

# Capabilities and Improvements to the OSCOM System

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## Abstract

Optical and Spectral characterization of CubeSats for Operational Missions (OSCOM) is a system designed at Embry-Riddle Aeronautical University that uses custom software and inexpensive commercial-off-the-shelf (COTS) equipment to perform space situational awareness tasks for satellites ranging in size from the International Space Station (ISS) to CubeSats and small orbital debris. OSCOM can provide high frame rate photometry of many small satellites, but has also acquired resolved images of the ISS, planes and rockets. The OSCOM systems is portable and can be deployed to various locations to perform simultaneous multi-point observations to help gather additional information from the satellites observed. Currently, improvements to OSCOM's tracking program, Auriga, are being made to implement a GUI interface, easier selection of satellites and optical tracking. This poster will discuss both completed and planned improvements to Auriga along with examples of photometry of satellites and resolved images of objects taken with the OSCOM system.

## System Overview

The OSCOM system contains multiple telescopes, mounts and machine vision cameras. It tracks satellites as they pass over a local area and produce time resolved photometry of them. The display of the photometry over time yields a light curve. These light curves, such as the one shown in Figure 3, can show characteristics of a satellite such as its spin rate. OSCOM has successfully tracked and imaged satellites as large as the International Space Station (ISS) and CubeSats, 10cm cubes of 1kg mass.



Software Bisque Paramount    Celestron CPC    Losmandy Titan

Figure 1: Shows the mounts that OSCOM can and will be able to support. The Paramount and Losmandy mounts are currently supported in OSCOM's new tracking program, with the Paramount having the most use. Celestron CPC mount support is on-going.

## Capabilities

OSCOM has primarily used a Celestron 11" RASA with an Allied Vision machine vision camera to produce light curves. OSCOM was able to assist the Japan Aerospace Exploration Agency (JAXA) with observing the tumbling X-ray satellite, Hitomi, which experienced an attitude control failure in March 2016. In addition, OSCOM has been able to produce photometry of CubeSats such as the Dynamic Ionosphere CubeSat Experiment 2 (DICE-2), shown in Figure 3. Here, OSCOM has been able to resolve the spin rate of DICE-2, 6.34 rpm, which is close to the previously known spin rate of 6 rpm.

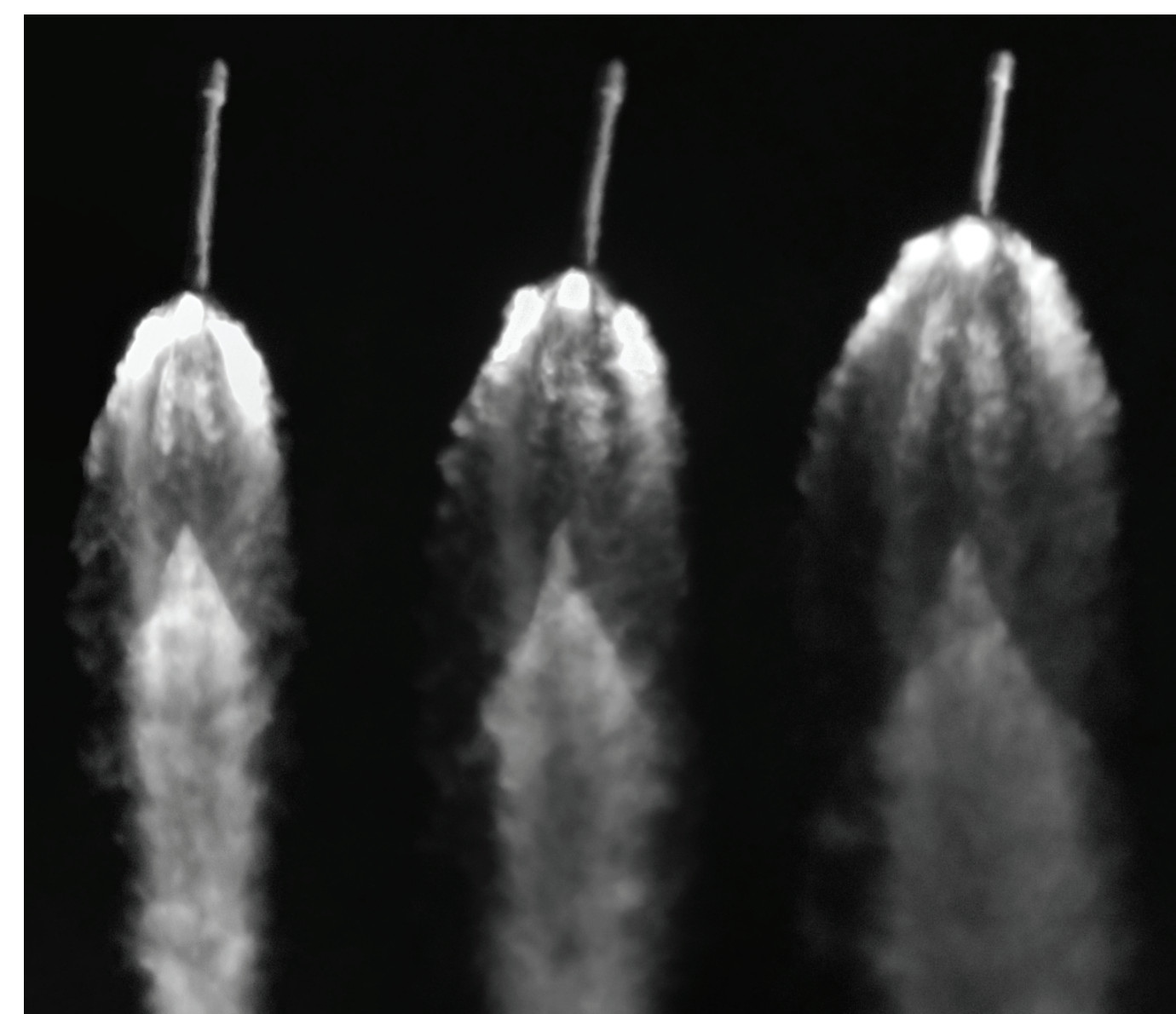


Figure 2: Series of images of the SES-10 SpaceX rocket launch from Cape Canaveral, Florida on March 30, 2017. The figure shows the rocket at three instances during its launch, with time increasing from left to right. These images were acquired using a Celestron 14" Edge HD from Daytona Beach at a distance of over 90 miles away.

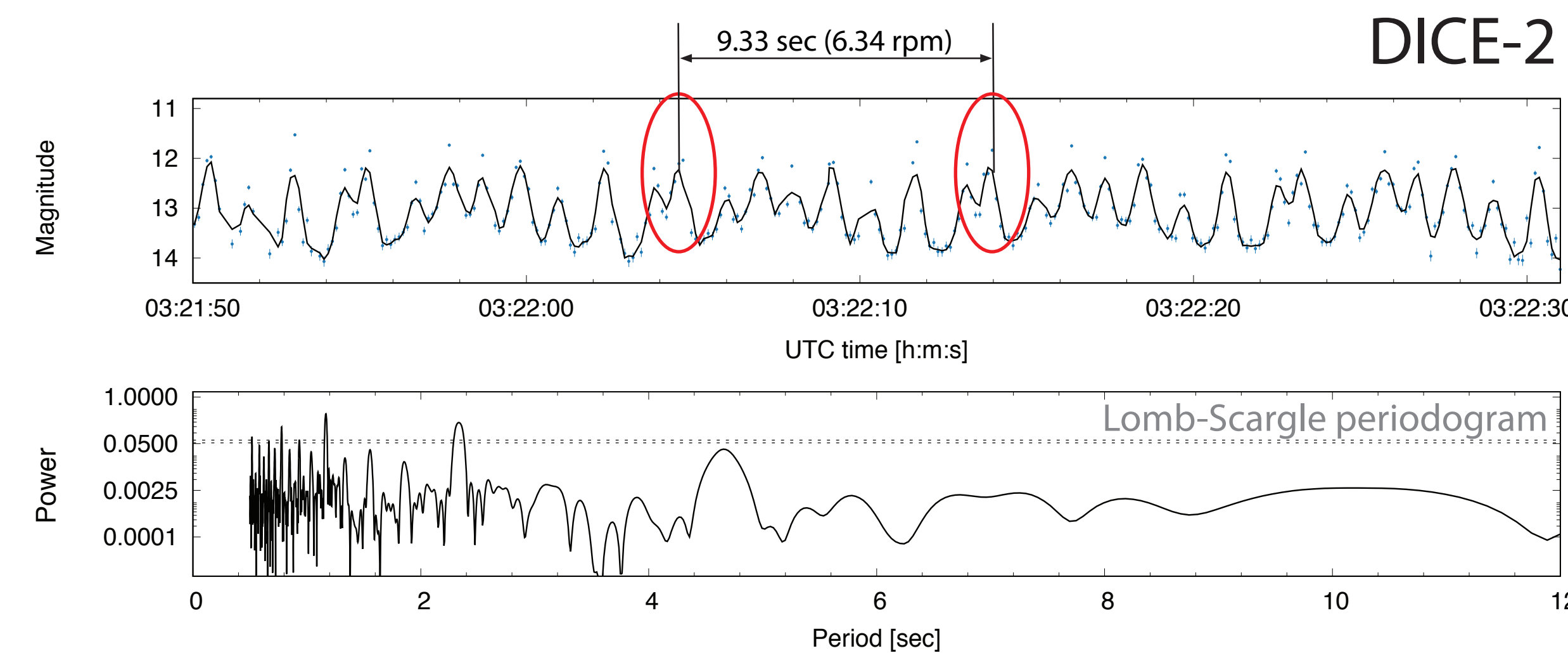


Figure 3: Shows photometry of DICE-2 (Dynamic Ionosphere CubeSat Experiment). Data was collected on August 1, 2015 at a frame rate of 7.6 fps. The two features in the light curve, top plot, are separated by 9.33 seconds or 6.34 rpm. The satellite was operational as of 2014. It was last known to be spin stabilized at around 6 rpm.

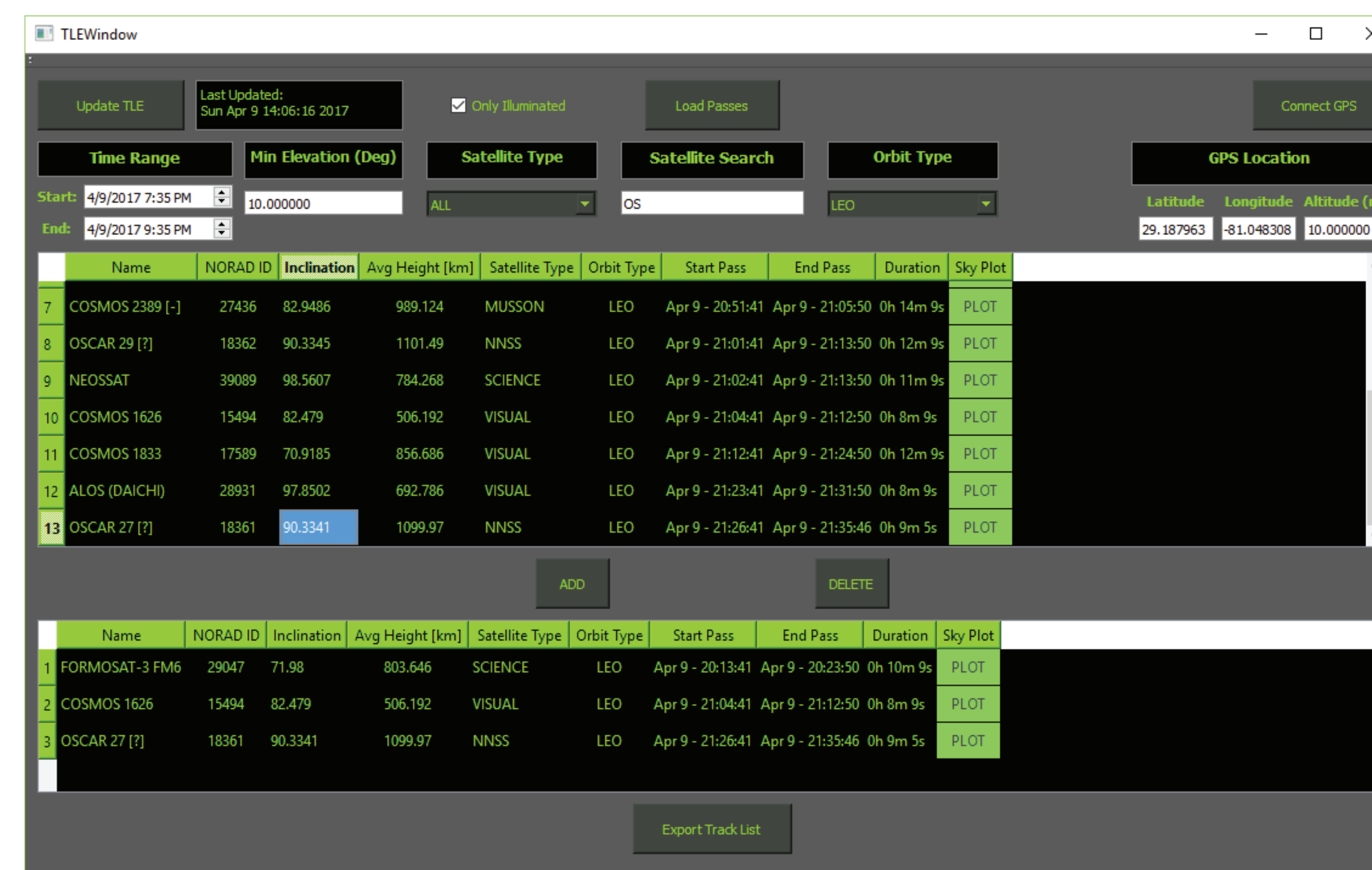


Figure 4: Shows the TLE selection window. The user can search for available passes within specific criteria such as time, satellite and orbit type. The user selects from the list of available passes and the TLE is passed to the tracking window below. Each satellite is provided with basic information such as average orbit height and NORAD ID to help the user identify the satellite and select the pass. Sky plots showing the path of the satellite over the local area allow the user to determine the quality of the pass (e.g. elevation angle).

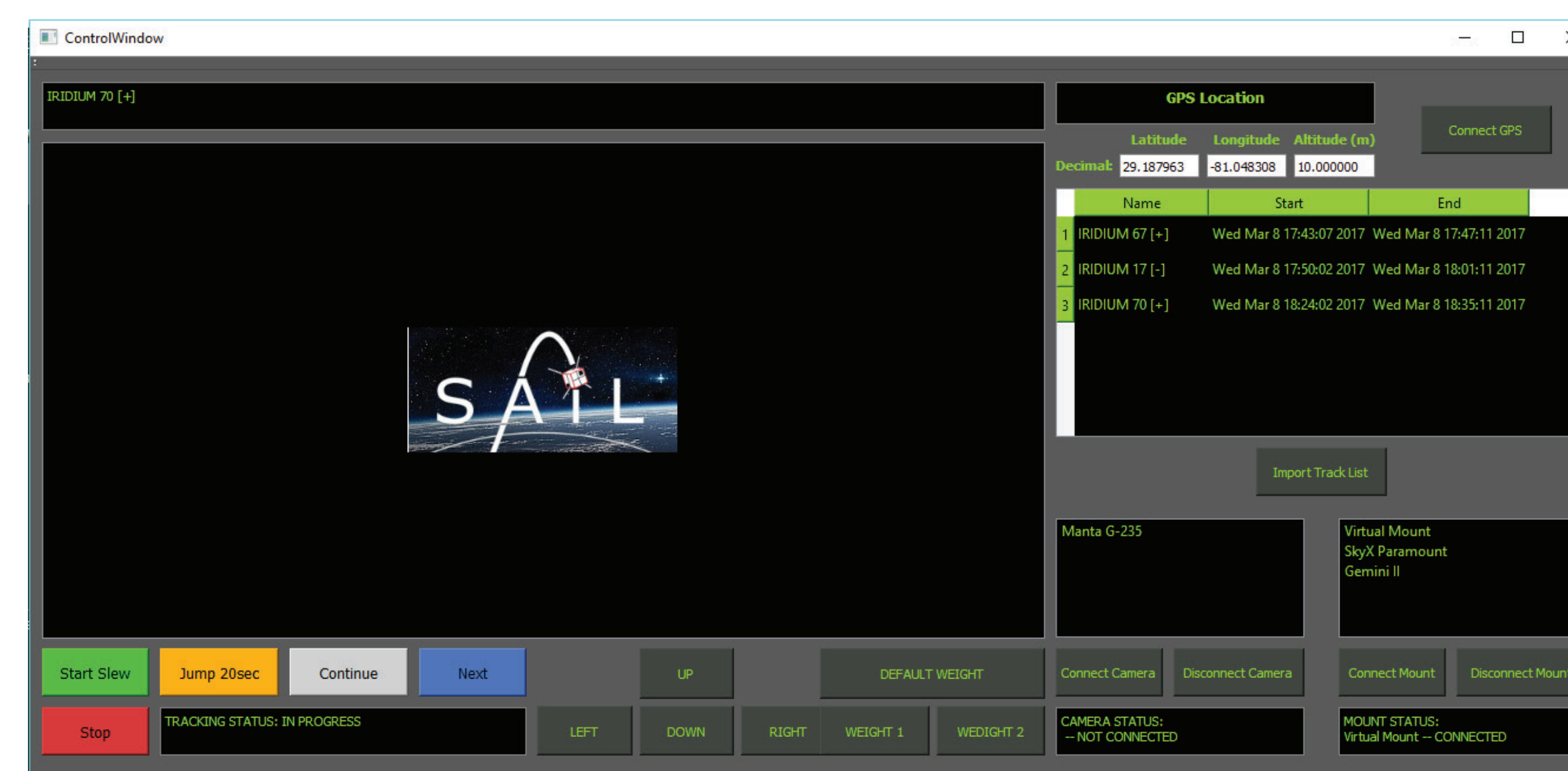


Figure 5: Shows the tracking command window which uses a Paramount or Losmandy mount to track satellites using the TLE's selected from the window shown in Figure 4. Users can start, stop, jump 20 seconds ahead of the current satellite position and adjust track rates manually.

## Graphical User Interface

The graphical user interface (GUI) is being designed in C++, utilizing the QT framework. Two main windows provide basic GUI functionality, the TLE Selection Window and the Satellite Tracking Window. The TLE Selection Window displays user provided or downloaded satellites from Celestrack's database, which pass over a specified location with a minimum specified elevation angle and in a desired time frame. Additionally, this window allows the user to input custom TLE, filter over satellite inclination, and illumination and plot the propagated satellite's path using the SkyPlotWidget tool. The Satellite Tracking Window allows the user to specify which satellite or a number of satellites to track, select a mount and camera from a variety of different types and initialize tracking. To control the tracking process, the GUI provides buttons for track rate adjustments, functionality to jump 20 seconds ahead of the currently tracked satellite, ability to go to the next satellite and stop tracking entirely. This window also has a small section that is planned to feature a live feed from the camera.

## Communication Architecture

The communication architecture, written in C++, requires a modularized structure to allow support from various mount and camera types which have vastly different operating protocols. The Windows Network Sockets is used to communicate with the individual mounts. Currently supported mounts are Bisque Paramounts and Losmandy mounts with Gemini II. Genika Astro is used to communicate with the camera. It enables high speed image capture, image capture adjustments, histogram stretch and real-time image display. To interface with the GUI, the communication architecture also utilizes the QT framework. This framework provides the thread library that allows the GUI to run in parallel with the continuous satellite tracking process. During tracking, any command can be invoked by either clicking the button on the GUI interface or by pressing the specified button on the keyboard. The keyboard commands can be easily redefined by the user at any time without the need to modify any source code of the program.

## Tracking Overview

Current improvements to the tracking software feature obtaining satellite TLEs from a Celestrack database by a user, initiated download on the GUI. The orbital elements are then propagated to determine whether a satellite pass occurs over a given location and time. The list of orbital elements goes through several filters such as an illumination filter, which determines whether a satellite is in Earth's shadow, operational status filter, and mission type filter. The user can select which satellites to track from the simplified, filtered list. Once a satellite is selected, its orbit is propagated and a spline is fit. Using the spline and its derivative, the mount is slewed to its acquisition location and waits for the satellite to enter the field of view. When the time for the satellite to pass occurs, the TLE-based tracking begins. If the satellite TLE is slightly inaccurate, a manual correction using the GUI or keyboard commands can be applied to keep the satellite in the field of view of the image.

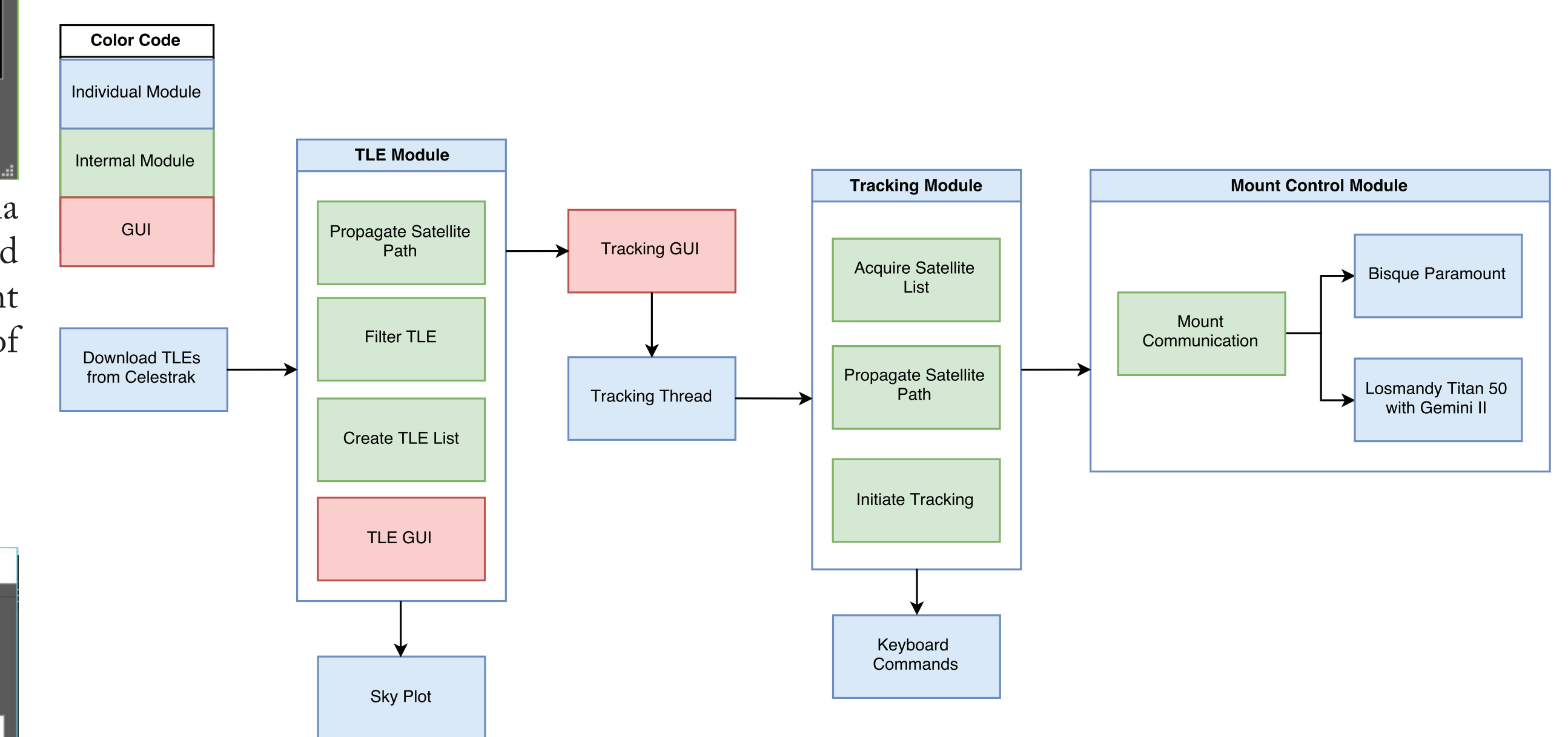


Figure 3: Shows the new tracking program flow chart, which details the processes that occur for each module currently embedded in the software.

## Optical Feedback Loop Tracking

The optical feedback feature is currently under development and includes interfacing with the machine vision camera and implementing an analysis algorithm on the acquired images. Interfacing with the camera will allow the user to see images on the GUI while tracking. The algorithm will allow for a closed loop tracking of satellites. This feature is planned to contain two modes, the streak detection and rate track adjustments. The streak detection feature will mainly be used to capture the illuminated streak of a passing satellite. The track rate adjustments feature will be executed during the continuous satellite tracking process. The algorithm will analyze the offset of the captured satellite from the central image frame and send commands directly to the mount to account for the offset. At the moment, several modules of the optical feedback have been developed and tested on static images and previous satellite pass videos, with high signal-to-noise ratios, and have presented valuable results.