ERTS ORBIT MAINTENANCE

Arthur J. Fuchs

The ERTS orbit maintenance problem arises from the requirements on the ERTS spacecraft to repeat its orbit every 18 days to within a tolerance of ±18.5 kilometers for a one-year period, and to maintain the orbit in a sun-synchronous mode. In Figure 1 are the error sources that might cause the ground trace to drift outside of the tolerance bounds.

The ERTS requirements, particularly the ground trace requirement, are very sensitive to small errors in the orbit and the dynamic model. The first three items, uncertainty in orbit determination, orbit adjust performance errors, and dynamic model uncertainties, are very common. They give rise to errors in both knowing what the orbit is and in predicting the orbit drifts.

Let me dwell for a moment on the fourth item – the unmodeled errors. In designing an orbit maintenance procedure, we were concerned about a number of possible unmodeled errors, such as fuel leaks in the orbit adjust system, fuel leaks in the attitude control system, and uncoupled thrusts in the attitude control system. This last item turned out to be extremely important. One approach that we could have taken in maintaining the orbit was to choose the best dynamic model possible in the design of an orbit, that would satisfy the requirements for a one-year period, and to continually correct to this orbit if we drift outside our tolerances.

In light of the sensitivity of the requirements to small errors, we felt this procedure would require frequent corrections and we looked for another approach. In doing this we asked: Is there other information available that we may utilize? Another requirement that we have for the ERTS project is to determine the position of the spacecraft in its orbit very accurately for the ground data handling system, or specifically for the data processing facility. We made use of this information.

In Figure 2, the solid line on the lower portion of the curve represents the actual ground trace errors that the spacecraft experienced over the first 3½ repeat cycles. We've modeled

- UNCERTAINTY IN ORBIT DETERMINATION
- ORBIT-ADJUST SYSTEM PERFORMANCE ERRORS
- DYNAMIC MODEL UNCERTAINTIES
- UNMODELED ERRORS

Figure 1. ERTS requirements error sources.

these ground trace errors in terms of some key parameters, namely the mean semi-major axis and inclination and their rates of change. We fit the actual data to our model in a least squares sense, and deduce from the data the initial offsets to these key parameters as well as their rates of change. We can then extrapolate forward analytically what the drift in the ground trace is going to be in the future.

As you can see from Figure 2, the ground trace error rapidly exceeded the 18.5 kilometer tolerance. The value of da/dt = 2.79 (times the nominal semi-major axis decay) is interesting. The nominal decay is based upon our model of atmospheric drag, solar pressure, and so on. The actual data tell us that the spacecraft is experiencing a decay almost three times this value. Although in implementing this procedure it is not necessary to know the cause of the increased rate of change, this can be examined a posteriori. We now know that this dynamic behavior is due to the spacecraft attitude control system thrusting on a regular basis. How can we use this information?

In Figure 3, the solid line on the left is the same ground trace error of Figure 2 drawn to a different scale. Recall that the tolerance on this error is ±18.5 kilometers. We hypothesize that our best estimate of what the orbit is going to do in the future can be based on what

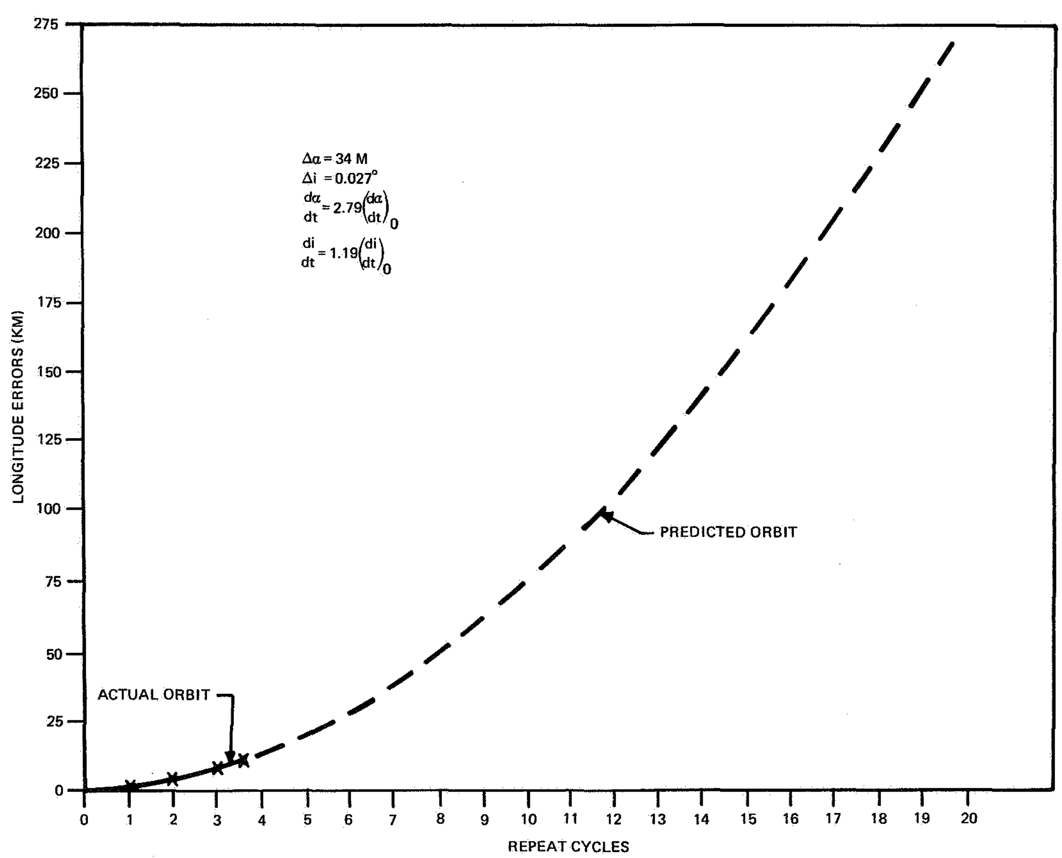

Figure 2. Orbit maintenance, least squares solution.

it has done in the past. By using the dynamic behavior determined over the actual part of the orbit, we can easily compute a correction to the orbit. This correction will reverse the error drift to keep our requirements within the ±18.5 kilometer bounds. Approximately one month prior to the time when the ground trace would have exceeded the bounds, we notified the ERTS Project of the drift and decided on a time to make a maneuver.

The curve which is labeled "best-estimate orbit" is an extrapolation of this correction, using the dynamic behavior deduced from the actual data in our analytic model. The curved solid line represents actual data points that have been determined since the correction was made. As you can see, we're tracking this curve very well. By implementing this procedure we feel that we can limit the frequency of corrections and the amount of fuel that we'll have to use in maintaining the ERTS orbit.

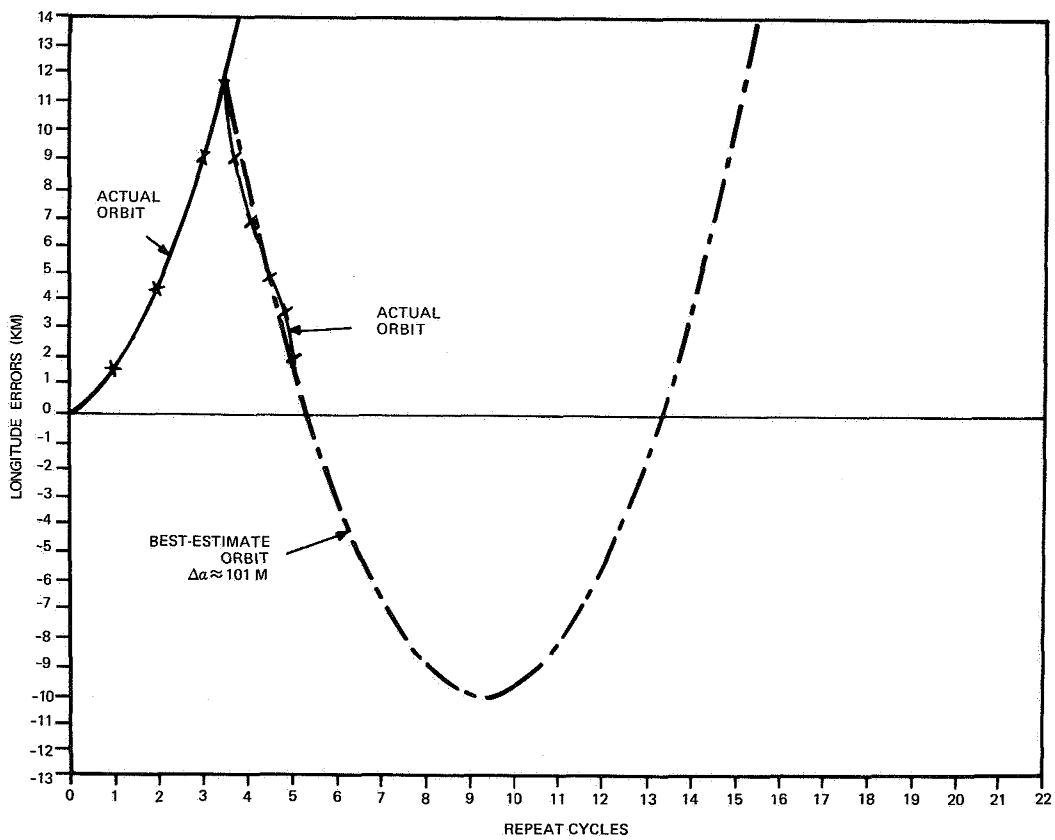

Figure 3. Actual and predicted ground trace history.