

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

E. Cordelli

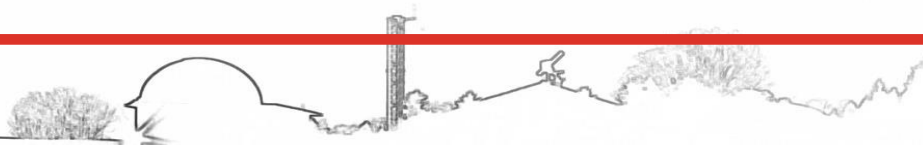
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21<sup>st</sup> International Workshop on Laser Ranging  
5–9 November 2018  
Canberra, Australia

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# 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

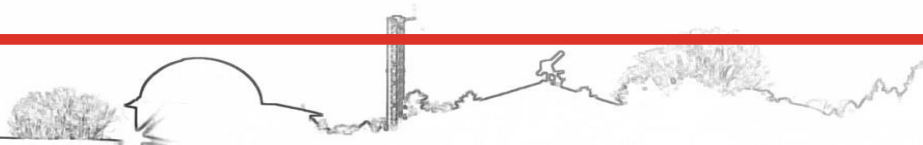
- **Telescope: ZIMLAT**
  - 1-m Aperture Ritchey-Crétien
  - Coudé focus for Laser
  - Nasmyth Focus for tracking and CCD cameras (available focal lengths: 1.2m, 2x4m, 8m)
- **Camera: Neo 5.5 sCMOS**
  - 1 e- read noise
  - TE cooling to  $-40^{\circ}\text{C}$
  - 5.5 megapixel sensor,  $6.5\ \mu\text{m}$  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



ZIMLAT  
Zimmerwald Laser and Astrometry Telescope

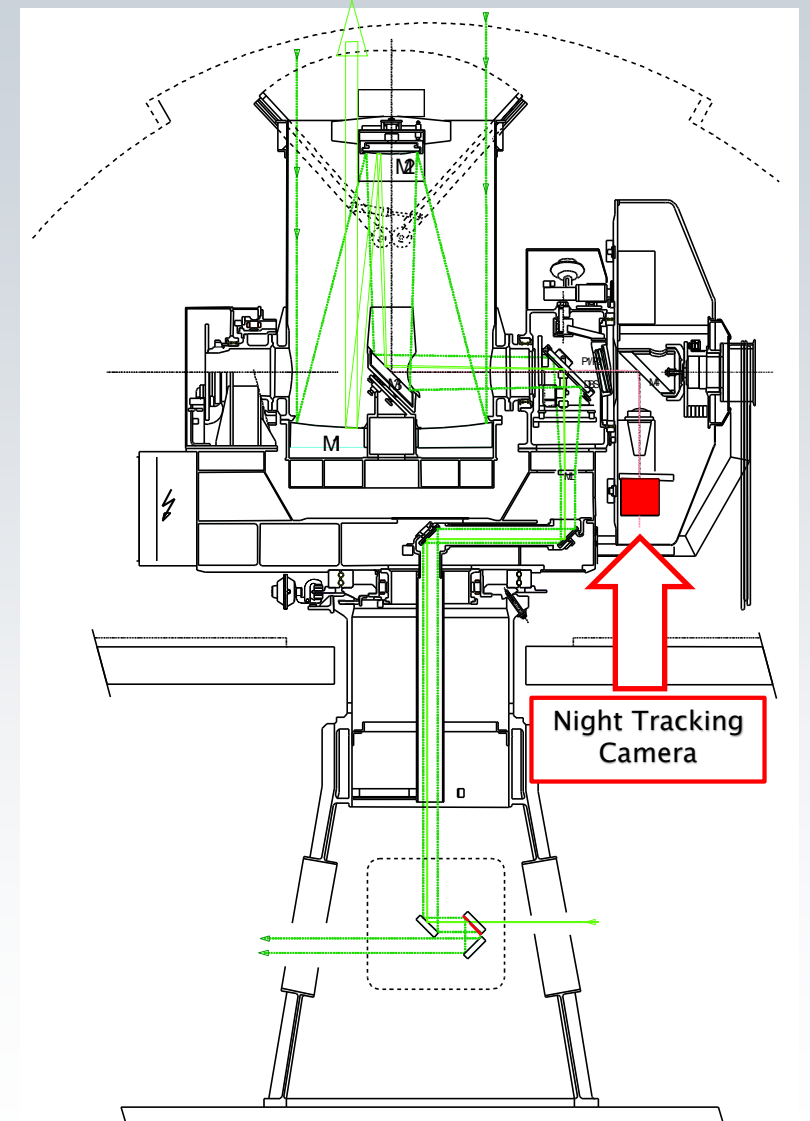
Credits: Oxford Instruments 2018

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**

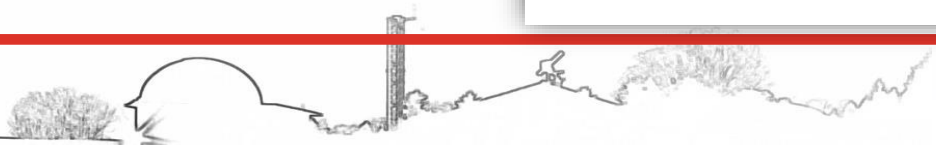
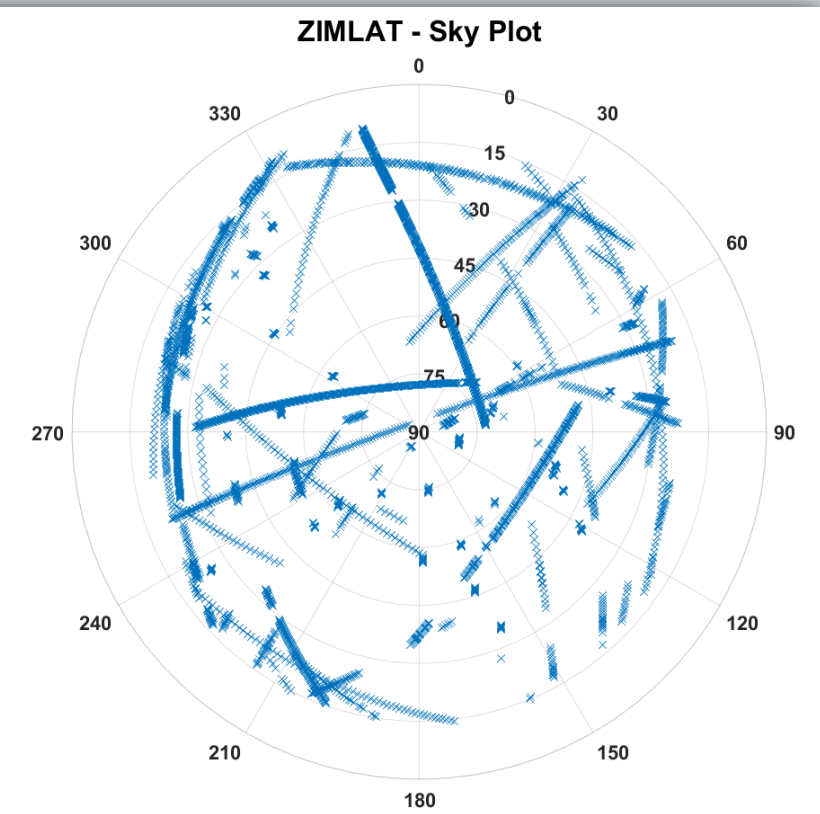
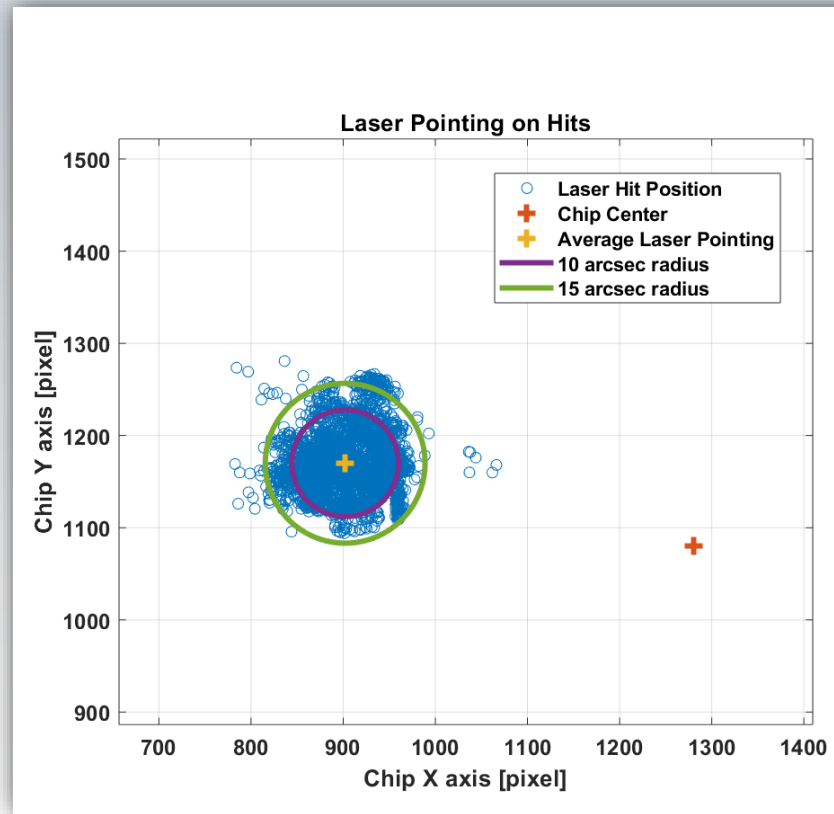


# Derivation of Pointing Model

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

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

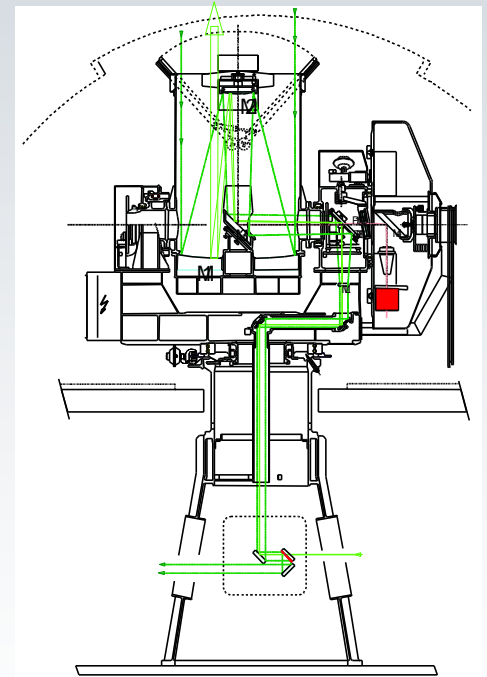
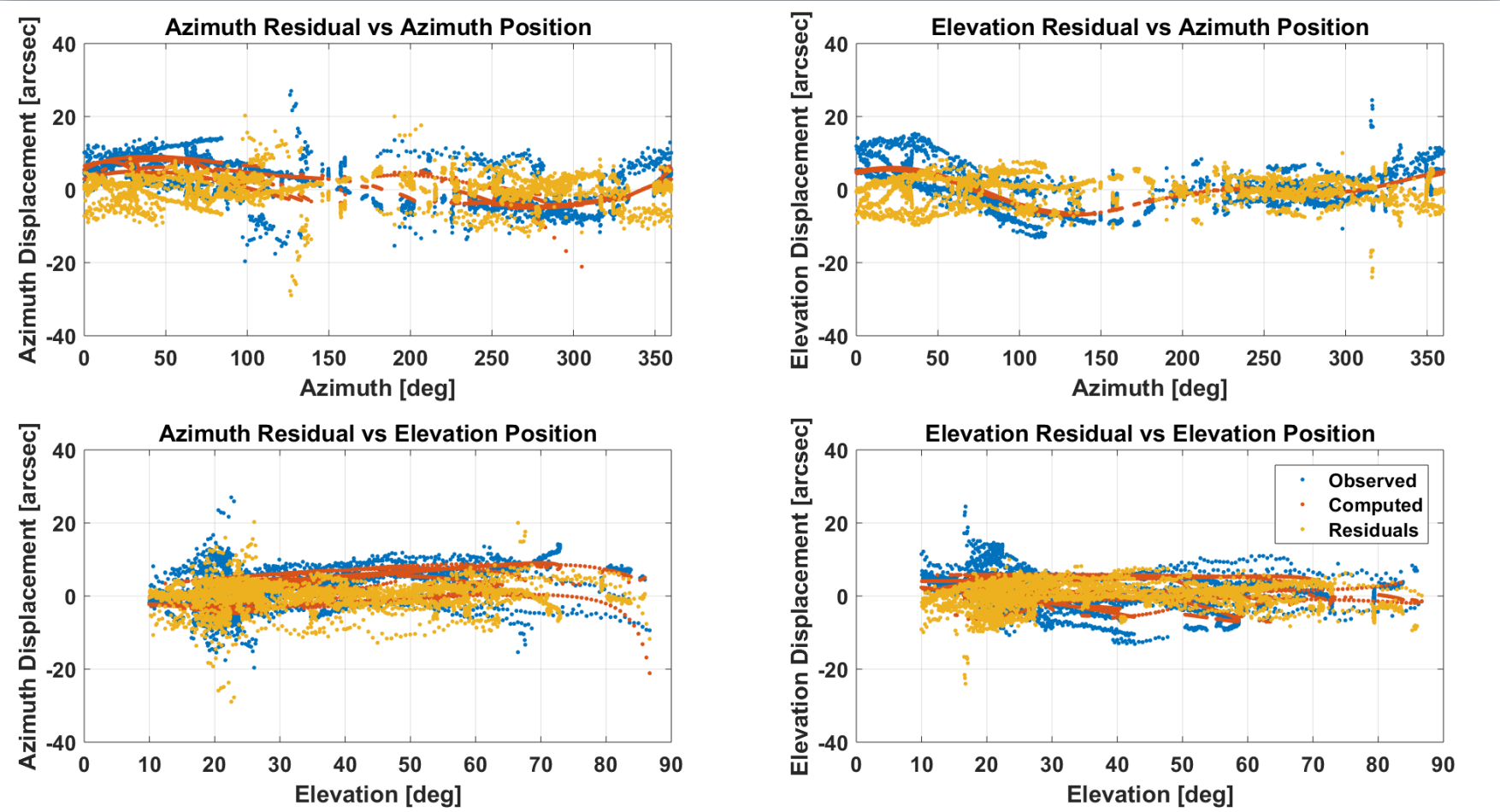
Star fields for camera orientation  
Derived from images when laser hits the target





# 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



E. Cordelli, Use of a Night-Tracking Camera for Real Time Correction of Pointing of the SLR System. 21st ILRS Workshop, Canberra, Australia, 5-9 November 2018.

# The NightCam Software

## NightCam Capabilities

### • Set up camera parameters

- Exp. Time
- Binning
- Shutter mode
- Readout frequency

### • Target Acquisition

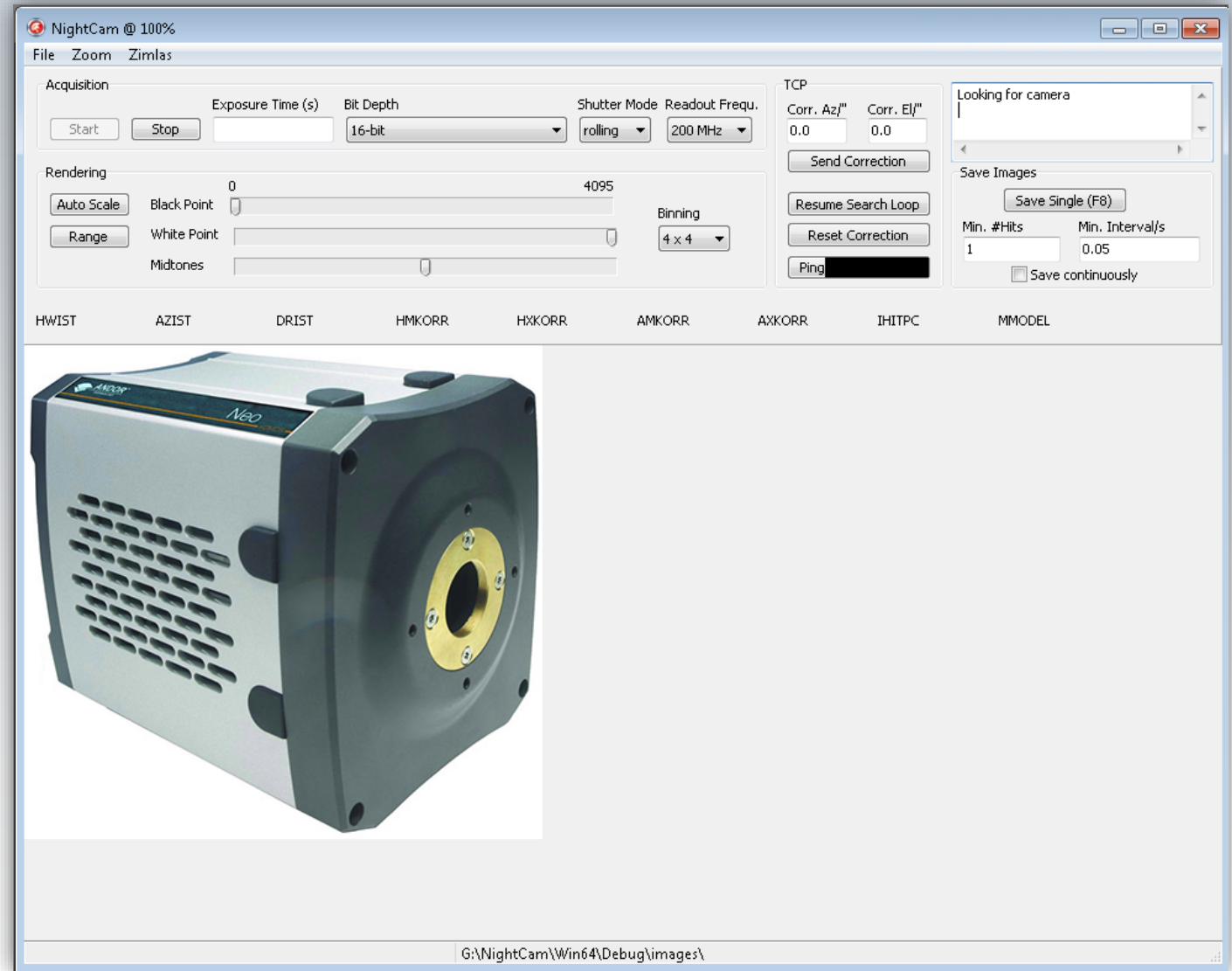
- Target Position w.r.t. Laser Position
- Azimuth/Elevation ephemeris correction handling
- Storing of Images with telescope data (pointing directions and measurement epoch)

### • Synchronous observations acquisition

- Azimuth/Elevation
- Range
- Light curve

### • Monitor telescope parameters

- Pointing directions
- Correction to pointing direction





# NightCam at Work

E. Cordelli, Use of a Night-Tracking Camera for Real Time Correction of Pointing of the SLR System. 21st ILRS Workshop, Canberra, Australia, 5-9 November 2018.

Before

Target: TOPEX

Date: 2018/10/19

Initial Ephemeris offset: ~68 arcsec

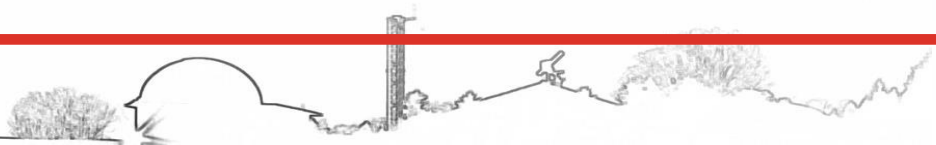
After

NightCam @ 38.8%  
 File Zoom Zimlas  
 Acquisition: Start Stop Exposure Time (s) 0.2 Bit Depth 16-bit Shutter Mode rolling Readout Freq. 200 MHz TCP Corr. Az 0.0 Corr. El 0.0 Frame rate: 1.1 Acquisition stopped  
 Rendering: Auto Scale Black Point 6 White Point 9 Midtones Binning 1x1  
 Save Images: Save Single (F8)  
 Min. #Hits 1 Min. Interval/s 0.05 Save continuously  
 HWIST=20.42 AZIST=309.72 DRIST=40.00 HMKORR=930.17 HXKORR=0.00 AMKORR=806.54 AXKORR=0.00 IHITPC=0 MMODEL=40

NightCam @ 38.8%  
 File Zoom Zimlas  
 Acquisition: Start Stop Exposure Time (s) 0.2 Bit Depth 16-bit Shutter Mode rolling Readout Freq. 200 MHz TCP Corr. Az 0.0 Corr. El 0.0 AutoImage 96 AutoImage 97  
 Rendering: Auto Scale Black Point 6 White Point 9 Midtones Binning 1x1  
 Save Images: Save Single (F8)  
 Min. #Hits 1 Min. Interval/s 0.05 Save continuously  
 HWIST=33.90 AZIST=294.89 DRIST=40.00 HMKORR=937.98 HXKORR=-41.98 AMKORR=764.86 AXKORR=69.70 IHITPC=23 MMODEL=40

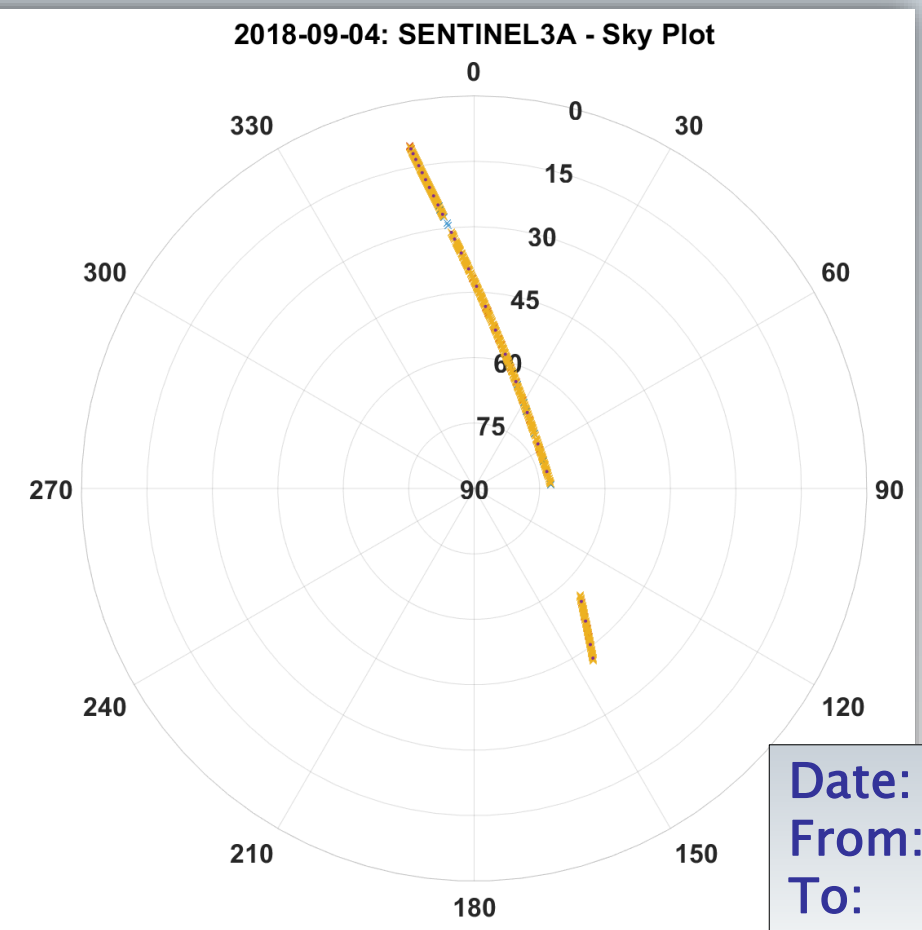
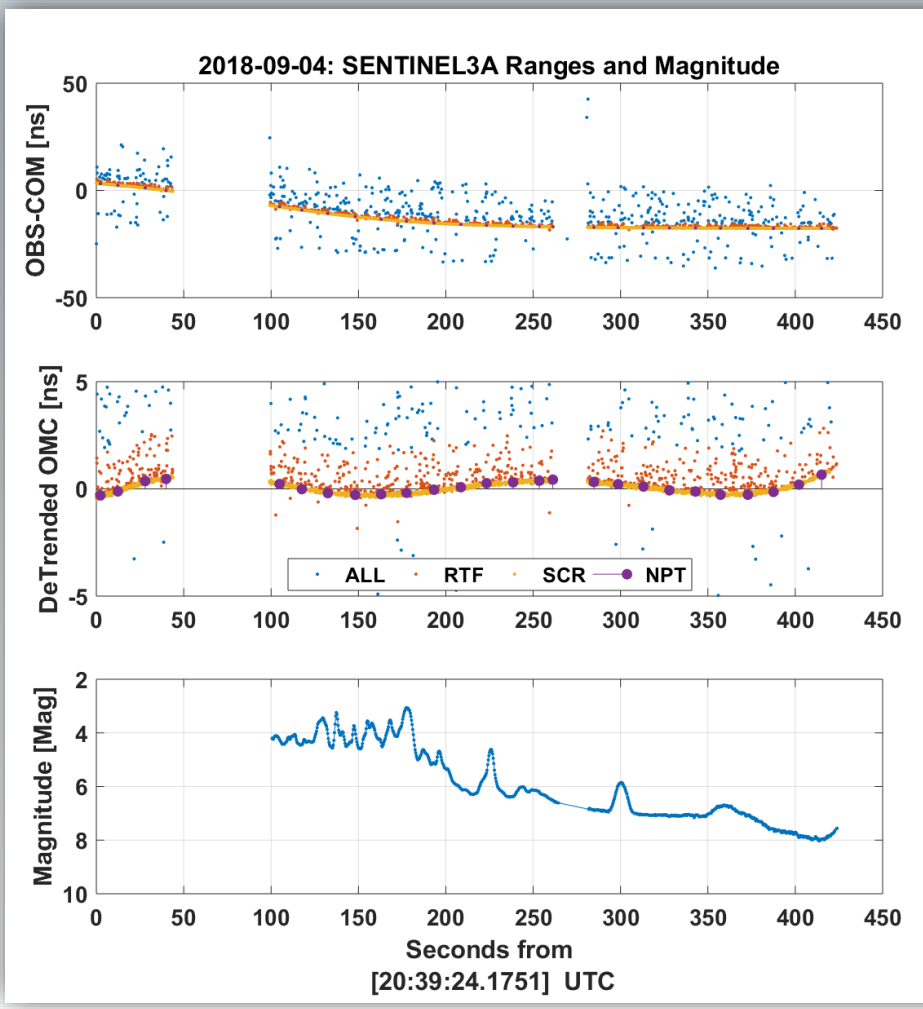
Name	Date modified	Type
Topex	18.10.2018 19:27	File folder
prefix20181018-210557-816.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210558-206.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210558-596.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210558-976.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210559-356.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210559-746.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210600-136.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210600-516.fit	18.10.2018 21:06	MaxIm DL
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prefix20181018-210601-696.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210602-096.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210602-486.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210602-866.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210603-246.fit	18.10.2018 21:06	MaxIm DL
prefix20181018-210603-636.fit	18.10.2018 21:06	MaxIm DL

Cooling status: Stabilised / Sensor temperature: -30.3 °C  
 G:\NightCam\Win64\Debug\images\20181018\



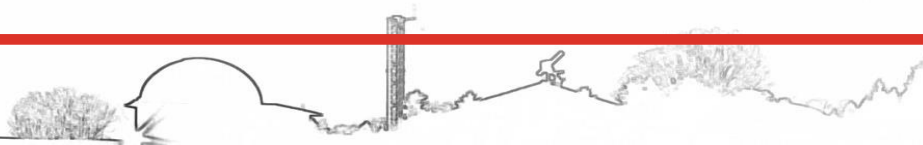
# NightCam Output

E. Cordelli, Use of a Night-Tracking Camera for Real Time Correction of Pointing of the SLR System. 21st ILRS Workshop, Canberra, Australia, 5-9 November 2018.



**Date:** 2018/09/04  
**From:** 20:39 UTC  
**To:** 20:47 UTC  
**Target:** SENTINEL 3A  
**Exp. Time:** 0.1s

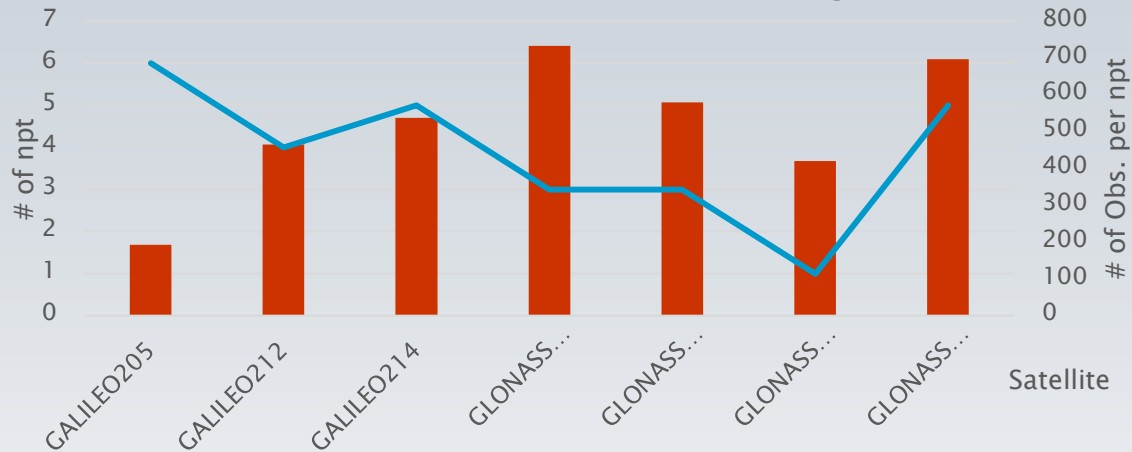
\*OBS-COM Difference from expected (given by ephemeris) and measured time of flight of the laser pulse.



# First Performance Analysis

2018/09/25 18:00 UTC – 2018/09/25 22:00 UTC

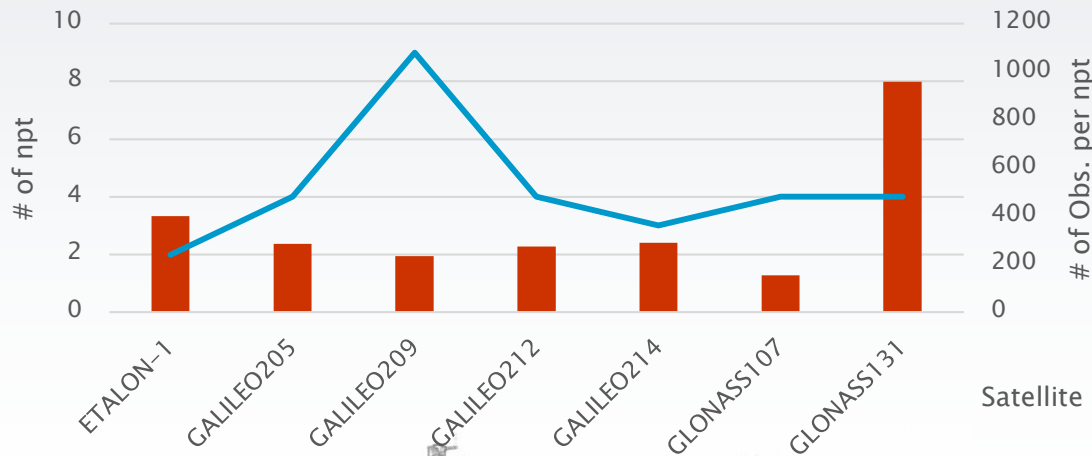
Only Laser Obs. Standard Tracking



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

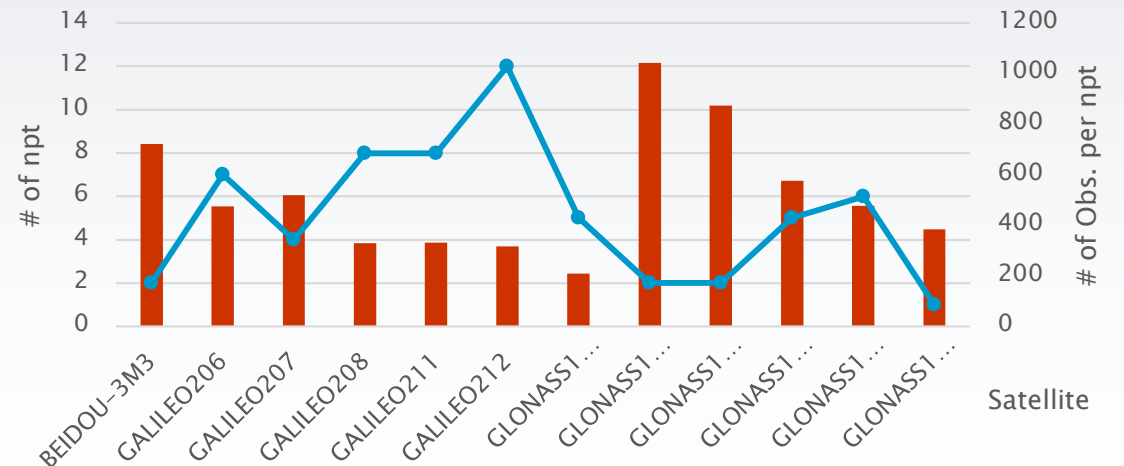
2018/10/5 17:00 UTC – 2018/10/5 21:00 UTC

Only Laser Obs. Standard Tracking



2018/10/18 17:00 UTC – 2018/10/18 22:00 UTC

Only Laser Obs. NightCam Tracking

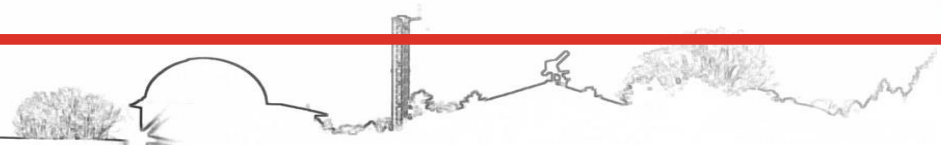


## Summary

- 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 observation condition
- First performance analysis on observation results obtained by employing the Night-tracking camera and the automated telescope pointing corrections for satellite tracking

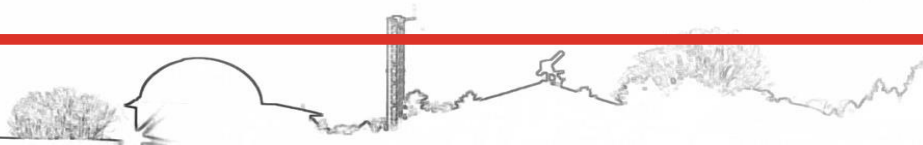
## Interesting outcomes

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



## 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

