Status of Telescope Fabra ROA Montsec (TFRM)

Optical Observations for Space Surveillance & Tracking

Fors O.[1,2], Montojo F.J.[3], Núñez J.[1,2], Muiños J.L.[3], Boloix, J.[3], Baena R.[1,2], Morcillo R.[3], Merino M.[1,2]

(1): Observatori Fabra, Reial Acadèmia de Ciències i Arts de Barcelona

(2): Dept. d'Astronomia i Meteorologia and Institut de Ciències del Cosmos (ICC), Universitat de Barcelona (UB/IEEC)

(3): Real Instituto y Observatorio de la Armada (ROA)

Contact: ofors@am.ub.es

Further info: http://www.am.ub.es/bnc

AMOS 2011, 13-16 September 2011

Overview

- Historic background of the TFRM

- TFRM refurbishment project

- First year of TFRM operations

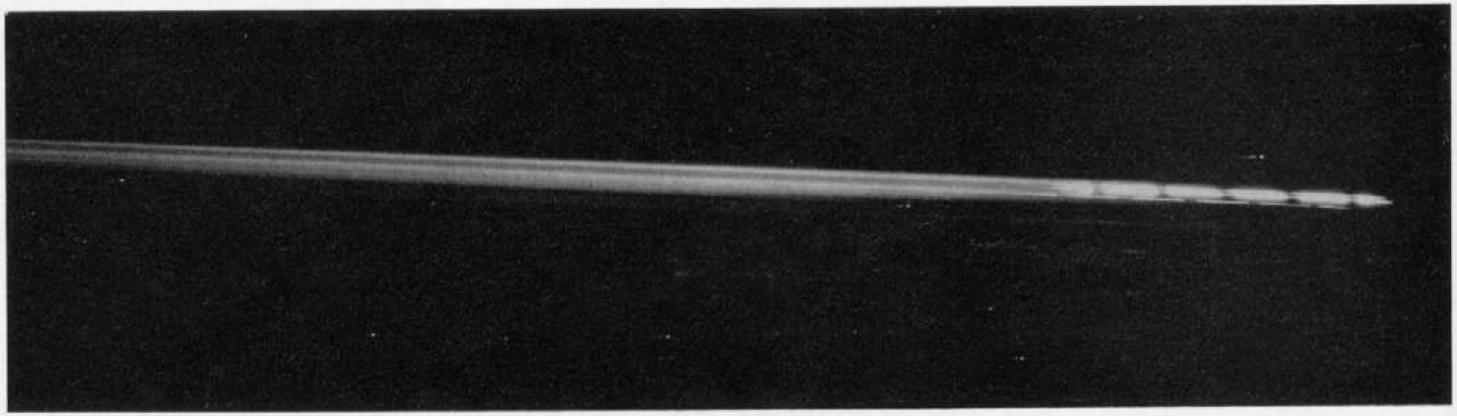
- First SST observations

- Preliminary SST results

- Immediate plans

Historic background of TFRM

- 21 Baker-Nunn Cameras (BNCs) were constructed by the Smithsonian Institution on early 60s for satellites photographic observation.
- One BNC was installed at ROA in 1958.



The fiery reentry and breakup of the rocket body that launched the Soviet satellite Cosmos 197, as seen during the beginning of the carrier's last revolution around the earth. This photograph was taken by Francisco Cano on the morning of January 8, 1968, with the Baker-Nunn camera at the Smithsonian Astrophysical Observatory's satellite tracking station at San Fernando, Spain. Breaks in the image were caused by the rotating shutter of the camera. A smoke train was visible for more than a minute. Final decay was probably halfway around the world in the South China Sea.

222 SKY AND TELESCOPE, *April, 1968*

- After GEODSS program superseded BNCs, ROA BNC was donated to this institution.
- ROA BNC remained inactive since 80s.

Ref.Proj.: mechanical modifications

- Conversion of altazimuthal to equatorial mount.

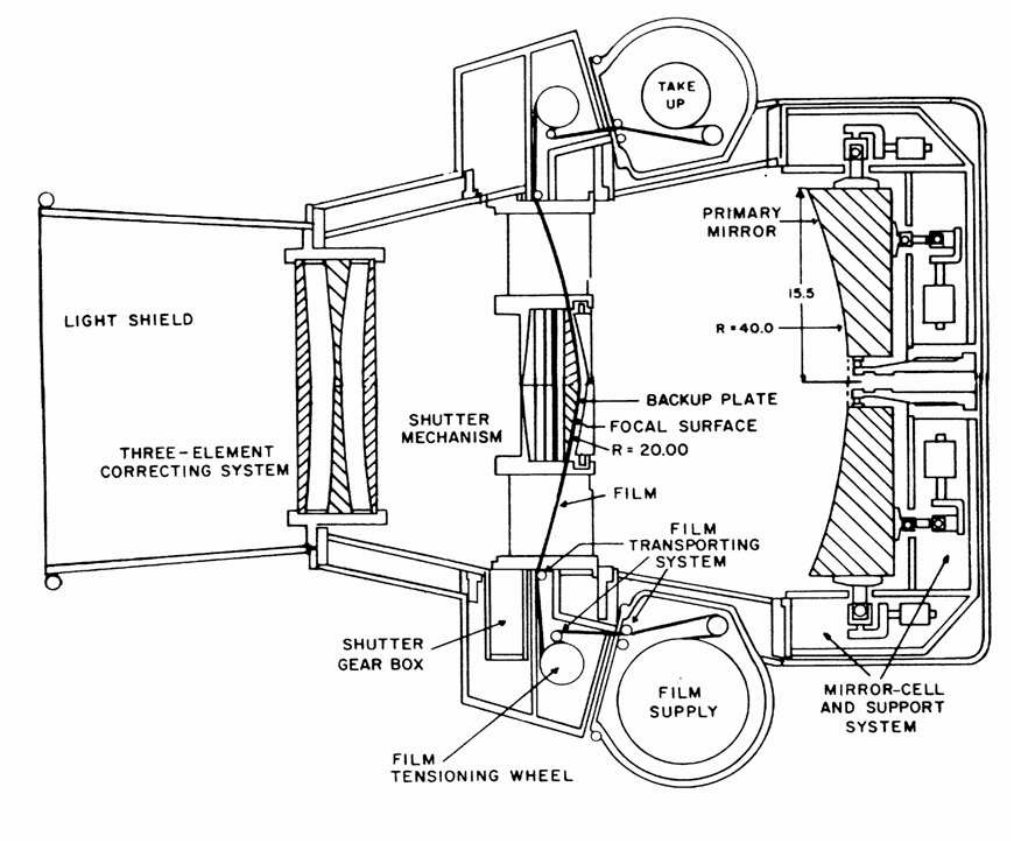
- Hour angle and declination axes are servo driven with absolute encoders feedback.

- Design and building of spider vanes which supports corrective optics, CCD, and focus motor (~10μm error).

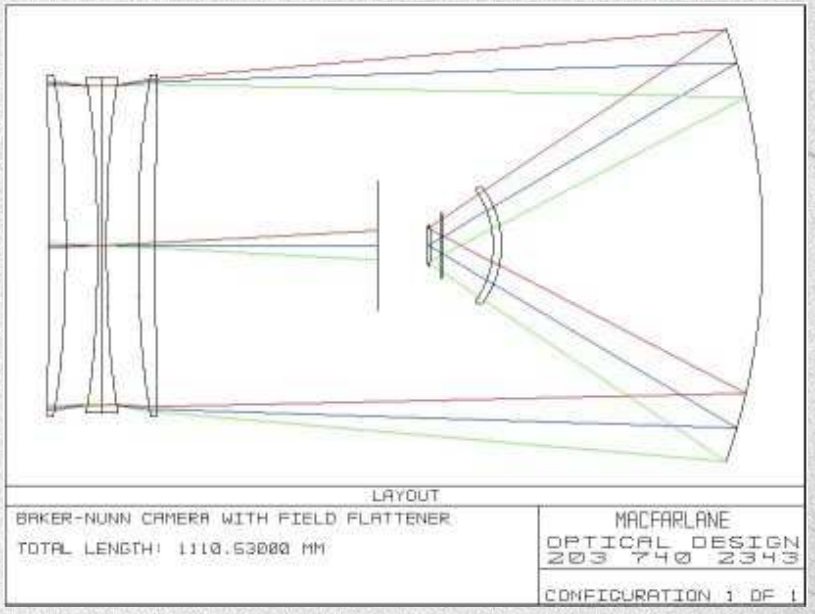
- 3D tip-tilters for accurate collimation of the system.

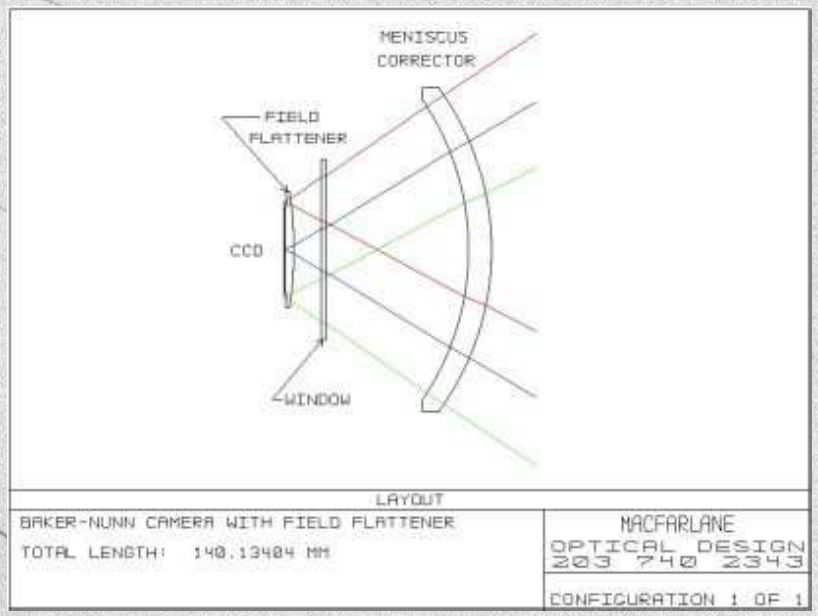
Ref.Proj.: optics refiguring

- Original focal plane is curved
- A new two-element corrective optics has been added
- The outermost surface of the 0.5m corrector plate is repolished and MgF_2 coated
- 0.78m primary mirror is realuminizated



Ref.Proj.: optics refiguring (II)



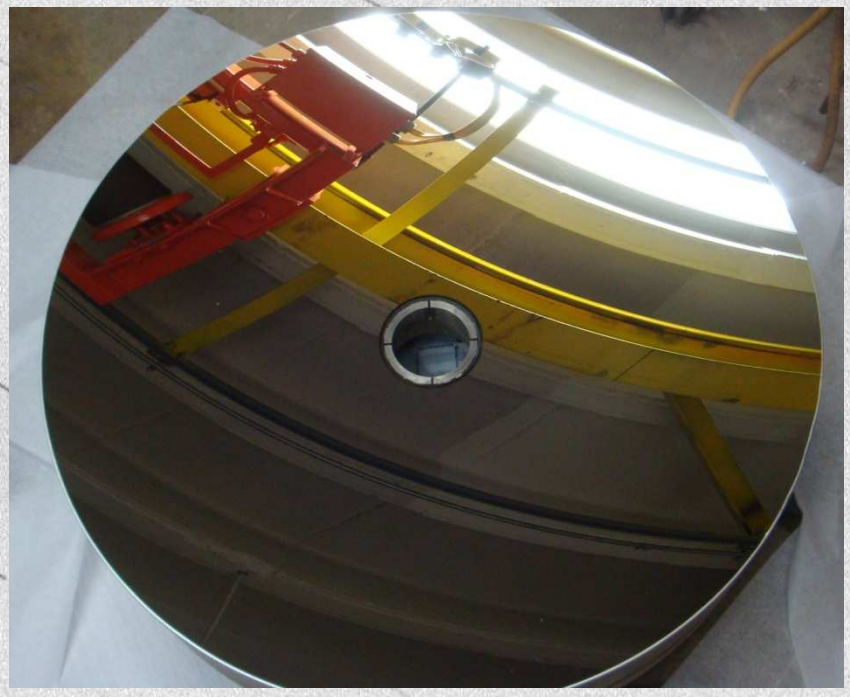


CaF field flattener lens **Ellipsoidal corrective meniscus** **Color filter**

Ref.Proj.: optics refiguring (III)

BEFORE

AFTER



DiamondBrite©

(97% reflectivity) and

high durability

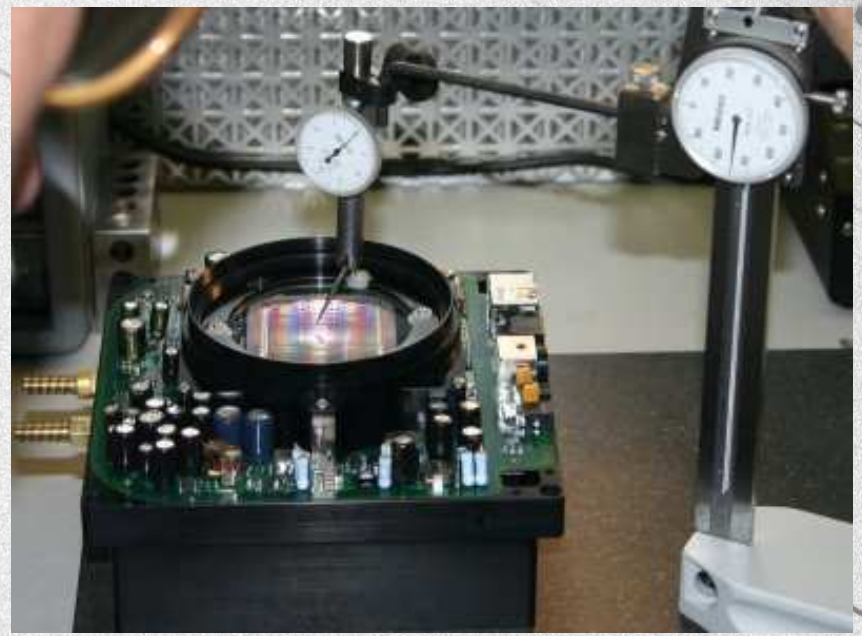
Ref.Proj.: optics refiguring (IV)

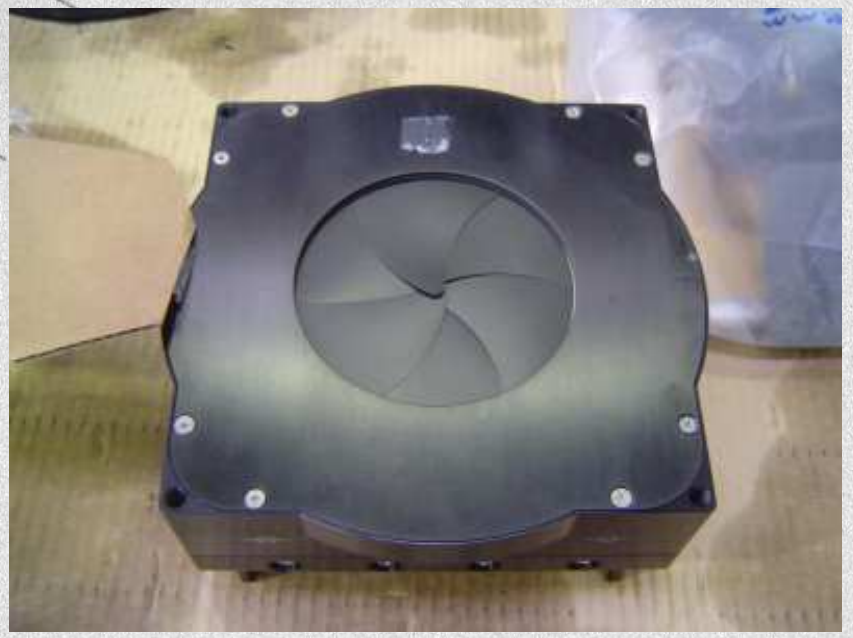
BEFORE

AFTER

Ref.Proj.: custom CCD

- CCD custom designed by FLI
- 4096x4096 9μm pixel CCD
- CCD FoV is 4.4ºx4.4º. Scale of 3.88arcsec/pixel
- Field flattener lens is only 0.65mm over the CCD chip
- CCD chip is Peltier cooled. Heat is pumped out the tube by refrigerated glycol recirculation



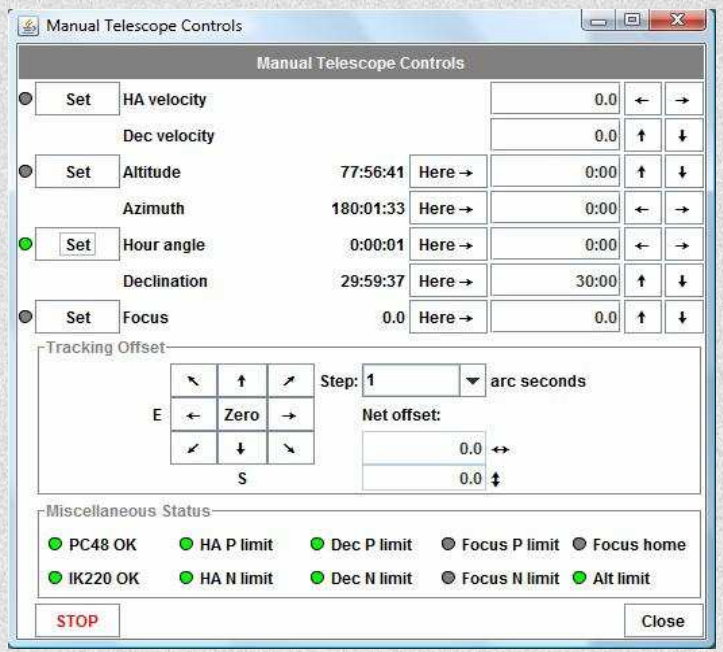


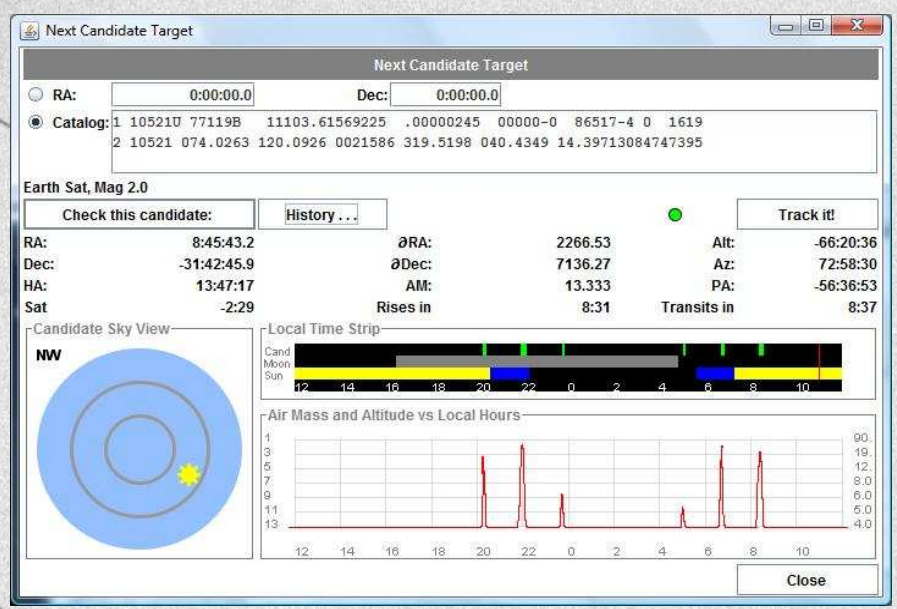
Ref.Proj.: observatory Control Software

- Based on Instrument-Neutral Distributed Interface (INDI) protocol, created by Elwood C. Downey (Clear Sky Institute, Inc.)

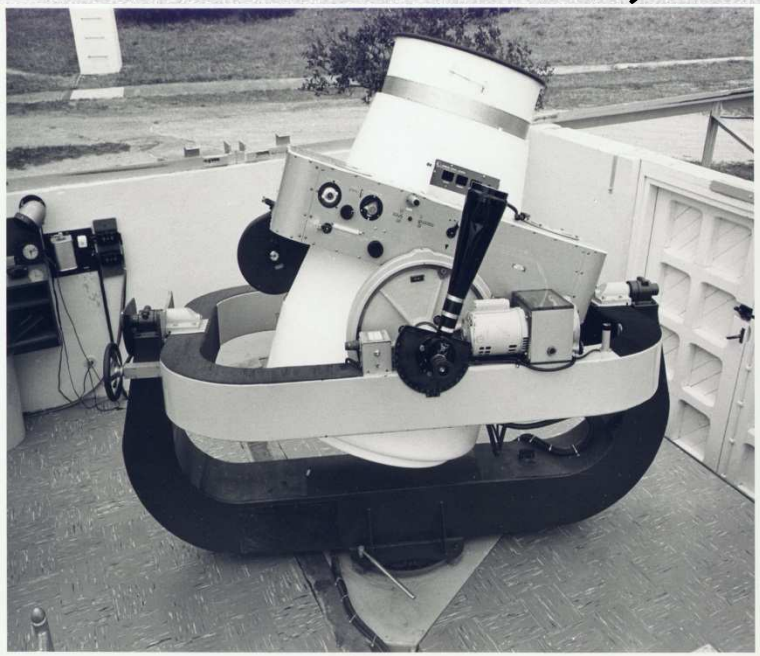
- INDI allows remote and robotic control of every observatory device from custom Java clients and schedulers

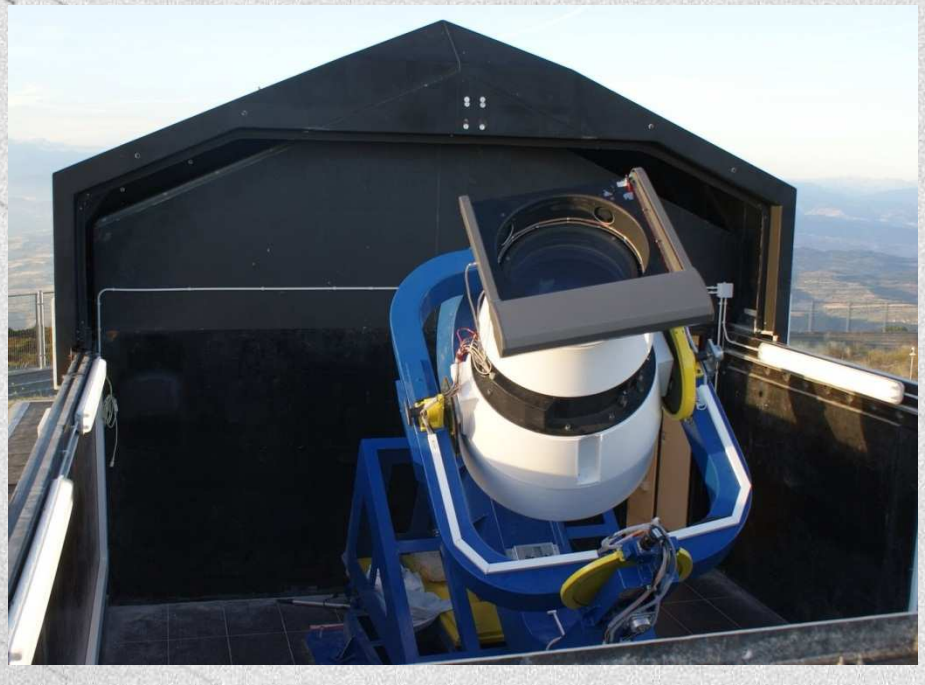
- Complex decisions can be automatically taken in basis of circumstances (weather, target visibility, etc.), with user high-level scripts (Python, Perl, bash)





Ref.Proj.: before and after





Ref.Proj.: specifications comparison

Original BNC

Mechanics	
Mount type	Altazimutal
Azimuth	Manual
Elevation	Manual
Optics	
Design	Original Baker-Nunn: Modified Schmidt with spherical mirror and 3-element plate corrector
Aperture	0.5m
Focal ratio	f/1
Scale	410arcsec/mm
Primary mirror	0.78m
Campo visual	5deg x 30deg
Spot size	<20µm throughout the FoV
Detector	
Detector	Cinemascope film

Refurbished TFRM

Mechanics	
Mount type	Ecuatorial
Hour angle	Digital servo driven motors
Declination	Digital servo driven motors
Optics	
Design	Baker-Nunn with corrective optics: field flattener and meniscus
Aperture	0.5m
Focal ratio	f/0.96
Scale	3.88arcsec/pixel
Primary mirror	0.78m
CCD FoV	4.41deg x 4.41deg
Spot size	<20µm throughout the FoV
Detector	
Sensor	Kodak KAF-16803, 4kx4k, 9µm
CCD QE	60% a 550nm
Camera	FLI PL16803, custom design

First year of the TFRM operations

- Early Sep 2010: installation of TFRM at Montsec Astronomical Observatory (OAdM)
- 10 Sep 2010: collimation of TFRM
- 11 Sep 2010: first light of TFRM
- 16 Sep 2010: inauguration of TFRM
- Late Dec 2010: INDI control software tunning
- 07 Feb 2011: first remote observation
- 25 Feb 2011: first unsupervised robotic observation
- Since then, intensive testing under commissioning period.
  TFRM conducted numerous programs: detection of exoplanets, SST, NEOs, and γ–ray optical counterparts monitoring.

First SST observations

TFRM specifications make an efficient facility to track and survey from faint GEOs to fast LEOs objects:

- **Fully robotic telescope**
- **Huge FoV (4.4º x 4.4º) free of optical aberrations**
- **Moderate limiting magnitude (V~20mag ≡ 15cm size @ GEO orbit) with 30s integration**
- **Arbitrary rate tracking simultaneously in RA and DEC (target tracking by TLE specification)**
- **CCD shutter triggering several times at will during an exposure, with 0.1ms timestamp accuracy**
- **Astrometric accuracies of 0.25arcsec for point-like objects**
- **Astrometric accuracies of 0.5arcsec for trailed stars**

First SST observations (II)

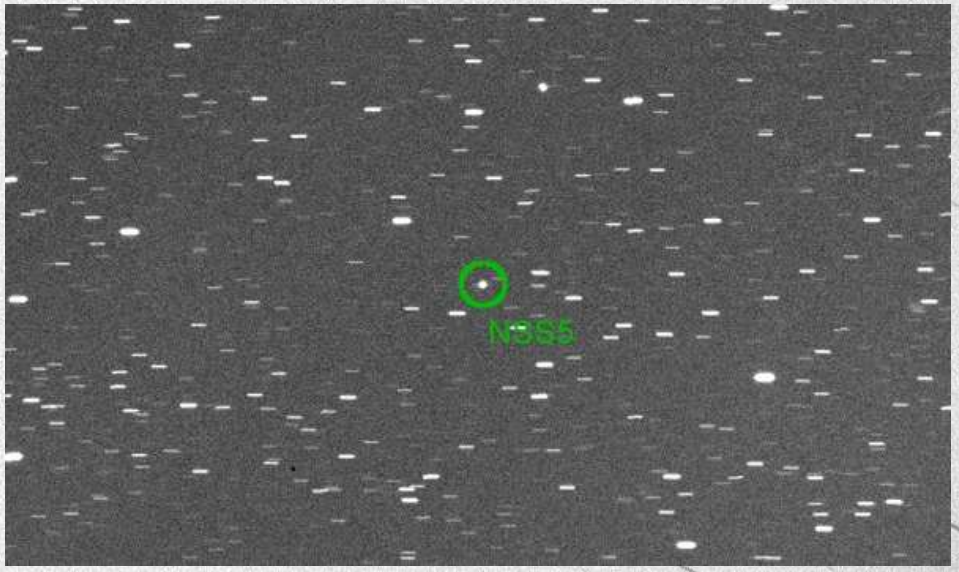
GEOs TRACKING observations:

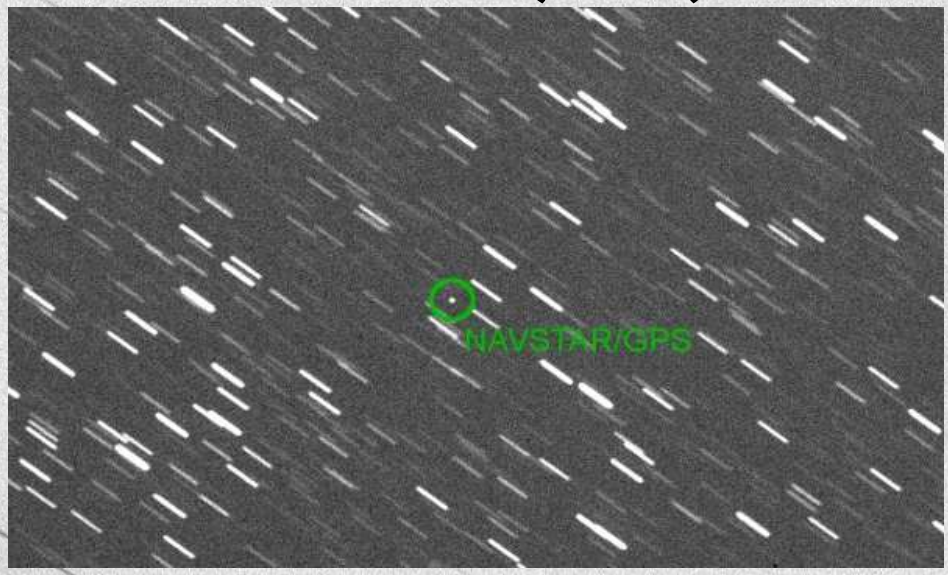
- TFRM participated in the 3rd run of the ESA CO-VI satellite tracking campaign of the SST/Space Surveillance Awareness Preparatory Program (SST/SSA-PP).
- 13 telescopes and radars from different European countries participated, coordinated by the Astronomical Institute University of Bern (AIUB) office.
- From 30 Jan 2011 to 7 Feb 2011, TFRM conducted systematic observations of artificial satellites to determine 1137 accurate position measurements.

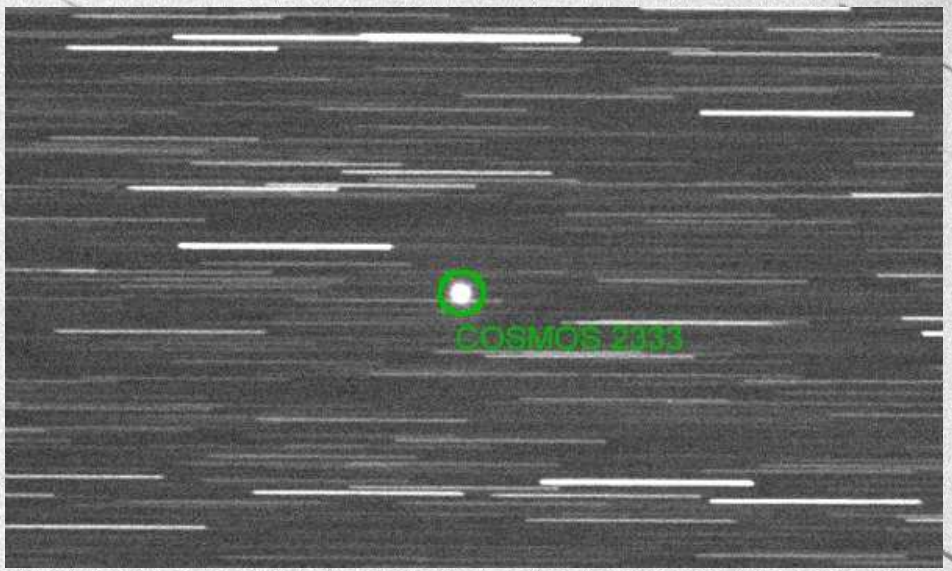
GEOs SURVEY observations:

- TFRM started to participate with ISON network as external collaborator. Preliminary results are encouraging but still deserve further observations to conclude survey efficiency, accuracy and other key parameters.

First SST observations (III)







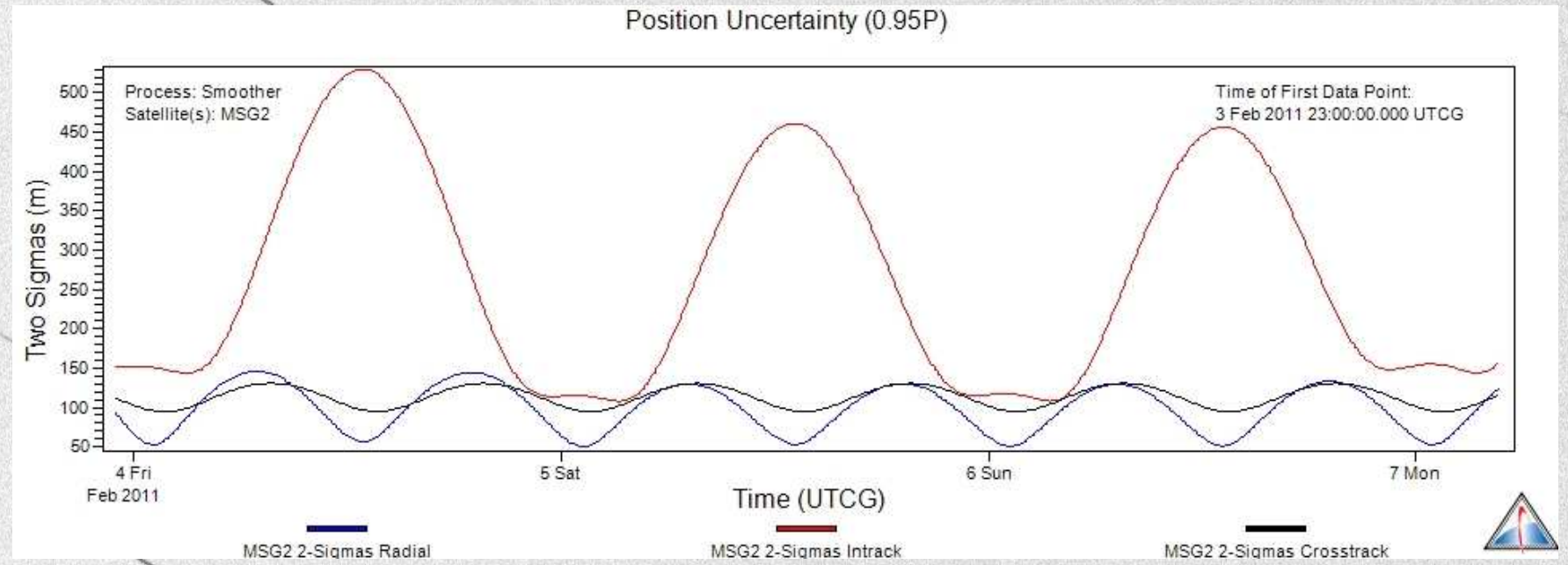
NSS5: 5s exp.time

NAVSTAR/GPS: 5s exp.time

COSMOS 2333: 1s exp.time

Preliminary SST results

Computation of Orbit Determination from the angular measurements of the ESA CO-IV SST observations with Orbit Determination Tool Kit (ODTK) software package (AGI).



2-sigma (95%) uncertainties obtained over the MSG2 satellite, with 175 angular measurements along the 4-night interval. Mean uncertainties in the classical elements (semiaxis, eccentricity and inclination), are of the order of 12m, $1.8 \cdot 10^{-6}$ and $1.5 \cdot 10^{-4}$deg respectively.

Immediate plans

- Some hardware and software upgrades are currently being carried out at the TFRM.

- We plan to calibrate our GEO tracking performance through the intensive observation of known GEO satellites and the comparison with the orbital elements provided by the Satellite Control Agencies (EUMETSAT, HISPASAT).

Thank you!