Orbit Analysis for Coastal Zone Oceanography Observations

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Theme

ORBITAL characteristics of a satellite dedicated to monitoring the coastal zone of the United States are analyzed in terms of the maximum frequency of coverage obtainable under various sun-lighting conditions. Orbits are defined that cover primarily the eastern seaboard with secondary coverage of the west coast because the eastern coastal waters face a greater pollution hazard[1] than the western coastal waters. These trajectory results in conjunction with the systems defined in previous studies[2-3] will be valuable to the development of a pollution monitoring satellite program.

Contents

There are several important parameters that must be considered in defining the orbit of a satellite dedicated to coastal zone observations. One of the key parameters is the inclination of the orbital plane to Earth's equatorial plane. Since the east coast is the area of primary interest, an inclination can be determined that has a ground track which, in general, follows the coastline. Because of the irregular shape of the coastline, various cities as shown in Fig. 1 were considered in the definition of the best inclination for observing the entire coast.

The swath width required to cover all 25 cities identified in Fig. 1 is illustrated in Fig. 2 as a function of inclination angle.

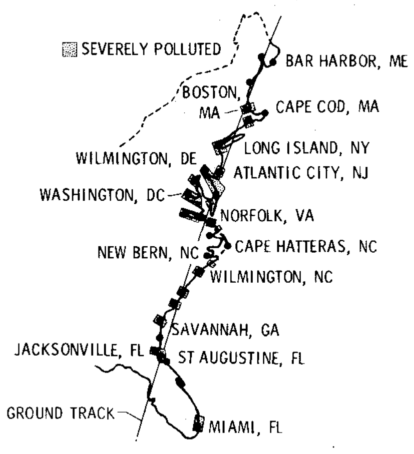

Fig. 1 Cities used to define the east coast.

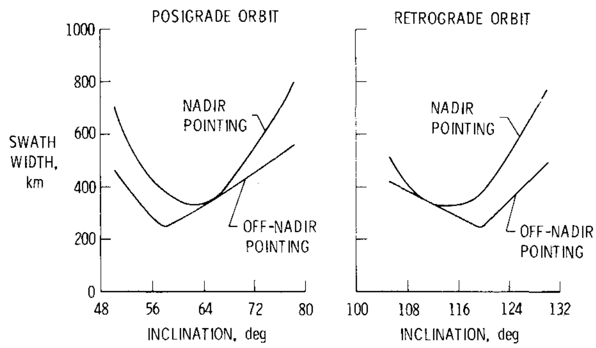

Fig. 2 Requirements for coverage of east coast in a single pass.

Consideration is given to both posigrade and retrograde orbits as well as nadir and off-nadir pointing. For nadir pointing, inclinations of 63° and 113° provided the minimum swath width requirement of 330 km. The required swath width can be reduced to 250 km by use of the off-nadir pointing which involves pointing the sensor off-nadir to the east in covering the southern cities, then near mid-latitude, say Cape Hatteras, switching to off-nadir pointing to the west for covering the northern cities. Reduction in swath width would provide the capability of reducing the orbital altitude for a given sensor system. Thus, the resolution could be improved in proportion to the reduced altitude.

Orbital altitude is also a critical parameter in the definition of the orbit cycle as illustrated in Fig. 3 for various inclinations. From consideration of practical limitations on altitude, the orbit repetition parameter, Q, ranges from $13\frac{1}{2}$ to $15\frac{1}{2}$ orbits/day. This means that a satellite will repeat its ground tracks every two days if $Q = 13\frac{1}{2}$ or $15\frac{1}{2}$ and repeat every day for $Q = 14$ or 15.

The combination of Q and inclination must be chosen to maximize the ground coverage for which good sun lighting conditions exist for optical measurements. Variation of the sun elevation angle at a representative site along the east coast is shown in Fig. 4 for three inclinations of interest. For inclinations

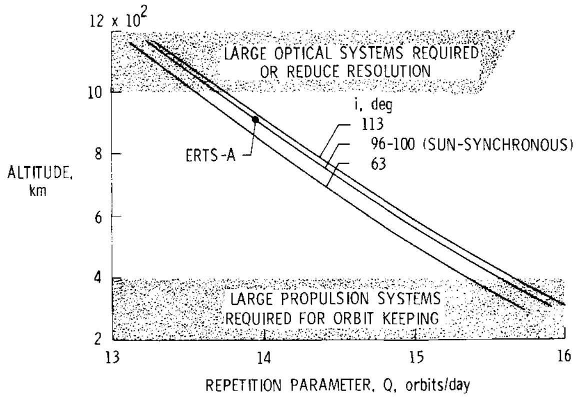

Fig. 3 Effect of altitude on orbit repetition.

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Index categories: Earth-Orbital Trajectories; Earth Satellite Systems, Unmanned; Atmospheric, Space, and Oceanographic Sciences.

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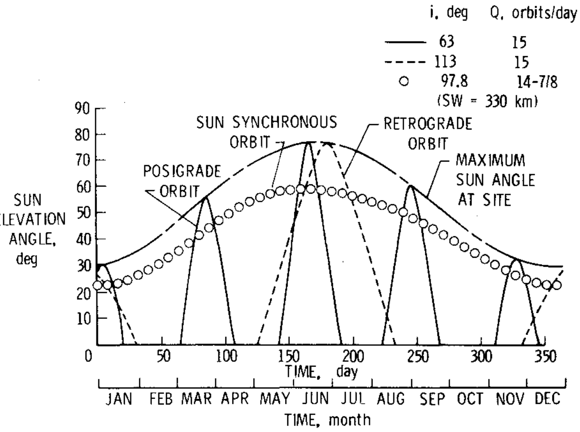

Fig. 4 Variations of sun elevation at Norfolk, Va.

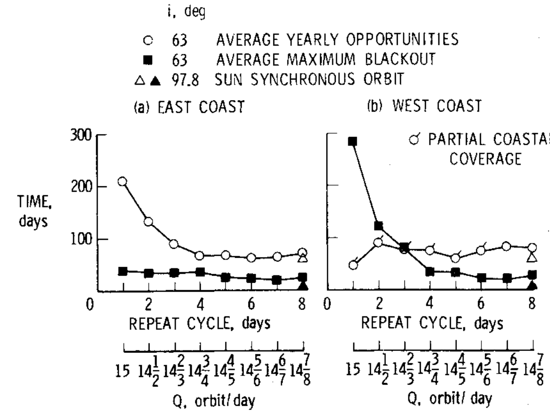

Fig. 5 Observability frequency of coastal zones ($sw = 330$ km, sun angle = 0 to 90°).

of 63° and 113° and a Q of 15, the satellite passes over the east coast daily, but at a different time each day. Consequently, there are periods of time for which sunlight opportunities do not exist. These are referred to as periods of blackout. The posigrade orbit ($i = 63°$) is characterized by five periods of ground coverage and five periods of blackout. The retrograde orbit ($i = 113°$) exhibits only two periods of coverage each year, each followed by a lengthy period of blackout. The difference in coverage for these two orbits is the result of the orbit nodal rate which is negative for the posigrade orbit and positive for the retrograde orbit. Also shown is the coverage obtained from a sun synchronous orbit. In this case the satellite passes over the site at the same time of day for each opportunity, but the orbit track does not follow the coastline since the inclination is 97.8°. As a result, this orbit repeats the ground coverage only every eight days. During specific seasons of the year, it is desirable to have a series of opportunities or consecutive days since observability will be reduced due to cloud cover. The nonsynchronous ($i = 63°$ and 113°) orbits, therefore, are more applicable to east coast coverage than the synchronous orbits.

The effect of repeat cycle and Q on the frequency of coverage and blackout period for both the east and west coasts are presented in Fig. 5. The coastlines were defined by a number of representative cities and the days of observations and periods of blackout were averaged. These averages clearly indicate that the best repetition parameter for the east coast is $Q = 15$ (daily repeat cycle). As the repeat cycle is extended to eight days, less coverage for the east coast is obtained. However, for all points on the west coastline to be covered from the orbit and swath width designed for the east coast, the repeat cycle must be seven days or greater. The coverage provided for the west coast is only slightly greater than that from sun sychronous orbit and is considerably less than that obtainable for the east coast with a daily repeat cycle ($Q = 15$). Both the east and west coasts could, however, be accommodated by applying a small impulsive velocity ($\simeq 20$ m/s) to change the altitude and thus Q from 15 to $14\frac{7}{8}$. This would enable the satellite to cover the east coast until a blackout period and then shift for better coverage of the west coast.

References

[1] "National Estuary Study," Vol. 1, U.S. Dept. of Interior Fish and Wildlife Service, Washington, D.C., Jan. 1970,

[2] Adams, D. A., et al., "Advanced Study of Coastal Zone Oceanographic Requirements for ERTS E & F," CR-111823, 1971, NASA.

[3] Gerding, R. B., et al., "Coastal-Zone Oceanographic Requirements for Earth Observatory Satellites A & B," CR-111816, 1971, NASA.