I)	X	Y	Z
-6.6700000000E+05	2.6837162202E+06	4.7273962497E+06	-3.1697992662E+06
-6.6700000000E+05	2.6146776015E+06	4.7659279361E+06	-3.1697992662E+06
6.6700000000E+05	2.5450858839E+06	4.8034514565E+06	-3.1697992662E+06
-6.6700000000E+05	2.4749557887E+06	4.8399588733E+06	-3.1697992662E+06
6.6700000000E+05	2.4043021509E+06	4.8754424639E+06	-3.1697992662E+06
6.6700000000E+05	2.3331399163E+06	4.9098947221E+06	-3.1697992662E+06
-6.6700000000E+05	2.2614841383E+06	4.9433083602E+06	-3.1697992662E+06
6.6700000000E+05	2.1893499746E+06	4.9756763098E+06	-3.1697992662E+06
-6.6700000000E+05	2.1167526843E+06	5.0069917241E+06	-3.1697992662E+06
6.6700000000E+05	2.0437076243E+06	5.0372479786E+06	-3.1697992662E+06
6.6700000000E+05	1.9702302462E+06	5.0664386731E+06	-3.1697992662E+06
6.6700000000E+05	1.8963360932E+06	5.0945576327E+06	-3.1697992662E+06
-6.6700000000E+05	1.8220407966E+06	5.1215989092E+06	-3.1697992662E+06
-6.6700000000E+05	1.7473600725E+06	5.1475567825E+06	-3.1697992662E+06
-6.6700000000E+05	1.6723097186E+06	5.1724257613E+06	-3.1697992662E+06
-6.6700000000E+05	1.5969056108E+06	5.1962005852E+06	-3.1697992662E+06
6.6700000000E+05	1.5211636997E+06	5.2188762249E+06	-3.1697992662E+06
-6.6700000000E+05	1.4451000074E+06	5.2404478835E+06	-3.1697992662E+06
0.	1.3687306243E+06	5.2609109981E+06	-3.1697992662E+06
-6.6700000000E+05	1.2920717052E+06	5.2802612398E+06	-3.1697992662E+06
6.6700000000E+05	1.2151394662E+06	5.2984945154E+06	-3.1697992662E+06
0.	1.1379501813E+06	5.3156069678E+06	-3.1697992662E+06
6.6700000000E+05	1.0605201788E+06	5.3315949773E+06	-3.1697992662E+06
-6.6700000000E+05	9.8286583800E+05	5.3464551617E+06	-3.1697992662E+06
6.6700000000E+05	9.0500358550E+05	5.3601843776E+06	-3.1697992662E+06
6.6700000000E+05	8.2694989204E+05	5.3727797208E+06	-3.1697992662E+06
6.6700000000E+05	7.4872126878E+05	5.3842385268E+06	-3.1697992662E+06
6.6700000000E+05	6.7033426391E+05	5.3945583718E+06	-3.1697992662E+06
-6.6700000000E+05	5.9180545911E+05	5.4037370726E+06	-3.1697992662E+06
-6.6700000000E+05	5.1315146606E+05	5.4117726878E+06	-3.1697992662E+06
6.6700000000E+05	4.3438892294E+05	5.4186635174E+06	-3.1697992662E+06
-6.6700000000E+05	3.5553449085E+05	5.4244081039E+06	-3.1697992662E+06
-6.6700000000E+05	2.7660485037E+05	5.4290052319E+06	-3.1697992662E+06
-6.6700000000E+05	1.9761669797E+05	5.4324539292E+06	-3.1697992662E+06
-6.6700000000E+05	1.1858674249E+05	5.4347534660E+06	-3.1697992662E+06
6.6700000000E+05	3.9531701623E+04	5.4359033560E+06	-3.1697992662E+06
6.6700000000E+05	2.6606330030E+06	4.6867349035E+06	-3.2481305219E+06
0.	2.5921882002E+06	4.7249351707E+06	-3.2481305219E+06
6.6700000000E+05	2.5231950559E+06	4.7621359433E+06	-3.2481305219E+06
6.6700000000E+05	2.4536681647E+06	4.7983293520E+06	-3.2481305219E+06
6.6700000000E+05	2.3836222340E+06	4.8335077406E+06	-3.2481305219E+06
-6.6700000000E+05	2.3130720809E+06	4.8676636676E+06	-3.2481305219E+06
-6.6700000000E+05	2.2420326296E+06	4.9007399078E+06	-3.2481305219E+06
-6.6700000000E+05	2.1705189073E+06	4.9328794538E+06	-3.2481305219E+06
6.6700000000E+05	2.0985460418E+06	4.9639255175E+06	-3.2481305219E+06
6.6700000000E+05	2.0261292579E+06	4.9939215315E+06	-3.2481305219E+06
-6.6700000000E+05	1.9532838745E+06	5.0228611506E+06	-3.2481305219E+06
-6.6700000000E+05	1.8800253009E+06	5.0507382530E+06	-3.2481305219E+06
-6.6700000000E+05	1.8063690341E+06	5.0775469417E+06	-3.2481305219E+06
6.6700000000E+05	1.7323306549E+06	5.1032815457E+06	-3.2481305219E+06
6.6700000000E+05	1.6579258251E+06	5.1279366212E+06	-3.2481305219E+06
6.6700000000E+05	1.5831702841E+06	5.1515069527E+06	-3.2481305219E+06
-6.6700000000E+05	1.5080798454E+06	5.1739875543E+06	-3.2481305219E+06
-6.6700000000E+05	1.4326703932E+06	5.1953736706E+06	-3.2481305219E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	1.3569578795E+06	5.2156607775E+06	-3.2481305219E+06
-6.6700000000E+05	1.2809583202E+06	5.2348445836E+06	-3.2481305219E+06
6.6700000000E+05	1.2046877918E+06	5.2529210309E+06	-3.2481305219E+06
6.6700000000E+05	1.1281624285E+06	5.2698862955E+06	-3.2481305219E+06
6.6700000000E+05	1.0513984180E+06	5.2857367887E+06	-3.2481305219E+06
-6.6700000000E+05	9.7441199873E+05	5.3004691575E+06	-3.2481305219E+06
6.6700000000E+05	8.9721945612E+05	5.3140802854E+06	-3.2481305219E+06
6.6700000000E+05	8.1983711916E+05	5.3265672933E+06	-3.2481305219E+06
6.6700000000E+05	7.4228135702E+05	5.3379275397E+06	-3.2481305219E+06
6.6700000000E+05	6.6456857554E+05	5.3481586215E+06	-3.2481305219E+06
6.6700000000E+05	5.8671521379E+05	5.3572583744E+06	-3.2481305219E+06
-6.6700000000E+05	5.0873774056E+05	5.3652248736E+06	-3.2481305219E+06
-6.6700000000E+05	4.3065265091E+05	5.3720564337E+06	-3.2481305219E+06
-6.6700000000E+05	3.5247646266E+05	5.3777516097E+06	-3.2481305219E+06
-6.6700000000E+05	2.7422571290E+05	5.3823091969E+06	-3.2481305219E+06
6.6700000000E+05	1.9591695448E+05	5.3857282311E+06	-3.2481305219E+06
-6.6700000000E+05	1.1756675255E+05	5.3880079892E+06	-3.2481305219E+06
-6.6700000000E+05	3.9191681003E+04	5.3891479887E+06	-3.2481305219E+06
-6.6700000000E+05	2.6369866885E+06	4.6450816551E+06	-3.3257836747E+06
6.6700000000E+05	2.5691501874E+06	4.6829424183E+06	-3.3257836747E+06
6.6700000000E+05	2.5007702181E+06	4.7198125699E+06	-3.3257836747E+06
-6.6700000000E+05	2.4318612455E+06	4.7556843105E+06	-3.3257836747E+06
6.6700000000E+05	2.3624378463E+06	4.7905500520E+06	-3.3257836747E+06
6.6700000000E+05	2.2925147062E+06	4.8244024190E+06	-3.3257836747E+06
6.6700000000E+05	2.2221066163E+06	4.8572342505E+06	-3.3257836747E+06
6.6700000000E+05	2.1512284705E+06	4.8890386014E+06	-3.3257836747E+06
-6.6700000000E+05	2.0798952622E+06	4.9198087439E+06	-3.3257836747E+06
-6.6700000000E+05	2.0081220809E+06	4.9495381690E+06	-3.3257836747E+06
-6.6700000000E+05	1.9359241091E+06	4.9782205879E+06	-3.3257836747E+06
-6.6700000000E+05	1.8633166194E+06	5.0058499332E+06	-3.3257836747E+06
6.6700000000E+05	1.7903149709E+06	5.0324203603E+06	-3.3257836747E+06
-6.6700000000E+05	1.7169346061E+06	5.0579262486E+06	-3.3257836747E+06
0.	1.6431910476E+06	5.0823622027E+06	-3.3257836747E+06
6.6700000000E+05	1.5690998947E+06	5.1057230535E+06	-3.3257836747E+06
-6.6700000000E+05	1.4946768205E+06	5.1280038592E+06	-3.3257836747E+06
-6.6700000000E+05	1.4199375681E+06	5.1491999069E+06	-3.3257836747E+06
6.6700000000E+05	1.3448979476E+06	5.1693067126E+06	-3.3257836747E+06
-6.6700000000E+05	1.2695738326E+06	5.1883200231E+06	-3.3257836747E+06
6.6700000000E+05	1.1939811568E+06	5.2062358163E+06	-3.3257836747E+06
6.6700000000E+05	1.1181359109E+06	5.2230503025E+06	-3.3257836747E+06
6.6700000000E+05	1.0420541388E+06	5.2387599248E+06	-3.3257836747E+06
6.6700000000E+05	9.6575193456E+05	5.2533613600E+06	-3.3257836747E+06
-6.6700000000E+05	8.8924543889E+05	5.2668515194E+06	-3.3257836747E+06
-6.6700000000E+05	8.1255083567E+05	5.2792275493E+06	-3.3257836747E+06
-6.6700000000E+05	7.3568434857E+05	5.2904368318E+06	-3.3257836747E+06
6.6700000000E+05	6.5866223765E+05	5.3006269851E+06	-3.3257836747E+06
6.6700000000E+05	5.8150079585E+05	5.3096458641E+06	-3.3257836747E+06
6.6700000000E+05	5.0421634562E+05	5.3175415612E+06	-3.3257836747E+06
-6.6700000000E+05	4.2682523541E+05	5.3243124060E+06	-3.3257836747E+06
-6.6700000000E+05	3.4934383623E+05	5.3299569663E+06	-3.3257836747E+06
6.6700000000E+05	2.7178853820E+05	5.3344740480E+06	-3.3257836747E+06
-6.6700000000E+05	1.9417574707E+05	5.3378626956E+06	-3.3257836747E+06
-6.6700000000E+05	1.1652188075E+05	5.3401221924E+06	-3.3257836747E+06
-6.6700000000E+05	3.8843365842E+04	5.3412520602E+06	-3.3257836747E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	2.6127820847E+06	4.6024449738E+06	-3.4027422660E+06
-6.6700000000E+05	2.5455682472E+06	4.6399582173E+06	-3.4027422660E+06
-6.6700000000E+05	2.4778159299E+06	4.6764899419E+06	-3.4027422660E+06
-6.6700000000E+05	2.4095394650E+06	4.7120324198E+06	-3.4027422660E+06
-6.6700000000E+05	2.3407532954E+06	4.7465781326E+06	-3.4027422660E+06
6.6700000000E+05	2.2714719719E+06	4.7801197726E+06	-3.4027422660E+06
-6.6700000000E+05	2.2017101499E+06	4.8126502444E+06	-3.4027422660E+06
6.6700000000E+05	2.1314825867E+06	4.8441626667E+06	-3.4027422660E+06
0.	2.0608041379E+06	4.8746503736E+06	-3.4027422660E+06
-6.6700000000E+05	1.9896897545E+06	4.9041069156E+06	-3.4027422660E+06
6.6700000000E+05	1.9181544798E+06	4.9325260619E+06	-3.4027422660E+06
6.6700000000E+05	1.8462134461E+06	4.9599018005E+06	-3.4027422660E+06
-6.6700000000E+05	1.7738818715E+06	4.9862283407E+06	-3.4027422660E+06
6.6700000000E+05	1.7011750567E+06	5.0115001133E+06	-3.4027422660E+06
6.6700000000E+05	1.6281083820E+06	5.0357117725E+06	-3.4027422660E+06
-6.6700000000E+05	1.5546973035E+06	5.0588581966E+06	-3.4027422660E+06
6.6700000000E+05	1.4809573503E+06	5.0809344894E+06	-3.4027422660E+06
-6.6700000000E+05	1.4069041211E+06	5.1019359809E+06	-3.4027422660E+06
-6.6700000000E+05	1.3325532809E+06	5.1218582285E+06	-3.4027422660E+06
6.6700000000E+05	1.2579205574E+06	5.1406970179E+06	-3.4027422660E+06
6.6700000000E+05	1.1830217383E+06	5.1584483642E+06	-3.4027422660E+06
-6.6700000000E+05	1.1078726673E+06	5.1751085121E+06	-3.4027422660E+06
-6.6700000000E+05	1.0324892412E+06	5.1906739375E+06	-3.4027422660E+06
-6.6700000000E+05	9.5688740632E+05	5.2051413478E+06	-3.4027422660E+06
6.6700000000E+05	8.8108315516E+05	5.2185076825E+06	-3.4027422660E+06
-6.6700000000E+05	8.0509252307E+05	5.2307701143E+06	-3.4027422660E+06
6.6700000000E+05	7.2893158480E+05	5.2419260491E+06	-3.4027422660E+06
6.6700000000E+05	6.5261645116E+05	5.2519731270E+06	-3.4027422660E+06
-6.6700000000E+05	5.7616326555E+05	5.2609092228E+06	-3.4027422660E+06
6.6700000000E+05	4.9958820058E+05	5.2687324461E+06	-3.4027422660E+06
6.6700000000E+05	4.2290745464E+05	5.2754411421E+06	-3.4027422660E+06
-6.6700000000E+05	3.4613724850E+05	5.2810338916E+06	-3.4027422660E+06
6.6700000000E+05	2.6929382182E+05	5.2855095115E+06	-3.4027422660E+06
6.6700000000E+05	1.9239342976E+05	5.2888670552E+06	-3.4027422660E+06
6.6700000000E+05	1.1545233953E+05	5.2911058122E+06	-3.4027422660E+06
6.6700000000E+05	3.8486826962E+04	5.2922253092E+06	-3.4027422660E+06
-6.6700000000E+05	2.5880241185E+06	4.5588335384E+06	-3.4789899674E+06
6.6700000000E+05	2.5214471798E+06	4.5959913173E+06	-3.4789899674E+06
-6.6700000000E+05	2.4543368639E+06	4.6321768778E+06	-3.4789899674E+06
6.6700000000E+05	2.3867073670E+06	4.6673825656E+06	-3.4789899674E+06
6.6700000000E+05	2.3185729952E+06	4.7016009332E+06	-3.4789899674E+06
-6.6700000000E+05	2.2499481614E+06	4.7348247422E+06	-3.4789899674E+06
-6.6700000000E+05	2.1808473623E+06	4.7670469647E+06	-3.4789899674E+06
6.6700000000E+05	2.1112852751E+06	4.7982607845E+06	-3.4789899674E+06
6.6700000000E+05	2.0412765548E+06	4.8284595986E+06	-3.4789899674E+06
6.6700000000E+05	1.9708360307E+06	4.8576370191E+06	-3.4789899674E+06
-6.6700000000E+05	1.8999786035E+06	4.8857868737E+06	-3.4789899674E+06
-6.6700000000E+05	1.8287192622E+06	4.9129032078E+06	-3.4789899674E+06
6.6700000000E+05	1.7570730807E+06	4.9389802852E+06	-3.4789899674E+06
6.6700000000E+05	1.6850552147E+06	4.9640125899E+06	-3.4789899674E+06
0.	1.6126808986E+06	4.9879948264E+06	-3.4789899674E+06
-6.6700000000E+05	1.5399654422E+06	5.0109219217E+06	-3.4789899674E+06
-6.6700000000E+05	1.4669242275E+06	5.0327890260E+06	-3.4789899674E+06
-6.6700000000E+05	1.3935727052E+06	5.0535915134E+06	-3.4789899674E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	1.3199263920E+06	5.0733249836E+06	-3.4789899674E+06
-6.6700000000E+05	1.2460008666E+06	5.0919852621E+06	-3.4789899674E+06
0.	1.1718117670E+06	5.1095684017E+06	-3.4789899674E+06
6.6700000000E+05	1.0973747868E+06	5.1260706829E+06	-3.4789899674E+06
6.6700000000E+05	1.0227055722E+06	5.1414886149E+06	-3.4789899674E+06
6.6700000000E+05	9.4782021844E+05	5.1558189362E+06	-3.4789899674E+06
0.	8.7273426641E+05	5.1690586154E+06	-3.4789899674E+06
-6.6700000000E+05	7.9746369953E+05	5.1812048519E+06	-3.4789899674E+06
-6.6700000000E+05	7.2202444025E+05	5.1922550762E+06	-3.4789899674E+06
0.	6.4643244671E+05	5.2022069510E+06	-3.4789899674E+06
-6.6700000000E+05	5.7070370934E+05	5.2110583709E+06	-3.4789899674E+06
6.6700000000E+05	4.9485424750E+05	5.2188074637E+06	-3.4789899674E+06
6.6700000000E+05	4.1890010611E+05	5.2254525900E+06	-3.4789899674E+06
6.6700000000E+05	3.4285735220E+05	5.2309923442E+06	-3.4789899674E+06
-6.6700000000E+05	2.6674207157E+05	5.2354255545E+06	-3.4789899674E+06
-6.6700000000E+05	1.9057036535E+05	5.2387512830E+06	-3.4789899674E+06
-6.6700000000E+05	1.1435834660E+05	5.2409688262E+06	-3.4789899674E+06
6.6700000000E+05	3.8122136938E+04	5.2420777151E+06	-3.4789899674E+06
-6.6700000000E+05	2.5627178351E+06	4.5142562361E+06	-3.5545105836E+06
-6.6700000000E+05	2.4967919007E+06	4.5510506778E+06	-3.5545105836E+06
6.6700000000E+05	2.4303378046E+06	4.5868324078E+06	-3.5545105836E+06
-6.6700000000E+05	2.3633696042E+06	4.6217438464E+06	-3.5545105836E+06
0.	2.2959014657E+06	4.6556276191E+06	-3.5545105836E+06
6.6700000000E+05	2.2279476610E+06	4.6885265583E+06	-3.5545105836E+06
6.6700000000E+05	2.1595225649E+06	4.7204337046E+06	-3.5545105836E+06
6.6700000000E+05	2.0906406517E+06	4.7513423086E+06	-3.5545105836E+06
0.	2.0213164924E+06	4.7812458319E+06	-3.5545105836E+06
-6.6700000000E+05	1.9515647516E+06	4.8101379490E+06	-3.5545105836E+06
-6.6700000000E+05	1.8814001843E+06	4.8380125480E+06	-3.5545105836E+06
6.6700000000E+05	1.8108376329E+06	4.8648637324E+06	-3.5545105836E+06
6.6700000000E+05	1.7398920239E+06	4.8906858223E+06	-3.5545105836E+06
6.6700000000E+05	1.6685783648E+06	4.9154733555E+06	-3.5545105836E+06
6.6700000000E+05	1.5969117411E+06	4.9392210883E+06	-3.5545105836E+06
6.6700000000E+05	1.5249073129E+06	4.9619239973E+06	-3.5545105836E+06
6.6700000000E+05	1.4525803110E+06	4.9835772800E+06	-3.5545105836E+06
6.6700000000E+05	1.3799460371E+06	5.0041763561E+06	-3.5545105836E+06
-6.6700000000E+05	1.3070198541E+06	5.0237168679E+06	-3.5545105836E+06
0.	1.2338171892E+06	5.0421946820E+06	-3.5545105836E+06
-6.6700000000E+05	1.1603535273E+06	5.0596058897E+06	-3.5545105836E+06
-6.6700000000E+05	1.0866444087E+06	5.0759468079E+06	-3.5545105836E+06
-6.6700000000E+05	1.0127054256E+06	5.0912139799E+06	-3.5545105836E+06
-6.6700000000E+05	9.3855221862E+05	5.1054041760E+06	-3.5545105836E+06
-6.6700000000E+05	8.6420047396E+05	5.1185143947E+06	-3.5545105836E+06
-6.6700000000E+05	7.8966591966E+05	5.1305418625E+06	-3.5545105836E+06
-6.6700000000E+05	7.1496432247E+05	5.1414840353E+06	-3.5545105836E+06
-6.6700000000E+05	6.4011148448E+05	5.1513385984E+06	-3.5545105836E+06
-6.6700000000E+05	5.6512323978E+05	5.1601034671E+06	-3.5545105836E+06
-6.6700000000E+05	4.9001545109E+05	5.1677767875E+06	-3.5545105836E+06
6.6700000000E+05	4.1480400641E+05	5.1743569363E+06	-3.5545105836E+06
6.6700000000E+05	3.3950481570E+05	5.1798425215E+06	-3.5545105836E+06
6.6700000000E+05	2.6413380744E+05	5.1842323829E+06	-3.5545105836E+06
6.6700000000E+05	1.8870692534E+05	5.1875255917E+06	-3.5545105836E+06
6.6700000000E+05	1.1324012490E+05	5.1897214513E+06	-3.5545105836E+06
6.6700000000E+05	3.7749370087E+04	5.1908194972E+06	-3.5545105836E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	2.5368683973E+06	4.4687221612E+06	-3.6292880565E+06
-6.6700000000E+05	2.4716074399E+06	4.5051454674E+06	-3.6292880565E+06
-6.6700000000E+05	2.4058236481E+06	4.5406157725E+06	-3.6292880565E+06
-6.6700000000E+05	2.3395309377E+06	4.5751255732E+06	-3.6292880565E+06
6.6700000000E+05	2.2727433320E+06	4.6085675695E+06	-3.6292880565E+06
6.6700000000E+05	2.2054749589E+06	4.6412346660E+06	-3.6292880565E+06
6.6700000000E+05	2.1377400481E+06	4.6728199736E+06	-3.6292880565E+06
6.6700000000E+05	2.0695529280E+06	4.7034168109E+06	-3.6292880565E+06
0.	2.0009280226E+06	4.7330187056E+06	-3.6292880565E+06
6.6700000000E+05	1.9318798487E+06	4.7616193957E+06	-3.6292880565E+06
-6.6700000000E+05	1.8624230124E+06	4.7892128312E+06	-3.6292880565E+06
6.6700000000E+05	1.7925722062E+06	4.8157931750E+06	-3.6292880565E+06
6.6700000000E+05	1.7223422063E+06	4.8413548046E+06	-3.6292880565E+06
6.6700000000E+05	1.6517478687E+06	4.8658923126E+06	-3.6292880565E+06
6.6700000000E+05	1.5808041267E+06	4.8894005085E+06	-3.6292880565E+06
6.6700000000E+05	1.5095259875E+06	4.9118744194E+06	-3.6292880565E+06
-6.6700000000E+05	1.4379285290E+06	4.9333092914E+06	-3.6292880565E+06
-6.6700000000E+05	1.3660268967E+06	4.9537005901E+06	-3.6292880565E+06
6.6700000000E+05	1.2938363003E+06	4.9730440021E+06	-3.6292880565E+06
-6.6700000000E+05	1.2213720107E+06	4.9913354356E+06	-3.6292880565E+06
-6.6700000000E+05	1.1486493568E+06	5.0085710212E+06	-3.6292880565E+06
-6.6700000000E+05	1.0756837221E+06	5.0247471130E+06	-3.6292880565E+06
-6.6700000000E+05	1.0024905414E+06	5.0398602891E+06	-3.6292880565E+06
-6.6700000000E+05	9.2908529765E+05	5.0539073526E+06	-3.6292880565E+06
-6.6700000000E+05	8.5548351881E+05	5.0668853320E+06	-3.6292880565E+06
6.6700000000E+05	7.8170077429E+05	5.0787914821E+06	-3.6292880565E+06
-6.6700000000E+05	7.0775267179E+05	5.0896232842E+06	-3.6292880565E+06
6.6700000000E+05	6.3365485403E+05	5.0993784469E+06	-3.6292880565E+06
-6.6700000000E+05	5.5942299536E+05	5.1080549068E+06	-3.6292880565E+06
-6.6700000000E+05	4.8507279850E+05	5.1156508285E+06	-3.6292880565E+06
-6.6700000000E+05	4.1061999121E+05	5.1221646051E+06	-3.6292880565E+06
0.	3.3608032296E+05	5.1275948588E+06	-3.6292880565E+06
6.6700000000E+05	2.6146956156E+05	5.1319404408E+06	-3.6292880565E+06
-6.6700000000E+05	1.8680348991E+05	5.1352004318E+06	-3.6292880565E+06
6.6700000000E+05	1.1209790256E+05	5.1373741424E+06	-3.6292880565E+06
6.6700000000E+05	3.7368602457E+04	5.1384611127E+06	-3.6292880565E+06
-6.6700000000E+05	2.5104810846E+06	4.4222406137E+06	-3.7033064686E+06
-6.6700000000E+05	2.4458989410E+06	4.4582350618E+06	-3.7033064686E+06
-6.6700000000E+05	2.3807994014E+06	4.4933364214E+06	-3.7033064686E+06
6.6700000000E+05	2.3151962366E+06	4.5275372674E+06	-3.7033064686E+06
-6.6700000000E+05	2.2491033241E+06	4.5607303756E+06	-3.7033064686E+06
-6.6700000000E+05	2.1825346450E+06	4.5929587245E+06	-3.7033064686E+06
-6.6700000000E+05	2.1155042809E+06	4.6242154966E+06	-3.7033064686E+06
6.6700000000E+05	2.0480264112E+06	4.6544940800E+06	-3.7033064686E+06
-6.6700000000E+05	1.9801153099E+06	4.6837880697E+06	-3.7033064686E+06
6.6700000000E+05	1.9117853426E+06	4.7120912688E+06	-3.7033064686E+06
-6.6700000000E+05	1.8430509636E+06	4.7393976904E+06	-3.7033064686E+06
-6.6700000000E+05	1.7739267127E+06	4.7657015580E+06	-3.7033064686E+06
6.6700000000E+05	1.7044272122E+06	4.7909973075E+06	-3.7033064686E+06
-6.6700000000E+05	1.6345671637E+06	4.8152795878E+06	-3.7033064686E+06
-6.6700000000E+05	1.5643613452E+06	4.8385432625E+06	-3.7033064686E+06
6.6700000000E+05	1.4938246077E+06	4.8607834104E+06	-3.7033064686E+06
6.6700000000E+05	1.4229718723E+06	4.8819953269E+06	-3.7033064686E+06
-6.6700000000E+05	1.3518181270E+06	4.9021745250E+06	-3.7033064686E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	1.2803784232E+06	4.9213167359E+06	-3.7033064686E+06
6.6700000000E+05	1.2086678731E+06	4.9394179105E+06	-3.7033064686E+06
-6.6700000000E+05	1.1367016461E+06	4.9564742196E+06	-3.7033064686E+06
6.6700000000E+05	1.0644949656E+06	4.9724820553E+06	-3.7033064686E+06
-6.6700000000E+05	9.9206310595E+05	4.9874380312E+06	-3.7033064686E+06
-6.6700000000E+05	9.1942138908E+05	5.0013389838E+06	-3.7033064686E+06
-6.6700000000E+05	8.4658518135E+05	5.0141819724E+06	-3.7033064686E+06
-6.6700000000E+05	7.7356989026E+05	5.0259642803E+06	-3.7033064686E+06
-6.6700000000E+05	7.0039096117E+05	5.0366834150E+06	-3.7033064686E+06
6.6700000000E+05	6.2706387407E+05	5.0463371092E+06	-3.7033064686E+06
-6.6700000000E+05	5.5360414030E+05	5.0549233206E+06	-3.7033064686E+06
-6.6700000000E+05	4.8002729925E+05	5.0624402331E+06	-3.7033064686E+06
0.	4.0634891507E+05	5.0688862565E+06	-3.7033064686E+06
6.6700000000E+05	3.3258457341E+05	5.0742600272E+06	-3.7033064686E+06
6.6700000000E+05	2.5874987808E+05	5.0785604085E+06	-3.7033064686E+06
6.6700000000E+05	1.8486044781E+05	5.0817864906E+06	-3.7033064686E+06
6.6700000000E+05	1.1093191287E+05	5.0839375913E+06	-3.7033064686E+06
-6.6700000000E+05	3.6979911819E+04	5.0850132554E+06	-3.7033064686E+06
0.	2.4835612928E+06	4.3748210982E+06	-3.7765500462E+06
0.	2.4196716610E+06	4.4104790430E+06	-3.7765500462E+06
6.6700000000E+05	2.3552701812E+06	4.4452040121E+06	-3.7765500462E+06
-6.6700000000E+05	2.2903704766E+06	4.4789986599E+06	-3.7765500462E+06
-6.6700000000E+05	2.2249862759E+06	4.5118258397E+06	-3.7765500462E+06
-6.6700000000E+05	2.1591314102E+06	4.5437086053E+06	-3.7765500462E+06
6.6700000000E+05	2.0928198101E+06	4.5746302122E+06	-3.7765500462E+06
6.6700000000E+05	2.0260655030E+06	4.6045841195E+06	-3.7765500462E+06
-6.6700000000E+05	1.9588826098E+06	4.6335639908E+06	-3.7765500462E+06
6.6700000000E+05	1.8912853421E+06	4.6615636959E+06	-3.7765500462E+06
6.6700000000E+05	1.8232879992E+06	4.6885773117E+06	-3.7765500462E+06
6.6700000000E+05	1.7549049650E+06	4.7145991240E+06	-3.7765500462E+06
6.6700000000E+05	1.6861507049E+06	4.7396236281E+06	-3.7765500462E+06
6.6700000000E+05	1.6170397631E+06	4.7636455306E+06	-3.7765500462E+06
-6.6700000000E+05	1.5475867588E+06	4.7866597498E+06	-3.7765500462E+06
6.6700000000E+05	1.4778063841E+06	4.8086614174E+06	-3.7765500462E+06
6.6700000000E+05	1.4077133998E+06	4.8296458794E+06	-3.7765500462E+06
6.6700000000E+05	1.3373226333E+06	4.8496086966E+06	-3.7765500462E+06
6.6700000000E+05	1.2666489748E+06	4.8685456464E+06	-3.7765500462E+06
6.6700000000E+05	1.1957073742E+06	4.8864527227E+06	-3.7765500462E+06
6.6700000000E+05	1.1245128382E+06	4.9033261377E+06	-3.7765500462E+06
6.6700000000E+05	1.0530804272E+06	4.9191623220E+06	-3.7765500462E+06
-6.6700000000E+05	9.8142525154E+05	4.9339579256E+06	-3.7765500462E+06
-6.6700000000E+05	9.0956246899E+05	4.9477098188E+06	-3.7765500462E+06
-6.6700000000E+05	8.3750728111E+05	4.9604150925E+06	-3.7765500462E+06
6.6700000000E+05	7.6527493016E+05	4.9720710592E+06	-3.7765500462E+06
-6.6700000000E+05	6.9288069590E+05	4.9826752530E+06	-3.7765500462E+06
-6.6700000000E+05	6.2033989234E+05	4.9922254310E+06	-3.7765500462E+06
-6.6700000000E+05	5.4766786446E+05	5.0007195729E+06	-3.7765500462E+06
-6.6700000000E+05	4.7487998503E+05	5.0081558817E+06	-3.7765500462E+06
-6.6700000000E+05	4.0199165133E+05	5.0145327847E+06	-3.7765500462E+06
6.6700000000E+05	3.2901828185E+05	5.0198489326E+06	-3.7765500462E+06
-6.6700000000E+05	2.5597531312E+05	5.0241032011E+06	-3.7765500462E+06
-6.6700000000E+05	1.8287819636E+05	5.0272946901E+06	-3.7765500462E+06
6.6700000000E+05	1.0974239425E+05	5.0294227246E+06	-3.7765500462E+06
6.6700000000E+05	3.6583377651E+04	5.0304868544E+06	-3.7765500462E+06

MASSES(I)	X	Y	Z
6.6700000000E+05	2.4561145328E+06	4.3264733222E+06	-3.8490031636E+06
-6.6700000000E+05	2.3929309691E+06	4.3617371979E+06	-3.8490031636E+06
-6.6700000000E+05	2.3292412140E+06	4.3960784084E+06	-3.8490031636E+06
6.6700000000E+05	2.2650587402E+06	4.4294896895E+06	-3.8490031636E+06
-6.6700000000E+05	2.2003971246E+06	4.4619639734E+06	-3.8490031636E+06
6.6700000000E+05	2.1352700455E+06	4.4934943906E+06	-3.8490031636E+06
6.6700000000E+05	2.0696912796E+06	4.5240742714E+06	-3.8490031636E+06
6.6700000000E+05	2.0036746991E+06	4.5536971469E+06	-3.8490031636E+06
-6.6700000000E+05	1.9372342691E+06	4.5823567509E+06	-3.8490031636E+06
6.6700000000E+05	1.8703840440E+06	4.6100470208E+06	-3.8490031636E+06
6.6700000000E+05	1.8031381650E+06	4.6367620991E+06	-3.8490031636E+06
6.6700000000E+05	1.7355108572E+06	4.6624963347E+06	-3.8490031636E+06
6.6700000000E+05	1.6675164260E+06	4.6872442837E+06	-3.8490031636E+06
6.6700000000E+05	1.5991692549E+06	4.7110007111E+06	-3.8490031636E+06
-6.6700000000E+05	1.5304838017E+06	4.7337605916E+06	-3.8490031636E+06
6.6700000000E+05	1.4614745958E+06	4.7555191107E+06	-3.8490031636E+06
6.6700000000E+05	1.3921562352E+06	4.7762716655E+06	-3.8490031636E+06
-6.6700000000E+05	1.3225433833E+06	4.7960138663E+06	-3.8490031636E+06
6.6700000000E+05	1.2526507656E+06	4.8147415367E+06	-3.8490031636E+06
6.6700000000E+05	1.1824931670E+06	4.8324507153E+06	-3.8490031636E+06
-6.6700000000E+05	1.1120854284E+06	4.8491376559E+06	-3.8490031636E+06
6.6700000000E+05	1.0414424435E+06	4.8647988286E+06	-3.8490031636E+06
-6.6700000000E+05	9.7057915587E+05	4.8794309205E+06	-3.8490031636E+06
-6.6700000000E+05	8.9951055567E+05	4.8930308364E+06	-3.8490031636E+06
6.6700000000E+05	8.2825167648E+05	4.9055956994E+06	-3.8490031636E+06
-6.6700000000E+05	7.5681759213E+05	4.9171228516E+06	-3.8490031636E+06
-6.6700000000E+05	6.8522341350E+05	4.9276098546E+06	-3.8490031636E+06
0.	6.1348428534E+05	4.9370544900E+06	-3.8490031636E+06
6.6700000000E+05	5.4161538309E+05	4.9454547600E+06	-3.8490031636E+06
-6.6700000000E+05	4.6963190960E+05	4.9528088874E+06	-3.8490031636E+06
-6.6700000000E+05	3.9754909200E+05	4.9591153168E+06	-3.8490031636E+06
-6.6700000000E+05	3.2538217838E+05	4.9643727140E+06	-3.8490031636E+06
-6.6700000000E+05	2.5314643468E+05	4.9685799670E+06	-3.8490031636E+06
-6.6700000000E+05	1.8085714136E+05	4.9717361857E+06	-3.8490031636E+06
6.6700000000E+05	1.0852959021E+05	4.9738407025E+06	-3.8490031636E+06
6.6700000000E+05	3.6179081131E+04	4.9748930722E+06	-3.8490031636E+06
6.6700000000E+05	2.4281464299E+06	4.2772071951E+06	-3.9206503459E+06
-6.6700000000E+05	2.3656823459E+06	4.3120695163E+06	-3.9206503459E+06
-6.6700000000E+05	2.3027178345E+06	4.3460196789E+06	-3.9206503459E+06
0.	2.2392662151E+06	4.3790505013E+06	-3.9206503459E+06
6.6700000000E+05	2.1753409099E+06	4.4111549962E+06	-3.9206503459E+06
6.6700000000E+05	2.1109554415E+06	4.4423263724E+06	-3.9206503459E+06
-6.6700000000E+05	2.0461234297E+06	4.4725580360E+06	-3.9206503459E+06
-6.6700000000E+05	1.9808585889E+06	4.5018435919E+06	-3.9206503459E+06
-6.6700000000E+05	1.9151747248E+06	4.5301768452E+06	-3.9206503459E+06
6.6700000000E+05	1.8490857321E+06	4.5575518023E+06	-3.9206503459E+06
-6.6700000000E+05	1.7826055909E+06	4.5839626725E+06	-3.9206503459E+06
0.	1.7157483642E+06	4.6094038688E+06	-3.9206503459E+06
-6.6700000000E+05	1.6485281947E+06	4.6338700097E+06	-3.9206503459E+06
-6.6700000000E+05	1.5809593019E+06	4.6573559195E+06	-3.9206503459E+06
6.6700000000E+05	1.5130559791E+06	4.6798566302E+06	-3.9206503459E+06
-6.6700000000E+05	1.4448325902E+06	4.7013673821E+06	-3.9206503459E+06
-6.6700000000E+05	1.3763035670E+06	4.7218836248E+06	-3.9206503459E+06
-6.6700000000E+05	1.3074834059E+06	4.7414010185E+06	-3.9206503459E+06

MASSES(I)	X	Y	Z
-6.6700000000E+05	1.2383866647E+06	4.7599154345E+06	-3.9206503459E+06
-6.6700000000E+05	1.1690279601E+06	4.7774229563E+06	-3.9206503459E+06
-6.6700000000E+05	1.0994219637E+06	4.7939198805E+06	-3.9206503459E+06
0.	1.0295833999E+06	4.8094027174E+06	-3.9206503459E+06
6.6700000000E+05	9.5952704194E+05	4.8238681917E+06	-3.9206503459E+06
-6.6700000000E+05	8.8926770935E+05	4.8373132436E+06	-3.9206503459E+06
6.6700000000E+05	8.1882026449E+05	4.8497350288E+06	-3.9206503459E+06
6.6700000000E+05	7.4819960956E+05	4.8611309198E+06	-3.9206503459E+06
6.6700000000E+05	6.7742068336E+05	4.8714985059E+06	-3.9206503459E+06
6.6700000000E+05	6.0649845820E+05	4.8808355940E+06	-3.9206503459E+06
6.6700000000E+05	5.3544793669E+05	4.8891402089E+06	-3.9206503459E+06
0.	4.6428414859E+05	4.8964105940E+06	-3.9206503459E+06
6.6700000000E+05	3.9302214761E+05	4.9026452112E+06	-3.9206503459E+06
-6.6700000000E+05	3.2167700825E+05	4.9078427417E+06	-3.9206503459E+06
0.	2.5026382256E+05	4.9120020861E+06	-3.9206503459E+06
-6.6700000000E+05	1.7879769704E+05	4.9151223646E+06	-3.9206503459E+06
-6.6700000000E+05	1.0729374933E+05	4.9172029170E+06	-3.9206503459E+06
-6.6700000000E+05	3.5767105123E+04	4.9182433032E+06	-3.9206503459E+06
6.6700000000E+05	2.3996627234E+06	4.2270328263E+06	-3.9914762731E+06
6.6700000000E+05	2.3379313829E+06	4.2614861902E+06	-3.9914762731E+06
6.6700000000E+05	2.2757054854E+06	4.2950380958E+06	-3.9914762731E+06
6.6700000000E+05	2.2129981939E+06	4.3276814455E+06	-3.9914762731E+06
0.	2.1498227734E+06	4.3594093342E+06	-3.9914762731E+06
6.6700000000E+05	2.0861925876E+06	4.3902150503E+06	-3.9914762731E+06
-6.6700000000E+05	2.0221210967E+06	4.4200320772E+06	-3.9914762731E+06
-6.6700000000E+05	1.9576218540E+06	4.4490340948E+06	-3.9914762731E+06
-6.6700000000E+05	1.8927085036E+06	4.4770349810E+06	-3.9914762731E+06
-6.6700000000E+05	1.8273947769E+06	4.5040888124E+06	-3.9914762731E+06
-6.6700000000E+05	1.7616944902E+06	4.5301898662E+06	-3.9914762731E+06
-6.6700000000E+05	1.6956215414E+06	4.5553326211E+06	-3.9914762731E+06
-6.6700000000E+05	1.6291899074E+06	4.5795117585E+06	-3.9914762731E+06
0.	1.5624136408E+06	4.6027221636E+06	-3.9914762731E+06
-6.6700000000E+05	1.4953066673E+06	4.6249589266E+06	-3.9914762731E+06
0.	1.4278837823E+06	4.6462173437E+06	-3.9914762731E+06
-6.6700000000E+05	1.3601586482E+06	4.6664929178E+06	-3.9914762731E+06
-6.6700000000E+05	1.2921457915E+06	4.6857813600E+06	-3.9914762731E+06
6.6700000000E+05	1.2238595992E+06	4.7040785901E+06	-3.9914762731E+06
6.6700000000E+05	1.1553145164E+06	4.7213807375E+06	-3.9914762731E+06
6.6700000000E+05	1.0865250428E+06	4.7376841423E+06	-3.9914762731E+06
6.6700000000E+05	1.0175057298E+06	4.7529853556E+06	-3.9914762731E+06
0.	9.4827117765E+05	4.7672811407E+06	-3.9914762731E+06
6.6700000000E+05	8.7883603185E+05	4.7805684735E+06	-3.9914762731E+06
6.6700000000E+05	8.0921498046E+05	4.7928445433E+06	-3.9914762731E+06
6.6700000000E+05	7.3942275086E+05	4.8041067532E+06	-3.9914762731E+06
6.6700000000E+05	6.6947410661E+05	4.8143527209E+06	-3.9914762731E+06
6.6700000000E+05	5.9938384440E+05	4.8235802790E+06	-3.9914762731E+06
6.6700000000E+05	5.2916679083E+05	4.8317874754E+06	-3.9914762731E+06
6.6700000000E+05	4.5883779936E+05	4.8389725742E+06	-3.9914762731E+06
0.	3.8841174711E+05	4.8451340554E+06	-3.9914762731E+06
6.6700000000E+05	3.1790353174E+05	4.8502706156E+06	-3.9914762731E+06
-6.6700000000E+05	2.4732806828E+05	4.8543811683E+06	-3.9914762731E+06
6.6700000000E+05	1.7670026599E+05	4.8574648439E+06	-3.9914762731E+06
6.6700000000E+05	1.0603512521E+05	4.8595209900E+06	-3.9914762731E+06
-6.6700000000E+05	3.5347534163E+04	4.8605491719E+06	-3.9914762731E+06

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This report develops locally valid Chebyshev polynomial representations of gravitational disturbance accelerations to use, for example, in inertial guidance calculations. The gravity field can be accurately represented in this fashion, the computational speed is increased by about a factor of twenty in comparison to point mass representations.

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