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Chapter 21

Artificial Satellite Observations and Their Scientific Usage in Czechoslovakia*

Ladislav Sehnal†

Abstract

The first artificial satellite observations concerned the transmission of the radio signals from the Soviet *Sputnik* satellite. The Institute of Radiotechnics and Electronics in Prague recorded the radio data and the Astronomical Institute supplemented this with Doppler determinations of the satellite's position. These visual observations joined a set of observational data, from which the first determination of the oblateness of Earth was made (with the results published in *Nature*). Visual observations were quickly made and easily analyzed. However, they revealed the absence of precise time measurements as a principal drawback to satellite position determinations. Progress came with construction of four axially mounted cameras, which had a focus of 50–100 cm. The Soviet Academy of Sciences supplied the cooperating countries with AFU-75 cameras and the Carl Zeiss Jena-developed SBG cameras. Groups of these movable cameras made a useful and relatively accurate satellite observation net. The use of photographic

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† Astronomical Institute, Czech Academy of Sciences, Czech Republic. [**Editor's note**: Dr. Sehnal passed away 26 October 2011, without providing a final complete version of his conference paper. This chapter has therefore been prepared using the partial paper and PowerPoint presentation he had previously provided and was never reviewed by the author prior to publication. Any errors of fact or interpretation are therefore the responsibility of the editor.]

cameras as the main devices for satellite position determination came to an end when laser ranging offered a new and precise method of satellite positioning.

In the early 1970s, there was a rapid growth in the number of stations, and also the quality of satellite laser ranging. The first satellite laser ranging device in Eastern Europe was put into operation at the Ondřejov Observatory in 1973. Most of the main parts of the instrumentation were manufactured in the former Czechoslovakia, which enabled a rapid increase in the number of observing sites with laser-ranging systems. Observed satellite positions were used for satellite orbit analysis, and especially for the analysis of orbital perturbations. The main interest was devoted to the disturbing effects of non-gravitational forces, especially the study of atmospheric perturbations. The final goal was aimed at the construction of models of thermospheric density distribution and changes. Even though the laser data brought in a large quantity of relatively accurate data sets, the necessity for in-situ measurements was increasingly felt. A new push came with construction of micro-accelerometers, which determined drag acceleration directly by in-orbit measurement of the displacement of drag-free masses in a closed space.

In Czechoslovakia, such a device was put into operation in 1993 and built according to the construction of the French D5B satellite. The experiment used a Soviet satellite, on which the Czech micro-accelerometer was mounted. This was followed by a very successful experiment with a cubic accelerometer on board the Space Shuttle *Atlantis* in 1996.

Introduction

The principal astronomical organization in the former Czechoslovakia was the Astronomical Institute, part of the centralized scientific institutions of the Czechoslovak Academy of Sciences. Its main observatory was the Ondřejov Observatory (located near the village of Ondřejov, 35 km southeast of Prague). This institute had a long tradition in astronomy, especially in the areas of celestial mechanics and theoretical astronomy, although it suffered from the lack of large observing instruments.

Immediately after the launch of the first Soviet satellite, *Sputnik-1*, the Institute of Radiotechnics and Electronics in Prague recorded the transmission of radio signals from the satellite. This radio data was supplemented by Doppler determinations of the satellite's position, undertaken by the Astronomical Institute.

Exploiting the Observation of Artificial Satellites

The Astronomical Institute took part in the exploitation of the observations of *Sputnik-1* and its successors. Other astronomical institutions (researchers, observatories, radio institutions, et cetera) also made their contributions to position measurements of these new man-made bodies. (The background for these endeavors was the previous Czech observations of meteors.) To assist with the satellite observations, the Soviet Academy of Sciences made a gift to the Czechoslovak Academy of Sciences of 50 telescopes specially designed for satellite observations (Figure 21–1). The results of these observations were published in various professional publications.

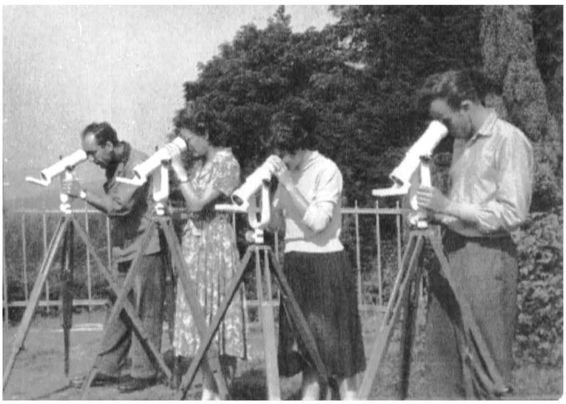

Figure 21–1: A group of astronomers observing the third Soviet satellite (*Sputnik-3*), using special satellite observing telescopes donated by the Soviet Academy of Sciences.

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$1957\alpha_1,\alpha_2$, 1957β a $1958\delta_1,\delta_2$

The Visual Observations of Artificial Satellites
$1957\alpha_1,\alpha_2$, 1957β and $1958\delta_1,\delta_2$

Edited by V. [illegible] and L. [illegible]

NAKLADATELSTVÍ ČESKOSLOVENSKÉ AKADEMIE VĚD
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Figure 21–2: Cover of an Astronomical Institute publication detailing satellite observations for 1957 and 1958.

Astronomers, geodesists, and electronics specialists made some interesting contributions toward the practical exploitation of their experiments and observations. The most important contribution was made by Emil Buchar, Professor of Astronomy and Geodesy at the Prague Technical University. As early as 1958, he made the first determination of the oblateness of Earth based on the space data derived from satellite observations, and he published his results in *Nature* in the same year.

It was obvious that the professional exploitation of artificial satellite observations would need a vast international cooperative effort. Therefore a "Commission of the Academies of the Socialist Countries for the Scientific Usage of Artificial Satellites" was founded in Moscow in 1961. This commission held its annual meetings in different socialist countries, even outside Europe. (For example, meetings were held in Erevan and Ulan Bator.) The commission was chaired throughout its life by Professor A. G. Massevich. The commission not only held organizational and scientific meetings, but also published the proceedings of its scientific deliberations as the issues of *Observations of the Artificial Satellites of the Earth* (in Russian).

Figure 21–3: Cover of an issue of *Observations of the Artificial Satellites of the Earth* published in Czechoslovakia.

The commission for satellite observations was later included in the Interkosmos cooperation in 1966, as its Fourth Section.

Photographic Satellite Observations

Visual observations were quickly made and easily analyzed. However, they revealed the absence of precise time measurements as a principal drawback to satellite position determinations. Therefore, visual satellite observations were soon replaced by the use of photographic techniques. Accurate time measurements created difficult and new astronomical problems, and many technical solutions were tried in developing cameras that had to cope with faint and fast-moving celestial objects.

Progress came with construction of four axially mounted cameras, which had a focus of 50–100 cm. The Soviet Academy of Sciences supplied the cooperating countries with AFU-75 cameras, which had a 75 cm focus and a movable focal plane, and the Carl Zeiss Jena-developed SBG cameras. Groups of these movable cameras made a useful and relatively accurate satellite observation network. The cameras were capable of observing fast-moving bodies of the tenth magnitude. All the observations were centrally collected in the Astrosoviet in Moscow.

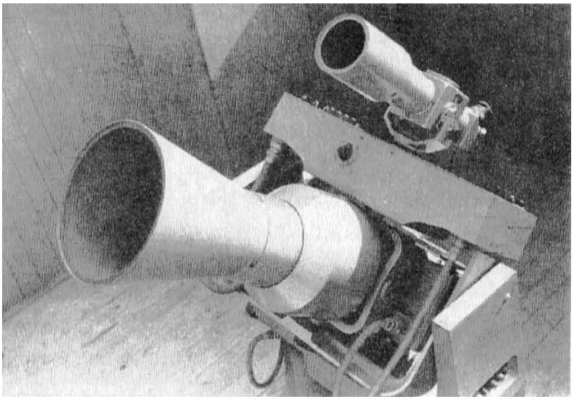

Figure 21–4: The AFU-75 camera, capable of taking images of faint satellites, installed at the Ondřejov Observatory in 1968.

Laser Ranging

The use of photographic cameras as the main devices for satellite position determination came to an end when laser ranging offered a new and precise method of satellite positioning. The first satellite laser ranging device in eastern Europe was put into operation at the Ondřejov Observatory in 1973. Range measurements were performed with an accuracy of 1.5 m. Several models of this instrument were built until the year 2000.

In the early 1970s, there was rapid growth in the number of stations, and also the quality of satellite laser ranging. In Czechoslovakia, laser radars achieved a fast technical perfection and most of the main parts of the instrumentation were manufactured within the country, which enabled a rapid increase in the number of the observing sites with laser ranging systems.

The group of people working on laser radars at the Czech Technical University was headed by Professor K. Hamal. As the technical development of the instruments proceeded rapidly, the first laser radar for another country was supplied to Borowiec in Poland; many new instruments of this kind were built for use in foreign countries. Satellites to be used for laser ranging must have onboard special corner cube reflectors. The first satellite equipped with such reflectors of Czech origin was Interkosmos 17.

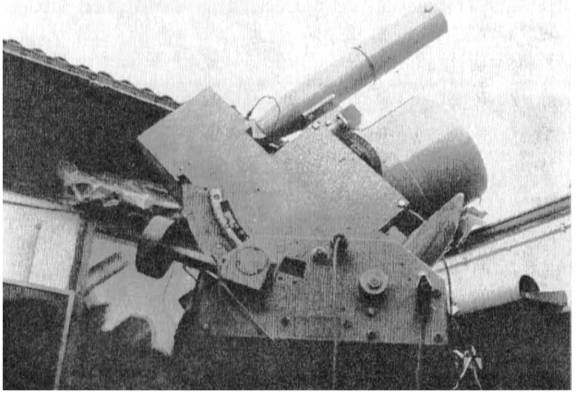

Figure 21–5: The first satellite laser radar used at the Ondřejov Observatory, 1972–1975. It became operational in 1973.

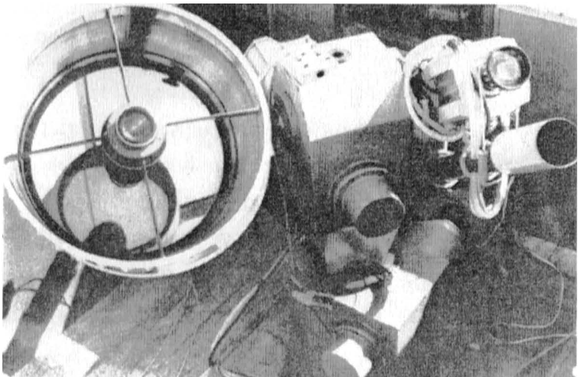

Figure 21–6: A new, automatically guided satellite laser radar, put into operation in 1980.

Among those laser radars observing the artificial satellites, the station at Helwan served as a principal site for technical improvements and general development. The accuracy of the ranging measurements reached the millimeter level, and the Helwan station was known as one of the best satellite-ranging facilities.

The theoretical background for satellite tracking (the satellite ephemerides) was initially determined from the two line elements. Later, however, the orbital elements were determined directly from the laser observations themselves.

Scientific Analysis of the Observational Data

The observed satellite positions were used for orbit analysis, and especially for the analysis of orbital perturbations. Satellites in low Earth orbits suffered strong perturbations at specific intervals in their lives, caused by orbital resonance effects. Great perturbations can be observed in changes of orbital inclination, from which, by backward analysis, special sets of gravity coefficients can be derived.

The main interest was the analysis of the disturbing effects of non-gravitational forces (solar radiation pressure, electromagnetic forces, et cetera) and especially the study of atmospheric perturbations. The final goal was aimed at the construction of models of thermospheric density distribution and changes.

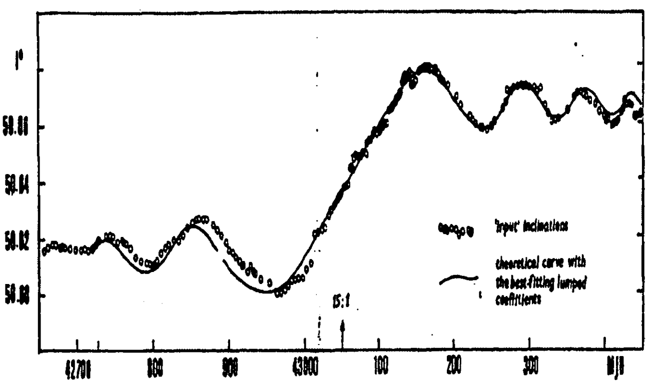

Figure 21–7: Resonance effects on satellite orbits.

Space-Based Experiments

Even though the laser observations brought in a large quantity of relatively accurate data sets, the necessity for in-situ measurements was increasingly felt. A new push came with construction of micro-accelerometers, which determined drag acceleration directly by the in-orbit measurement of the displacement of drag-free masses in a closed space. In Czechoslovakia, such a device was put into operation in 1992 and built along the lines of the French D5B satellite. The experiment flew on the Russian Resurs F-1 satellite (launched 23 June 1992), on which the Czech micro-accelerometer was mounted. This was followed by a very successful experiment with a cubic accelerometer on board Space Shuttle *Atlantis*, during the STS-79, in September 1996. The instrument provided data for calculating the Shuttle's trajectory in the critical part of its journey before it docked with the Soviet space station *Mir*.