Use of a Night-Tracking Camera for Real Time Correction of the Pointing of the SLR System

E. Cordelli
P. Schlatter, P. Lauber, T. Schildknecht

Astronomical Institute, University of Bern, Switzerland

21st International Workshop on Laser Ranging
5-9 November 2018
Canberra, Australia

Table of Contents

Motivation

- Time observation capacity of telescope exhausted
  - High number of targets
  - More and more targets to come
  - Different projects

- What can we optimize?
  - Satellite acquisition time
  - Number of observation per NPT
  - Pass Observation rate
  - Successful satellite acquisition (by visual inspection)

- Side product
  - Space debris applications

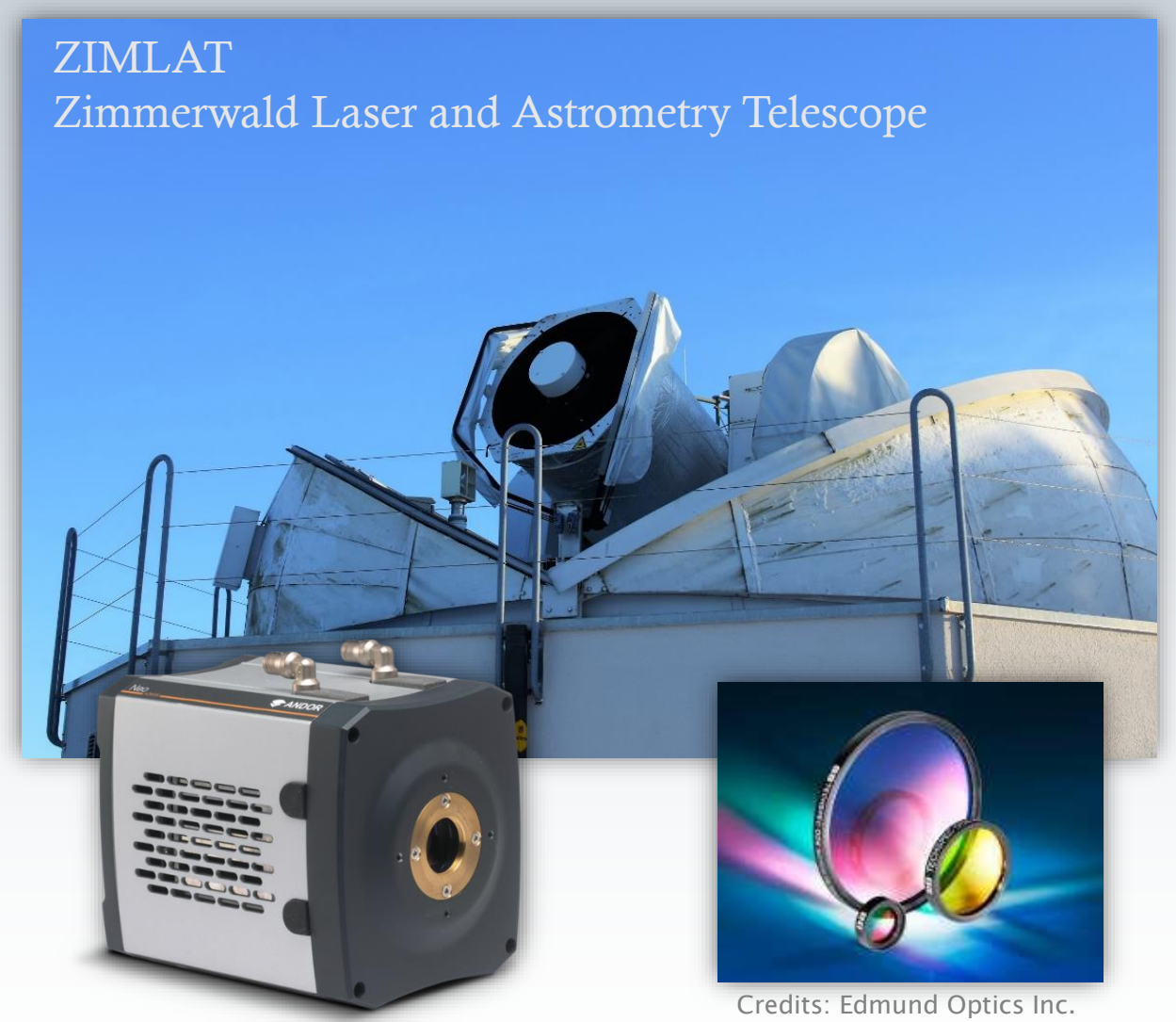
Hardware Selection

Needed hardware for Tracking Camera

- **Telescope: ZIMLAT**
  - 1-m Aperture Ritchey-Crétien
  - Coudé focus for Laser
  - Nasmyth Focus for tracking and CCD cameras (available focal lengths: 1.2m, 2x4m, 8m)

- **Camera: Neo 5.5 sCMOS**
  - 1 e- read noise
  - TE cooling to -40° C
  - 5.5 megapixel sensor, 6.5 µm pixels
  - 22 mm diagonal field of view
  - Rolling and Global Shutter
  - Rapid frame rates
    - 30 fps over extended kinetic series
    - Burst to memory at 100 fps full frame

- **Notch Filter**
  - 2x 532nm, 25mm Dia., OD 6 Blocking Notch Filter

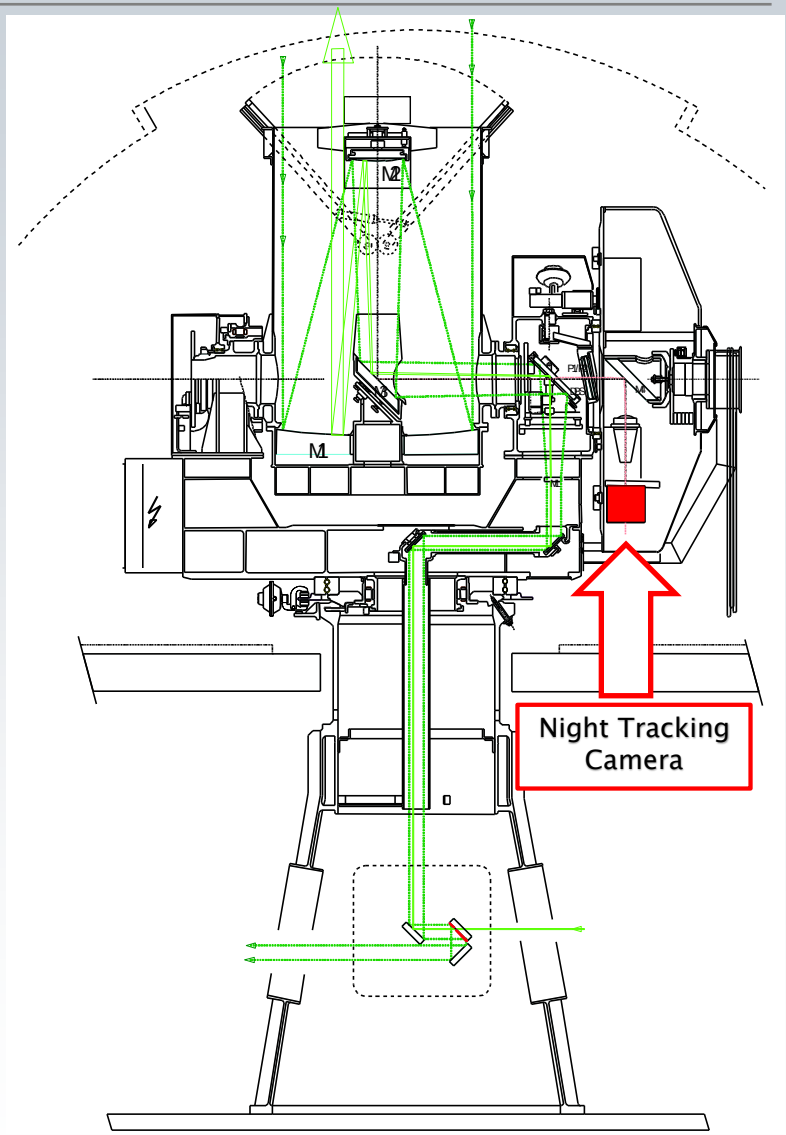


Credits: Oxford Instruments 2018

Credits: Edmund Optics Inc.

NightCam Implementation

- **Hardware integration**
  - Camera installation
  - Notch filter
  - Focal Station Selection
- **Software development**
  - Development of camera control software
  - Determination of Laser beam position on camera
  - Calculation of telescope pointing corrections (in real time)
- **Software integration with existing laser observations software**
- **Development of an observation/analysis pipeline**



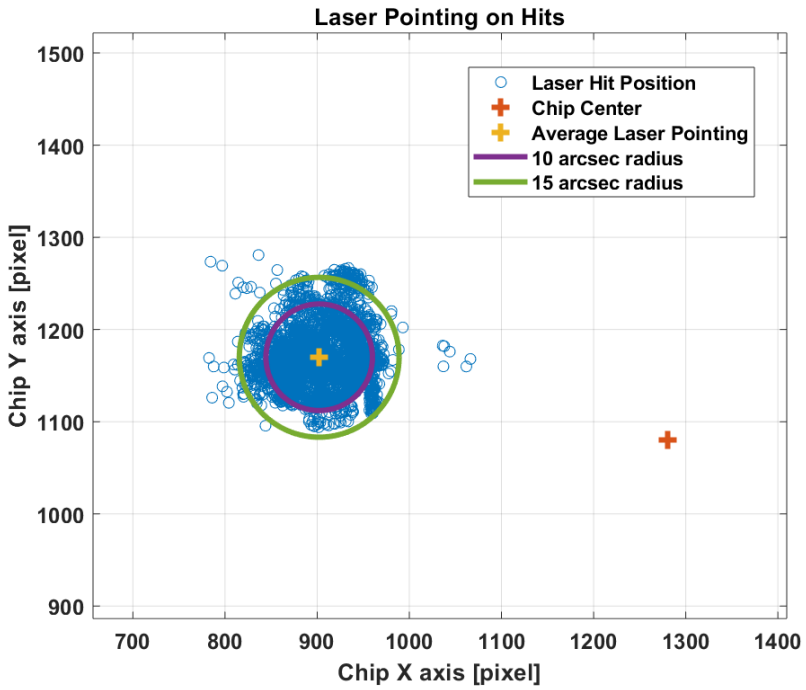
Derivation of Pointing Model

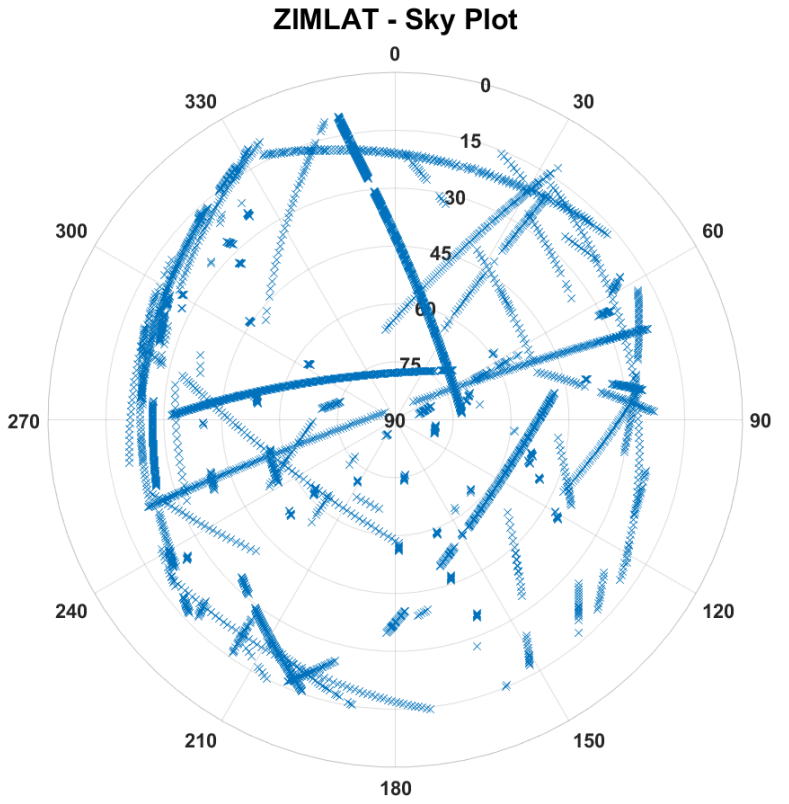
To apply corrections to satellite ephemeris, we needed to determine:

- The Azimuth Elevation direction in the camera system
  - Number of reflections
  - Camera oritentation
  - Derotator position
- The pointing of the laser on the camera
  - Telescope pointing direction
  - Derotator position

Star fields for camera orientation

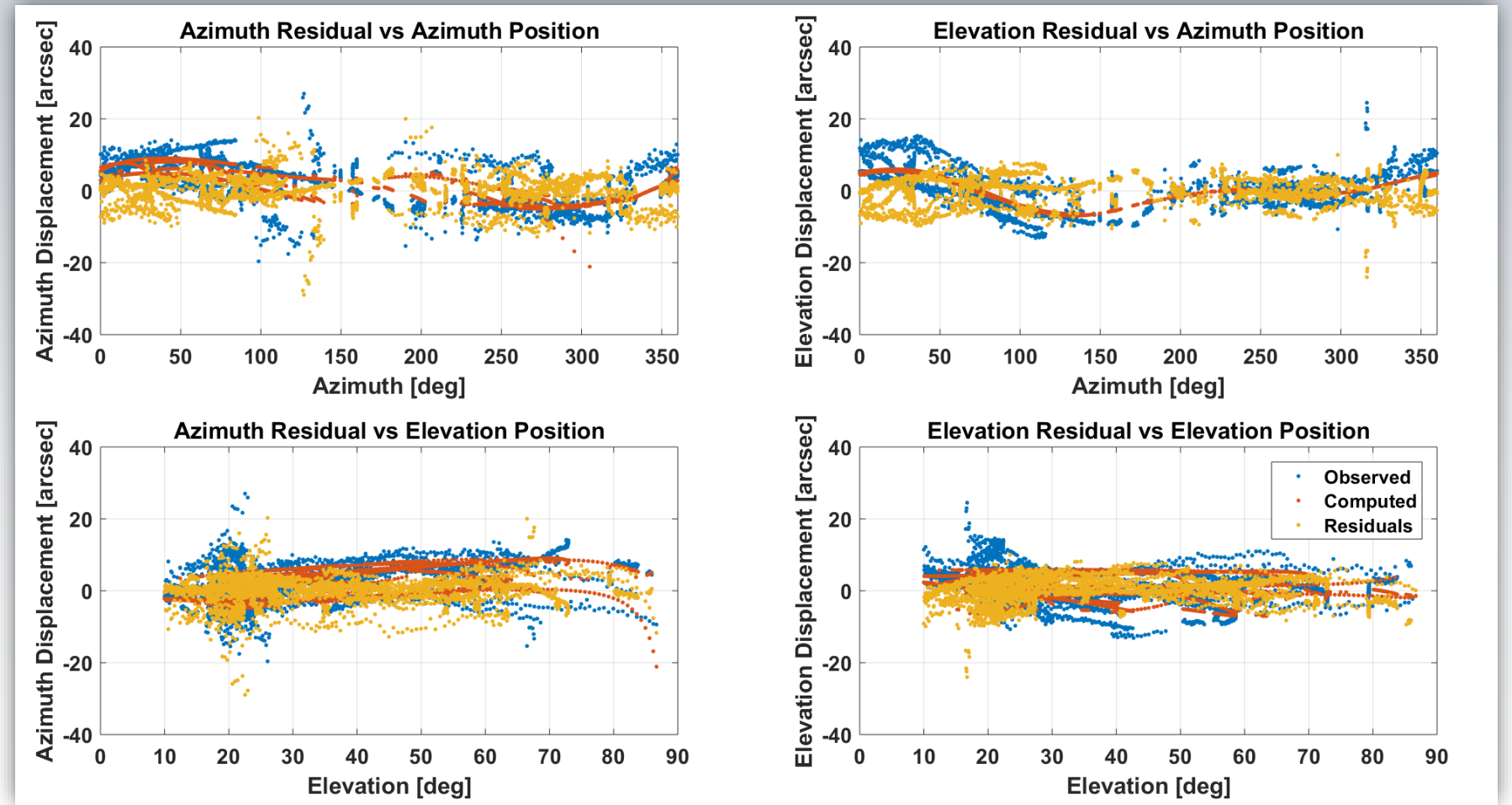
Derived from images when laser hits the target

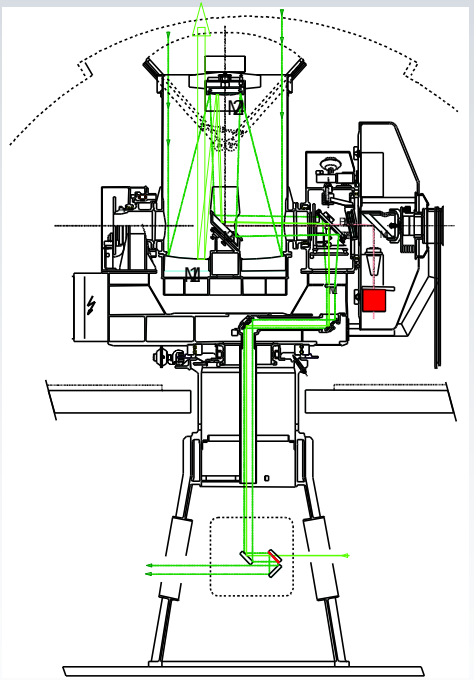




Improvement of the Pointing Model

- Temporary Solution → Average Laser coordinates on chip
- Optimal Solution → Modelling of the wobble due to telescope pointing direction → To be implemented

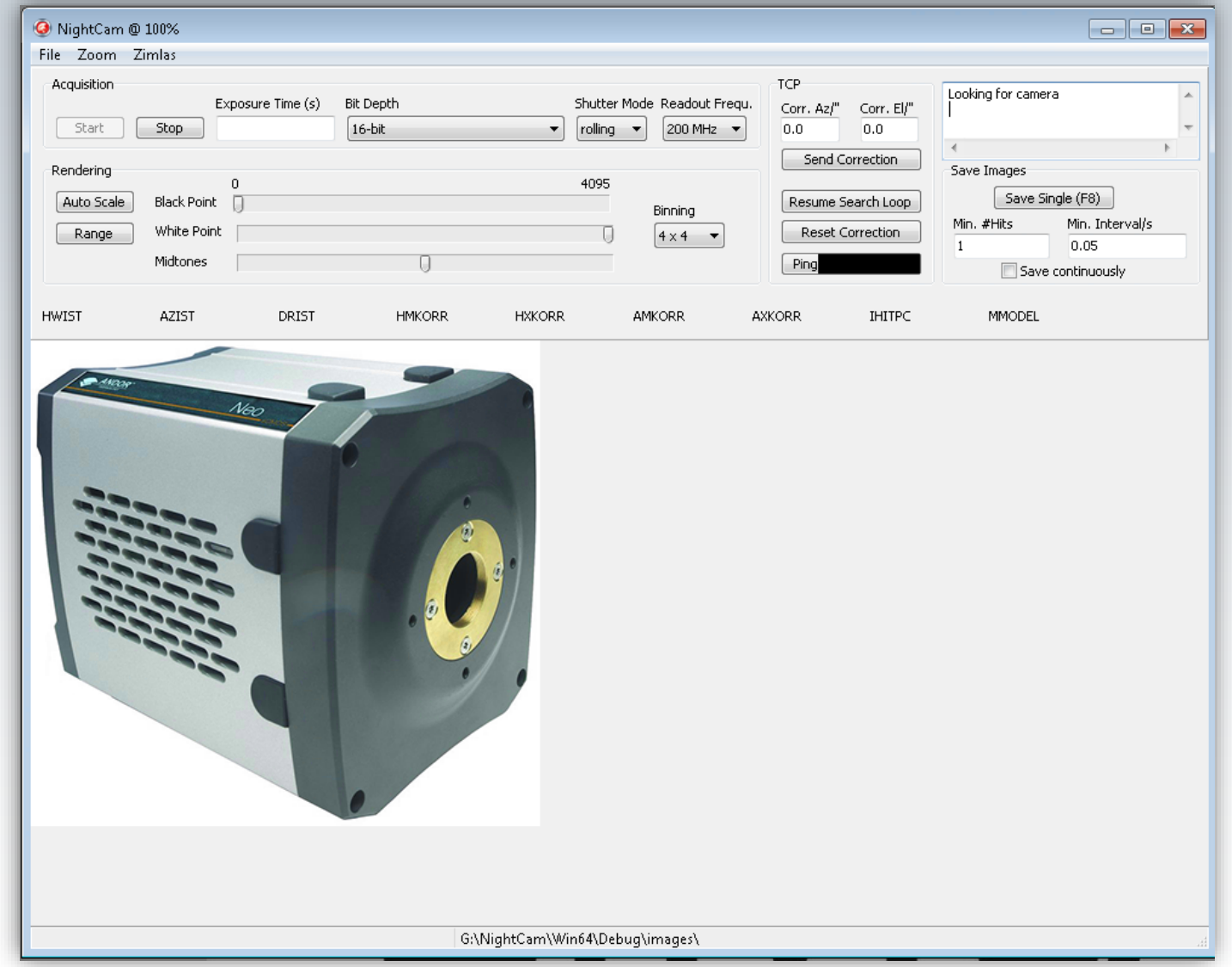




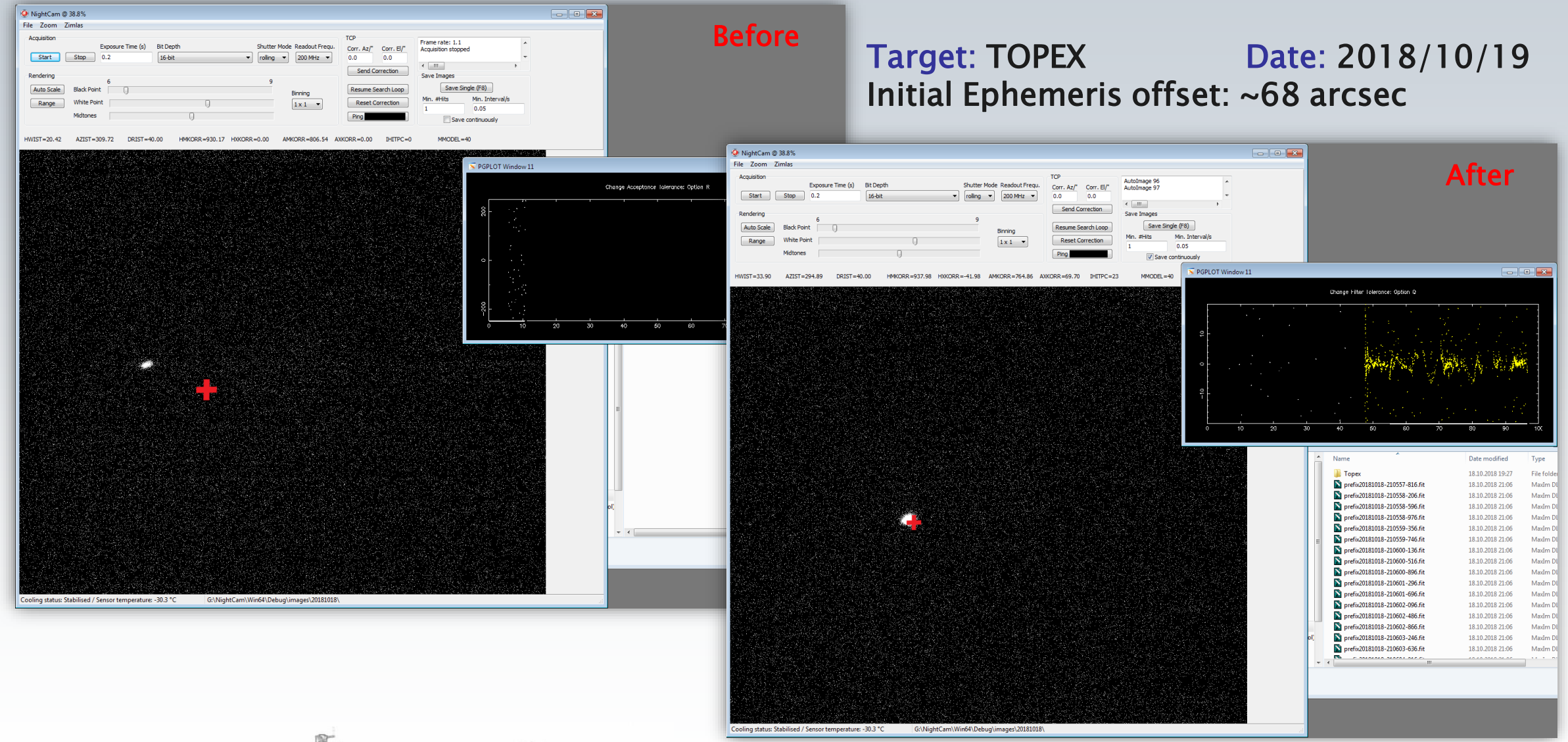
The NightCam Software

NightCam Capabilities

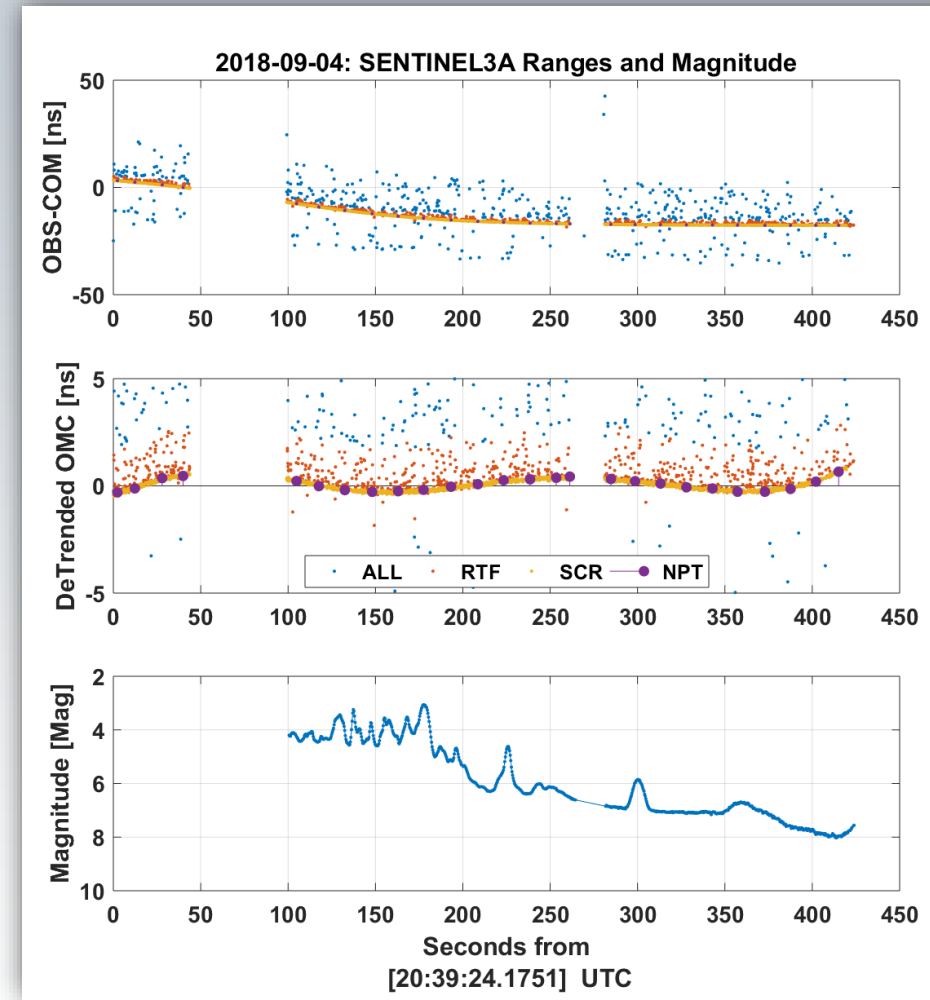
- Set up camera parameters
  - Exp. Time
  - Binning
  - Shutter mode
  - Readout frequency
- Target Acquisition
  - Target Position w.r.t. Laser Position
  - Azimuth/Elevation ephemeris correction handling
  - Storing of Images with telescope data (pointing directions and measurement epoch)
- Synchronous observations acquisition
  - Azimuth/Elevation
  - Range
  - Light curve
- Monitor telescope parameters
  - Pointing directions
  - Correction to pointing direction

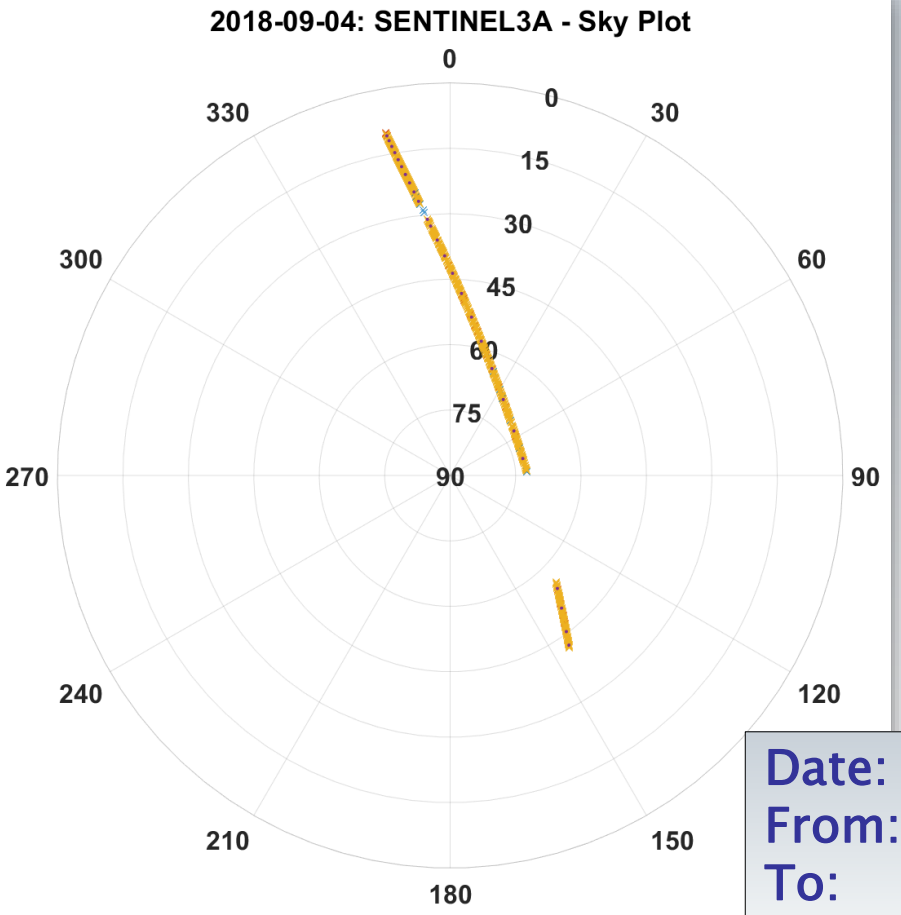


NightCam at Work



NightCam Output





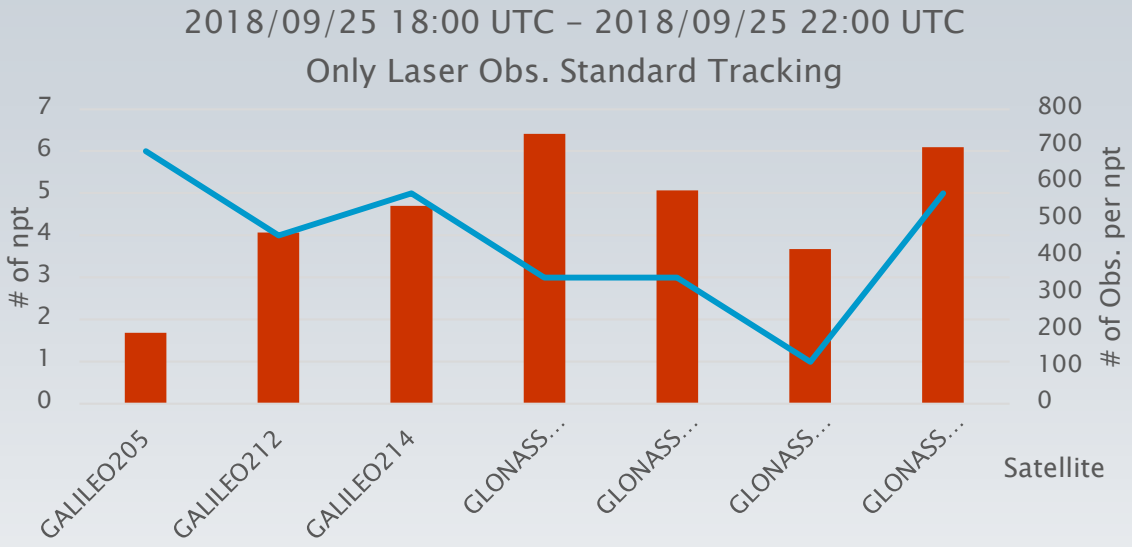
Date: 2018/09/04
From: 20:39 UTC
To: 20:47 UTC

Target: SENTINEL 3A

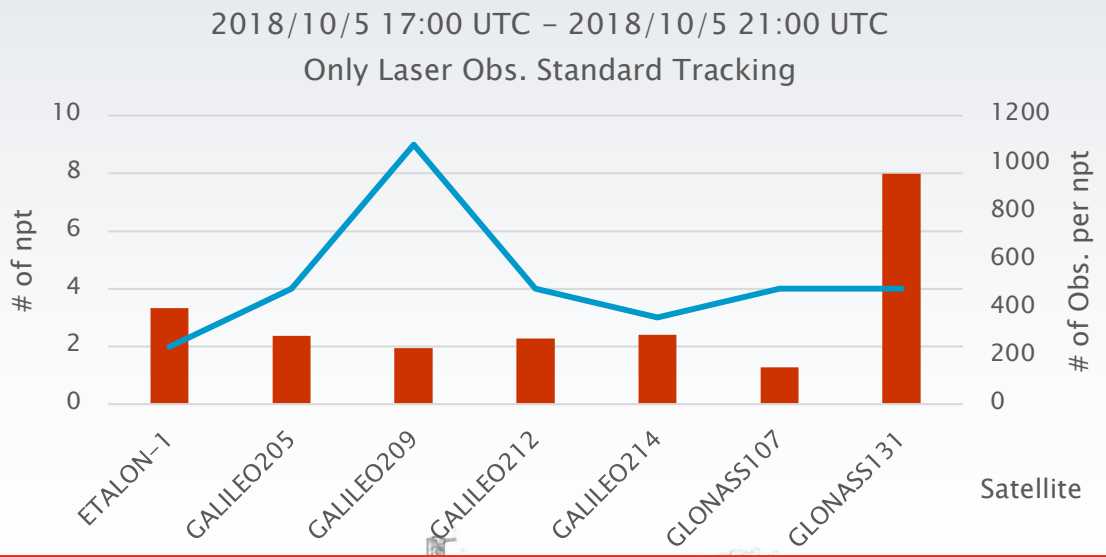
Exp. Time: 0.1s

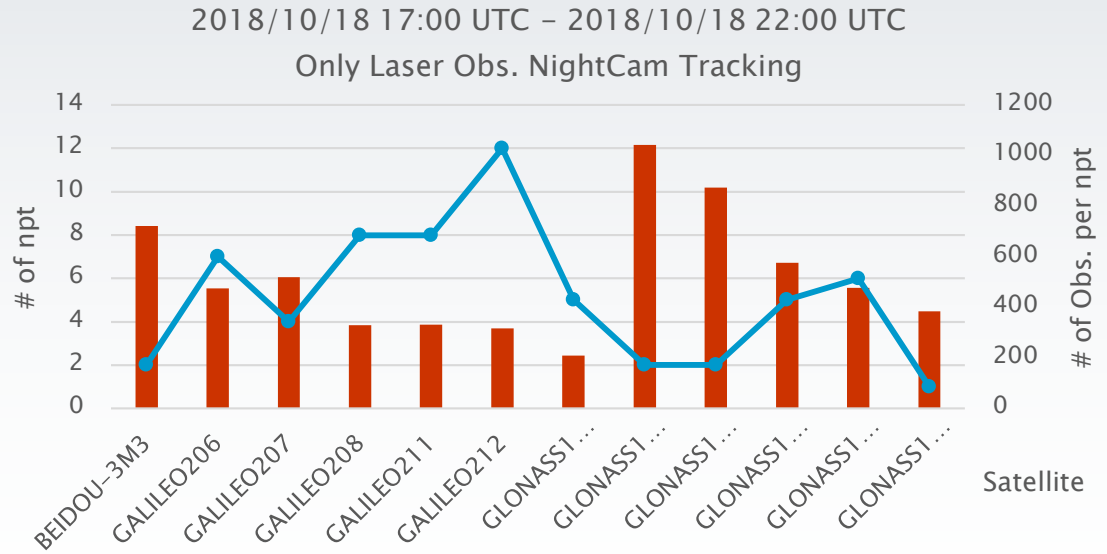
*OBS-COM Difference from expected (given by ephemeris) and measured time of flight of the laser pulse.

First Performance Analysis



Date	Hour of Obs.	MEO NPT/Hour	Obs./MEO NPT	Ave. NPT/MEO
2018/09/25	4	6,75	517	3,86
2018/10/05	4	7,5	370	4,28
2018/10/17	4	10	855	3,78
2018/10/18	5	12,4	522	5,17





Conclusion

Summary

- Hardware and software integration of tracking camera into SLR system
- Development of observation and tracking software to:
  - Control the camera
  - Calculate and send corrections to the laser observation system
- Real time orbit improvement via ephemeris correction
- Validation of the implemented tracking camera system in real obervation condition
- First performance analysis on observation results obtained by employing the Night-tracking camera and the automated telescope pointing corrections for satellite tracking

Interesting outcomes

- Improvement of the observation efficiency
- Capability of tracking defunct satellite with poor ephemeris in LEO and MEO

Outlook

Next Steps

- Improvement of laser pointing model on camera
  - Derotator Correction
  - Implementation of the model of the laser position changes on the camera due to telescope pointing direction
- Automatization
  - Object Recognition
  - Ephemeris Correction
- Correction improvement from Azimuth, Elevation to Along-, Cross-track
- Day time Application?!

Thank you for your attention