VISUAL TRACKING OF ARTIFICIAL SATELLITES AT THE UNIVERSITY OF THE PHILIPPINES

Foreword

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Satellite tracking in the 60s, earth observation today.

In 1958, one year after Sputnik was launched by the Russians, a world-wide group of volunteer observers was formed into 240 teams for the MOONWATCH PROJECT—when the USA had to track the satellite it had also launched to ensure that it is maintaining its orbit. It was directed by the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts in observance of the International Geophysical Year. Reports were immediately sent by telegram right after observation. Detailed and complete written reports were sent as well to Cambridge thru the post.

The Philippine team was composed of 24 volunteers from UP College of Engineering, mostly from the Department of Geodetic Engineering; it was led by the Weather Bureau (now PAGASA) under Mr. Ricardo C. Cruz, GE'39 the Chief Astronomer and an alumnus of the Department. Observations were done at the PAGASA Observatory in UP (at the back of the College of Home Economics).

The objective of the project was: To determine the position of the satellite in the sky and the time it occupied that position. Positional accuracy was set to 1° arc and time accuracy was set to 1 sec. Knowledge of the satellite's orbit as it revolves around the earth is an important information to know more about the shape and size of the earth and the distribution of the land masses on it. Most of all, the satellite's orbit provides a plane of reference for measuring precise geodetic positions at widely separated points. This plane of reference, detached from the surface of the earth, makes for an independent observation plane to accurately determine locations and monitor the condition of our planet. This became the basis for the establishment of the now ubiquitous and multi-purpose global positioning system (GPS).

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by ROLANDO A. DANAO, G.E. '60

The Artificial Satellite Age began on October 5, 1957 when a Russian test vehicle started to circle the earth. This first artificial earth satellite was joined later by many others as the Russians and the Americans vied for supremacy in a world-wide scientific program known as the International Geophysical Year.

One of the important aspects of the Artificial Satellite Program is the determination of the satellite's orbit as it revolves around the earth. Being very close to the earth, the orbit is subject to numerous variations. Knowledge of an artificial satellite's orbit can yield results of important geophysical data such as the precise shape of the earth, the distribution of the land masses, density of the atmosphere, and the gravitational field of the earth. It can also give important geodetic information. The satellite's orbit provides a plane of reference for the measurement of precise geodetic positions at widely separated geographical points.

To determine its orbit, a satellite must be observed and tracked with an accuracy comparable to good astronomical observations. The tracking is done in two ways; namely, visual tracking and tracking by radio signals.

The visual tracking program has for its mainstay a world-wide group of volunteer observers organized into teams. Known as the Moonwatch Project it is directed by the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, U.S.A. There are 240 teams the world over. One such team was organized by the Weather Bureau as part of the Philippine participation in the International Geophysical Year program immediately after the successful launching of Sputnik I, the first artificial satellite. This moonwatch team was composed of 24 volunteer observers from the College of Engineering of the University of the Philippines. Under the supervision of Mr. Ricardo C. Cruz, the chief astronomer of the Weather Bureau, the group held frequent meetings to study the methods of artificial satellite tracking before starting the observations. Lectures were illustrated by demonstrations of actual observing devices. Site of their moonwatch operations is the Philippine Astronomical Observatory located at the University of the Philippines campus in Diliman, Quezon City.

The present paper will tell on how the U.P. Moonwatch team conducted their tracking of the artificial earth satellites.

PREDICTION OF SATELLITE PATHS

Visual tracking of artificial satellites is governed by three factors; namely, 1) the apparent brightness of the satellite, 2) weather conditions, and 3) the time of passage over the observing station. It would be futile for moonwatch observers to track an earth satellite which is so faint that it could hardly be seen even with the aid of the observing telescopes. No observations are possible under thick clouds. The time of passage is a very important factor because visual observation is limited to the twilight period only. The twilight period is the time of the day which is two hours before sunrise and two hours after sunset. At other times of the day either it is too dark or too bright that the satellite is not visible.

Visibility Forecasts

When a new satellite is launched, the Moonwatch Headquarters at Cambridge promptly notifies each team and issues tables showing the times and areas where the satellite can be observed. These visibility forecasts are made on the basis that the satellite will be bright enough to be seen at the end of the twilight period in the evening and at the beginning of the twilight period in the morning. Given the launching time and the orbit inclination of the satellite, an approximate angular elevation of the satellite is predicted as it crosses the meridian of an observing station.

These relatively accurate predictions are given for only a short period in advance—two weeks at most. This is because the desired accuracy can be maintained only by frequent corrections to the elements of the orbit which are subject to small changes from variable drag. Atmospheric resistance causes the artificial satellite to shorten its period of revolution from three to five seconds a day.

As reports pour in to the computing center at Cambridge more accurate predictions are made and the satellite observers are provided with charts showing the conditions of visibility; namely, height, brightness and altitude.

"Modified Orbital Elements"

For weeks at a time an artificial satellite may remain observable only from a particular zone of geographical latitude. There is a need for an approximate method of preparing a world-wide long-range forecasts of the visibility zones. This method is termed as the "Modified Orbital Elements." This was devised by three agencies which are cooperating in the International Geophysical Year program. It is described in a manual entitled *Simplified Satellite Prediction from Modified Orbital Elements.*

OBSERVATION TECHNIQUES

The primary objective in satellite tracking is the determination of the position of the satellite in the sky and the time it occupied that position. The basic requirement is that the position be given to an accuracy of one degree of arc and the time correct to one second. To satisfy these requirements two basic techniques were employed; namely, the fundamental and the differential methods.

Fundamental method

The fundamental method involves the direct measurements by means of the vertical circle attached to the telescope. For example, as a satellite crosses the meridian, its altitude is found by reading directly the angle on the vertical circle.

Differential method

The differential method involves the measurement of the differences in position on a star map between the satellite whose position is desired and the nearby stars whose positions are already known. The stars provide a background against which the position of the satellite can be determined at any moment during its passage across the field of the telescope.

OBSERVING METHODS

There are two methods of tracking artificial satellites by visual means; namely, telescope tracking and phototracking.

Telescope tracking

Equipment and accessories: The equipments necessary for a successful moonwatch observation are telescopes, tape-recorder, star map, a short-wave radio receiver, and tables.

The telescopes are standard moonwatch telescopes specially built of satellite tracking. They are of the elbow type with a magnification of six diameters and a field of view of 12 degrees.

The tape-recorder keeps a record every time an observer shouts "TIME" as the satellite croses his field of view.

The star map is a chart showing the positions of the stars as they are seen on a cloudless night.

Set-up for table-top observation: The table is placed as horizontally as possible to facilitate the setting up of the telescopes. The telescopes are arranged in two rows on each side of the table. They are all aligned to the meridian of the station by resting their bases on parallel straight edges clamped on the table. These cleats are oriented to the meridian with a magnetic compass. In this way the vertical crosshairs of the instruments are automatically aligned to the meridian. Accuracy in aligning the telescopes to the meridian is very important since the crossing of the satellite across it gives the data needed by the computing center.

On one side of the table the telescopes point to the north while on the other they point to the south. The basic principle here is that in the team of observers each maintain a continuous watch over a specified area in the sky along the meridian. These areas overlap so that the satellite can not cross the "optional fence" without being detected. The observers are seated around the table while the leader takes charge of the tape recorder and the short wave radio receiver for time signals.

When a satellite is predicted to pass over the Philippines the team leader, Mr. Ernesto Calpo, immediately alerts his members for observing during the indicated twilight period. The members are on the observing line at least 15 minutes ahead of the predicted time of passage. Each is provided with a star map. Five minutets before the critical time of passage the observers start their observations. As soon as an observer sees the appearance of the satellite at the edge of his field of view he shouts "TIME". When it passes the vertical cross-hair he again shouts "TIME". And finally, when the satellite leaves his field of view he again shouts "TIME". If it happens that in his field of view there is a bright star or a group of conspicuous stars he also says "TIME" as the satellite passes near the star or the group of stars. During the entire period the tape recorder directly records the time signals from the short wave radio receiver. After the satelltite has left the field of view, the observer plots the satellite's path on the star map and indicates the direction of motion..

Phototracking

For precision tracking of a satellite a special photographing telescope is used. Phototracking employs the differential method of determining the position in the sky which the satellite occupies at a particular time. Photographed against a background of stars whose positions in the sky can be precisely determined, the position of the satellite can likewise be determined with the same high degree of precision.

TRANSMISSION OF DATA

Essential data recorded

There are two essential data recorded by the moonwatch team for every observation session:

1. The position of the satellite in the sky
2. The time it occupied that position.

Other informations such as the angular velocity and the direction of motion is left at the option of the team leader to give.

Transmission of data

Promptness in transmitting the observations to the computing center in Cambridge is essential to the success of the program because the orbit of the satellite is changing very rapidly. Preliminary reports are sent by wire. More complete reports are sent in written reports to the computing center where they are converted into expressions that are fed to digital computing machines.

In the case of photographs, they are immediately developed and a rough position of the satellite is measured and transmitted to the computing center for improving the predictions of the satellite's fiight. The film itself is sent to the computing center for high precision measurements.

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