possible to obtain an extremely accurate plot of the orbit. (Cosmos 387 was launched from Plesetsk as an unannounced payload; its visual magnitude of m = 6 makes it a relatively easy object to track.)[10]

Optical tracking stations have enabled the compilation of lists of satellites and their magnitudes. In turn, extrapolation and analyses of these lists have been used to identify the shapes and sizes of satellites under observation; this has permitted the determination of detailed information on secret and otherwise unannounced payloads. For example, observation of the "flash rate" gives information on the tumbling of rocket bodies, which has allowed the histories of many satellites and/or their rockets to be accurately traced. Such data are the guide by which successes and failures of satellite missions, whether announced or unannounced, can be determined. Accuracies in orbital determination using visual observations tend to be in the range of only a few metres.

One widely-published photograph clearly showed the "hammerhead" appearance of Sputnik 2, although it was taken with a 24-inch tracking telescope with a 500-inch focal length that managed to capture the satellite at a range of 200 miles.[11] The photograph was taken in 1957 with a purely optical system. Satellite measurements and imaging systems in the 1980's are much more sophisticated.

Chapter Four

Ground-Based Electro-Optical Deep Space Surveillance (GEODSS)

During the 1960's, it became apparent to individuals involved in satellite tracking that there were inherent problems with conventional tracking systems. Radar was either of insufficient resolution or of too short a range to satisfy upcoming program requirements for the greatly detailed surveillance of satellites. Similarly, optical systems had insufficient accuracy, sensitivity and speed. A major problem with optical systems was their inability to cope and function in real-time. But in the 1970's, with developing silicon diode technology and the dawn of the age of micro-processors, several laboratories were assigned the task of designing a *real-time* photoelectric system for satellite tracking. A design was accepted in 1974, and in September 1975, an experimental test site was put into operation at the White Sands Missile Range near Socorro, New Mexico. It was the first station in the GEODSS program developed by the USAF Systems Command. In 1979, the cost of installing a network of five sites was set at $62 million. The second and third sites are at Taegu, South Korea, and on Mount Haleakala, on Maui, Hawaii. A fourth site is presently being installed on the island of Diego Garcia in the Indian Ocean. Construction on a fifth site is expected to begin by 1985 "somewhere along zero degrees longitude in the eastern Atlantic", possibly in Portugal or on Ascension Island. (Original plans for the fourth and fifth GEODSS sites had called for installation in Iran and Morocco.)[12] The GEODSS system was given five major missions: 1) initial detection, 2) tracking, 3) catalog maintenance, 4) collection of

10 Many studies of individual satellites have been published in the journal *Planetary and Space Science*. In particular, King-Hele and Pilkington have performed detailed analyses of optical tracking. See King-Hele, D.G., "Analysis of the Orbit of Cosmos 387 (1970-111A). Near 15th-order Resonance", *Planetary and Space Science*, V. 22, pp. 509-524; and Pilkington, J.A. "The Visual Appearance of Artificial Satellites", *Planetary and Space Science*, V. 14, 1966, pp. 1281-1289.

11 Published by Stine, G.H. "How the Soviets Did It In Space", *Analog*, V. 81, no. 6, Aug. 1968, pp. 48-71.

12 Details on the operation and development of the GEODSS system have been presented in a large number of publications. A good, readable summary is given by Beatty, J.K. "The GEODSS Difference", *Sky and Telescope*, V. 63, no. 5, pp. 469-473. Another important source is: Smith, B.A. "Ground-Based Electro-Optical Deep Space Surveillance System Passes Reviews", *Aviation Week and Space Technology*, 27 Aug. 1979, pp. 48-53. A considerable number of documents have been released by MIT's Lexington Lincoln Laboratory, Electronic Systems Division, at Hanscom AFB. A good review at a semi-technical level is given by Weber, R. "Passive Ground-Based Electro-Optical Detection of Artificial Earth Satellites", *Optical Engineering*, V. 18, no. 1, 1979, pp. 82-91. Specific MIT technical reports relevant to GEODSS, used as references to the following discussion, are: ESD TR-77-125; 78-33; 78-270; 79-277; 79-326; and 79-350.