# SOFTWARE AUTOMATION OF GEOSYNCHRONOUS EARTH SATELLITE OBSERVATIONS

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## Abstract

Software automation of observations of geosynchronous Earth satellites is an important tool for effective monitoring of outer space. The program "Plan" presented in the work was created to automate the process of planning observations with the Takahashi BRC-250M telescope. The development is based on algorithms that take into account the visibility of satellites, the phase of the Moon, breaks between frames, as well as optimization of telescope movements to reduce observation time. The program integrates with the telescope via the TCP/IP protocol and generates text files of plans that are used for guidance. The use of such tools allows for accurate and systematic observations, and also contributes to effective resource management. A feature of the solution is support for updating TLE data to determine satellite coordinates and take into account the individual parameters of each object. This provides the ability to adapt to the specific needs of observing geostationary satellites.

## Key words
Observation, Automation, Artificial Earth Satellites, Python, Script.

## 1. Introduction

Geostationary orbit (GEO) is highly advantageous for various applications, including scientific research, military operations, navigation, and communications. Satellites in GEO maintain a fixed position relative to the Earth's surface, providing consistent coverage over specific areas, which is essential for tasks such as weather monitoring, surveillance, and broadcasting [1]. Due to the intensive utilization of GEO by developed nations, there is a growing recognition that its capacity is finite. This realization underscores the importance of maintaining space control systems to ensure the continued functionality and safety of satellites operating in this orbit [2]. While radar can determine the coordinates of geostationary satellites, optical observations remain the primary method for monitoring and cataloging objects in GEO. Ground-based optical systems offer a cost-effective means to track satellites, verify orbital maneuvers, and assess the dynamic state of space assets. These observations are crucial for space situational awareness, helping to detect, identify, and track resident space objects to maintain a sustainable GEO environment. In summary, the strategic importance of geostationary orbit for multiple applications necessitates diligent monitoring and maintenance. Optical observation methods play a vital role in ensuring the effective management and safety of satellites within this heavily utilized orbital region [3].
The problem of planning observations and their automation is always relevant for observatories working with a large number of observations. Currently, several existing packages for planning observations are known, such as *astroplan* [4-7], but unfortunately it is quite difficult to apply it to observations of geosynchronous satellites.
The authors developed their own program "Plan" to automate observations of satellites in geostationary orbit for the Takahashi BRC-250M telescope [8 - 11] (F=1268 mm, D=250 mm), located at the Derenivka observation point (village of Nyzhne Solotvino) of the educational and scientific laboratory of space research of the Uzhhorod National University [12]. The development environment is Python 3. Program is accessible on the website: https://github.com/vkudak/plan

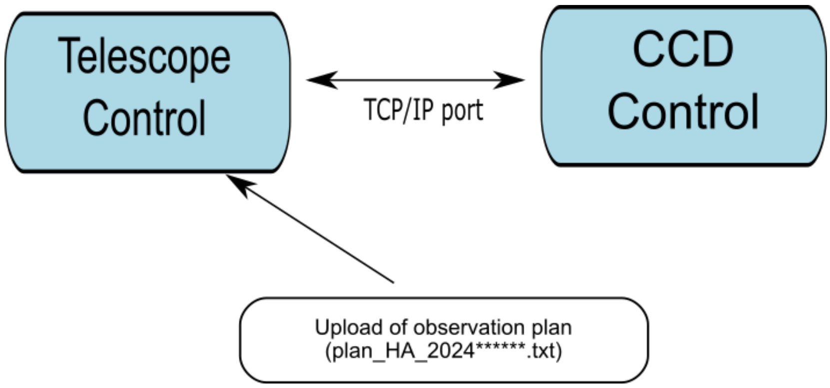


Fig.1 Organization of communication between the program and the telescope and CCD camera control system

## 2. A problems that are solved by a script

The “Plan” program generates a plan for observing geosynchronous Earth satellites. The program cooperates with a telescope control module and a CCD camera control module, which are organized by a communication channel with each other via the TCP/IP protocol on a specified port (Fig. 1.). The task of the script is to create a text file (*plan_YYYY-MM-DD.txt*) with the coordinates and time of successive pointing of the telescope at various satellites from the observer’s list. The created file is uploaded to the telescope control program so that it knows in what order to point the tube at the planned objects and with what exposure parameters to obtain their images.

The peculiarities of the program are as follows - satellites are observed in a specific way - 7-10 frames of the object are taken in a row, or with a break of several seconds (let's call this one measurement of one object, when we have obtained all frames of all the objects, we have obtained a series of observations of all objects), and such actions are repeated 2-3 more times during the night (depends on configuration file) with a minimum interval of 30 minutes, thus we obtain 2-3 series of measurements of all objects. In this case, it is necessary to take into account the minimum movements of the telescope, which is achieved by simply sorting the objects by the value of the hour angle of the object at the time of the start of the observations. We start the observations from east to west, since in the east in the evening the phase angle for observations is better. At the end we start from the beginning. Ideally, we need to take into account the phase angle of the object, look for an object with a minimum phase angle, falling into the shadow, the priority of the object, etc. The time of shooting one frame, and the time of moving the telescope between objects (at the moment it is simply set manually fixed with a margin) are also taken into account. The object falling into the Earth's shadow is also taken into account, in which case it is not visible and there is no point in observing it. The general algorithm of the script is presented in Figure 2.

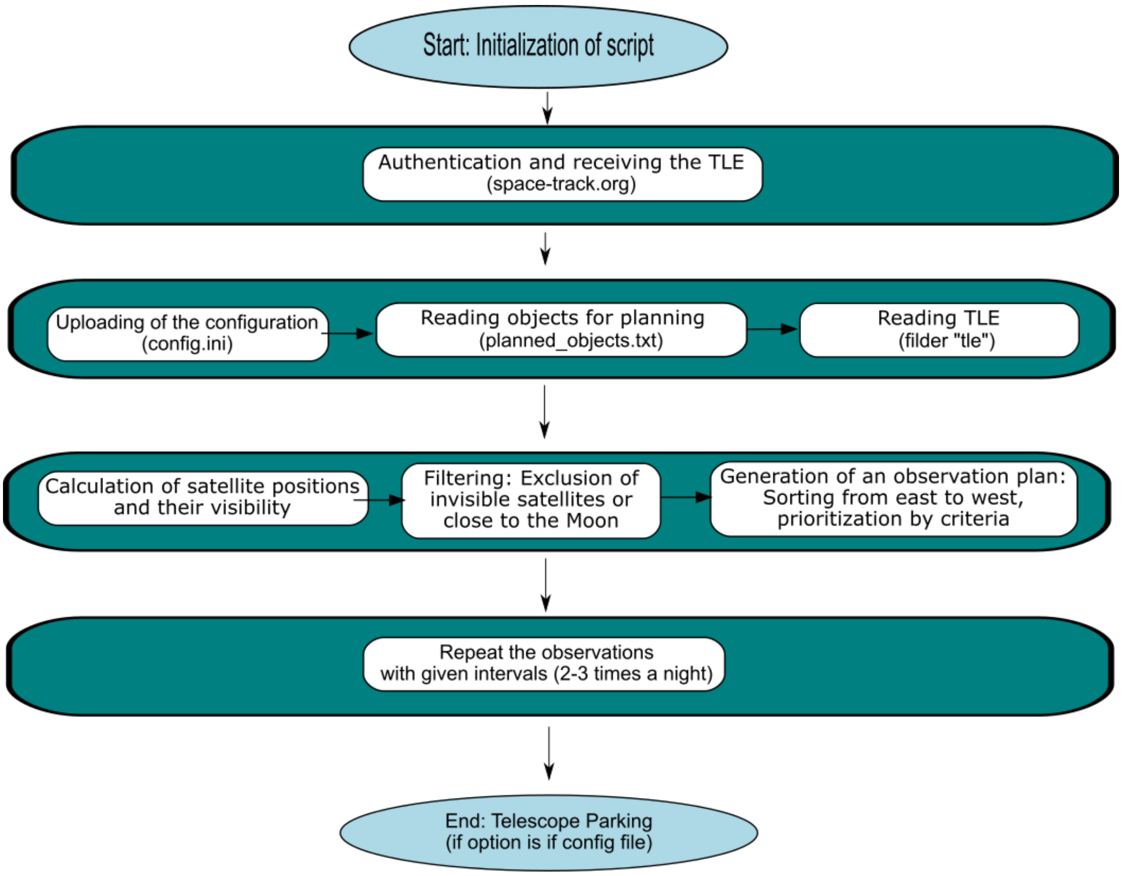


Fig.2 General algorithm of the program operation.

Scheduling starts at twilight, or from the moment when script was started if twilight has already passed for the given night. No date is specified for the script, calculations are made on the current date.

Almost all settings are placed in a separate configuration file *config.ini* for convenience. The configuration file also contains sections for parking the telescope, if the user needs such an option, it is suggested to specify the coordinates where the telescope should be directed upon completion of the task.

The plan calculation is carried out in two variants (plan_type) - right ascension and declination (α, δ) or hour angle and declination (t, δ). Usually the second option (HA, DEC) is used for observations of geosynchronous satellites. It is also possible to track the object with a mount if the object has its own speed relative to the earth's surface greater than a specified threshold value.

Observing objects in moonlight is quite a big problem, so we have provided for preserving the angular distance in degrees from the Moon - *dist1* during the period when the Moon phase is less than 50% and *dist2* (a larger distance in degrees) when the phase is more than 50%.

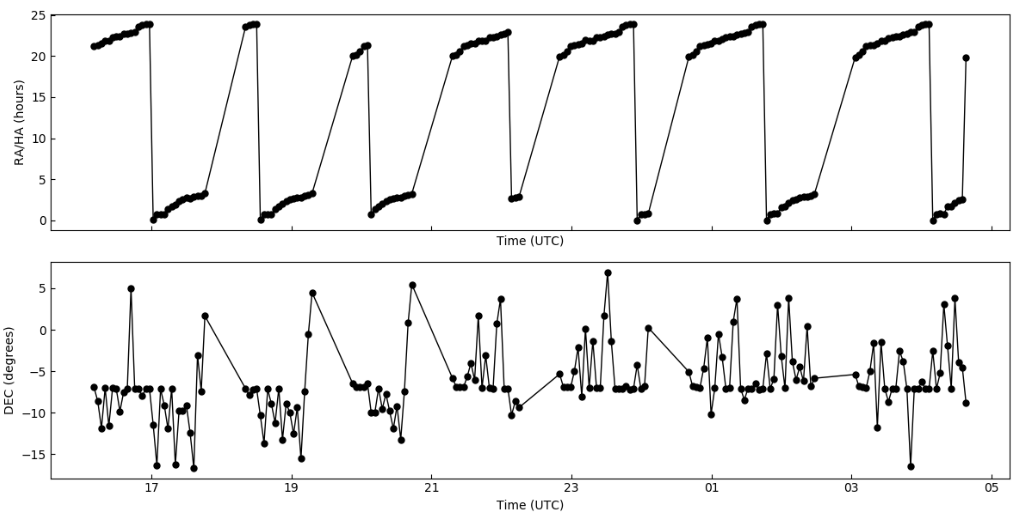

Fig. 3a Plan for observing 18 satellites by telescope based on the “Plan” program.

For the date 2024-12-13, Moon phase 98%

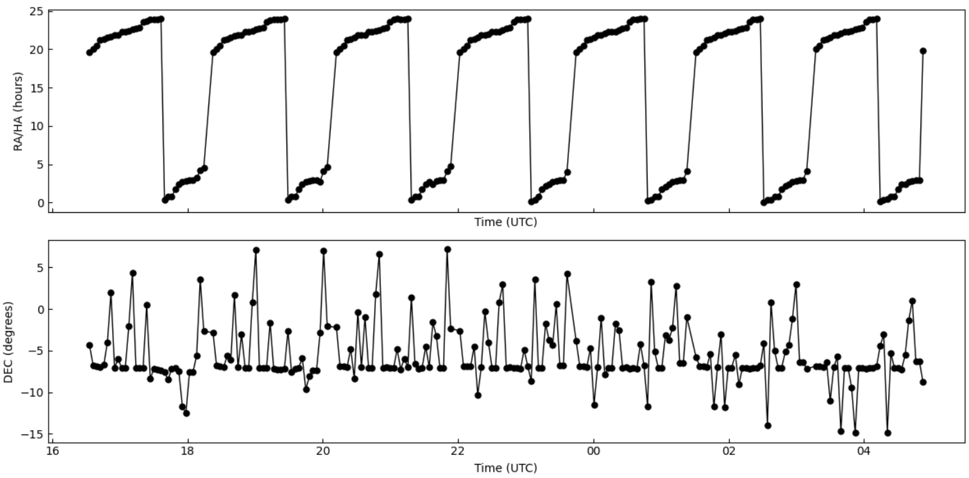


Fig. 3b Plan for observing 18 satellites by telescope based on the “Plan” program.

For the date 2025-01-27, Moon phase 5%

The configuration file also contains an authentication section for obtaining TLE elements from specialized sites (space-track.org, n2yo.com). For this, additional scripts are used that must be launched before planning begins. Files with TLE elements are placed in the “tle” folder, which is located in the same folder as the planning script. The TLE elements are used to calculate the exact location of the object at the time of observations [13, 14], for this purpose additional Python packages are used – *ephem* [15].

The result of the program’s work – planning of observations of satellites located in geostationary orbit is shown in Figures 3a and 3b. In Figure 3b the moon does not interfere with the observations.

## 3. Conclusion

The developed software for planning the operation of the telescope allows you to obtain a plan for observing artificial satellites in geostationary orbit depending on many factors - the priority of the satellites' localization in orbit, their visibility, and taking into account the phase of the Moon during observation. The program's operation is based on a generally accepted algorithm for calculating the motion of bodies according to the laws of celestial mechanics and physics. The input data is loaded and processed in the form of script files, taking into account orbit TLE elements, which are promptly updated and are publicly available.

The advantage of observations in automatic mode with planning is that it is possible to obtain a longer time interval of observations with less load on the observer and more autonomous operation of the telescope. The goal was to automate the observation process, the observer only needs to start observations that should subsequently take place without his participation. The role of the observer is reduced to controlling and processing the results at the end of the observations.

## Conflict of Interest

The authors state that there are no financial or other potential conflicts regarding this work.

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