Chapter Two

Photographic Observations of Satellites

The Baker-Nunn camera was developed at about the same time as the MOONWATCH program. Its optics were designed by James G. Baker who was the inventor of the Super-Schmidt meteor camera. The mount and drive were developed by Joseph Nunn. Twelve such cameras were produced by the Perkin-Elmer Corporation of Connecticut and installed in locations around the globe. The first became operational in New Mexico, in November 1957, a full month after Sputnik 1 was launched. For that month, orbital data were available only through MOONWATCH stations. It is probably this fact that spurred the rapid development of satellite tracking technology in the following years.

Baker-Nunn systems are best suited for detecting high-altitude satellites, up to 40,000 km or more. Because of this, they complement radar tracking systems which are restricted to altitudes of less than 7,000 km. Baker-Nunn cameras are passive systems detecting the reflected light of satellites against the background of stars. Once a general set of coordinates is identified, a photograph is taken. The objects on the photograph are compared with a star chart using an overlay, and a satellite's position is noted. Successive photographs can determine the orbit of the satellite to within about 30 seconds of arc and in some cases to 2 or 3 seconds of arc. The position of the satellite is reported to the Space Defense Center so that the NORAD computer catalog can be updated.[5]

The major problem with the Baker-Nunn system is that the time required to develop the film may be as long as 90 minutes. That is certainly inadequate for rapid tracking and orbit determination since some satellites can change orbit in a shorter time. Ideally, information should be available in a time frame much closer to real-time to permit early warning of sudden orbit changes.

The limiting magnitude (i.e. the faintest apparent magnitude that may be observed) of the Baker-Nunn camera is also relevant to its capability for satellite tracking. This limiting magnitude is dependent on several variables, including zenith distance, the angular velocity of the photographed object, its visual magnitude and the sensitivity of the film emulsion. Another factor is the exposure time, which is inversely related to the magnitude. For an exposure at one second as a standard, the visual magnitude varies between $m = 12$ and $m = 14$, depending on the film used, which at many stations was Kodak Royal-X Pan.[6]

Most satellites have magnitudes averaging about $m = 14$, and they therefore fall within the range of the Baker-Nunn system. (The limiting magnitude for the human eye is about $m = 7.5$.)

5 Various studies of the Baker-Nunn system have been published. For example, see Solomon, L.H. "Some Results at Baker-Nunn Tracking Stations", *SAO Special Report*, no. 244, 1967.

6 A rather thorough description of optical and photographic tracking systems can be found in Veis, G. "Optical Tracking of Artificial Satellites", *Space Science Reviews*, V. 2, 1963, pp. 250-296.