# Letters to the Editor

551.507.362.2(213)

## A CONCEPTION OF AN EQUATORIAL ORBITING METEOROLOGICAL SATELLITE FOR THE TROPICS

A polar-orbiting meteorological satellite (*e.g.,* NOAA-6, which is now operational) passes over the polar regions once in each orbital revolution, but views any given tropical area only twice in 24 hours. Considering the time scales of tropical weather events, two APT/HRPT pictures received per day can have only a limited use as a forecasting aid. Geostationary satellites, which provide pictures at intervals of 30 minutes or less, are ideal for this purpose, but geostationary imagery cannot be obtained in the simple and inexpensive manner of the APT (Ensor 1978).

Physical considerations impose a finite limit on the number of geostationary satellites, meteorological and others, which can be placed in geostationary orbits. This limit is so low that even if the developing countries of the tropics were to mobilise resources for putting up their own geostationary satellites, as India plans to do, they would face a shortage of "parking space".

Keeping the needs of such countries primarily in view, this paper envisages a meteorological satellite in a type of orbit not hitherto used, *viz.,* a non-geostationary equatorial orbit having zero inclination and eccentricity. This satellite will cover the entire tropical belt during one orbital revolution, enabling countries within it to receive APT pictures of their region of interest much more frequently than it is now possible with polar-orbiters. Since only a single equator orbiting spacecraft can satisfy the requirements of a large number of countries the cost-benefit ratio would work out very low.

2. While designing an orbit for the equatorial orbiting meteorological satellite (EOMS), the foremost consideration is to get satellite pictures of the tropical areas as frequently as possible. This calls for a reduction in the orbital period, $T$,

for which the altitude $h$ must be reduced, but when the satellite is nearer to the earth, it can view a relatively smaller area of the earth's surface. In order to design an orbit for EOMS which would be an acceptable compromise in this regard, several possibilities were considered.

We first define :

(*a*) Earth-Scan Angle, ESA, as a certain limiting angle about the nadir, beyond which the data are not acceptable.

(*b*) Earth-Scan Boundary, ESB, as the limiting north/south latitude viewed by the satellite as determined by ESA. ESB can be increased by increasing either $h$ or ESA upto a certain limit imposed by line-of-sight considerations.

(*c*) Turn-Around Time, $T_p'$, or $T_r'$, as the interval between the two successive passes over a given place on the equator, with the suffixes $p$, $r$ representing prograde and retrograde orbits respectively. It is easy to show that :

$$T_p' = T + T^2/(1440 - T) \text{ and } T_r' = T - T^2/(1440 + T)$$

3. To begin with, a value of 55.4 was chosen for ESA. This is the same as that of the AVHRR of the TIROS-N series (Schwalb 1978). For this ESA, latitudes beyond 34.6° N/S will be outside the line of sight of the EOMS scanning radiometer. ESB can thus have a maximum value of 34.6° which covers the entire tropical belt. The altitude and the orbital period of the satellite were computed as 1370 km and 113 min respectively, with $T_p'$ and $T_r'$ as 122.6 and 104.8 min respectively. This procedure was repeated with successive reductions in ESB, *viz.,* 30, 20, 10. This means that the satellite views smaller and smaller widths of the tropical belt, but with an increased number of orbits per day and higher image resolution. For ESB=10, 24 major tropical countries would be viewed; for ESB = 20, an additional 23 and for ESB = 30, all the 59 (Table 1).

**TABLE 1**

Major tropical countries falling within EOMS Earth-Scan

| ESB | Latitudes scanned | Asia and Australia | Africa | Central & South America |
|---|---|---|---|---|
| 10 | 10° N to 10°S (Zone 1) | Sri Lanka, Malaysia, Indonesia, Papua, New Guinea, Philippines | Ghana, Nigeria, Chad, Central Africa Rep., Angola, Zaire, Sudan, Ethopia, Somali Rep., Kenya, Uganda, Tanzania. | Panama, Venezuela, Columbia, Ecuador, Peru, Brazil, Guyana. |
| 20 | 20° N to 20° S (Zone 2) | Countries in Zone 1 and Saudi-Arabia, Yemen, Oman, India, Burma, Thailand, Kampuchea, Vietman, Fiji, Northern Australia. | Countries in Zone 1 and Senegal, Mali, Niger, Zambia, Malawi, Mozambique, Malagasy, Nambia. | Countries in Zone 1 and Guatemala, Nicaragua, West-Indies, Honduras. |
| 30 | 30° N to 30° S (Zone 3) | Countries in Zone 2 and Iran, Pakistan, Nepal, Bangladesh, China, southern Australia. | Countries in Zone 2 & Algeria, Libya, Egypt. | Countries in Zone 2 and Cuba, Chile, Argentina, Paraguay. |

Several more sets of computations were carried out with different values of ESA (45, 50) and ESB (10, 20, 30, 40). It is seen that $T_r'$ is substantially less than $T_p'$, the difference ranging from 13 to 28 minutes in the various cases examined. Therefore, a retrograde orbit is to be preferred for EOMS.

Among the retrograde orbits, the lowest turn-around time of 1 hour 31.8 minutes corresponds to ESA $= 55.4$, ESB $= 10$ and $h = 666$ km. This orbit will cover only about 24 countries situated in the latitude belt from 10° S to 10° N (zone 1) but would provide 16 pictures a day. The highest turn-around time (retrograde) of 2 hours 8.5 minutes corresponds to ESA$=45$, ESB$=40$ and $h = 2603$ km. This will cover not only all the tropical countries but also those a little outside the tropical belt. However, only 11 pictures a day can be received. Here as well as in the following discussion, the number of pictures refers to I-R pictures. It is obvious from illumination considerations that the corresponding number of visible pictures will be smaller.

It appears that the optimum orbit would be with ESA$=50$ and ESB$=30$ with $h=1819$ km and $T_r' = 113.3$ min. This would fully cover zone 3 (30°N-30°S) with 12.7 pictures a day.

If ESB $='40$, $h = 1947$ km, $T_r' = 115.8$ min, one could get 12.4 pictures a day. Either of these orbits or an intermediate orbit could be adopted depending upon how much extra-tropical coverage is desired.

4. Since satellites like EOMS are not in existence, it is difficult to comment upon its technological feasibility, nor is it the objective of this study. However, no insurmountable problems are anticipated.

The need for EOMS arose primarily from meteorological considerations. However, it has great potential for other applications like communications and earth resources survey.

5. The authors are greatly indebted to Dr. P. K. Das, Director General of Meteorology, for kindly going through the manuscript.

**References**

Ensor, G. J., 1978, "User's Guide to the operation of the NOAA Geostationary Satellite System", NOAA/NESS, 101 pp.

Schwalb, A., 1978, "The TIROS-N NOAA A-G Satellite Series", NOAA Tech. Memo NESS 95, 75 pp.

R. R. KELKAR

SANT PRASAD

P. N. KHANNA

*India Meteorologcial Department, New Delhi*
*14 September 1981*