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EARTH ZONAL HARMONICS FROM RAPID NUMERICAL ANALYSIS OF LONG SATELLITE ARCS

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ABSTRACT

A zonal geopotential is presented to degree 21 from evaluation of mean elements for 21 satellites including 2 of low ($< 20°$) inclination. Each satellite is represented by an arc of at least one apsidal rotation. The lengths range from 200 to 800 days. Differential correction of the initial elements in all of the arcs, together with radiation pressure and atmospheric drag coefficients, is accomplished simultaneously with the correction for the zonal harmonics. The satellite orbits and their variations are generated by numerical integration of the Lagrange equations for mean elements. Disturbances due to precession and nutation of the earth's pole, atmospheric drag, radiation pressure and luni-solar gravity are added at from 1- to 8-day intervals in the integrated orbits.

The results agree well with recent solutions from other authors using different methods and different satellite sets. These comparisons show the zonal coefficients are now known to better than 0.02×10^{-6} (fully normalized) to at least as high as degree 10, but that above degree 10, many of the terms are not yet significantly different from zero.

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INTRODUCTION

The evaluation of the longitude averaged, or zonal, part of the geopotential has been advanced significantly since the advent of the artificial earth satellite. Radio tracking of the early Sputniks and Vanguards before 1960 established the gravitational oblateness of the earth (J_2) to better than one part in ten-thousand and discovered the earth's significant "pear shapedness"[1,2,3] (J_3). These spherical harmonic terms were calculated from their secular and long periodic perturbations of the Kepler elements of close earth satellites.

The even zonal terms (having equatorial symmetry) were the first to be evaluated to high degree with significant accuracy, from the easily observed secular movement of the node and perigee of the orbits.[4,5] (For $J_{even} > 2$, these secular rates are of order 0.01°/day.) The odd zonal terms (asymmetric with respect to the equator) were more difficult to evaluate, having no secular effects on satellite orbits. Their determination required observation of perigee altitude oscillations of the order of only 10 km over apsidal rotation periods of the order of months. Nevertheless, by 1964 Kozai had "determined" a complete zonal harmonic field to J_{14} from 9 satellites,[6] and by 1969 King-Hele had evaluated odd zonal terms as high as J_{31} from 22 satellites.[7] A complete zonal field to J_{21} was available by 1969, due to Kozai, ultimately from the precise Baker-Nunn tracking of 12 satellites.[8] By 1971 this latter determination was improved by the addition of 3 satellites of low inclination.[9]

All the above solutions for the zonal geopotential have used semi analytic methods in rationalizing the observed perturbations (of mean Kepler elements) with theory. The word 'semi' is used since the actual data reduction in these determinations involved many empirical and numerical procedures, especially in the removal of the effects of drag and radiation pressure.[10] No adequate theory exists for these perturbations on many orbits. Purely numerical methods (of integration) have also been used to evaluate zonal harmonics directly from tracking data. The first comprehensive solution of this kind (to J_7) was obtained from the Tranet doppler tracking of 5 satellites[11] in 1965. However, in this determination tracking arcs were generally less than one week. The secular and long period zonal effects on the orbits were not well observed and the zonal solution is relatively weak particularly since only a few satellites were used.

More recently, at Goddard Space Flight Center, a quite respectable zonal field to J_{21} has been computed, using numerical integration, from weekly arcs of optical observations on over 20 satellites.[12] The strength of this solution is felt to arise primarily from the significant number of different orbits observed as well as the large number of arcs used (over 300).

However the determination of the zonal geopotential from satellite observations using straight numerical integration of osculating elements will always suffer from excessive computation time if the secular and long periodic effects are to be well observed. On the other hand, the semi analytic methods, while extremely efficient for evaluating long term effects on mean elements, have always been subject to a considerable amount of approximation in both the theory and its application. The theory for the evolution of the elements is limited by the difficulty or impossibility of obtaining exact solutions. In the applications, only some of the element data is actually used. Furthermore, no assessment is made of the effects of the variability of the elements in a long arc on the geopotential partial derivatives. However, great simplification and reduction of arbitrariness in the analytic methods can be achieved by analyzing the evolution of mean elements directly by numerical integration of their variations.

The integration of mean (or orbit averaged) Kepler elements is extremely rapid.[13] Furthermore the inclusion of complex disturbances, such as drag, radiation pressure and high order gravitational effects, is relatively straight foreward since the disturbance is integrated numerically. In 1970, a preliminary application of this method for zonal determination was made to mean elements determined from Minitrack interferometer data on only 2 satellites.[14] In this solution J_2, J_3 and J_4 were recovered with good accuracy considering the limitations of the data. In the present solution a full complement of satellite orbits of all inclinations and a wide range of altitudes are analyzed for effects through J_{21}.

THE DATA

My aim was to use at least as many satellites as harmonics evaluated, with a good distribution of inclinations and altitudes to separate terms of high from low degree. The 21 satellites chosen for analysis are shown in Table 1 (with pertinent orbit and spacecraft data). Their orbit characteristics are displayed in Figure 1. Arc lengths were chosen to have a minimum of one apsidal rotation, containing at least 25 element sets, to give a good description of the principal long periodic effect.

Two agencies were responsible for the mean element "observations" used; The Smithsonian Astrophysical Observatory (SAO) and Goddard Space Flight Center (GSFC). Mean elements for six SAO satellite arcs (Vanguard 2, Echo 1 Rocket, Transit 4A, Midas 4, GEOS 1, BE-B; supplied by Kozai[15]) were determined from precision reduced Baker-Nunn optical observations and were used in his 1969 solution. Three additional SAO satellite arcs contained mean elements derived from field reduced Baker-Nunn observations (TELSTAR 1, ANNA 1B and Explorer 11). The GSFC mean elements (on the remaining 12 satellites) were determined predominantly from Minitrack interferometer observations except for the cases of PEOLE and GEOS 2 where some optical and laser tracking data was also used. About half of the GSFC satellite arcs were in King-Hele's 1969 odd zonal solution.[7] Eight of the satellite orbits here were also analyzed (with seven others) in Cazenave's 1971 solution.[9] This French determination was the first to include orbits of low inclination, of which PEOLE and SAS are also used here. Indeed the present solution most resembles the French, as will be seen later.

Finally, the full complement of mean element data analyzed (after preprocessing, to be described) is given in Table 2.

PREPROCESSING

The description of SAO mean elements is found briefly in the Smithsonian reports from which the elements for TELSTAR, ANNA 1B and EXPLORER 11 were extracted.[16,17,18] Gaposchkin gives a more detailed discussion of them.[19] From this it is evident that their definition only requires a shift of the nodal reference (from the equinox of 1950.0 as given in the reports) to the equinox of date, in order to be compatible with the orbit integrator used in the numerical analysis. However, the mean semimajor axes were not taken directly from the reports or from Kozai's data; they were calculated from the given mean mean motions ($\bar{n}$) by a variant of Kepler's law, scaled to the earth constants used in the integrator.[13, p.134]

The original elements determined at GSFC were of two kinds, Brouwer mean (double primed) and Cowell osculating. The Brouwer double primed elements were converted to single primed means by adding back the long period terms given by Brouwer[20] in 1959. The single primed means are essentially osculating elements with only the short period terms removed. They are precisely the coordinates analyzed by the integrator (to be described). The zonal constants implicit in the original GSFC mean elements for TIROS 9, TIROS 5, OSO 3, EXPLORER 27, FR-1, ESSA 1, PEGASUS 3 and EGRS-3 were: $10^6 J_2 = 1082.19$, $10^6 J_3 = -2.29$, $10^6 J_4 = -2.12$ and $10^6 J_5 = -0.23$. For ISIS 1 and SAS 1 the constants were $10^6 J_2 = 1082.48$, $10^6 J_3 = -2.56$, $10^6 J_4 = -1.84$ and $10^6 J_5 = -0.06$. For the GSFC satellite arcs PEOLE and GEOS 2 osculating elements were originally determined by a Cowell type numerical integrator. First order short period terms in the 6 Kepler elements, due to J_2 through J_4, and second order terms in the semimajor axis due to J_2 (from Brouwer[20] and Kozai[21]) were subtracted from the original PEOLE elements. All relevant first order short period terms (zonal and non-zonal) through $J_{4,4}$ (from Kaula[22, p.40]) were removed analytically from the original GEOS 2 elements. The remaining short period variations were removed by numerically averaging the residual effects of the geopotential, luni-solar gravity, radiation pressure and atmospheric drag over one orbit revolution.[23]

The set of mean elements so produced (in Table 2) was now ready to be analyzed for zonal geopotential effects.

ANALYSIS

The ROAD (Rapid Orbit Analysis and Determination) program was the principal analytic tool in this investigation.[24, 25] This program integrates numerically the Lagrange planetary equations[22, p.29] for mean (or orbit averaged) Kepler elements by considering as disturbances only effects not in the mean anomaly of the satellite. For the geopotential, Kaula's form[22, p.37] is employed because it enables the analyst to select the (first order) long period (and secular) terms simply by choosing the ℓ, m, p, q indices such that $\ell - 2p + q = 0$. The geopotential analyzed in ROAD, in the standard form of Legendre polynomials $P_\ell(\varphi)$, is:

$$V = \frac{\mu}{r}\left[1 - \sum_{\ell=2}^{\infty} J_\ell \left(\frac{r_e}{r}\right)^{\ell} P_\ell(\varphi)\right],$$

where μ is the earth's gaussian constant (3.9803×10^5 km^3/sec^2 in the program), r_e is the equatorial radius of the earth (6378.16 km in the program), φ is the geocentric latitude, r the distance to the earth's center of mass and the J's are the unnormalized zonal coefficients.

The ROAD integrator also considers orbit averaged disturbances from atmospheric drag, radiation pressure, the interaction of short period J_2 effects, and the effects of precession and nutation of the earth's polar axis. Direct luni-solar gravity perturbations are handled in the same manner as the geopotential, by expressing them as functions of the Kepler elements of both satellite and third body.[26] Only first order long period or secular terms are chosen (by index selection) for integration.

The program also integrates variational equations for the six epoch Kepler elements of the satellite orbit; a (semimajor axis), e (eccentricity, I (inclination), ω (argument of perigee), N (right ascension of the ascending node), and M (mean anomaly). In fact, full differential correction capability exists for up to 50 geopotential constants common to any number of satellite arcs as well as an extended state for each arc. The extended state can consist of model radiation pressure and atmospheric drag coefficients or a large number of Kepler elements rates to absorb model errors empirically.

The drag disturbance acceleration is modeled as $(1/2)\ (C_D)\ \rho\ v^2 A/m$ where C_D is the empirically derived coefficient of drag, ρ is the atmospheric density, v is the satellite's velocity relative to an atmosphere rotating with the earth and A/m is the satellite's projected area to mass ratio. The radiation pressure acceleration is formulated as (C_R) (I/C) (A/m), where C_R is the radiation pressure coefficient, I is the solar flux, C the velocity of light and A the projected area in the satellite-sun line. The data used in these "state" and geopotential corrections are the "observed" Kepler elements themselves which are "best fitted" in a least squares sense to the trajectories from the ROAD integrator.

The theory for the evolution of these elements due to the geopotential, is well known since the pivotal paper by Brouwer[20] in 1959. The even zonals cause distinct secular rates in the node and perigee as well as long period oscillations in all the elements (except a) with a fundamental period of half a perigee rotation. The odd zonals cause long period oscillations in all the elements (except a) with a fundamental period of the rotation of perigee. Therefore the minimum span of data which should be considered in a zonal solution is a rotation of perigee for all orbits. To distinguish even zonal long period effects, a minimum of 12 element sets per half rotation period was felt to be necessary, or 25 sets per arc. In most cases these minimum specifications were far exceeded. But in any case, as Kozai points out,[10, pp. 833-834] there is a limit to the accuracy of the zonal solution, set by the accuracy with which the satellite elements are known. The ROAD solution for the initial elements simultaneously with the geopotential automatically accounts for the effects of these uncertainties. Furthermore the ROAD trajectories and partial derivatives continuously refer to an orbit closest to the originally observed data. (An example of a "run" where some of the epoch elements (in particular; e, I, ω, N) were constrained is given in Table 3 to show the possible extent of this error.)

Theoretically, the 21 satellites examined here should supply at least 42 independent strong condition equations for the (10) even zonals (to J_{20}) from the node and perigee data. But actually this number is reduced considerably because of the many high altitude and nearly circular orbits examined. Nevertheless, the highest correlation coefficient for even zonals in the present solution is only 0.65 between J_4 and J_{14}. Examination of Kozai's normals in his 12 satellite 1969 solution[8] shows many correlations greater than 0.90 between even zonals. The conditioning is much poorer with odd zonals. Here, even though long period effects are present in 5 elements, they are poorly observed (compared to the secular effects from the even zonals). Furthermore, the oscillations in e and I are not independent of each other (i.e. they differ only by an orbit constant) to provide separation of odd zonal effects.[10, p.839] In fact, the near circular orbits (of which there are 7 here with $e < .01$) provide only 2 significant independent oscillations due to odd zonals (in e or I and N) since ω and M are not well determined. The result is that the separation of the odd zonals is quite poor in this solution with 8 correlation coefficients above 0.70, but none above 0.92. Nevertheless, this conditioning for odd zonals is still better than in Kozai's 1969 solution (where many correlations above 0.95 existed) because of the greater number of satellites employed and the use of all element data were given.

RESULTS

The most satisfactory least squares solution for 20 zonal coefficients from the data in Table 2, is shown in Table 3 (as WAG 72). The accompanying radiation (C_R) and drag (C_D) parameters determined for the 21 satellites by the same data is shown in Table 1. Except for the radiation pressure coefficient of EGRS-3, all the "extended state" parameters appear to be well determined. They are not significantly far from the theoretical average values of 1.5 for C_R (in diffuse reflection from a sphere) and 2.3 for CD (in free molecular flow about a sphere). The area to mass ratios (in Table 1) were calculated from King-Hele's spacecraft/orbit data.[27] Considering all the uncertainties in the effective spacecraft geometry and surface characteristics and the model atmosphere, it is remarkable that the program determined such realistic coefficients.

Also listed in Table 3 are the formal standard deviations of the ROAD solution and the results of 4 other perturbations of the principal solution to test its sensitivity to various error sources. The first, a truncation test, lists the changes in the coefficients (absolute values) when only J_2 through J_{19} are solved for. The "truncation error" for J_{20} and J_{21} are estimated on the basis of the worst changes in the lower degree set. The second test fixes the starting elements E, I, ω and N at values determined from the preliminary orbits used for data editing. Changes in the solution (absolute values) with this restriction gage the likely bias in the final result due to these initial elements adjusting to absorb some of the geopotential effects. The third perturbation reduced the weight of the mean anomaly data in the solution by 1/2. Even though the average quality for M was only 0.3° in the 21 arcs, decreasing it to 0.6° had a significant effect on the solution. This data is vital to the determination of the semimajor axis, whose uncertainty is a significant contributor to the zonal error in the semi-analytic solutions.[22, p. 116]

In future ROAD evaluations, the mean anomaly data will be weighted as strongly as allowed by other unmodeled effects (i.e. drag, and non-zonal resonance). In so doing, 'a' will be determined more strongly and the secular and long period zonal effects in M will be better observed leading to a better conditioned solution.

A final solution perturbation was made to test the influence of neglected short period ($\sim$14 day) lunar terms and integrator error. The basic solution did not include these lunar terms because most of the original orbit data were already mean elements determined over weekly arcs. These elements could be expected to have either removed these terms (analytically, as in the 9 SAO satellite arcs) or largely smoothed over them (as in all the GSFC arcs except PEOLE and GEOS 2).

The numerical integrator, a fixed step 8th order predictor-corrector process, employed a one day step size in the basic solution. The final perturbed solution had a 1/2 day step size and, as seen in Table 3, showed mostly insignificant changes. The root sum of squares of the formal standard deviation (s.d.) and the changes in the 4 perturbed solutions, as shown in Table 3, is to be regarded as a more realistic estimate of the 1σ values of the zonal coefficients. The zonal solution itself is presented dynamically in Figure 2 by the secular rates ($\dot{\omega} + \dot{N}$) and eccentricity oscillations induced on a 14 revolutions/day satellite with $e = 0.1$. The secular rates were calculated from the Lagrange planetary equations (with $\omega = 0.$, $N = 0.$, $M = 0.$) considering only even zonal effects (including those of J_2^2) to order e^5. The eccentricity amplitude was calculated as $\dot{e}/\dot{\omega}$ from the Lagrange equations including only odd zonal terms except those in J_2 and J_2^2. These perturbations are very close to those calculated by Kozai in his 1966 review paper.[10] (In fact the orbit characteristics were chosen to match Kozai's and facilitate comparison with his results).

Two other recent zonal fields to J_{21} were compared with this new one, from diverse sources. The first, called FR 71, was the French solution.[9] It combined Kozai's normals from his 12 satellite 1969 solution[8] with condition equations for secular rates and amplitudes of long period oscillations due to zonal effects on the 3 low inclination orbits of SAS 1, DIAL and PEOLE. Another 1971 solution, from SAO,[28] is also listed in Table 3 to show the divergence between two determinations from essentially the same orbits and (analytic) method. SAO 71 also starts with Kozai's 1969 normals but adds condition equations on only SAS 1 and PEOLE. In spite of the near identity of the data and processing, these two results differ by 0.016×10^{-6} rms over the fully normalized values of the 20 zonal coefficients. (The normalized coefficients, of greater physical significance,[22, p. 7] are obtained from the unnormalized ones on dividing by $(2\ell + 1)^{1/2}$.) The French solution seems to be somewhat superior to the SAO. It has fewer consecutive changes of sign in the ill conditioned odd zonal set and compares more favorably with GEM 2, another recent zonal field (listed in Table 3) determined by a wholly distinct method. GEM 2 was derived simultaneously with all the non-zonal geopotential terms through (16,16) by a combination of normals found from 1; directly fitting numerically integrated orbits to precision optical data, with 2; surface gravity information.[12] GEM 2 contains no low inclination orbit information but is a well conditioned solution (compared to the other strictly satellite results) having a highest correlation coefficient of only 0.48. Nevertheless, the new ROAD solution appears to be closest to FR 71, both in the rms normalized coefficient difference (0.012×10^{-6}) and in tests of individual arcs on 27 satellites (Table 4).

These arcs include the 21 used in the ROAD solution. Overall weighted rms residuals are listed with all 6 Kepler elements fitted as data weighted by the quality shown in preliminary "screening" orbits. All arc lengths were over 75 days. Full orbit determinations were performed on this data with these fields, including a solution for drag and radiation pressure coefficients. For the WAG 72 field, the average rms 'residual' in the 21 solution arcs is significantly lower than with orbits using the comparison fields, but is still considerably greater than 1.0. There remain some significant secular and long periodic residuals in the new solution which require better modeling from the geopotential (more zonal and resonance terms) the effects of atmospheric drag, and luni-solar gravity (both direct and indirect or tidal terms).

It was a great surprise that GEM 2 did so well with this data. It was a solution tailored to short period satellite terms and short wavelength surface gravity effects ($5° \times 5°$ anomalies). Yet Table 4 shows it did almost as well with these long arcs of satellite data as FR-71 which is a long arc solution exclusively. After-the-fact, one might say the great bulk of diverse data in GEM 2 produced a credible representation even for very sensitive long term satellite dynamics. Yet the result is still surprising and gratifying. In fact, for the PEOLE arc, GEM 2 was significantly superior to FR 71 even though it did not have the benefit of low inclination satellite data. The only surprise in the 6 arcs not used in the present solution, was the remarkable faithfulness of WAG 72 in recovering the DIAL data compared to FR-71 which (again) employed data from this low inclination satellite.

On the other hand the results of the other "new" arcs show little discrimination between these 3 recent solutions. This is further emphasized in Figures 3 and 4 which show differences (between the recent solutions and WAG 72) of secular rates and long period oscillations, calculated for a "typical" geodetic satellite and for the actual (observed) data on the six "new" satellites. The measured differences are 'residual' rates and amplitudes from those calculated by WAG 72 minus those actually observed on the satellites, as seen in the orbit fits (using WAG 72) with the data from these satellites. Some of the observed secular rates are not well predicted by any field while most of the odd zonal oscillations were too poorly determined to be of much help in discriminating between them. More well determined satellite orbits of low altitude (a < 1.1 e.r.) will have to be tested and used to further improve the zonal geopotential. But it does appear that the present field is a significantly improved low inclination solution over any of the other recent fields.

Finally, in Figure 5 is the geometric representation of the "new" field as a zonal geoid height profile with respect to an ellipsoid of flattening of 1/298.255. Differences of this profile with FR-71 and GEM 2 again show that the "new" field is "closest" to FR-71 (rms difference ~0.3m).

CONCLUSIONS

A new "fixed" zonal harmonic field (to J_{21}) has been calculated with especially superior characteristics for predicting the evolution of low inclination satellite orbits. Overall, the recent zonal solutions appear to be capable of reproducing the secular rates of "new" orbits to better than 7×10^{-4} degrees/day and the oscillations of eccentricity to better than 0.7×10^{-4}. The absolute accuracy of individual coefficients (fully normalized) varies from less than 2×10^{-8} for $\ell \lesssim 10$ to less than 4×10^{-8} for $\ell \lesssim 21$. However it is clear from an examination of the various solutions and errors in Table 3, that for $\ell \gtrsim 15$, the coefficients are not yet determined to be significantly different from zero.

It should be noted that the earth induced luni-solar tides (time varying) are not taken into account in this assessment. They will reduce the earth fixed or constant part of J_2 by about 1×10^{-8} and have lesser effect on the other even zonals.[29]

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TABLE 1
SATELLITES USED IN RECENT ZONAL SOLUTIONS

SATELLITE	ZONAL SOLUTIONS			SATELLITE/ORBIT CHARACTERISTICS						
	GEM 2	WAG 72	FR 71	I°	h_p (Km)	h_a (Km)	e	A/M (cm^2/gm)	C_D (2.3)	C_R (1.5)
SAS-1		X	X	3.0	530	560	0.002	0.11	2.2	1.4
DIAL (1970-17A)			X	5.4	310	1600	0.09			
PEOLE (1970-109A)		X	X	15.0	530	760	0.02	0.20	1.7	1.4
COURRIER 1B (1960-7A)	X		X	28.3						
EXPLORER II (1961-7A)		X		28.8	490	1800	0.086	0.10	1.6	1.1
PEGASUS 3 (1965-60A)		X		28.9	510	550	0.002	0.11	2.2	1.2
OSO 3 (1967-20A)		X		32.9	910	950	0.002	0.05	1.6	2.0
VANGUARD 2 (1959-1A)	X	X	X	32.9	550	3280	0.165	0.21	1.2	1.1
VANGUARD 3 (1959-5A)	X			33.4						
OVI-2	X			35.7(144.3)						
DI-D	X			39.5						
DI-C	X			40.0						
BE-C (EX.27) (1965-32A)	X	X		41.2	940	1320	0.025	0.17	2.4	1.3
TELSTAR-I (1962-29A)	X	X	X	44.8	950	5630	0.242	0.08	2.7	1.3
ECHO-I ROCKET (1960-9B)	X	X	X	47.2	1500	1670	0.011	0.21	2.6	1.0
GRS (1963-26A)	X		X	49.7						
ANNA-IB (1962-60A)	X	X	X	50.1	1080	1200	0.008	0.06	2.3	1.9
TIROS 5 (1962-25A)		X		58.1	590	960	0.026	0.06	2.1	2.3
TIROS 7 (1963-24A)				58.2						
GEOS 1 (1965-89A)	X	X	X	59.4	1110	2380	0.072	0.07	2.7	1.4
TRANSIT 4A (1961-15A)	X	X	X	66.8	880	980	0.008	0.11	2.7	1.3
SECOR 5 (1965-63A)	X			69.2						
AGENA ROCKET (1964-1A)	X		X	69.9						
EGRS-3 (1965-16E)		X		70.1	900	940	0.003	0.10 ?	3.3	-0.2
GEOS 2 (1968-2A)	X	X		74.2(105.8)	1080	1580	0.032	0.04	3.1	1.3
FR-1 (1965-101A)		X		75.9	740	750	0.001	0.11	2.8	1.2
BE-B (1964-64A)	X	X	X	79.7	890	1080	0.013	0.18	2.8	1.4
ALOUETTE 2 (1965-98A)	X			79.8						
ESSA I (1966-8A)		X		82.1(97.9)	710	850	0.010	0.06	2.3	1.3
TIROS 9 (1965-4A)	X	X		83.6(96.4)	690	2560	0.117	0.05	1.4	0.3
MIDAS 4 (1961-28A)	X	X	X	84.2(95.8)	3500	3740	0.012	0.06	1.9	1.6
OGO-2 (1965-81A)	X		X	87.4						
ISIS-I (1969-9A)		X		88.4	580	3520	0.175	0.10	1.0	1.8
OSCAR 7	X			89.7						
5-BN2 (1965-48C)	X			90.0						
TOTALS	23	21	15							

TABLE 2
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

a. VANGUARD 2 (1959 1A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
36940.0000000	1.30324800	.1654216	32.8743	39.0783	129.0718	NOT GIVEN
36944.0000000	1.30323830	.1656869	32.8735	60.6971	115.0321	
36952.0000000	1.30323223	.1655966	32.8733	102.8379	86.9488	
36956.0000000	1.30322794	.1655179	32.8745	123.8612	72.9080	
36964.0000000	1.30321391	.1652279	32.8799	166.0078	44.8256	
36968.0000000	1.30320434	.1650665	32.8832	187.1085	30.7870	
36972.0000000	1.30320063	.1649624	32.8860	208.2193	16.7502	
36976.0000000	1.30318653	.1647219	32.8875	229.3835	2.7111	
36984.0000000	1.30317907	.1646568	32.8889	271.6745	334.6358	
36996.0000000	1.30316444	.1648306	32.8836	335.1257	292.5229	
37000.0000000	1.30315916	.1649775	32.8804	356.2562	278.4827	
37008.0000000	1.30314928	.1652937	32.8743	38.4488	250.3982	
37010.0000000	1.30314576	.1653540	32.8731	48.9805	243.3755	
37012.0000000	1.30314367	.1653984	32.8721	59.5085	236.3540	
37020.0000000	1.30313090	.1654261	32.8712	101.6052	208.2643	
37024.0000000	1.30312177	.1653434	32.8719	122.6590	194.2201	
37034.0000000	1.30308832	.1648775	32.8771	175.3733	159.1125	
37038.0000000	1.30307764	.1646929	32.8790	196.5034	145.0701	
37042.0000000	1.30306621	.1645444	32.8809	217.6494	131.0272	
37050.0000000	1.30304501	.1644071	32.8833	259.9741	102.9424	
37052.0000000	1.30303886	.1643762	32.8839	270.5570	95.9214	
37058.0000000	1.30302439	.1644099	32.8847	302.3006	74.8586	
37062.0000000	1.30301564	.1644738	32.8839	323.4564	60.8172	
37070.0000000	1.30298964	.1647740	32.8815	5.7321	32.7323	
37082.0000000	1.30295843	.1651358	32.8751	68.9831	350.5971	
37086.0000000	1.30294838	.1651679	32.8744	90.0472	336.5493	
37092.0000000	1.30292667	.1650638	32.8759	121.6394	315.4803	
37096.0000000	1.30291118	.1649344	32.8772	142.7175	301.4298	
37104.0000000	1.30288402	.1645936	32.8804	184.9424	273.3353	
37108.0000000	1.30287374	.1644507	32.8819	206.0878	259.2893	
37116.0000000	1.30285316	.1642745	32.8830	248.4131	231.1956	
37120.0000000	1.30284129	.1642489	32.8823	269.5846	217.1467	
37130.0000000	1.30281389	.1643758	32.8800	322.5195	182.0213	
37136.0000000	1.30279687	.1645767	32.8781	354.2483	160.9452	
37140.0000000	1.30278460	.1647427	32.8763	15.3768	146.8944	
37144.0000000	1.30277423	.1649161	32.8746	36.4852	132.8418	
37148.0000000	1.30276332	.1650577	32.8731	57.5745	118.7884	
37156.0000000	1.30274617	.1651498	32.8727	99.7330	90.6782	
37160.0000000	1.30273508	.1650891	32.8744	120.7424	76.6209	
37168.0000000	1.30268088	.1647851	32.8797	162.9720	48.5091	
OBSERVATION WEIGHTS USED	.000005,	.00002,	.0003,	.005,	.005,	

b. TRANSIT 4A (1961 15A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
37522.0000000	1.14701309	.0077764	66.8174	265.2240	353.0665	NOT GIVEN
37534.0000000	1.14701248	.0077596	66.8178	256.2892	323.9729	
37556.0000000	1.14701073	.0078163	66.8138	240.7523	270.6265	
37572.0000000	1.14700966	.0078380	66.8151	229.2915	231.8275	
37602.0000000	1.14700753	.0078977	66.8136	207.8188	159.0878	
37610.0000000	1.14700721	.0079206	65.8132	202.1632	139.6895	
37616.0000000	1.14700678	.0079468	66.8123	198.0562	125.1403	
37622.0000000	1.14700653	.0079527	66.8138	193.7621	110.5907	
37628.0000000	1.14700634	.0079714	66.8152	189.6034	96.0424	
37634.0000000	1.14700596	.0080055	56.8152	185.5604	81.4956	
37640.0000000	1.14700548	.0079935	66.8175	181.2182	66.9464	
37646.0000000	1.14700510	.0080148	66.8169	177.1080	52.3992	
37652.0000000	1.14700505	.0080336	66.8166	173.0348	37.8512	
37658.0000000	1.14700495	.0080489	66.8161	168.8916	23.3027	
37664.0000000	1.14700473	.0080626	66.8159	164.7431	8.7539	
37670.0000000	1.14700445	.0080799	66.8160	160.5833	354.2045	
37678.0000000	1.14700407	.0080914	66.8162	155.1056	334.8063	
37684.0000000	1.14700377	.0081340	66.8170	150.8570	320.2590	
37712.0000000	1.14700257	.0081961	66.8135	131.7270	252.3690	
37724.0000000	1.14700196	.0082162	66.8135	123.5636	223.2710	
37732.0000000	1.14700143	.0082192	66.8156	118.1847	203.8743	
37762.0000000	1.14700009	.0082264	66.8133	97.9055	131.1358	
37772.0000000	1.14699970	.0082307	66.8132	91.1492	106.8870	
37782.0000000	1.14699890	.0082306	66.8148	84.4060	82.6391	
37806.0000000	1.14699682	.0082242	66.8171	68.2619	24.4493	
37814.0000000	1.14699656	.0082247	66.8162	62.8691	5.0519	
37820.0000000	1.14699646	.0082145	66.8158	58.8384	350.5026	
37826.0000000	1.14699629	.0082019	66.8158	54.7912	335.9538	
37828.0000000	1.14699624	.0081995	66.8158	53.4345	331.1042	
37834.0000000	1.14699598	.0081810	66.8148	49.3357	316.5548	
37840.0000000	1.14699567	.0081661	66.8168	45.2375	302.0077	
37846.0000000	1.14699546	.0081511	66.8165	41.0474	287.4596	
37858.0000000	1.14699663	.0081084	66.8154	32.9990	258.3643	
37866.0000000	1.14699518	.0080913	66.8134	27.4120	238.9658	
37878.0000000	1.14699480	.0080569	66.8129	19.2046	209.8674	
37904.0000000	1.14699355	.0079763	66.8152	1.2757	146.8254	
37916.0000000	1.14699311	.0079367	66.8149	-7.0435	117.7275	
37930.0000000	1.14699279	.0078913	66.8142	343.2061	83.7772	
37942.0000000	1.14699211	.0078562	66.8155	334.7115	54.6777	
37964.0000000	1.14699048	.0078064	56.8175	318.9014	1.3340	
37972.0000000	1.14699005	.0077934	66.8168	313.3305	341.9352	
37984.0000000	1.14698963	.0077736	66.8151	304.7958	312.8344	
37996.0000000	1.14698874	.0077560	66.8160	296.2551	283.7340	
38016.0000000	1.14698788	.0077503	66.8148	282.1525	235.2377	
38034.0000000	1.14698735	.0077023	66.8130	269.0333	191.5895	
38058.0000000	1.14698481	.0077151	66.8168	-108.194	133.3897	
38062.0000000	1.14698611	.0077526	66.8149	248.9232	123.6938	
OBSERVATION WEIGHTS USED	.000002,	.00001,	.0003,	.01,	.005,	

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

c. MIDAS 4 (1961 28A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (o)	W ARG. OF PER. (o)	N R.A. OF ASC. NODE (o)	M MEAN ANOMALY (o)
37734.0000000	1.56815655	.0113468	95.8661	251.1214	325.9815	NOT GIVEN
37742.0000000	1.56815667	.0113917	95.8649	242.7973	327.6668	
37750.0000000	1.56815678	.0114456	95.8628	234.4864	329.3513	
37754.0000000	1.56815666	.0114771	95.8618	230.3486	330.1931	
37762.0000000	1.56815677	.0115527	95.8597	222.1051	331.8765	
37770.0000000	1.56815664	.0116340	95.8580	213.9244	333.5590	
37778.0000000	1.56815664	.0117322	95.8558	205.8484	335.2411	
37786.0000000	1.56815651	.0118279	95.8542	197.7642	336.9223	
37792.0000000	1.56815662	.0119094	95.8531	191.8021	338.1825	
37798.0000000	1.56815650	.0119921	95.8523	185.8539	339.4430	
37806.0000000	1.56815649	.0120996	95.8508	178.0212	341.1227	
37814.0000000	1.56815649	.0122071	95.8502	170.2602	342.8021	
37822.0000000	1.56815649	.0123268	95.8501	162.5641	344.4812	
37830.0000000	1.56815637	.0124168	95.8505	154.9231	346.1603	
37834.0000000	1.56815637	.0124706	95.8501	151.1468	346.9999	
37842.0000000	1.56815637	.0125619	95.8509	143.6037	348.6793	
37850.0000000	1.56815637	.0126426	95.8521	136.1226	350.3585	
37858.0000000	1.56815637	.0127149	95.8532	128.6918	352.0387	
37866.0000000	1.56815638	.0127661	95.8547	121.2865	353.7187	
37872.0000000	1.56815626	.0128120	95.8557	115.7328	354.9794	
37878.0000000	1.56815627	.0128302	95.8570	110.2256	356.2402	
37886.0000000	1.56815639	.0128597	95.8590	102.8756	357.9222	
37894.0000000	1.56815640	.0128636	95.8606	95.5107	359.6043	
37902.0000000	1.56815640	.0128560	95.8620	88.1895	1.2871	
37910.0000000	1.56815653	.0128471	95.8634	80.8331	2.9708	
37914.0000000	1.56815653	.0128315	95.8640	77.1435	3.8126	
37922.0000000	1.56815665	.0127985	95.8651	69.7757	5.4966	
37930.0000000	1.56815678	.0127517	95.8654	62.3812	7.1809	
37938.0000000	1.56815678	.0126861	95.8660	54.9342	8.8656	
37946.0000000	1.56815678	.0126359	95.8655	47.4941	10.5499	
37952.0000000	1.56815678	.0125800	95.8654	41.8877	11.8131	
37958.0000000	1.56815678	.0125076	95.8649	36.2580	13.0764	
37966.0000000	1.56815689	.0124320	95.8630	28.7525	14.7610	
37974.0000000	1.56815701	.0123170	95.8624	21.0986	16.4436	
37982.0000000	1.56815689	.0122356	95.8610	13.2280	18.1262	
37990.0000000	1.56815688	.0121059	95.8596	5.6521	19.8085	
37998.0000000	1.56815700	.0120020	95.8570	-2.1436	21.4905	
38006.0000000	1.56815687	.0118967	95.8555	-10.0945	23.1713	
38014.0000000	1.56815699	.0117927	95.8539	-18.0576	24.8514	
38022.0000000	1.56815687	.0116950	95.8527	-26.0693	26.5317	
38030.0000000	1.56815662	.0116053	95.8511	-34.1686	28.2109	
38034.0000000	1.56815662	.0115618	95.8512	-38.2416	29.0508	
38042.0000000	1.56815674	.0114833	95.8505	-46.4282	30.7296	
38050.0000000	1.56815662	.0114156	95.8503	-54.6669	32.4090	
38058.0000000	1.56815650	.0113553	95.8506	-62.9803	34.0878	
38070.0000000	1.56815663	.0113113	95.8519	-75.5318	36.6075	
38074.0000000	1.56815675	.0112883	95.8524	280.3529	37.4477	
38082.0000000	1.56815748	.0112647	95.8538	271.9866	39.1285	
38090.0000000	1.56815760	.0112680	95.8558	263.6117	40.8096	
38098.0000000	1.56815773	.0112899	95.8572	255.2397	42.4919	
38106.0000000	1.56815750	.0113255	95.8598	246.8924	44.1746	
OBSERVATION WEIGHTS USED	.000002,	.00001,	.0003,	.01,	.005,	

d. BE-B (1964 64A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (o)	W ARG. OF PER. (o)	N R.A. OF ASC. NODE (o)	M MEAN ANOMALY (o)
38682.0000000	1.15372938	.0136978	79.6931	132.6306	127.2850	NOT GIVEN
38698.0000000	1.15373475	.0140109	79.6929	94.9772	110.0293	
38702.0000000	1.15373687	.0140074	79.6934	85.6079	105.7157	
38706.0000000	1.15373491	.0139759	79.6942	76.2333	101.4022	
38710.0000000	1.15373530	.0139132	79.6943	66.8259	97.0894	
38760.0000000	1.15375048	.0119974	79.6978	-59.5825	43.1782	
38764.0000000	1.15373369	.0119300	79.6963	-70.5569	38.8654	
38768.0000000	1.15373542	.0118957	79.6964	-81.5546	34.5514	
38772.0000000	1.15373274	.0118893	79.6965	267.4038	30.2373	
38776.0000000	1.15373537	.0119152	79.6964	256.3691	25.9229	
39780.0000000	1.15373335	.0119736	79.6961	245.3878	21.6087	
38844.0000000	1.15372672	.0140139	79.6951	85.3813	312.6063	
38852.0000000	1.15372785	.0139398	79.6947	66.5871	303.9787	
38856.0000000	1.15372757	.0138518	79.6942	57.1418	299.6644	
38860.0000000	1.15373222	.0137376	79.6948	47.7372	295.3506	
38864.0000000	1.15373218	.0136031	79.6931	37.9936	291.0348	
38868.0000000	1.15373100	.0134386	79.6932	28.3244	286.7207	
38876.0000000	1.15372859	.0130752	79.6941	8.5505	278.0921	
38884.0000000	1.15373174	.0127172	79.6932	-11.8685	269.4625	
38890.0000000	1.15373030	.0124606	79.6920	332.5345	262.9905	
38892.0000000	1.15372636	.0123171	79.6948	327.3322	260.8354	
38896.0000000	1.15372512	.0121297	79.6956	316.6028	256.5224	
38904.0000000	1.15372413	.0119150	79.6946	294.6735	247.8954	
38908.0000000	1.15371890	.0118380	79.6966	283.5257	243.5845	
38912.0000000	1.15372130	.0118565	79.6976	272.5319	239.2728	
38920.0000000	1.15371811	.0119066	79.6982	-109.303	230.6489	
38924.0000000	1.15371284	.0120222	79.6984	-120.266	226.3370	
38928.0000000	1.15372260	.0121593	79.6962	228.8040	222.0228	
38932.0000000	1.15372360	.0123113	79.6963	218.2223	217.7100	
38940.0000000	1.15372333	.0126435	79.6947	196.9513	209.0840	
38948.0000000	1.15372589	.0130286	79.6958	176.5972	200.4572	
38952.0000000	1.15372837	.0132124	79.6941	166.5145	196.1444	
38956.0000000	1.15372551	.0133993	79.6944	156.5657	191.8315	
38960.0000000	1.15372315	.0135666	79.6944	146.8226	187.5184	
38964.0000000	1.15372085	.0137145	79.6949	137.1629	183.2060	
38968.0000000	1.15372033	.0138258	79.6964	127.7854	178.8928	
39020.0000000	1.15371577	.0130461	79.6942	3.2913	122.8323	
39028.0000000	1.15372216	.0126965	79.6935	-16.9808	114.2039	
39032.0000000	1.15371909	.0125123	79.6936	-27.3983	109.8893	
OBSERVATION WEIGHTS USED	.000001,	.00001,	.0003,	.015,	.005	

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

e. GEOS 1 (1965 89A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (o)	W ARG. OF PER. (o)	N R.A. OF ASC. NODE (o)	M MEAN ANOMALY (o)
39074.0000000	1.26571981	.0722646	59.3800	151.8106	91.9806	NOT GIVEN
39078.0000000	1.26571809	.0722098	59.3816	154.4025	82.9936	
39082.0000000	1.26571898	.0721556	59.3828	156.9981	74.0067	
39086.0000000	1.26571805	.0720945	59.3839	159.5959	65.0205	
39098.0000000	1.26571930	.0719148	59.3851	167.3961	38.0631	
39106.0000000	1.26571937	.0717894	59.3850	172.6076	20.0904	
39110.0000000	1.26571952	.0717321	59.3847	175.2150	11.1044	
39118.0000000	1.26571973	.0716165	59.3846	180.4316	353.1313	
39130.0000000	1.26571986	.0714566	59.3854	188.2698	326.1736	
39134.0000000	1.26571669	.0714066	59.3855	190.8674	317.1877	
39142.0000000	1.26572093	.0712980	59.3848	196.1308	299.2175	
39150.0000000	1.26572103	.0711963	59.3838	201.3793	281.2469	
39152.0000000	1.26572111	.0711698	59.3833	202.6931	276.7553	
39158.0000000	1.26572183	.0710990	59.3822	206.6433	263.2769	
39162.0000000	1.26572008	.0710564	59.3818	209.2849	254.2907	
39174.0000000	1.26572137	.0709163	59.3806	217.1910	227.3334	
39186.0000000	1.26572077	.0708030	59.3829	225.1153	200.3770	
39190.0000000	1.26572075	.0707620	59.3841	227.7576	191.3930	
39194.0000000	1.26572081	.0707340	59.3845	230.4068	182.4089	
39206.0000000	1.26571976	.0706577	59.3844	238.3665	155.4554	
39214.0000000	1.26571977	.0706151	59.3835	243.6821	137.4854	
39218.0000000	1.26571992	.0706008	59.3832	246.3448	128.5003	
39230.0000000	1.26571922	.0705477	59.3832	254.3202	101.5429	
39232.0000000	1.26571950	.0705387	59.3833	255.6510	97.0504	
39238.0000000	1.26571933	.0705197	59.3848	259.6446	83.5719	
39240.0000000	1.26571938	.0705140	59.3856	260.9753	79.0795	
39248.0000000	1.26572110	.0704997	59.3874	266.2828	61.1103	
39260.0000000	1.26572179	.0705210	59.3891	274.2509	34.1589	
39272.0000000	1.26572022	.0705219	59.3882	282.2328	7.2064	
39316.0000000	1.26572039	.0708124	59.3845	311.4601	268.3744	
39326.0000000	1.26572022	.0709131	59.3821	318.0864	245.9114	
39338.0000000	1.26572038	.0710455	59.3810	326.0165	218.9539	
39342.0000000	1.26572066	.0710908	59.3810	328.6568	209.9677	
39350.0000000	1.26572036	.0711870	59.3818	333.9374	191.9962	
39358.0000000	1.26572050	.0717848	59.3812	5.4222	84.1643	
39550.0000000	1.26571839	.0729033	59.3795	103.3929	102.6454	
39552.0000000	1.26571819	.0729008	59.3788	104.6818	98.1514	
39554.0000000	1.26571841	.0728944	59.3787	105.9647	93.6569	
39566.0000000	1.26571811	.0728466	59.3795	113.6725	66.6905	
39574.0000000	1.26571871	.0728011	59.3814	118.8221	48.7136	
OBSERVATION WEIGHTS USED	.000001	.00001	.0003	.015	.005	

f. ECHO 1 ROCKET BODY (1960 9B)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (o)	W ARG. OF PER. (o)	N R.A. OF ASC. NODE (o)	M MEAN ANOMALY (o)
37190.0000000	1.25005248	.0120775	47.2314	101.6638	158.6256	NOT GIVEN
37194.0000000	1.25005043	.0120361	47.2316	112.9477	146.2208	
37198.0000000	1.25004573	.0119730	47.2312	124.2608	133.8160	
37202.0000000	1.25004580	.0118939	47.2308	135.6893	121.4109	
37210.0000000	1.25004839	.0116686	47.2312	158.7888	96.5995	
37214.0000000	1.25005066	.0115282	47.2306	170.4685	84.1933	
37218.0000000	1.25004549	.0113992	47.2325	182.4004	71.7889	
37222.0000000	1.25004793	.0112698	47.2332	194.4500	59.3844	
37230.0000000	1.25005035	.0110305	47.2351	218.9435	34.5764	
37232.0000000	1.25004932	.0109817	47.2353	225.1375	28.3747	
37236.0000000	1.25005014	.0109953	47.2353	237.6077	15.9710	
37240.0000000	1.25004946	.0108445	47.2352	250.2085	3.5671	
37248.0000000	1.25004750	.0108145	47.2342	275.4780	338.7590	
37252.0000000	1.25004792	.0108455	47.2339	288.1293	326.3543	
37256.0000000	1.25004807	.0109030	47.2333	300.7326	313.9493	
37260.0000000	1.25004622	.0109835	47.2335	313.2369	301.5442	
37268.0000000	1.25004855	.0112089	47.2331	337.9078	276.7346	
37270.0000000	1.25004958	.0112763	47.2328	344.0463	270.5320	
37274.0000000	1.25004528	.0114116	47.2326	356.0961	258.1282	
37278.0000000	1.25004086	.0115484	47.2320	7.9912	245.7245	
37286.0000000	1.25004676	.0118133	47.2306	31.4356	220.9150	
37290.0000000	1.25004514	.0119241	47.2298	42.9769	208.5096	
37294.0000000	1.25004542	.0120147	47.2295	54.3984	196.1041	
37298.0000000	1.25004290	.0120816	47.2291	65.7458	183.6981	
37306.0000000	1.25004561	.0121387	47.2301	88.3203	158.8873	
37310.0000000	1.25004690	.0121209	47.2308	99.5874	146.4823	
37312.0000000	1.25004477	.0121089	47.2310	105.2179	140.2800	
37316.0000000	1.25004571	.0120496	47.2319	116.5174	127.8749	
37324.0000000	1.25005128	.0118561	47.2335	139.3618	103.0646	
37328.0000000	1.25004209	.0117513	47.2321	150.8636	90.6622	
37332.0000000	1.25004385	.0116146	47.2327	162.5196	78.2565	
37336.0000000	1.25004405	.0114806	47.2327	174.3234	65.8510	
37344.0000000	1.25004274	.0111936	47.2333	198.2916	41.0405	
37348.0000000	1.25004661	.0110660	47.2342	210.4934	28.6357	
37350.0000000	1.25004668	.0110102	47.2345	216.6526	22.4332	
37360.0000000	1.25005000	.0107914	47.2356	247.8056	351.4237	
37368.0000000	1.25004933	.0107338	47.2347	273.0493	326.6166	
OBSERVATION WEIGHTS USED	.000005	.000007	.0003	.03	.005	

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

g. PEOLE (1960 7A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (o)	W ARG. OF PER. (o)	N R.A. OF ASC. NODE (o)	M MEAN ANOMALY (o)
40962.0000000	1.09901590	.0166971	14.9999	224.0271	1.0922	238.3836
40963.7929629	1.09901699	.0164283	15.0000	248.4586	348.5954	77.8503
40965.9634722	1.09900281	.0163394	15.0042	278.0081	333.4639	130.0547
40973.7028125	1.09896221	.0167141	15.0020	20.7476	279.5469	356.9950
40977.0361458	1.09893448	.0168821	14.9958	64.5719	256.3332	131.8148
40980.0361458	1.09894211	.0168367	15.0013	103.4092	235.3943	290.3012
40981.0281944	1.09891144	.0167909	15.0035	116.2106	228.4787	180.8611
40986.0281944	1.09884947	.0164856	15.0047	182.1001	193.6169	205.2476
40989.0281944	1.09884987	.0162974	14.9972	222.0384	172.6819	4.1037
40996.1924653	1.09882286	.0163480	15.0075	318.0550	122.7432	51.6091
40998.0257986	1.09880358	.0164236	15.0105	342.7342	109.9517	109.0258
41003.4489236	1.09878489	.0167322	15.0091	54.1069	72.1350	233.5138
41007.2405902	1.09878175	.0167742	15.0045	103.4527	45.6894	297.5565
41014.2215393	1.09874694	.0163857	15.0055	195.0912	357.0032	92.8662
41021.0656134	1.09874155	.0161802	15.0031	286.8848	309.2834	237.0898
41026.8028703	1.0987167	.0165072	15.0041	3.3787	269.2657	238.9606
41031.0112037	1.0987263	.0166732	15.0016	58.7401	239.9130	6.9265
41033.2500000	1.0987135	.0166944	15.0048	88.0633	224.2887	69.3717
41038.1666667	1.0986963	.0165411	15.0048	152.0757	189.9884	17.2406
41041.1666667	1.0986741	.0163220	15.0044	191.8333	169.0600	180.3086
41041.1566667	1.0986743	.0163230	15.0044	191.8211	169.0600	180.3189
41043.5745833	1.0986543	.0162047	15.0064	223.6101	152.2648	65.2940
41043.5745833	1.0986534	.0161885	15.0074	223.6713	152.2538	65.2318
41055.2083333	1.0985997	.0164604	15.0059	19.3979	71.0969	206.1188
41060.0566897	1.0985558	.0166147	15.0038	82.9004	37.2672	153.2680
41061.0685648	1.0985496	.0166107	15.0030	95.9909	30.2002	152.1818
41067.0673379	1.0985176	.0163430	15.0052	174.6340	348.3351	118.6925
41070.0061458	1.0985232	.0161443	15.0057	213.8197	327.8240	318.4325
41076.4386921	1.0985111	.0161544	15.0076	300.1259	282.9453	78.5917
41080.0220254	1.0985174	.0162597	15.0079	348.2252	257.9377	117.3016
41083.2378356	1.0984879	.0164223	15.0061	30.4094	235.5003	356.2843
41087.2132986	1.0984790	.0165466	15.0049	84.5669	-153.032	328.8701
41093.0416667	1.0984802	.0163502	15.0046	158.8612	167.0357	109.0894
41098.2083333	1.0984727	.0160578	15.0033	227.5513	130.9670	317.7446
OBSERVATION WEIGHTS USED	.00002,	.0001,	.003,	.0.1,	.02,	2.0

h. SAS 1

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (o)	W ARG. OF PER. (o)	N R.A. OF ASC. NODE (o)	M MEAN ANOMALY (o)
40933.0000000	1.08653436	.0028360	3.0360	3.1770	13.4942	338.0019
40937.0000000	1.08649203	.0028349	3.0339	63.8047	343.4614	77.7509
40944.0000000	1.08644343	.0028720	3.0340	168.4112	290.8569	256.2430
40952.0000000	1.08640109	.0028600	3.0322	288.5852	230.7440	102.2238
40959.0000000	1.08636190	.0028564	3.0309	33.3951	178.1317	284.9113
40966.0000000	1.08632270	.0028537	3.0349	138.4469	125.4706	109.4365
40973.0000000	1.08627723	.0028249	3.0352	243.2846	72.8316	296.4908
40980.0000000	1.08623020	.0027880	3.0360	348.4734	20.2181	125.5025
40987.0000000	1.08617846	.0028107	3.0363	93.8913	327.5928	317.0869
40994.0000000	1.08614083	.0028012	3.0351	199.0172	274.9620	151.3297
41001.0000000	1.08610477	.0027945	3.0321	304.3760	222.2988	347.1563
41008.0000000	1.08606401	.0028112	3.0329	49.5058	169.5990	185.2282
41015.0000000	1.08602167	.0028027	3.0299	154.4737	116.8892	25.8051
41022.0000000	1.08598718	.0027962	3.0362	259.0023	64.1694	228.9003
41033.0000000	1.08592039	.0027819	3.0379	65.8179	341.4053	189.5549
41040.0000000	1.08588701	.0028042	3.0354	170.0338	288.7186	38.1979
41047.0000000	1.08585627	.0027464	3.0342	274.9108	236.0163	247.8399
41054.0000000	1.08582005	.0027432	3.0339	21.5906	183.2869	97.4935
41066.0000000	1.08574526	.0027843	3.0361	201.1790	92.9221	105.3418
41075.0000000	1.08571406	.0027273	3.0371	336.5532	25.1088	24.0770
41089.0000000	1.08563285	.0027845	3.0360	186.7193	279.6489	103.2718
41096.0000000	1.08561278	.0027071	3.0352	292.1688	226.9051	325.5511
41103.0000000	1.08559679	.0027227	3.0329	38.9393	174.1284	187.4293
41110.0000000	1.08557390	.0027719	3.0349	143.5375	121.3635	52.5590
41117.0000000	1.08555916	.0027320	3.0372	247.9956	68.6289	278.7635
41124.0000000	1.08554818	.0026925	3.0380	354.3658	15.8960	143.7912
41131.0000000	1.08552796	.0027440	3.0358	99.8251	323.1495	10.4794
41145.0000000	1.08548578	.0026805	3.0321	309.8218	217.6059	108.4433
41152.0000000	1.08546760	.0027103	3.0349	56.3774	164.7987	-23.62,0.0,
41159.0000000	1.08544847	.0027569	3.0349	160.9532	112.0241	209.2397
41173.0000000	1.08541554	.0026935	3.0360	12.2375	6.5079	313.5926
41180.0000000	1.08540269	.0027534	3.0349	117.5534	313.7336	187.3171
41187.0000000	1.08538340	.0027179	3.0341	221.6963	260.9347	63.0309
41194.0000000	1.08536161	.0026571	3.0341	327.9018	208.1245	297.7847
41201.0000000	1.08534436	.0027047	3.0348	74.2091	155.3358	173.4361
41208.0000000	1.08532712	.0027242	3.0350	178.6887	102.5479	51.8553
41229.0000000	1.08525186	.0027379	3.0339	135.3792	304.1448	51.1239
OBSERVATION WEIGHTS USED	.00001,	.00015,	.002,	1.5,	.02,	2.0

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

i. EXPLORER II (1961 7A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
37420.0000000	1.17876259	.0864540	28.7994	147.6130	236.5452	99.2340
37422.0000000	1.17874981	.0863140	28.8013	163.7600	226.5353	334.9584
37424.0000000	1.17875851	.0861920	28.8044	179.9680	216.5303	210.6576
37428.0000000	1.17875574	.0859700	28.8058	212.4390	196.5175	322.1280
37430.0000000	1.17875477	.0858700	28.8063	228.7040	186.5105	197.8848
37432.0000000	1.17875373	.0859120	28.8075	244.9890	176.5046	73.6416
37436.0000000	1.17875049	.0857850	28.8075	277.5640	156.4928	185.2236
37438.0000000	1.17874774	.0858120	28.8068	293.8510	146.4848	61.0524
37440.0000000	1.17874410	.0858600	28.8065	310.1300	136.4769	296.9172
37444.0000000	1.17873379	.0860490	28.8054	342.6430	116.4630	48.8124
37446.0000000	1.17872811	.0861700	28.8044	358.8660	106.4551	284.8752
37448.0000000	1.17872302	.0863180	28.8039	15.0670	96.4462	161.0028
37452.0000000	1.17871431	.0865610	28.8023	47.3950	76.4303	273.4452
37454.0000000	1.17871113	.0866110	28.7998	63.5080	66.4274	149.7672
37456.0000000	1.17870876	.0866730	28.7979	79.6390	56.4185	26.0928
37460.0000000	1.17870422	.0866360	28.7982	111.8820	36.3986	138.8520
37462.0000000	1.17870302	.0865570	28.7988	128.0240	26.3857	15.2546
37464.0000000	1.17870182	.0864700	28.7991	144.1740	16.3767	251.6688
37468.0000000	1.17869859	.0862410	28.8026	176.5250	356.3579	4.5612
37470.0000000	1.17869711	.0861690	28.8052	192.7450	346.3480	241.0236
37472.0000000	1.178695[illegible]	[illegible]	28.8067	-151.02	336.3390	117.5040
37474.0000000	1.17869365	[illegible]	28.8068	225.2400	326.3301	354.0096
37476.0000000	1.17869269	.0858030	28.8090	241.5030	316.3232	230.5368
37480.0000000	1.17869033	.0857700	28.8060	274.1020	296.3153	343.5804
37482.0000000	1.17868896	.0857900	28.8096	290.3760	286.3034	220.1537
37484.0000000	1.17868714	.0858570	28.8100	306.6480	276.2954	96.7356
37486.0000000	1.17868477	.0859220	28.8081	322.9200	266.2845	333.3384
37488.0000000	1.17868219	.0860230	28.8057	339.1830	256.2766	209.9592
37490.0000000	1.17867929	.0861480	28.8040	355.4080	246.2687	86.6304
37492.0000000	1.17867640	.0862800	28.8025	11.6270	236.2597	323.3304
37496.0000000	1.17866934	.0865100	28.7950	43.9310	216.2499	76.9032
37498.0000000	1.17866630	.0865940	28.7944	60.0820	206.2299	313.7472
37500.0000000	1.17866376	.0866600	28.7956	76.2370	196.2140	190.6092
37502.0000000	1.17866143	.0866340	28.7968	92.3510	186.2011	67.5360
37504.0000000	1.17866007	.0866400	28.7974	108.4450	176.1911	304.5024
37506.0000000	1.17865931	.0865600	28.7994	124.5810	166.1812	181.4364
37508.0000000	1.17865896	.0864830	28.8013	140.7260	156.1723	58.3884
37512.0000000	1.17865977	.0861890	28.8029	173.0920	136.1484	172.2708
37514.0000000	1.17866031	.0860470	28.8046	189.3210	126.1385	49.1832
37516.0000000	1.17866136	.0859460	28.8069	205.5570	116.1296	286.0963
OBSERVATION WEIGHTS USED	.000003,	.00001,	.0015,	0.1,	.004,	2.0

j. ANNA 18 (1962 60A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
37970.0000000	1.17727056	.0066710	50.1435	206.4700	48.5126	249.7680
37974.0000000	1.17728017	.0065580	50.1448	219.1900	34.0819	25.5600
37978.0000000	1.17728483	.0064100	50.1440	230.8000	19.6398	162.3600
37990.0000000	1.17729489	.0063000	50.1440	271.7000	336.3392	206.9640
37994.0000000	1.17729314	.0063000	50.1460	285.2000	321.9023	341.9640
37998.0000000	1.17728866	.0063800	50.1440	298.2000	307.4645	117.3960
38002.0000000	1.17728259	.0064300	50.1420	311.3000	293.0316	252.7560
38006.0000000	1.17727472	.0065800	50.1440	324.1000	278.5958	28.4760
38010.0000000	1.17726570	.0067100	50.1400	336.5000	264.1579	164.5560
38014.0000000	1.17725542	.0068580	50.1393	349.3000	249.7270	300.1680
38018.0000000	1.17724468	.0070360	50.1411	1.2000	235.2887	76.7160
38022.0000000	1.17723339	.0071900	50.1410	13.1000	220.8543	213.2640
38026.0000000	1.17722261	.0073300	50.1420	24.9000	206.4245	349.8840
38030.0000000	1.17723844	.0075300	50.1390	35.5000	191.9796	127.8360
38034.0000000	1.17723770	.0076200	50.1380	46.7200	177.5437	265.0680
38038.0000000	1.17723724	.0076600	50.1400	57.5000	163.1039	42.7680
38042.0000000	1.17723701	.0077900	50.1400	68.5000	148.6670	180.2520
38046.0000000	1.17723689	.0077600	50.1400	79.1000	134.2302	318.0600
38050.0000000	1.17723692	.0078400	50.1410	90.2000	119.7953	95.4360
38054.0000000	1.17723688	.0078200	50.1430	100.4900	105.3624	233.6040
38058.0000000	1.17723758	.0078300	50.1380	111.7000	90.9256	10.8000
38062.0000000	1.17723761	.0077000	50.1420	122.1000	76.4917	148.8600
38066.0000000	1.17723801	.0075700	50.1500	133.0000	62.0479	286.4880
38070.0000000	1.17723840	.0075400	50.1460	144.3000	47.6200	63.5760
38074.0000000	1.17723913	.0072600	50.1320	154.4000	33.1801	202.2840
38078.0000000	1.17723990	.0072200	50.1420	166.4000	18.7483	338.4000
38082.0000000	1.17724065	.0070500	50.1450	178.6000	4.3114	114.6600
38086.0000000	1.17724142	.0068700	50.1450	190.5000	349.8776	251.2800
38090.0000000	1.17724244	.0067300	50.1440	202.6000	335.4427	27.6120
38094.0000000	1.17724287	.0065400	50.1430	214.7000	321.0068	163.9440
OBSERVATION WEIGHTS USED	.00002,	.00002,	.001,	0.5,	.004,	0.8

TABLE 2 (continued)

SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

k. TELSTAR 1 (1962 29A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
37858.0000000	1.51670687	.2421300	44.7910	170.0500	198.8776	5.9652
37862.0000000	1.51670615	.2420830	44.7907	177.9930	191.4636	187.4916
37866.0000000	1.51670675	.2419990	44.7936	185.9560	184.0308	9.1076
37870.0000000	1.51670713	.2419400	44.7970	193.9070	176.5920	190.7280
37874.0000000	1.51670727	.2418100	44.7940	201.8410	169.1641	12.3444
37878.0000000	1.51670695	.2418800	44.8000	209.8200	161.7253	193.9356
37882.0000000	1.51670742	.2418420	44.8044	217.7610	154.2994	15.5480
37886.0000000	1.51670821	.2418180	44.8033	225.7190	146.8636	197.1522
37890.0000000	1.51670917	.2417450	44.8050	233.6420	139.4309	18.7733
37894.0000000	1.51670876	.2417330	44.8091	241.6140	132.0046	200.3328
37898.0000000	1.51670806	.2418230	44.8054	249.5932	124.5678	21.9154
37902.0000000	1.51670912	.2418410	44.8024	257.5505	117.1227	203.5037
37906.0000000	1.51670942	.2418440	44.8159	265.5036	109.6930	25.0808
37910.0000000	1.51670930	.2418240	44.8041	273.4693	102.2638	206.6454
37914.0000000	1.51670956	.2418520	44.8022	281.4230	94.8285	28.2319
37918.0000000	1.51670984	.2418710	44.8052	289.3800	87.3946	209.8037
37922.0000000	1.51670979	.2419200	44.8026	297.3450	79.9548	31.3736
37926.0000000	1.51671019	.2419450	44.8048	305.3108	72.5196	212.9386
37930.0000000	1.51670969	.2419970	44.8085	313.2538	65.0879	34.5161
37934.0000000	1.51671045	.2420430	44.8036	321.2050	57.6505	216.0824
37938.0000000	1.51670884	.2421430	44.8076	329.1684	50.2185	37.6394
37942.0000000	1.51670855	.2421020	44.8049	337.1410	42.7799	219.2051
37946.0000000	1.51670900	.2422020	44.8056	345.0730	35.3494	40.7912
37950.0000000	1.51670963	.2422620	44.8078	353.0370	27.9148	222.3392
37954.0000000	1.51670866	.2423510	44.8068	0.9900	20.4765	43.9002
37958.0000000	1.51670748	.2423780	44.8052	8.9210	13.0438	225.4932
37962.0000000	1.51670794	.2424700	44.8050	16.8760	5.6012	47.0700
37966.0000000	1.51670767	.2425500	44.8080	24.8290	358.1643	228.6468
37970.0000000	1.51670742	.2425980	44.8040	32.7660	350.7295	50.2308
37974.0000000	1.51670689	.2426400	44.8030	40.7000	343.2976	231.8220
37978.0000000	1.51670618	.2426900	44.8000	48.6400	335.8588	53.4168
37982.0000000	1.51670587	.2427700	44.7990	56.5800	328.4219	235.0152
37986.0000000	1.51670569	.2427700	44.7970	64.5000	320.9871	56.6316
37990.0000000	1.51670586	.2428200	44.7940	72.4210	313.5492	238.2444
37994.0000000	1.51670575	.2428690	44.7886	80.3600	306.1089	59.8554
37998.0000000	1.51670422	.2428140	44.7871	88.2797	298.6671	241.4862
38002.0000000	1.51670444	.2427900	44.7870	96.1960	291.2296	63.1256
38006.0000000	1.51670464	.2427800	44.7880	104.1100	283.7988	244.7604
38010.0000000	1.51670400	.2426700	44.7920	112.0700	276.3589	66.3624
38014.0000000	1.51670185	.2426200	44.7880	119.9600	268.9270	248.0292
38018.0000000	1.51670295	.2425800	44.7880	127.9100	261.4892	69.6780
38022.0000000	1.51670369	.2424900	44.7890	135.8700	254.0563	251.2944
38026.0000000	1.51670261	.2423600	44.7930	143.7980	246.6165	72.9288
38030.0000000	1.51670252	.2422700	44.7910	151.7200	239.1856	254.5956
38034.0000000	1.51670319	.2422000	44.7900	159.6600	231.7497	76.2552
38038.0000000	1.51670384	.2421000	44.7900	167.6300	224.3119	257.8860
38042.0000000	1.51670384	.2420800	44.7900	175.4800	216.8890	79.5780
OBSERVATION WEIGHTS USED	.000001,	.00002,	.0005,	0.1,	.02,	.05

l. GEOS 2 (1968 2A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
39930.0	01.208062	0.03277066	105.786827	066.461731	132.215678	115.03066
39937.0	01.208064	0.03268428	105.785499	055.365595	142.011925	047.32169
39944.0	01.208063	0.03257593	105.783609	044.235420	151.805765	339.64198
39958.0	01.208062	0.03228745	105.781544	021.853937	171.392324	204.41194
39965.0	01.208060	0.03212699	105.779887	010.584860	181.185609	136.87680
39972.0	01.208063	0.03195595	105.780023	359.264866	190.977388	069.39425
39979.0	01.208063	0.03178895	105.778401	347.876128	200.769449	001.98111
39986.0	01.208061	0.03162028	105.779459	336.428621	210.561394	294.62992
39993.0	01.208063	0.03147305	105.778343	324.921636	220.353728	227.33835
40000.0	01.208062	0.03134300	105.779728	313.353929	230.146125	160.11419
40007.0	01.208062	0.03123824	105.779538	301.746369	239.938622	092.93369
40021.0	01.208060	0.03111375	105.781161	278.419884	259.524945	318.71681
40027.5	1.20806080	.031117441	105.781490	267.567695	268.618370	98.949728
40034.5	1.20806055	.031138061	105.783151	255.884186	278.411281	31.885622
40100.0	01.208058	0.03245309	105.789414	148.692580	010.061574	177.31317
40107.0	01.208061	0.03258021	105.792173	137.532184	019.857982	109.80759
40114.0	01.208059	0.03268496	105.792192	126.402026	029.655493	042.27227
40121.0	01.208058	0.03276590	105.794307	115.306081	039.452985	334.70902
40128.0	01.208060	0.03281985	105.794915	104.224710	049.252083	267.12981
40135.0	01.208058	0.03284417	105.796476	093.164831	059.051242	199.53466
40149.0	01.208060	0.03279851	105.797565	071.042131	078.653207	064.35014
40156.0	01.208059	0.03273138	105.798945	059.965858	088.456241	356.77390
40160.5	1.20805891	.032697770	105.798321	52.815944	94.752101	258.933357
40253.0	01.208057	0.03113584	105.801044	261.715566	224.331267	197.03891
40260.0	01.208057	0.03117745	105.802573	250.068951	234.138751	130.10485
40267.0	01.208058	0.03125157	105.802298	238.438855	243.946440	063.15754
40274.0	01.208056	0.03135705	105.803367	226.842864	253.754031	356.18541
40285.5	1.20805690	.031578077	105.802257	207.915960	269.865302	191.413108
40291.5	1.20805675	.031711432	105.803638	198.081794	278.270281	185.341621
40297.5	1.20805667	.031858321	105.802350	188.299882	286.676198	179.217328
40312.0	01.208056	0.03222484	105.801103	164.845241	306.986877	197.45074
40319.0	01.208057	0.03238286	105.800238	153.609514	316.789994	130.14372
40326.0	01.208056	0.03252280	105.799180	142.433694	326.592969	062.77356
40333.0	01.208058	0.03264440	105.797525	131.292430	336.394029	355.37450
40340.0	01.208056	0.03273691	105.797452	120.187625	346.194522	287.93897
40347.0	01.208056	0.03280498	105.794876	109.097498	355.993847	220.49367
40354.0	01.208057	0.03284168	105.795330	098.026929	005.792639	153.03208
40361.0	01.208051	0.03285199	105.792052	087.102646	015.590359	085.43068
40368.0	01.208056	0.03282602	105.793127	075.899137	025.387614	018.11501
40516.5	1.20805448	.031772242	105.781859	193.000130	233.141737	135.235439
40519.5	1.20805434	.031845104	105.783441	188.107522	237.338744	312.200632
40526.0	01.208056	0.03202213	105.784663	177.551348	246.433839	098.78965
40533.0	01.208054	0.03219310	105.786478	166.229355	256.229134	031.62738
40540.0	01.208055	0.03235411	105.788523	154.984764	266.024562	324.39042
40547.0	01.208055	0.03250022	105.789558	143.774197	275.821476	257.12767
40554.0	01.208053	0.03262212	105.792023	132.628713	285.618152	189.80428
40561.0	01.208055	0.03271882	105.792214	121.514722	295.416286	122.45965
40568.0	01.208054	0.03279069	105.795201	110.415971	305.214120	055.10855
OBSERVATION WEIGHTS USED	.0000015,	.000002,	.0005,	.01,	.001,	2.0

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

m. EGRS-3 (1965 16E)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
39096.0000000	1.14449000	.0016129	70.0900	265.5948	314.1080	56.5892
39123.0000000	1.14449000	.0018650	70.0820	218.5999	257.0588	321.7331
39140.0000000	1.14449000	.0021520	70.0810	192.2873	221.1547	165.4667
39150.0000000	1.14449000	.0023227	70.0810	180.1773	199.9897	218.4347
39164.0000000	1.14449000	.0024998	70.0830	163.2470	170.4007	148.5860
39179.0000000	1.14449000	.0027098	70.0790	145.5598	138.7077	47.6102
39192.0000000	1.14449000	.0028439	70.0820	131.8895	111.2308	366.4635
39225.0000000	1.14449000	.0029998	70.0860	98.1965	41.4859	67.2855
39233.0000000	1.14449000	.0030296	70.0860	90.1058	24.5770	180.1822
39275.0000000	1.14449000	.0028325	70.0810	46.5605	295.8033	324.1445
39291.0000000	1.14449000	.0026186	70.0820	28.2123	261.9943	192.2787
39305.0000000	1.14449000	.0024580	70.0800	372.0771	232.4063	122.0249
39319.0000000	1.14449000	.0021838	70.0810	354.4661	202.8163	53.2770
39333.0000000	1.14449000	.0020188	70.0820	335.2799	173.2272	-13.8578
39349.0000000	1.14449000	.0018033	70.0820	310.0392	139.4182	221.3479
39363.0000000	1.14448000	.0016054	70.0810	284.1224	109.8301	161.0256
39377.0000000	1.14448000	.0016018	70.0780	258.0014	80.2380	100.9505
39391.0000000	1.14448000	.0017177	70.0820	232.6121	50.6769	40.1869
39405.0000000	1.14447897	.0019165	070.0850	209.2357	021.0638	337.4443
39419.0000000	1.14447897	.0021378	070.0840	188.6609	351.4727	271.9601
39433.0000000	1.14447740	.0024169	070.0810	171.0153	321.8807	203.6126
39447.0000000	1.14447740	.0026932	070.0800	155.0065	292.2927	133.6795
39461.0000000	1.14447584	.0028800	070.0830	139.9589	262.7057	62.8571
39475.0000000	1.14447584	.0029172	70.0800	124.2926	233.1078	352.7154
39489.0000000	1.14447584	.0030502	70.0790	110.4767	203.5329	280.7933
39503.0000000	1.14447427	.0030153	70.0830	93.7410	173.9310	211.8760
39517.0000000	1.14447270	.0030228	70.0830	80.4012	144.3531	139.6258
39531.0000000	1.14447270	.0029639	70.0830	66.3175	114.7702	68.2105
39545.0000000	1.14447113	.0028640	70.0810	51.0672	85.1792	-1.9552
39559.0000000	1.14446956	.0027624	70.0840	35.0162	55.5883	288.7738
39573.0000000	1.14446956	.0026152	70.0820	19.5189	25.9893	219.0772
39587.0000000	1.14446643	.0023882	70.0830	363.3740	356.4013	150.1740
39601.0000000	1.14446643	.0021726	70.0810	345.6308	326.8103	83.0123
39615.0000000	1.14446486	.0019201	70.0810	326.0209	297.2172	17.8231
39629.0000000	1.14446329	.0017514	70.0820	301.6619	267.6281	317.4841
39643.0000000	1.14446173	.0016552	70.0810	276.9075	238.0450	257.6325
39657.0000000	1.14446173	.0016772	70.0810	250.8447	208.4479	199.2093
39678.0000000	1.14446173	.0016772	70.0810	250.8447	208.4479	199.2093
39685.0000000	1.14446016	.0020370	70.0850	201.6026	149.2718	79.6343
39699.0000000	1.14446016	.0023095	70.0800	182.1635	119.6917	374.7465
39713.0000000	1.14445859	.0025003	70.0860	167.2133	90.1007	305.4307
39727.0000000	1.14445859	.0026339	70.0800	148.4666	60.5037	239.9774
39741.0000000	1.14445702	.0027852	70.0820	134.4270	30.8997	169.8950
39755.0000000	1.14445545	.0029263	70.0880	119.4965	1.3088	100.7825
OBSERVATION WEIGHTS USED	.0000015,	.00001,	.0015,	0.5,	.005,	2.0

n. PEGASUS 3 (1965 60A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
38971.5493056	1.08322000	.0011583	28.8881	306.3433	322.1731	173.3737
38976.0000000	1.08325000	.0016394	28.8890	351.9073	292.6892	297.9096
38997.0000000	1.08323000	.0015716	28.8870	183.9839	153.5678	237.4732
39004.0000000	1.08322000	.0012993	28.8871	278.5386	107.1930	187.6414
39011.0000000	1.08321000	.0017265	28.8880	364.8334	60.8152	146.4595
39018.0000000	1.08321000	.0022329	28.8879	70.1792	14.4401	126.6417
39025.0000000	1.08319000	.0020341	28.8869	127.6031	328.0568	115.2820
39039.0000000	1.08317000	.0012998	28.8871	298.5399	235.2991	38.1940
39053.0000000	1.08314000	.0022554	28.8859	81.0064	142.5180	352.4406
39067.0000000	1.08312000	.0013403	28.8891	219.3546	49.7439	313.3244
39074.0000000	1.08310000	.0013867	28.8891	319.4854	3.3611	263.9775
39081.0000000	1.08309000	.0019174	28.8880	33.2420	316.9652	241.6968
39095.0000000	1.08307000	.0017843	28.8870	150.3190	224.1618	229.1751
39102.0000000	1.08306000	.0013149	28.8871	239.3584	177.7729	193.0487
39123.0000000	1.08304000	.0021607	28.8879	104.6103	38.5739	128.9728
39137.0000000	1.08302000	.0013013	28.8881	258.9384	305.7770	84.1876
39165.0000000	1.08298000	.0015268	28.8880	181.1836	120.1348	27.5076
39172.0000000	1.08297000	.0012507	28.8891	280.5029	73.7240	345.9351
39179.0000000	1.08296000	.0016979	28.8890	365.2588	27.3112	19.5240
39186.0000000	1.08295000	.0021832	28.8879	70.3938	340.9011	313.4361
39193.0000000	1.08294000	.0020222	28.8869	127.8393	294.4828	315.5898
39207.0000000	1.08291000	.0012825	28.8871	299.7977	201.6421	264.8842
39214.0000000	1.08289000	.0018381	28.8870	21.4298	155.2172	245.3100
39228.0000000	1.08286000	.0019138	28.8890	138.7871	62.3488	254.3200
39235.0000000	1.08284000	.0013791	28.8891	219.8367	15.9369	237.7103
39242.0000000	1.08283000	.0013850	28.8881	319.0693	329.5011	203.8066
39249.0000000	1.08280000	.0019801	28.8870	34.5663	283.0642	194.6056
39256.0000000	1.08279000	.0021825	28.8859	94.0212	236.6270	202.5088
39270.0000000	1.08275000	.0013068	28.8861	238.5366	143.7429	195.2545
39277.0000000	1.08273000	.0014688	28.8880	335.0582	97.2932	168.8417
39291.0000000	1.08277000	.0021174	28.8879	105.5476	4.3959	181.4404
39305.0000000	1.08267000	.0012497	28.8891	260.6728	271.4830	172.3842
39312.0000000	1.08266000	.0015713	28.8860	352.7255	225.0302	154.4474
39319.0000000	1.08265000	.0021068	28.8859	60.9081	178.5561	161.0348
39326.0000000	1.08264000	.0020783	28.8879	116.7939	132.0959	180.6332
39340.0000000	1.08266000	.0012441	28.8881	284.1202	39.1700	166.7428
OBSERVATION WEIGHTS USED	.00001,	.00003,	.0005,	2.0,	.003,	5.0

TABLE 2 (continued)

SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

o. FR-1 (1965 101A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
39467.0000000	1.11765462	.0000970	75.8760	232.0879	220.7880	183.3371
39481.0000000	1.11764992	.0009116	75.8760	164.9065	197.7829	160.2464
39495.0000000	1.11764521	.0012277	75.8800	143.6466	174.7709	91.6213
39509.0000000	1.11763894	.0016008	75.8800	125.0287	151.7649	380.9252
39516.0000000	1.11763581	.0017256	75.8810	118.9349	140.2619	342.5400
39523.0000000	1.11763267	.0018604	75.8860	107.3167	128.7550	309.8372
39544.0000000	1.11762483	.0020045	75.8820	82.5905	94.2410	202.5366
39551.0000000	1.11762170	.0019477	75.8840	76.1944	82.7350	165.1807
39558.0000000	1.11761699	.0018575	75.8770	69.8428	71.2281	127.9763
39565.0000000	1.11761386	.0017280	75.8790	62.6667	59.7211	91.8284
39572.0000000	1.11760915	.0016145	75.8810	54.0780	48.2131	57.2871
39579.0000000	1.11760288	.0014823	75.8780	46.2048	36.7091	22.3013
39593.0000000	1.11759034	.0009448	75.8800	391.3767	13.7021	312.3824
39600.0000000	1.11758720	.0008153	75.8800	376.2274	2.1931	285.4707
39607.0000000	1.11758407	.0004235	75.8790	359.1030	350.6860	260.7031
39614.0000000	1.11758093	********	75.8750	278.7309	339.1840	299.3261
39621.0000000	1.11757936	.0003959	75.8810	189.6424	327.6740	346.8265
39628.0000000	1.11757623	.0005759	75.8790	168.0842	316.1630	326.9007
39635.0000000	1.11757309	.0009344	75.8810	160.7084	304.6559	292.9205
39642.0000000	1.11756682	.0011110	75.8810	149.5070	293.1459	263.0329
39649.0000000	1.11756369	.0012438	75.8810	140.7013	281.6369	230.9666
39656.0000000	1.11756212	.0014949	75.8790	133.9315	270.1329	196.9674
39663.0000000	1.11756212	.0015672	75.8780	120.2786	258.6259	169.9153
39670.0000000	1.11755898	.0017023	75.8770	112.5417	247.1209	137.0052
39674.0000000	1.11755004	.0019283	75.8760	73.4805	189.5860	-26.0685
39684.0000000	1.11755741	.0018773	75.8830	96.0769	224.1110	72.3940
39691.0000000	1.11755585	.0019964	75.8820	92.4377	212.6190	35.5902
39698.0000000	1.11755271	.0019728	75.8810	81.4220	201.0910	6.2380
39705.0000000	1.11755114	.0019282	75.8760	73.4758	189.5850	-26.0648
OBSERVATION		e. sin w		e. cos w		
WEIGHTS USED	.000001,	.0001,	.003,	.0001,	.0028,	0.2

p. OSO 3 (1967 20A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
39578.0000000	1.08707213	.0024537	32.8680	38.3491	78.0732	210.2378
39585.0000000	1.08704705	.0027018	32.8679	91.8031	34.1630	348.0249
39592.0000000	1.08703137	.0023466	32.8660	145.5987	350.2488	126.5464
39599.0000000	1.08701726	.0017728	32.8671	215.5152	306.3318	249.7429
39608.0000000	1.08698433	.0018136	32.8651	320.4422	249.8592	34.5897
39615.0000000	1.08696709	.0023897	32.8630	29.7478	205.9332	160.9940
39629.0000000	1.08694984	.0024684	32.8639	136.1648	118.0828	87.7403
39636.0000000	1.08693416	.0018944	32.8661	201.6942	74.1488	219.5869
39643.0000000	1.08691692	.0016975	32.8661	283.4394	30.2170	336.1906
39650.0000000	1.08690751	.0021108	32.8660	359.5880	346.2842	99.0799
39657.0000000	1.08690281	.0026487	32.8649	59.8530	302.3521	238.2129
39664.0000000	1.08689653	.0026544	32.8639	112.0468	258.4169	25.6913
39671.0000000	1.08688870	.0021810	32.8630	169.3737	214.4838	168.3964
39678.0000000	1.08688242	.0016784	32.8631	245.4097	170.5429	292.7484
39692.0000000	1.08687145	.0025960	32.8650	34.2919	82.6622	185.5080
39699.0000000	1.08686047	.0027219	32.8659	88.4440	38.7220	332.7610
39706.0000000	1.08684793	.0024135	32.8650	141.4779	354.7848	121.7842
39713.0000000	1.08684009	.0017909	32.8651	208.4898	310.8408	257.3773
39720.0000000	1.08683225	.0016730	32.8631	292.2457	266.8951	16.6453
39727.0000000	1.08682128	.0021276	32.8620	368.0333	222.9472	144.3596
39741.0000000	1.08679149	.0025337	32.8639	117.4591	135.0459	84.1619
39748.0000000	1.08677895	.0020599	32.8630	176.3420	91.0978	230.9771
39762.0000000	1.08674759	.0018712	32.8661	336.2763	3.1882	124.6066
39769.0000000	1.08673034	.0024658	32.8649	42.2631	319.2292	266.7788
39776.0000000	1.08671466	.0026796	32.8639	94.6203	275.2730	63.3748
39783.0000000	1.08670055	.0023256	32.8630	147.9971	231.3098	219.7860
39790.0000000	1.08668331	.0017484	32.8641	218.2922	187.3428	360.0809
39804.0000000	1.08664725	.0022190	32.8630	15.0644	99.3982	267.6284
39811.0000000	1.08663470	.0027017	32.8649	71.5860	55.4261	64.3740
39818.0000000	1.08661589	.0025780	32.8649	123.1139	11.4528	226.9272
39832.0000000	1.08657983	.0016309	32.8651	262.9200	283.4980	158.3430
39839.0000000	1.08656572	.0018825	32.8631	345.0573	239.5152	293.0326
39881.0000000	1.08644029	.0022281	32.8650	23.1058	335.5452	136.8082
39888.0000000	1.08641364	.0027244	32.8629	77.0112	291.5461	307.3858
39895.0000000	1.08638228	.0024803	32.8619	127.1375	247.5308	123.3705
39902.0000000	1.08636033	.0018257	32.8610	188.9388	203.5398	289.0953
39916.0000000	1.08631329	.0018835	32.8630	355.3462	115.5142	221.1087
39923.0000000	1.08628978	.0025622	32.8639	56.0734	71.4972	31.5775
OBSERVATION WEIGHTS USED	.00001,	.00003,	.0008,	1.0,	.005,	2.0

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

q. EXPLORER 27/BE-C (1965 32A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
38887.0000000	1.17696000	.0258467	41.1840	102.4930	207.6315	341.7111
38901.0000000	1.17696000	.0252844	41.1849	173.8426	148.0988	322.3847
38906.0000000	1.17696000	.0250221	41.1864	199.7454	126.8380	237.9209
38922.0000000	1.17696000	.0246654	41.1890	283.9583	58.8075	110.3496
38935.0000000	1.17696000	.0250991	41.1882	352.1168	3.5331	321.9480
38942.0000000	1.17696000	.0254571	41.1866	28.1858	333.7699	131.9010
38948.0000000	1.17696000	.0257058	41.1861	58.7502	308.2573	175.0796
38963.0000000	1.17696000	.0255772	41.1843	134.6085	244.4724	283.5177
38977.0000000	1.17696000	.0248776	41.1875	206.7281	184.9391	263.4021
38984.0000000	1.17696000	.0246371	41.1879	243.4857	155.1771	72.6584
38997.0000000	1.17696000	.0250572	41.1851	186.1134	235.1939	321.8279
39012.0000000	1.17696000	.0254035	41.1855	29.9172	36.1189	30.2805
39019.0000000	1.17696000	.0256437	41.1861	65.4978	6.3569	200.7080
39026.0000000	1.17696000	.0256905	41.1850	100.8303	335.5936	11.3868
39033.0000000	1.17696000	.0256704	41.1830	100.8301	306.8296	181.1690
39047.0000000	1.17696000	.0248218	41.1845	208.5129	274.2971	161.6893
39054.0000000	1.17696000	.0245697	41.1849	245.2807	217.5331	330.9355
39061.0000000	1.17696000	.0245117	41.1850	282.2011	187.7704	140.0309
39082.0000000	1.17696000	.0253496	41.1855	31.6425	98.4759	288.5513
39090.0000000	1.17696000	.0256012	41.1861	72.2729	64.4587	226.2130
39096.0000000	1.17696000	.0256165	41.1890	102.5897	38.9465	269.6213
39103.0000000	1.17696000	.0254108	41.1944	137.9263	9.1804	80.2919
39117.0000000	1.17696000	.0247368	41.1875	210.2416	309.6552	59.9597
39124.0000000	1.17696000	.0244530	41.1869	246.9669	279.8932	229.2353
39131.0000000	1.17696000	.0244254	41.1849	283.9460	250.1325	38.2329
39152.0000000	1.17696000	.0252850	41.1835	33.3324	159.8548	186.7664
39166.0000000	1.17696000	.0255422	41.1850	104.1873	100.3205	167.9168
39179.0000000	1.17696000	.0250699	41.1879	170.4277	46.0269	21.3546
39186.0000000	1.17696000	.0246979	41.1885	206.6891	15.2791	191.0751
39194.0000000	1.17696000	.0244168	41.1889	248.6819	341.2652	127.3702
39201.0000000	1.17696000	.0243496	41.1869	285.6592	311.5036	296.3847
39208.0000000	1.17696000	.0245578	41.1856	322.5911	282.7257	105.4367
39215.0000000	1.17696000	.0249005	41.1840	359.0657	252.9621	274.9420
39229.0000000	1.17696000	.0254849	41.1841	70.5366	193.4317	255.4953
39235.0000000	1.17696000	.0254904	41.1820	100.8184	167.9186	298.9346
39249.0000000	1.17696000	.0249824	41.1849	172.1076	108.3869	279.6367
39278.0000000	1.17696000	.0245110	41.1876	324.2660	345.0867	3.9247
39292.0000000	1.17696000	.0252146	41.1834	36.6399	285.5587	343.6768
OBSERVATION WEIGHTS USED	.00000015,	.00002,	.002,	.015,	.001,	.05,

r. ESSA 1 (1966 8A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
39216.0000000	1.12060000	.0105549	97.8991	57.1714	40.2349	225.6872
39237.0000000	1.12060000	.0095057	97.9040	356.7672	59.4968	60.2388
39244.0000000	1.12060000	.0090371	97.9020	334.8421	65.9198	246.9418
39250.0000000	1.12059000	.0087423	97.9059	315.3913	71.4259	304.7913
39257.0000000	1.12059000	.0085013	97.9069	291.6845	77.8509	133.3198
39272.0000000	1.12059000	.0085612	97.9069	240.3311	91.6171	280.7955
39279.0000000	1.12059000	.0088591	97.9069	217.0347	98.0432	108.9906
39298.0000000	1.12059000	.0099899	97.9090	158.5570	115.4882	49.4361
39305.0000000	1.12060000	.0103539	97.9080	138.7437	121.9132	234.2175
39319.0000000	1.12060000	.0107744	97.9071	100.2141	134.7690	242.7417
39326.0000000	1.12059000	.0107605	97.9101	81.4539	141.1960	66.5293
39333.0000000	1.12059000	.0106728	97.9091	62.5246	147.6229	250.5099
39340.0000000	1.12059000	.0104401	97.9090	43.2704	154.0508	74.8384
39347.0000000	1.12059000	.0101072	97.9100	23.5322	160.4798	259.6918
39354.0000000	1.12059000	.0096533	97.9100	362.9642	164.98	85.3908
39368.0000000	1.12059000	.0088221	97.9099	318.9802	179.7648	99.7125
39381.0000000	1.12059000	.0084066	97.9129	275.1395	191.7080	347.5586
39395.0000000	1.12058000	.0086924	97.9099	227.4856	204.5701	5.7718
39409.0000000	1.12057866	.0094602	97.9150	182.3496	217.4322	21.5784
39432.0000000	1.12057553	.0106290	97.9191	116.8170	238.5741	116.3385
39446.0000000	1.12057396	.0107914	97.9211	79.0782	251.4450	125.1040
39453.0000000	1.12057396	.0105991	97.9231	60.2590	257.8809	309.5095
39467.0000000	1.12057239	.0100129	97.9260	21.0295	270.7608	320.0345
39474.0000000	1.12057082	.0095938	97.9270	360.1256	277.2008	146.6684
OBSERVATION WEIGHTS USED	.000005,	.00002,	.0008,	0.1,	.001,	2.0

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

s. TIROS 5 (1962 25A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
37896.5215278	1.12240000	.0265366	58.0999	170.6395	136.1934	163.4936
37920.5215278	1.12240000	.0257433	58.1004	202.3607	51.7609	144.9974
37927.5215278	1.12240000	.0255074	58.1016	211.8385	27.1374	259.5077
37941.5215278	1.12239000	.0251764	58.1048	230.9417	337.8966	128.5957
37948.5215278	1.12239000	.0250171	58.0999	240.5818	313.2684	243.1618
37969.5215278	1.12239000	.0247555	58.1010	269.6204	239.4090	227.1716
37976.5215278	1.12239000	.0247793	58.1039	279.6105	214.7689	341.5826
37983.5215278	1.12238000	.0248300	58.1009	289.5408	190.1407	96.1215
38004.5215278	1.12238000	.0252345	58.1017	318.3993	116.2770	80.9004
38011.5215278	1.12238000	.0254552	58.1046	328.0162	91.6476	195.8896
38018.5215278	1.12238000	.0256307	58.1014	337.4855	67.0280	311.0574
38032.5215278	1.12238000	.0261032	58.1001	356.1464	17.7756	181.7516
38039.5215278	1.12238000	.0263327	58.1000	5.3759	353.1456	297.2471
38046.5215278	1.12238000	.0265714	58.0998	14.5042	328.5195	52.9008
38067.5215278	1.12237000	.0272223	58.0994	41.4600	254.6364	40.6528
38074.5215278	1.12238000	.0274063	58.0952	50.2623	230.0058	156.8554
38081.5215278	1.12237000	.0275217	58.0981	59.1219	205.3741	273.0327
38095.5215278	1.12238000	.0276790	58.0980	76.6771	156.1194	145.5811
38102.5215278	1.12237000	.0277177	58.0970	85.4357	131.4875	261.6954
38109.5215278	1.12238000	.0277184	58.0980	94.1527	106.8586	18.2682
38116.5215278	1.12237000	.0275810	58.0990	102.9089	82.2236	134.6189
38123.5215278	1.12237000	.0276265	58.1021	111.6769	57.5958	250.9697
38130.5215278	1.12237000	.0275165	58.1011	120.4352	32.9650	7.3383
38137.5215278	1.12237000	.0273527	58.0992	129.2588	8.3382	123.6695
38144.5215278	1.12237000	.0272590	58.1024	138.1022	343.7076	240.0301
38151.5215278	1.12237000	.0270776	58.0995	147.0344	319.0821	356.3318
38172.5215278	1.12237000	.0264503	58.1010	174.2171	245.1933	345.2180
38179.5215278	1.12236000	.0262419	58.0991	183.3825	220.5654	101.5015
38186.5215278	1.12237000	.0260064	58.0983	192.6627	195.9406	217.6994
38193.5215278	1.12237000	.0257565	58.0974	202.0474	171.3129	333.7897
38200.5215278	1.12236000	.0255427	58.1005	211.4797	146.6834	89.7605
38206.5215278	1.12236000	.0253414	58.1037	221.0479	122.0570	205.6184
38214.5215278	1.12237000	.0251497	58.0998	230.6452	97.4306	321.4702
38221.5215278	1.12237000	.0250195	58.1039	240.2575	72.8064	77.3040
38228.5215278	1.12236000	.0249135	58.1039	249.8128	48.1832	193.2199
38235.5215278	1.12236000	.0248412	58.1019	259.7575	23.5531	308.7584
38242.5215278	1.12237000	.0247863	58.1050	269.6298	358.9280	64.3882
38249.5215278	1.12237000	.0248784	58.1030	279.2328	334.3108	180.3153
38263.5215278	1.12236000	.0250312	58.1029	298.7063	285.0505	51.9892
38270.5215278	1.12236000	.0251306	58.1018	308.4906	260.4253	167.8109
38277.5215278	1.12236000	.0252901	58.0997	318.0477	235.8000	283.8989
38284.5215278	1.12236000	.0254493	58.1006	327.6045	211.1746	40.0163
38291.5215278	1.12236000	.0257141	58.1004	337.0671	186.5420	156.2758
OBSERVATION WEIGHTS USED	.000005,	.00002,	.002,	.06,	.003,	0.2

t. ISIS 1 (1969 9A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (°)	W ARG. OF PER. (°)	N R.A. OF ASC. NODE (°)	M MEAN ANOMALY (°)
40735.0000000	1.32087577	.1737352	88.4308	288.1848	238.0114	100.8181
40742.0000000	1.32087357	.1736598	88.4311	274.1644	237.2457	299.5782
40756.0000000	1.32086856	.1737080	88.4301	246.1195	235.7161	337.3104
40763.0000000	1.32086527	.1738237	88.4295	232.1045	234.9517	176.3189
40763.0000000	1.32086527	.1738237	88.4295	232.1045	234.9517	176.3189
40770.0000000	1.32086213	.1740307	88.4288	218.0959	234.1865	15.4194
40770.0000000	1.32086135	.1740826	88.4277	218.0806	234.1873	15.4324
40777.0000000	1.32085915	.1742431	88.4277	204.1189	233.4208	214.5944
40784.0000000	1.32085758	.1744947	88.4268	190.1564	232.6544	53.8209
40784.0000000	1.32086652	.1745842	88.4268	190.1622	232.6568	54.0503
40791.0000000	1.32085601	.1747677	88.4263	176.2180	231.8887	253.0779
40798.0000000	1.32085398	.1750489	88.4263	162.3080	231.1231	92.3594
40798.0000000	1.32085351	.1750597	88.4254	162.3127	231.1243	92.3548
40805.0000000	1.32085241	.1752846	88.4262	148.4111	230.3569	291.6866
40812.0000000	1.32085147	.1754841	88.4267	134.5399	229.5903	131.0255
40812.0000000	1.32085115	.1754716	88.4269	134.5398	229.5916	131.0232
40819.0000000	1.32084990	.1756351	88.4270	120.6761	228.8245	330.4043
40826.0000000	1.32084802	.1757162	88.4275	106.8323	228.0588	169.8116
40826.0000000	1.32084802	.1757160	88.4275	106.8309	228.0589	169.8126
40826.0000000	1.32084818	.1757019	88.4291	106.8307	228.0602	169.8140
40833.0000000	1.32084551	.1757644	88.4290	92.9817	227.2944	9.2974
40840.0000000	1.32084237	.1757194	88.4300	79.1405	226.5301	208.8588
40840.0000000	1.32084237	.1756970	88.4317	79.1351	226.5314	208.8649
40847.0000000	1.32083877	.1756312	88.4318	65.2886	225.7662	48.5508
40854.0000000	1.32083391	.1754781	88.4333	51.4262	225.0033	248.3742
40854.0000000	1.32083406	.1754697	88.4357	51.4206	225.0041	248.3795
40861.0000000	1.32082748	.1752932	88.4363	37.5419	224.2418	88.4043
40868.0000000	1.32082121	.1750817	88.4367	23.6512	223.4797	288.6384
40868.0000000	1.32082262	.1750909	88.4397	23.6484	223.4801	288.6544
40875.0000000	1.32081196	.1748609	88.4392	9.7386	222.7186	129.1466
40882.0000000	1.32080083	.1746476	88.4403	355.8073	221.9574	330.0062
40882.0000000	1.32080083	.1746132	88.4416	355.8056	221.9590	330.0034
40882.0000000	1.32080083	.1746132	88.4416	355.8056	221.9590	330.0034
40889.0000000	1.32079017	.1744007	88.4421	341.6543	221.1993	171.2278
40896.0000000	1.32077966	.1741953	88.4417	327.8883	220.4390	12.8230
40896.0000000	1.32077888	.1741365	88.4418	327.8864	220.4396	12.8202
40903.0000000	1.32077229	.1739914	88.4423	313.9102	219.6790	214.7109
40910.0000000	1.32076602	.1738186	88.4408	299.9131	219.9206	56.8265
40910.0000000	1.32076524	.1737590	88.4405	299.8906	218.9228	56.8422
40917.0000000	1.32076100	.1736862	88.4412	285.8997	218.1618	259.1489
40924.0000000	1.32075693	.1736325	88.4390	271.8885	217.4024	101.6043
40924.0000000	1.32075724	.1735102	88.4399	271.8510	217.4039	101.6385
40931.0000000	1.32075175	.1736334	88.4409	257.8620	216.6428	304.2223
40938.0000000	1.32074627	.1736697	88.4396	243.8309	215.8835	147.0279
40938.0000000	1.32074595	.1737035	88.4385	243.8055	215.8855	147.0492
40945.0000000	1.32074329	.1738031	88.4387	229.8180	215.1229	349.9486
40952.0000000	1.32074078	.1739666	88.4376	215.8131	214.3633	192.9449
40952.0000000	1.32074109	.1740235	88.4379	215.7914	214.3640	192.9648
40959.0000000	1.32073827	.1742039	88.4380	201.8229	213.6018	36.0005
40966.0000000	1.32073513	.1744327	88.4370	187.8575	212.8412	239.1291
40966.0000000	1.32073545	.1745022	88.4379	187.8526	212.8428	239.1381
40973.0000000	1.32073184	.1747256	88.4389	173.9169	212.0799	82.3380
40980.0000000	1.32072792	.1749715	88.4377	159.9979	211.3217	285.6355
40980.0000000	1.32072729	.1749559	88.4393	159.9978	211.3229	285.6298
40987.0000000	1.32072385	.1751813	88.4384	146.0987	210.5615	129.0424
40994.0000000	1.32072102	.1753942	88.4399	132.2165	209.8023	332.5566
40994.0000000	1.32072149	.1753527	88.4423	132.2241	209.8034	332.5555
41001.0000000	1.32071851	.1755307	88.4429	118.3590	209.0425	176.1203
41008.0000000	1.32071554	.1755903	88.4429	104.5027	208.2859	19.7725
41015.0000000	1.32071334	.1755983	88.4450	90.6514	207.5282	223.5028
41022.0000000	1.32071224	.1755639	88.4464	76.7969	206.7729	67.2944
41022.0000000	1.32071193	.1755710	88.4484	76.7848	206.7748	67.3017
41029.0000000	1.32071209	.1754897	88.4479	62.9422	206.0165	271.1165
41029.0000000	1.32071083	.1754762	88.4482	62.9562	206.0180	271.1000
41036.0000000	1.32071068	.1753446	88.4499	49.0835	205.2646	114.9727
41036.0000000	1.32071083	.1753402	88.4511	49.0863	205.2662	114.9739
41043.0000000	1.32071005	.1751617	88.4509	35.2051	204.5103	318.8620
41043.0000000	1.32071005	.1751617	88.4509	35.2051	204.5103	318.8620
41050.0000000	1.32070926	.1749492	88.4530	21.3013	203.7565	162.7872
41057.0000000	1.32070832	.1747336	88.4521	7.3830	203.0021	6.7571
41064.0000000	1.32070723	.1744784	88.4532	353.4416	202.2486	210.7960
41071.0000000	1.32070644	.1742678	88.4534	339.4960	201.4940	54.8653
41078.0000000	1.32070566	.1740541	88.4530	325.5197	200.7409	258.9887
OBSERVATION WEIGHTS USED	.000003,	.00005,	.0015,	.01,	.01,	0.1

TABLE 2 (continued)
SATELLITE ELEMENT DATA USED IN PRESENT SOLUTION (WAG 72)

u. TIROS 9 (1965 4A)

MJD	a SEMIMAJOR AXIS (er.)	e ECCENTRICITY	I INCLINATION (o)	W ARG. OF PER. (o)	N R.A. OF ASC. NODE (o)	M MEAN ANOMALY (o)
38851.0000000	1.25719411	.1176035	96.4156	37.5077	13.4037	285.1102
38852.0000000	1.25719465	.1175673	96.4158	35.3671	13.9166	315.7527
38853.0000000	1.25719535	.1175293	96.4148	33.2239	14.4291	346.3963
38854.0000000	1.25719601	.1174996	96.4146	31.0820	14.9402	17.0341
38855.0000000	1.25719695	.1174631	96.4141	28.9375	15.4519	47.6730
38856.0000000	1.25719769	.1174246	96.4146	26.7947	15.9634	78.3035
38857.0000000	1.25719809	.1173921	96.4144	24.6503	16.4753	108.9307
38858.0000000	1.25719831	.1173523	96.4144	22.5104	16.9868	139.5504
38859.0000000	1.25719817	.1173511	96.4146	20.3714	17.4986	170.1650
38860.0000000	1.25719770	.1173249	96.4147	18.2315	18.0105	200.7807
38861.0000000	1.25719681	.1172883	96.4150	16.0844	18.5232	231.4031
38862.0000000	1.25719595	.1172475	96.4145	13.9448	19.0342	262.0233
38863.0000000	1.25719501	.1172024	96.4150	11.7975	19.5482	292.6551
38864.0000000	1.25719414	.1171679	96.4137	9.6567	20.0614	323.2854
38865.0000000	1.25719347	.1171216	96.4152	7.4995	20.5754	353.9356
38866.0000000	1.25719305	.1170718	96.4161	5.3558	21.0892	24.5798
38867.0000000	1.25719338	.1170260	96.4152	3.1948	21.6036	55.2454
38868.0000000	1.25719388	.1169862	96.4152	1.0414	22.1146	85.9035
38869.0000000	1.25719460	.1169399	96.4137	358.8931	22.6262	116.5557
38870.0000000	1.25719596	.1169122	96.4137	356.7248	23.1377	147.2251
38870.0000000	1.25719598	.1169122	96.4137	356.7248	23.1377	147.2251
38871.0000000	1.25719728	.1168639	96.4132	354.5747	23.6497	177.8722
38872.0000000	1.25719792	.1168426	96.4129	352.4162	24.1611	208.5150
38873.0000000	1.25719864	.1167853	96.4129	350.2589	24.6731	239.1565
38874.0000000	1.25719893	.1167551	96.4133	348.1138	25.1854	269.7795
38875.0000000	1.25719864	.1167274	96.4145	345.9672	25.6982	300.3994
38876.0000000	1.25719788	.1166913	96.4149	343.8192	26.2107	331.0198
38877.0000000	1.25719756	.1166741	96.4152	341.6629	26.7228	1.6529
38880.0000000	1.25719345	.1165179	96.4124	335.1843	28.2615	93.5759
38881.0000000	1.25719345	.1164902	96.4124	333.0267	28.7732	124.2352
38882.0000000	1.25719322	.1164262	96.4117	330.8546	29.2875	154.9079
38883.0000000	1.25719375	.1164030	96.4143	328.6839	29.7977	185.5838
38884.0000000	1.25719457	.1163759	96.4113	326.5236	30.3122	216.2463
38885.0000000	1.25719545	.1163507	96.4118	324.3514	30.8237	246.9216
38886.0000000	1.25719659	.1163073	96.4112	322.1759	31.3361	277.5940
38887.0000000	1.25719767	.1162972	96.4125	320.0208	31.8469	308.2424
38888.0000000	1.25719817	.1162600	96.4117	317.8575	32.3592	338.8878
38889.0000000	1.25719886	.1162374	96.4129	315.7070	32.8721	9.5204
38890.0000000	1.25719907	.1161941	96.4132	313.5361	33.3843	40.1676
38891.0000000	1.25719857	.1161823	96.4128	311.3871	33.8979	70.7876
38892.0000000	1.25719781	.1161390	96.4144	309.2159	34.4093	101.4314
38893.0000000	1.25719700	.1161362	96.4127	307.0514	34.9221	132.0710
38894.0000000	1.25719607	.1161051	96.4121	304.8858	35.4345	162.7165
38895.0000000	1.25719534	.1160580	96.4119	302.7131	35.9471	193.3743
38896.0000000	1.25719457	.1160323	96.4116	300.5344	36.4600	224.0411
38897.0000000	1.25719396	.1160082	96.4115	298.3503	36.9727	254.7178
38898.0000000	1.25719454	.1159984	96.4109	296.1651	37.4850	285.4039
38899.0000000	1.25719366	.1159760	96.4130	293.9983	37.9971	316.0658
OBSERVATION WEIGHTS USED	.0000005,	.00002,	.0015,	.005,	.003,	.05

TABLE 3
ZONAL COEFFICIENTS FROM RECENT SOLUTIONS
(unnormalized in units of 10^{-6} except as noted)

J_ℓ	FR 71	SAO 71	GEM 2	WAG 72	FORMAL S.D. WAG 72 (10^{-9})	LIKELY SYSTEMATIC ERRORS IN WAG 72 FROM VARIOUS SOURCES (10^{-9})				TOTAL RSS S.D. ESTIMATE FOR WAG 72 (10^{-9})	ABS. VALUE WAG 72 −FR 71 Δ (10^{-9})	ABS. VALUE WAG−FR 71: Δ(NORMALIZED), (10^{-9})
						TRUNCATION	UNCERTAIN START. ELEM.	USE OF M. ANOM.	INTEGRATOR ERROR & S.P. LUNAR EFFECTS			
2	1082.637	1082.638	1082.631	1082.635	3	4	9	1	3	11	2	1
3	-2.543	-2.547	-2.526	-2.541	4	6	3	8	4	12	2	1
4	-1.619	-1.623	-1.610	-1.600	4	10	3	4	1	12	19	6
5	-0.226	-0.222	-0.241	-0.230	8	7	7	2	1	13	4	1
6	0.558	0.567	0.524	0.530	5	19	14	7	6	26	28	8
7	-0.365	-0.350	-0.337	-0.364	13	2	8	3	1	16	1	0
8	-0.209	-0.220	-0.164	-0.200	5	11	23	11	6	29	9	2
9	-0.118	-0.155	-0.144	-0.081	18	1	6	11	5	23	37	8
10	-0.233	-0.213	-0.297	-0.224	6	38	19	13	5	45	9	2
11	0.236	0.335	0.264	0.137	26	4	10	18	5	34	99	21
12	-0.188	-0.208	-0.106	-0.208	5	7	12	4	7	17	20	4
13	-0.202	-0.340	-0.225	-0.101	36	28	11	18	3	50	101	19
14	0.385	0.105	0.048	0.166	8	23	3	5	0	25	81	15
15	-0.081	0.139	-0.022	-0.072	40	31	8	30	2	59	9	2
16	0.048	0.022	0.149	0.003	7	47	7	26	8	55	45	8
17	-0.027	-0.252	-0.043	-0.204	41	1	29	51	8	72	177	30
18	-0.137	-0.118	-0.139	-0.086	13	11	14	50	12	56	51	8
19	-0.112	0.081	-0.096	0.047	42	13	15	26	2	53	159	25
20	-0.087	-0.087	0.004	-0.085	14	50	15	27	9	61	2	0
21	0.106	-0.040	0.077	0.015	29	50	8	20	8	62	91	14
												12 RMS

TABLE 4
TOTAL WEIGHTED RMS RESIDUALS
IN ROAD SOLUTIONS FOR LONG SATELLITE ARCS

21 SATELLITES USED IN PRESENT SOLUTION	WITH FIELD USED		
	PRESENT SOLUTION (WAG 72)	FR 71	GEM 2
VANG. 2	1.52	1.39	1.39
TRAN. 4A	2.90	3.01	7.40
MIDAS 4	1.63	2.18	2.30
BE-B	3.25	3.63	3.62
GEOS 1	0.62	0.56	0.56
ECHO 1 ROCKET	0.84	1.34	1.35
PEOLE	1.00	1.73	1.19
SAS 1	1.05	15.94	45.52
EXPLORER I	1.11	1.51	1.48
ANNA 1B	1.23	1.27	1.27
TELSTAR I	2.49	2.63	2.63
GEOS 2	3.34	7.99	9.77
EGRS 3	2.45	5.25	4.45
PEGASUS 3	1.45	1.80	1.91
FR-1	1.49	3.10	1.61
OSO 3	1.33	1.80	1.47
EXPLORER 27	1.47	4.09	4.02
ESSA 1	1.67	2.91	2.33
TIROS 5	1.27	3.53	3.32
TIROS 9	1.00	0.95	1.00
ISIS 1	1.44	2.26	2.16
AVG. RMS IN 21 ARCS	1.65	3.28	4.80
6 SATELLITES NOT USED IN PRESENT SOLUTION			
OAO 2 (a = 1.12 e = 0.001)	0.82	0.81	0.85
1965-34A (a = 1.51 e = 0.05)	1.44	1.46	1.45
ALOUETTE 2 (a = 1.27 e = 0.15)	1.37	1.32	1.47
COSMOS 382 (a = 1.60 e = 0.14)	2.95	2.97	3.00
DIAL (a = 1.15 e = 0.09)	1.79	3.09	7.59
EGRS 5 (SECOR 5) (a = 1.28 e = 0.08)	2.40	2.36	2.49

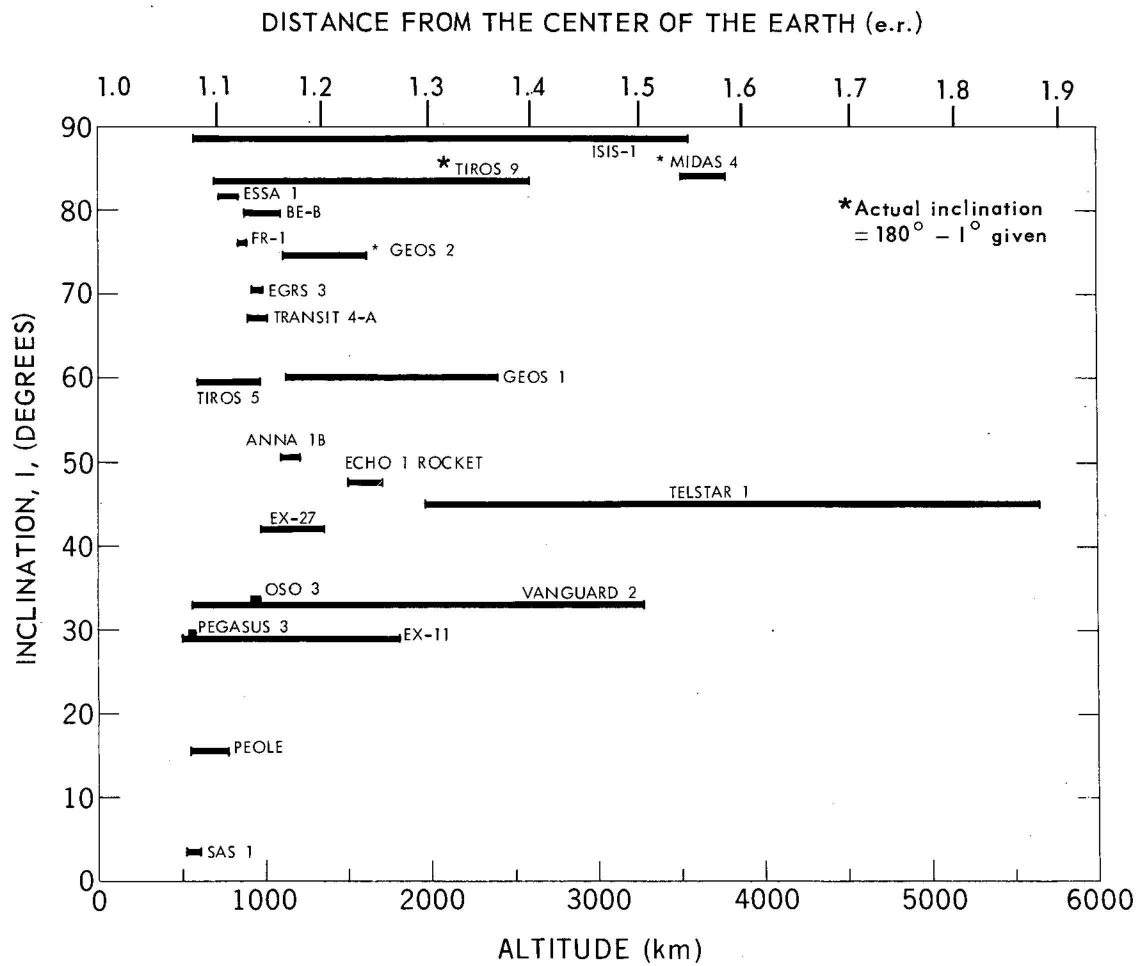

Figure 1. Satellites Used in Present Solution

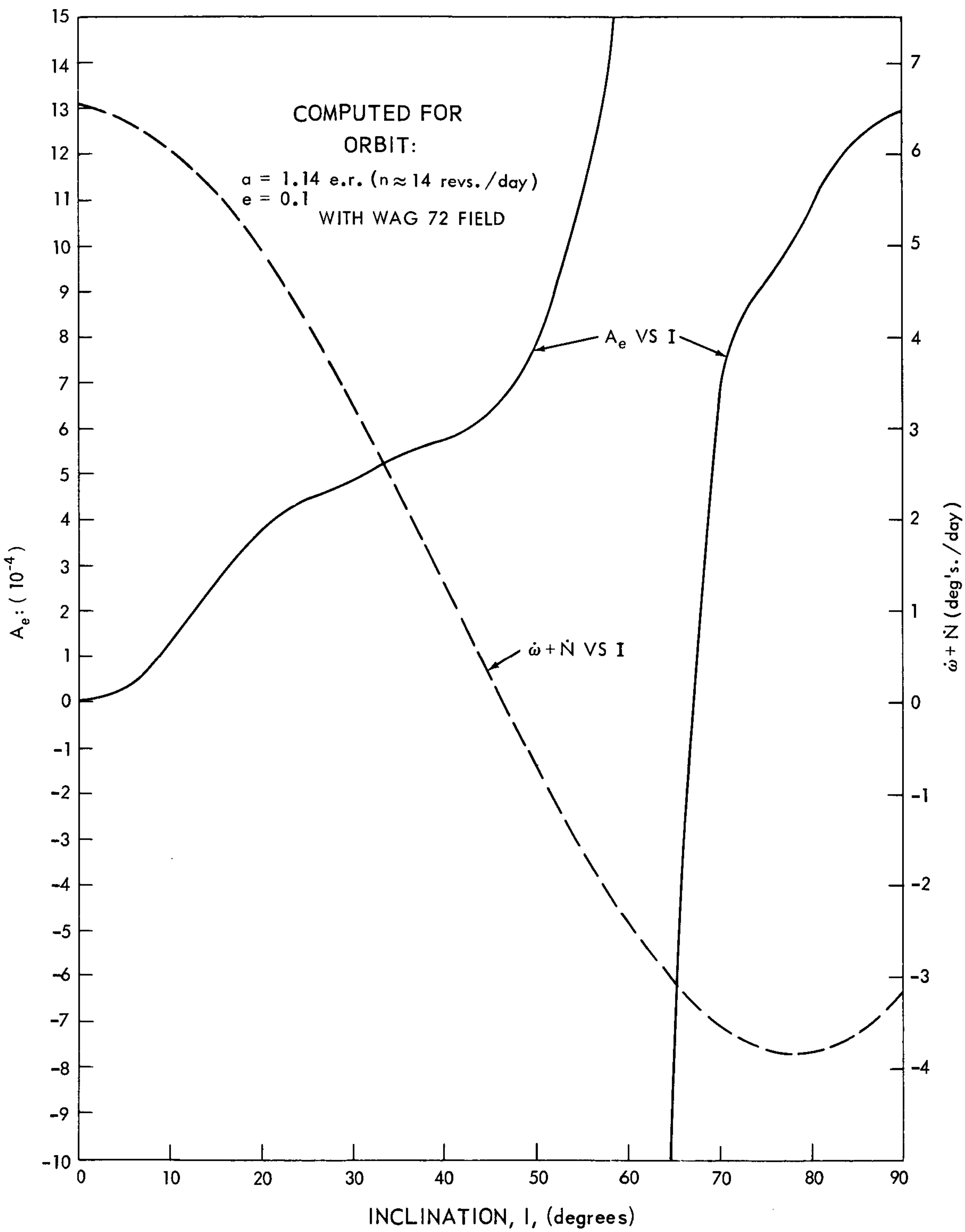

Figure 2. Secular Rates and Amplitude of Eccentricity Oscillation Due to Even and Odd Zonals

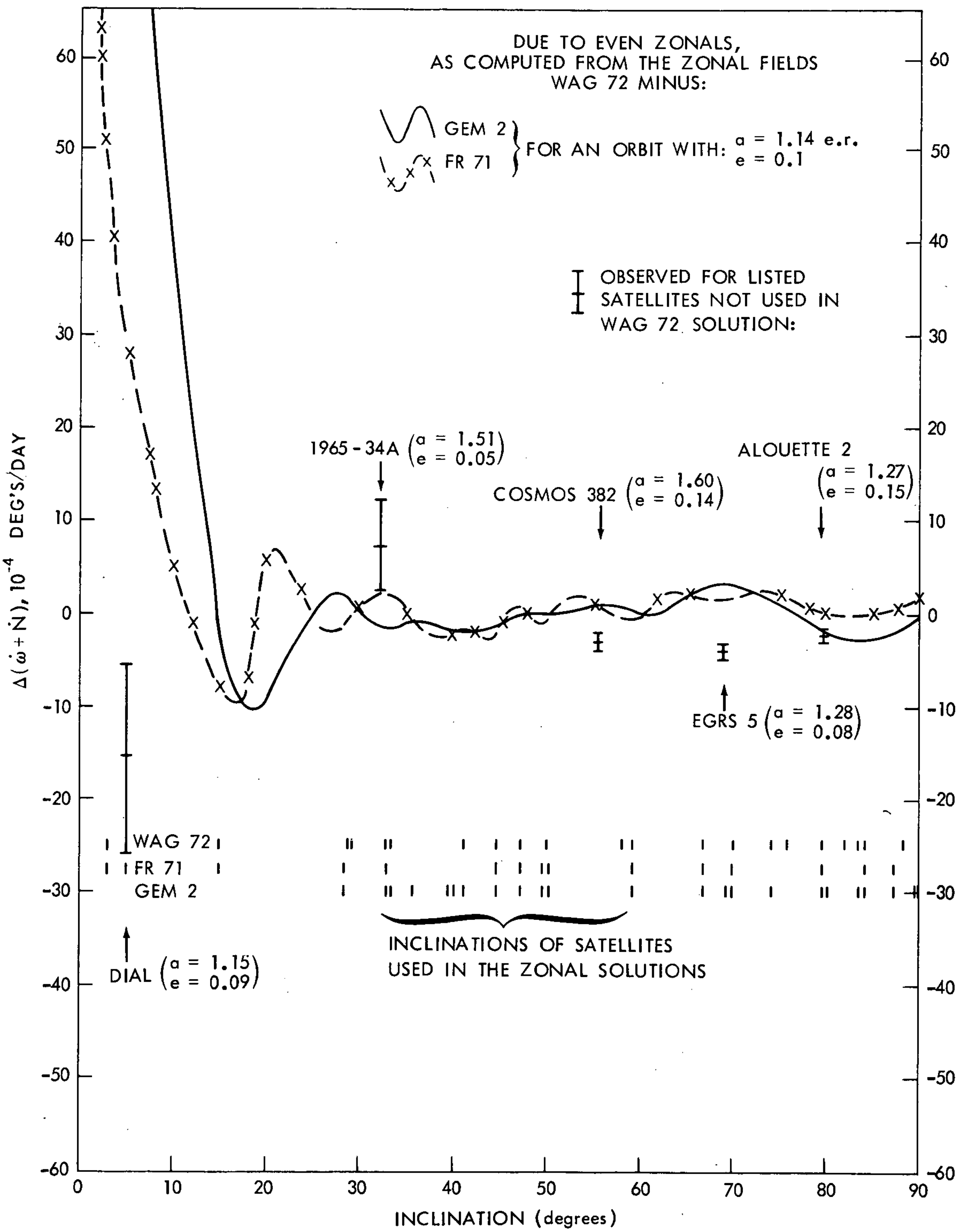

Figure 3. Differences in Secular Rates

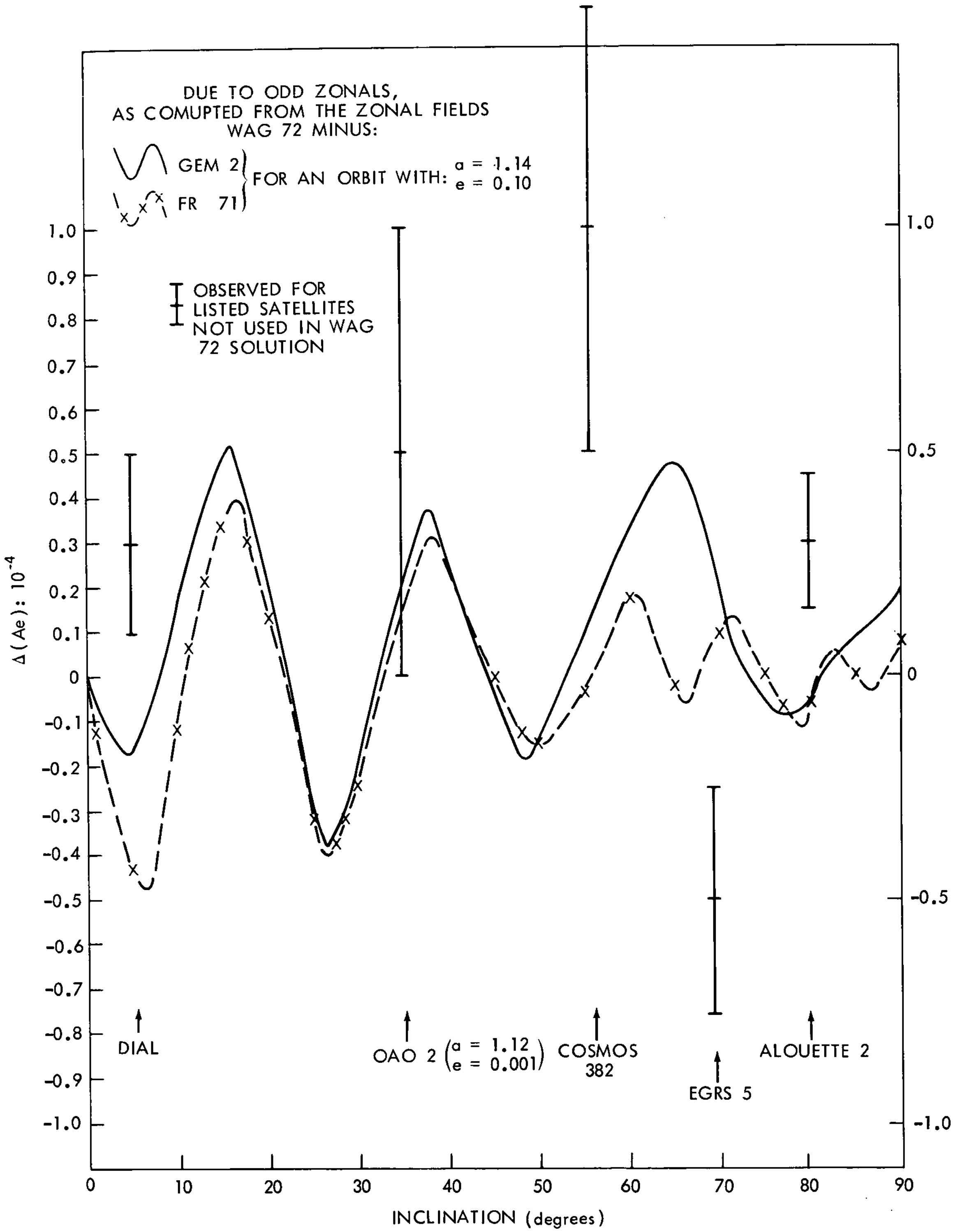

Figure 4. Differences in Amplitudes of Eccentricity Oscillation

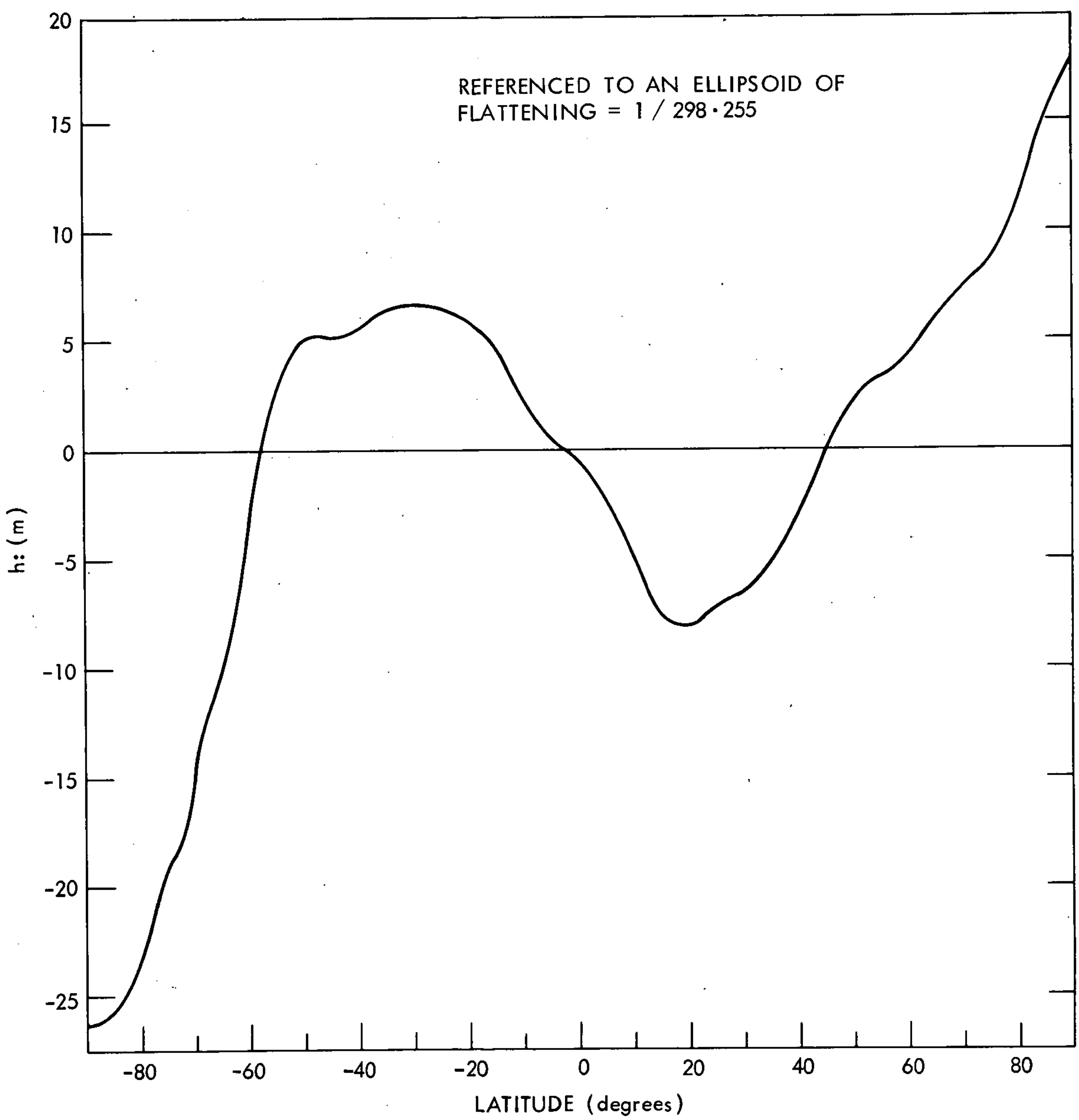

Figure 5. Zonal Geoid Profile for WAG 72

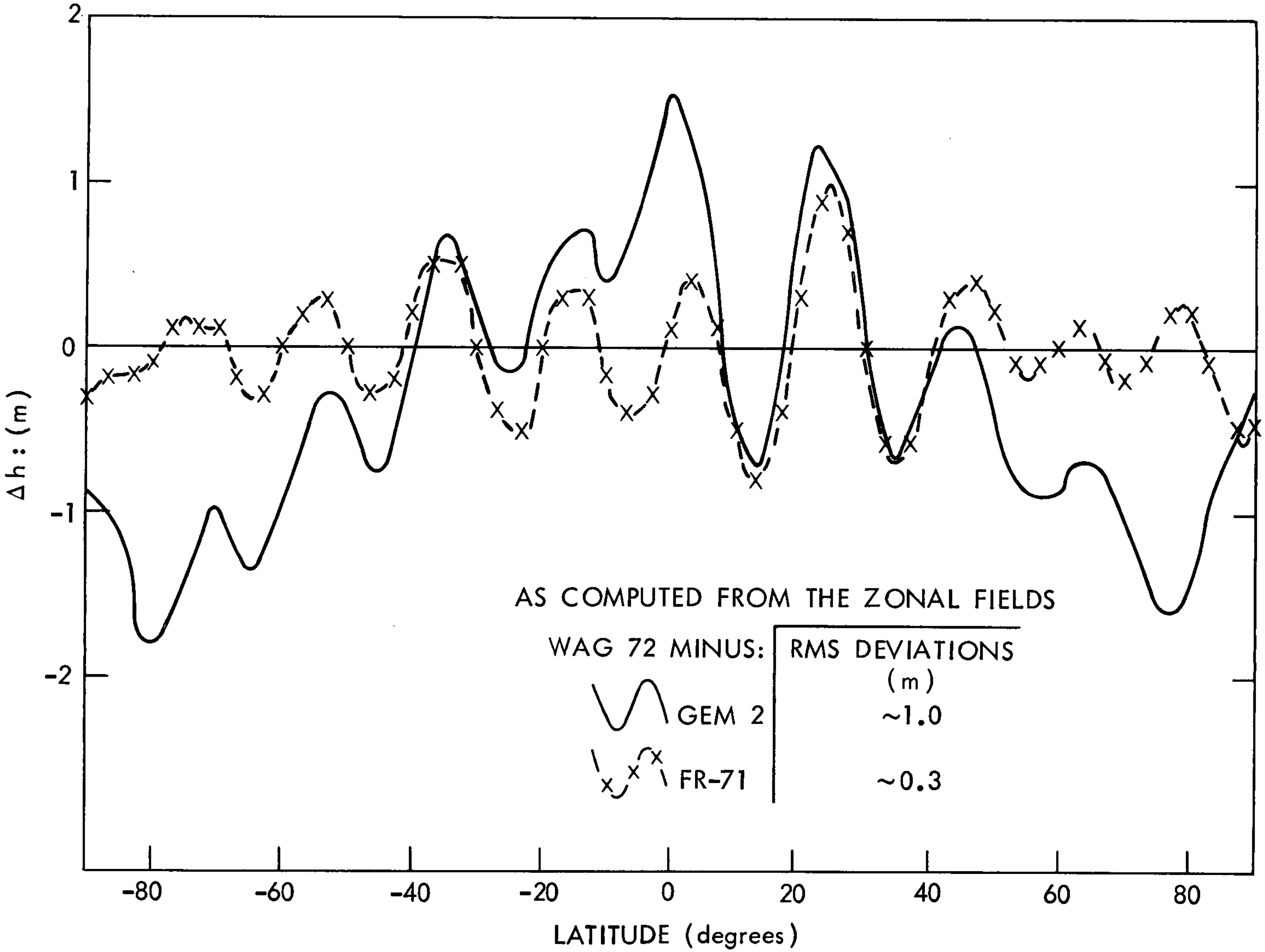

Figure 6. Differences in Zonal Geoid Profiles

* U.S. GOVERNMENT PRINTING OFFICE: 1972—735-961/28