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GODDARD ORBIT INFORMATION

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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ABSTRACT

A description is given of certain aspects of the preparation and presentation of orbit information, including the construction of an ephemeris on the basis of orbital arcs. Procedures used to specify orbital uncertainty estimate information are also described.

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INTRODUCTION

A number of spacecraft have yielded useful data for periods of well over a year. Various considerations associated with practical aspects of orbit determination, limitations in environment models, etc., have led to the practice of constructing the ephemeris of a satellite on the basis of a sequence of orbital arcs, each of which is determined using the tracking data obtained in an interval of its lifetime.

The individual orbital arcs are determined by means of a weighted least squares differential correction procedure. This aspect of the subject is discussed in Reference (a). The presentation of ephemeris and orbital uncertainty estimate information is discussed here.

EPHEMERIDES

The satellite ephemeris is based on a sequence of orbital arcs whose intervals are normally selected so as to over-lap. In a typical configuration the length of each interval is taken to be t_L, and the initial or starting epochs of adjacent intervals are separated by t_S units of time. It is convenient to consider a common or overlap interval whose length, t_C, is given by

$$t_C = t_L - t_S .$$

This kind of interval pattern is indicated schematically in Figure 1.

The ratio

$$r = \frac{t_C}{t_S} ,$$

can be thought of as an overlap parameter. Thus, for example, if

$$t_C = t_S ,$$

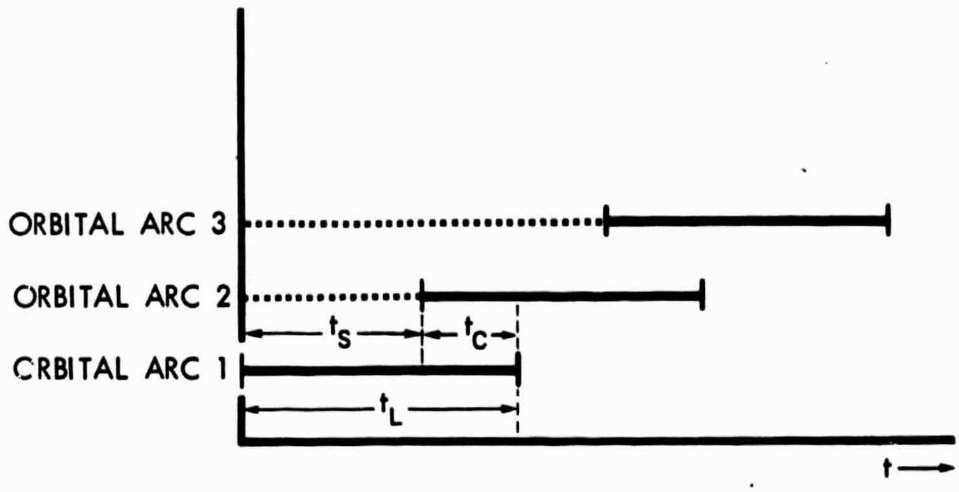

Figure 1. Schematic Indication of Time Intervals Spanned by Overlapping Orbital Arcs.

one says that the overlap parameter has the value unity or, simply, that one hundred percent overlap occurs. In the case of definitive orbit determination, the times are frequently chosen so as to provide one hundred percent overlap.

The ephemeris is constructed using portions of the overlapping orbital arcs. The transfer from the portion of the ephemeris corresponding to one interval to the portion corresponding to the next interval is usually made at the point in the overlap region at which the distance between the two ephemerides is at a minimum. Alternative possibilities come to mind. These could involve minimization of other parameters such as the difference in the magnetic flux density, for example. The criterion generally used, however, is based directly on the distance itself.

The actual lengths of the individual overlapping orbits for a given satellite may vary in accordance with the data patterns and other practical factors. They also vary from one satellite to another. Typical lengths range from a couple of days to about a week.

The ephemeris itself is specified in terms of a Cartesian coordinate system having its origin at the earth's center of mass. The x, y, and z axes of the system form a right-handed orthogonal set. They are chosen so that the z-axis is directed along the earth's north polar axis and the x-axis is directed toward the first point of Aries, i.e., $\lambda_G(t)$, the right ascension of the Greenwich meridian, can be calculated by means of the relation

$$\lambda_G(t) = \lambda_G(t_0) + w_E(t - t_0) \,.$$

where $\lambda_G(t_0)$ denotes the right ascension of Greenwich at a reference epoch, t_0, and w_E denotes the rotational rate of the earth. Here $\lambda_G(t)$ is taken to be the angle between the x-axis and the intersection of the Greenwich meridian plane and the earth's equatorial plane at the time, t. The satellite's position vector components are given in units of the earth's equatorial radius which is frequently taken to have the value 6378.166 kilometers. They are specified at times separated by regular intervals. Typical interval lengths are the minute and its multiples. The ephemeris is usually provided on a magnetic tape. The ephemeris tape format is given in Reference (b).

ORBITAL UNCERTAINTY ESTIMATES

The differences between satellite position vector components corresponding to two overlapping orbital arcs are often larger than the values indicated by the corresponding conventional statistical probable errors in these quantities which are associated with the two orbits. This is not unexpected when, as is frequently the case, the error models used to calculate these quantities do not completely represent the actual situation. Some users find it useful to supplement or supplant the conventional statistical probable errors with uncertainty estimates based upon overlap differences and values which reflect experience. Orbital uncertainty estimates are, accordingly, provided in certain cases. The orbital uncertainty estimate for a parameter such as a spacecraft position component is specified to be the largest one of the four quantities just indicated, namely, the statistical probable errors in the parameter associated with the two overlapping orbital arcs, the difference between the values of the parameter obtained from the two corresponding satellite positions, and a value reflecting experience. In some cases, for practical reasons, one or more of these quantities, such as the statistical probable errors associated with the overlapping ephemerides, for example, may not actually be available for use in this connection. The orbital uncertainty estimates are presented for three components of the spacecraft position, the radial component and two components normal to the radial direction, one in the orbital plane and one normal to the orbital plane. These directions are associated with the osculating position and velocity vectors which are denoted by $\underline{r}(t)$ and $\underline{v}(t)$, respectively. The radial direction is that of $\underline{r}^*(t)$, the direction normal to the orbital plane is that of $[\underline{r}(t) \times \underline{v}(t)]^*$, and the third direction of the set is that of $\{[\underline{r}(t) \times \underline{v}(t)] \times \underline{r}(t)\}^*$.

Sets of orbital arcs to be used for comparison could be chosen in other ways than those indicated above. They might, for example, be formed by using proper subsets of the tracking data defined according to time, tracking station, tracking system, or combinations of these criteria. Thus, one may select subsets from the total set of tracking data in a given period by taking data from two or more subintervals, and/or data from selected tracking stations, and/or data from designated tracking systems, etc. It can also be illuminating to examine orbits determined using fixed sets of tracking data but different environmental models, and orbits obtained for different satellites using a particular tracking system. These general kinds of things have been done. The results form part of the basis for the values reflecting experience which enter into the specification of the orbital uncertainty estimates. The partial data sets are useful for research. For purposes of regular orbit determination and uncertainty estimation, the overlapping, complete data sets referred to earlier appear to be more suitable than the partial sets just described since the latter are abbreviated, generally involve a greater investment of resources in terms of analysis and computer time, and yield less satisfactory results in a number of cases.

The orbital uncertainty estimate information is presented graphically on microfilm for each overlap interval. Typical graphs are shown in Figures 2 through 4. Two types of abscissa scales are available. These are Universal Time in units of an hour, and radial distance from the center of the earth in units of a megameter. The orbital uncertainty estimates for the position components are referred to ordinate scales which use the kilometer as the unit. Two types of ordinate scales are available, linear and logarithmic.

Tracking data on which the orbits are based are indicated by means of plots referred to a Universal Time abscissa scale. These appear in the lower part of the figure. The symbols LM, RR, and XY denote, respectively, Minitrack direction cosine data, range and range rate data, and x - y angular tracking data. Each of these three types of data is allotted a horizontal line in the figure. An asterisk in one of these lines denotes the fact that a tracking pass of this type of data, taken at the indicated date and time, was used in the orbit determination upon which the results are based.

The locations of the perigee and apogee passages are indicated by means of an asterisk near the abscissa axis when this axis is referred to radial distance. When the abscissa is referred to time, the satellite's radial distance is marked on the figure, usually at intervals of a megameter. When the abscissa is referred to radial distance, the time is similarly indicated, usually at intervals of an hour. The legend at the top of the figure which includes the spacecraft's name and number also gives the date on which the figure was made.

REFERENCES

a. The Goddard General Orbit Determination System, J. W. Siry, J. P. Murphy and I. J. Cole, Goddard Space Flight Center Report X-550-68-218, May 1968.

b. AOPB Systems Manual Program Description R 104 Master Orbit Tape Routine, R. C. Jones, Goddard Space Flight Center Report X-542-66-291, February 1966.

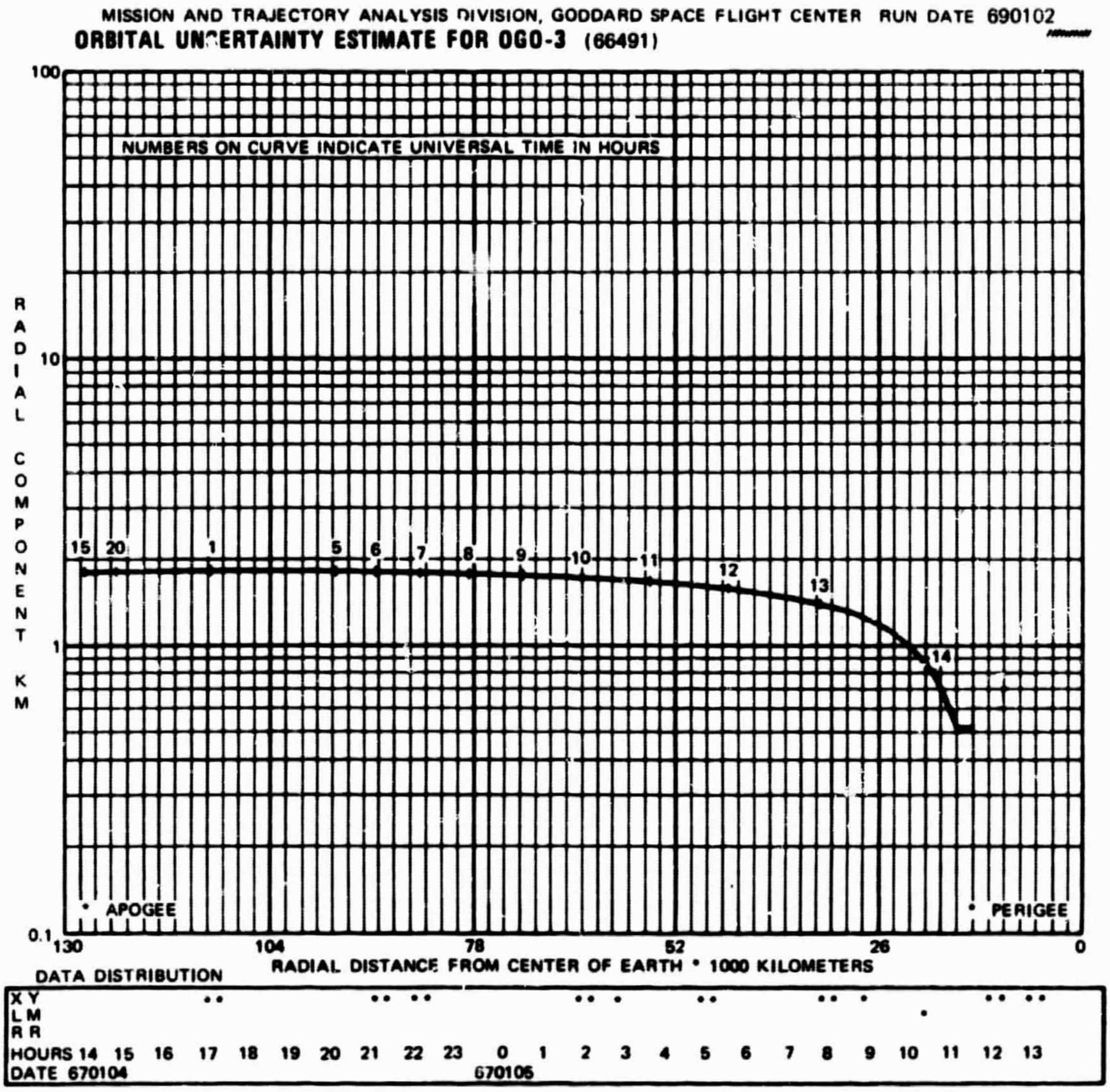

Figure 2. An Orbital Uncertainty Estimate for OGO III. The Radial Component is Shown.

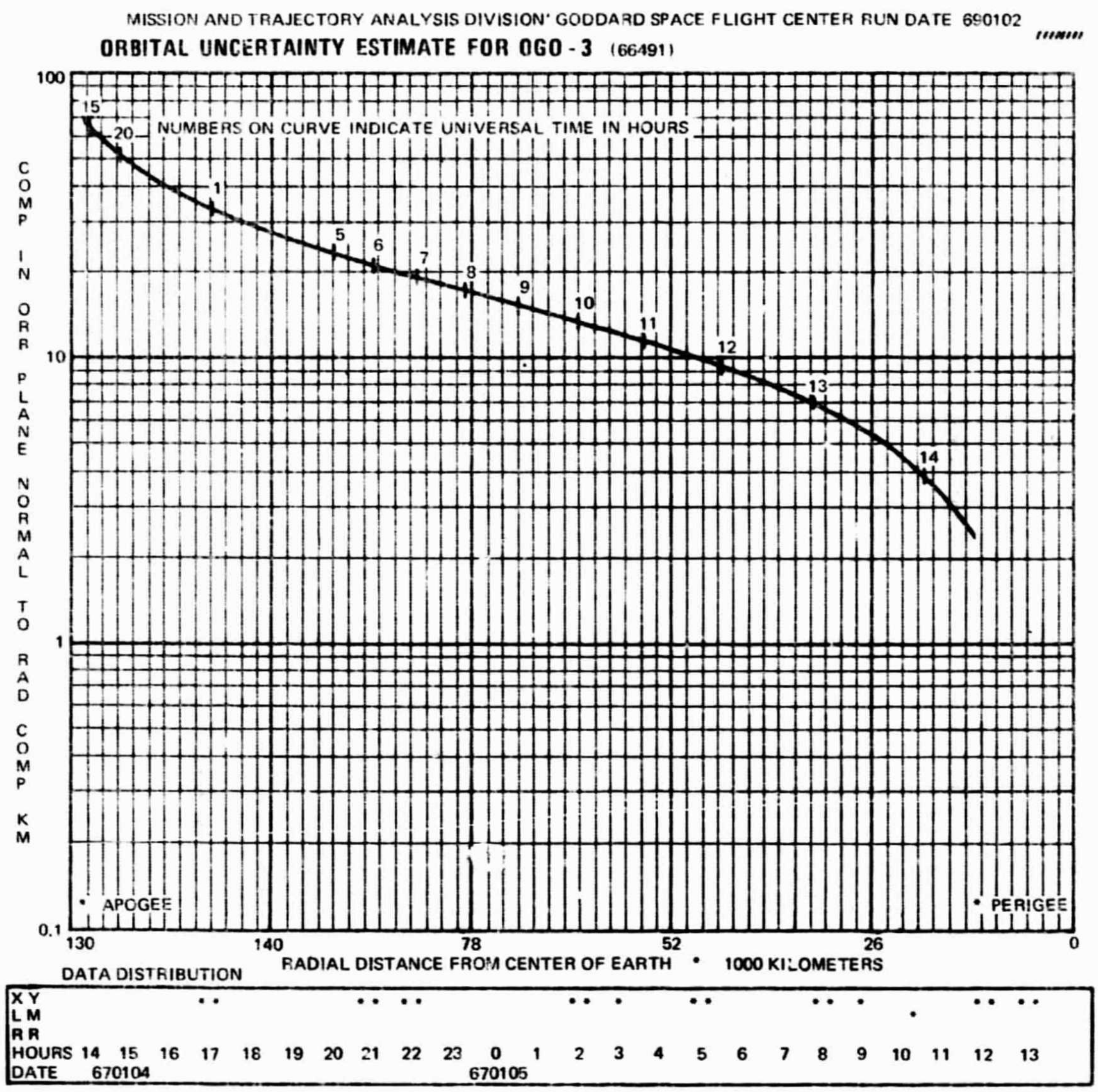

Figure 3. An Orbital Uncertainty Estimate for OGO III. The Component in the Orbital Plane Normal to the Radial Direction is Shown.

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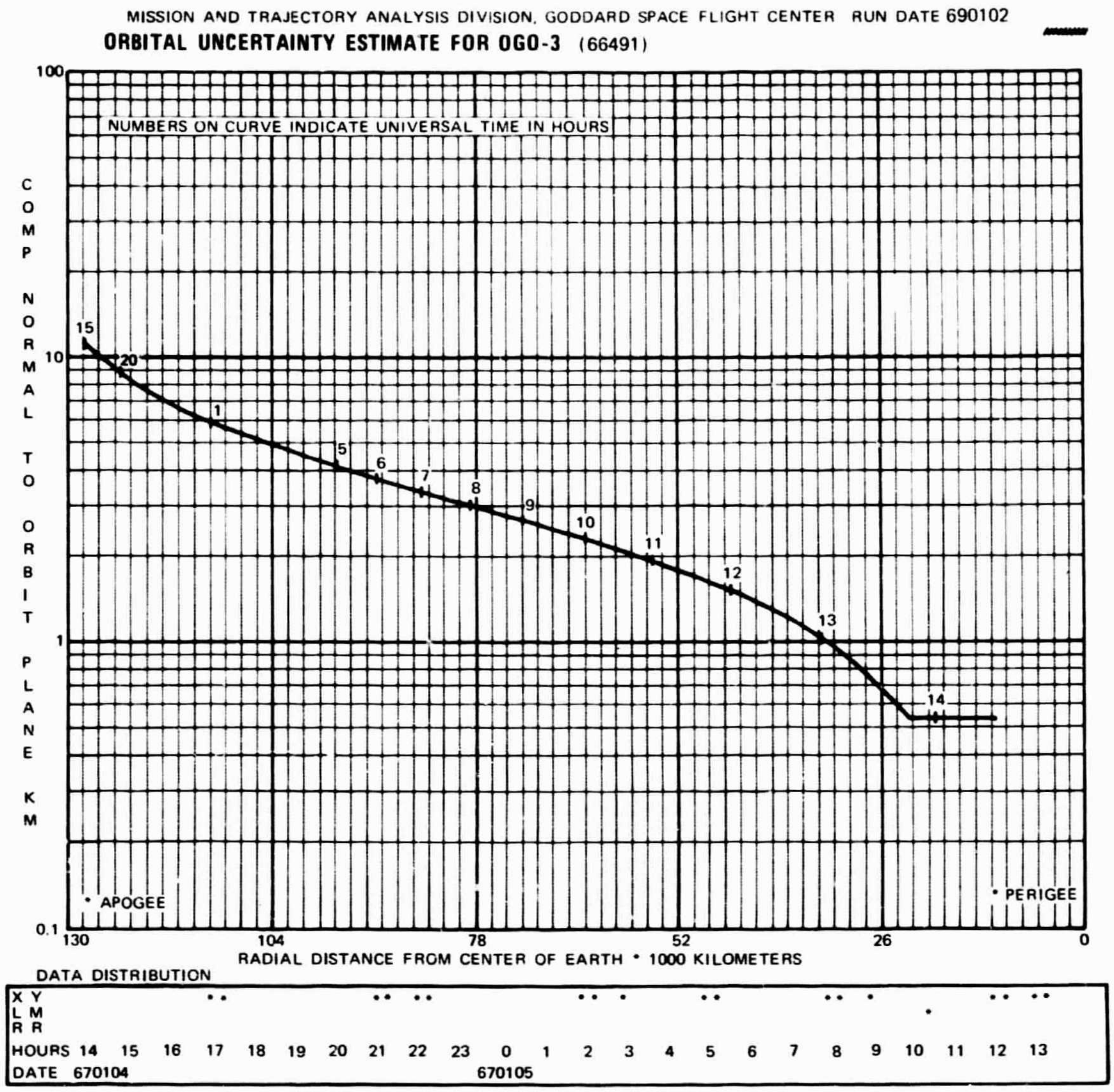

Figure 4. An Orbital Uncertainty Estimate for OGO III. The Component Normal to the Orbital Plane is Shown.

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