Chapter Five

Resolution of Space Objects

Regardless of the cost and number of years under development, optical satellite systems must abide by the laws of physics. There are limits to the resolving power of optics which are derived from calculations involving the camera apertures and the observed objects themselves.

The limiting magnitude for any telescope is defined as:

$$m = 2.7 + 5 \log D$$

where D is the diameter of the aperture in millimetres. Thus, the limit for a GEODSS system with a mirror of 1-metre diameter will be m = 17.7, sufficient to resolve most satellites.[15]

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Another factor for consideration is the smallest resolvable angle, which is defined as:

$$\phi = 120/D$$

where ϕ is given in seconds of arc. For the same GEODSS system, therefore, this angle will theoretically be about 0.12 seconds of arc. However, ϕ is limited also by the Earth's atmosphere which sets this ground-based limit at about 0.5 seconds of arc.

As an example, let us consider the case of Molniya 1, Flight 20, which is a communications satellite launched from Plesetsk on April 4, 1972. Its perigee is at a height of 480 km, and it has an apogee of nearly 40,000 km. The satellite is a cylinder 3.5 by 1.7 metres, with several "paddle wheel" solar arrays and two dish antennas. Let us assume it presents a 3-metre face towards a GEODSS station. We can calculate its angular diameter by using the relation:

$$d/h = \tan \phi$$

where d is the diameter of the satellite, h is its altitude and ϕ is its angular diameter, in degrees. When d is 3 m and h is 1,000 km, ϕ is 0.00017 degrees or 0.6 seconds of arc. This is within the capability of the GEODSS system defined in the example.

As a further example, let us use a reverse situation. Consider the "Big Bird" reconnaissance satellite of the United States. It is reportedly capable of a ground resolution (from orbit) of 150 mm. At the smallest resolvable angle, therefore, where ϕ is 0.5 seconds of arc, the altitude can be calculated to be a *maximum* of 61 km. This is obviously too low, since the maximum altitude of the Big Bird satellite is known to be about 150 km, and its perihelion cannot be 61 km as that would place it within a dense region of atmosphere. However, even for an altitude of 100 km, the resolution will be near 0.25 metres, still a respectable value (of the order of 10 inches).[16]

15 The limits discussed in this section are approximate values only and dependent on many variables. In general, the smallest resolvable angle is merely the wavelength divided by the aperture. Basic sources for these data include various astronomical publications, for example the *Observer's Handbook* of the Royal Astronomical Society of Canada (1983). Other sources are: Lambeck, K. "Probability of Recording Satellite Images Optically", *SAO Special Report*, no. 230, 1966; McCue, G.A., Williams, J.G. and Morford, J.M. "Optical Characteristics of Artificial Satellites", *Planetary and Space Science*, V. 19, 1971, pp. 851-868; and Veis, G. "Optical Tracking of Artificial Satellites", *Space Science Reviews*, V. 2, 1963, pp. 250-296. Curiously, one of the more useful sources on detection and resolution is Ayer, F. "Instrumentation for Unidentified Flying Object Searches", *in*: Gillmor, D.S., ed. *Final Report on the Scientific Study of Unidentified Flying Objects*, Bantam Books, N.Y., N.Y., 1969, pp. 761-804.

16 Information on USAF photoreconnaissance satellites and their Russian counterparts comes from: Bamford, J. *The Puzzle Palace*, Penguin, N.Y., N.Y., 1983; Brown, N. "Military Uses of Satellites", *in*: Fishlock, D., ed. *A Guide to Earth Satellites*, Elsevier, N.Y., N.Y., 1971, pp. 121-133; Canan, J. *War in Space*, Berkley Books, N.Y., N.Y., 1984; Clark, P.S. "Soviet Photoreconnaissance Satellites", *Spaceflight*, V. 25, no. 6; Karas, T. *The New High Ground*, Simon & Schuster, N.Y., N.Y., 1983; and Smolder, P.L. *Soviets in Space*, Butterworth Press, Guildford & Landon, 1973. In addition, the yearbooks of TRW Space Systems in California have provided ample data for consideration.