Green Bank, WV 19-24 September 2016, Workshop

Metrology and Control of Large Telescopes

New tools for SRT metrology: laser tracker & simulator for photogrammetric survey

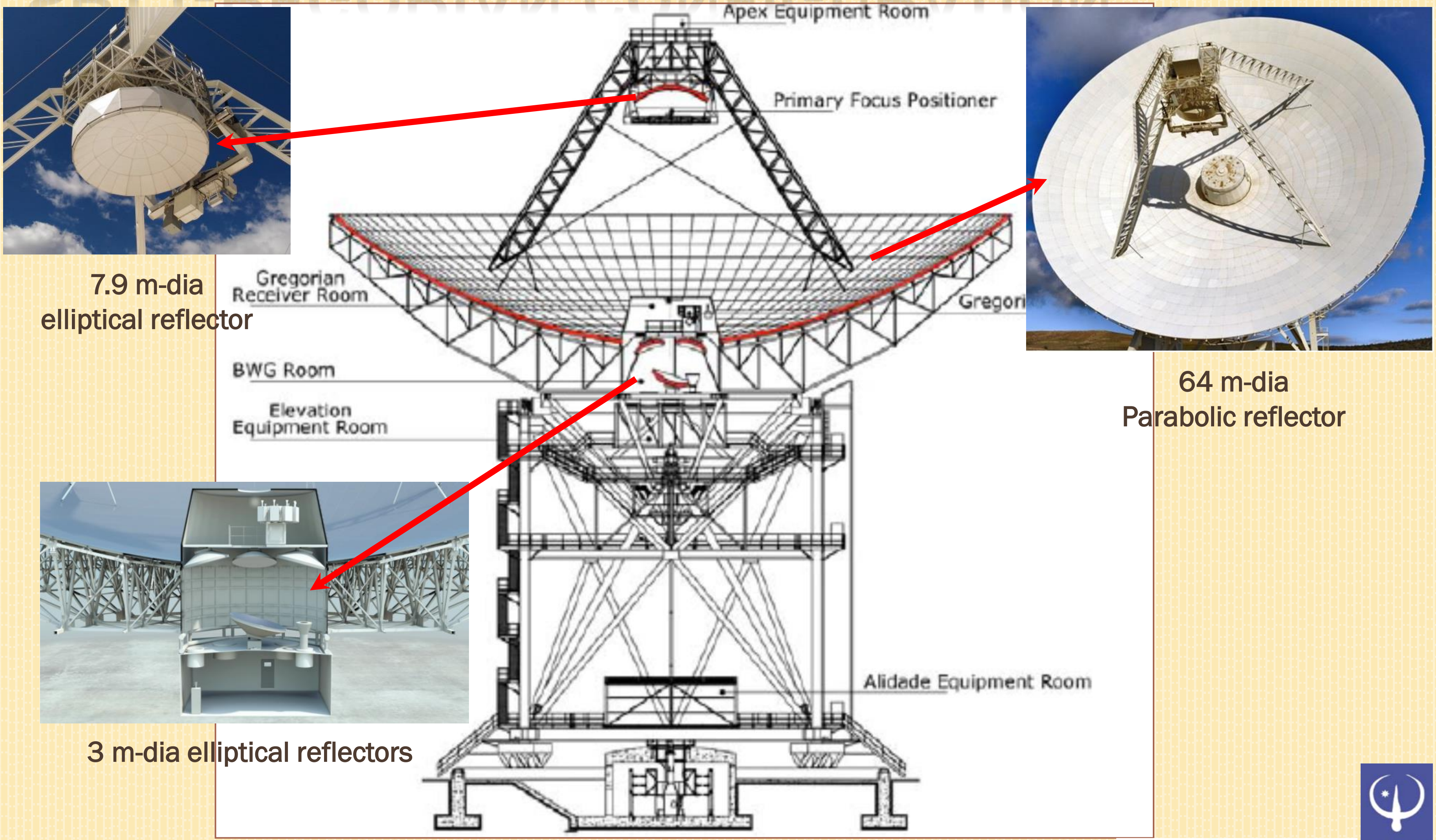
Serra G. [1], Buffa F.[1], Deiana G. L. [1], Marongiu P. [1], Pisanu T. [1], Poppi S. [1], Urru E. [1], G. Sanna[2]

[1]Astronomical Observatory of Cagliari (OAC) - Sardinia Radio Telescope (SRT)
Italian National Institute for Astrophysics (INAF)
[2]University of Cagliari,
Department of Civil, Environmental Engineering and Architecture, Italy

AGENDA

- SRT optical configuration
- Laser tracker measurement of SRT subreflector
- Simulation tool for close range photogrammetric survey for the SRT primary reflector
- Summary and discussion

SRT GREGORIAN CONFIGURATION



7.9 m-dia
elliptical reflector

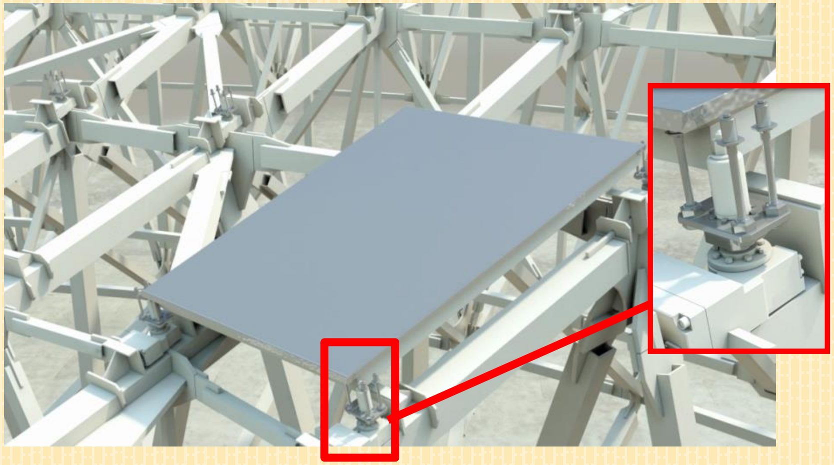
64 m-dia
Parabolic reflector

3 m-dia elliptical reflectors

SRT optical configuration

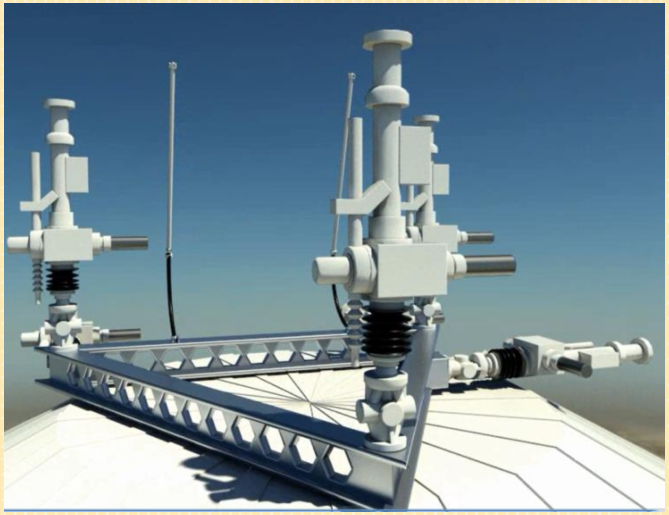
ACTIVE OPTICS

Primary reflector actuators



- 1116 electro-mechanical actuators (maximum stroke ± 15 mm)
- from a shaped profile to a parabolic profile (increase primary focus operating frequency)
- correct deformations induced by gravity

Subreflector actuators



- 6 electro-mechanical actuators able to:
  - **translate** sub-reflector paralelly (max ± 50 mm) and orthogonally (max ± 110 mm) to elevation axes , and long optical axis (max ± 110 mm)
  - **Rotate** sub-reflector around the same three axis (max ± 0.25 arcsec)
- Correct primary-secondary mirror misalignment and focal distance
- Compensate the rigid-body motions of the main mirror (those that primary mirror actuators can not correct)

Laser tracker (LT) measurement of the SRT subreflector

PRIMARY–SUBREFLECTOR ALIGNMENT

SIGMA 3D measurements (2012) with LT (Faro SN 3301)

- Alignment of the reflectors best fit axes at @ 45° elevation
- Measurements at 7 different elevations (step of 15° up to 90°, 45° as reference alignment)
- **look-up table (LUT**) corrections for the gravity deformations of the subreflector at all the elevation range by a polynomial fitting

Temporary subreflector LUT

El [deg]	Y-shift [mm]	Z-shift [mm]	X-rot [arcsec]
90°	-39,99	2,60	540
75°	-25,36	2,31	346
60°	-11,72	1,49	156
45°	0,00	0,00	0
30°	8,91	-1,77	-120
15°	14,96	-3,89	-196
5°	16,88	-5,56	-221

Y is orthogonal to the elevation axis
Z is parallel to the antenna optical axis
X is parallel to the elevation axis

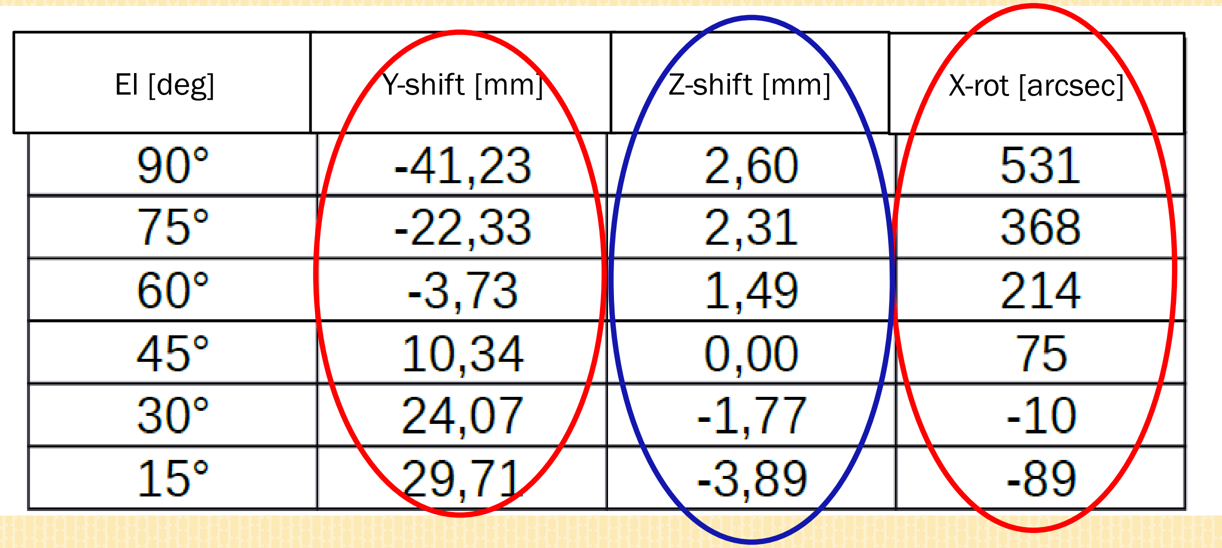
PRIMARY–SUBREFLECTOR ALIGNMENT

SRT technical commissioning (2013-14)

LUT was updated by astronomical observations:

- Z- shift for focus adjustment
- X-rotation and Y-shift to compensate for the rigid-body motion of the primary reflector (not being compensated by the primary mirror actuators once the active surface was enabled)

Current subreflector LUT



El [deg]	Y-shift [mm]	Z-shift [mm]	X-rot [arcsec]
90°	-41,23	2,60	531
75°	-22,33	2,31	368
60°	-3,73	1,49	214
45°	10,34	0,00	75
30°	24,07	-1,77	-10
15°	29,71	-3,89	-89

Y is orthogonal to the elevation axis
Z is parallel to the antenna optical axis
X is parallel to the elevation axis

Laser tracker measurement of SRT subreflector

NEW LASER TRACKER MEAS. ON THE SUBREFLECTOR

Leica Absolute Tracker AT 402
(2016)

LT and target reflector features

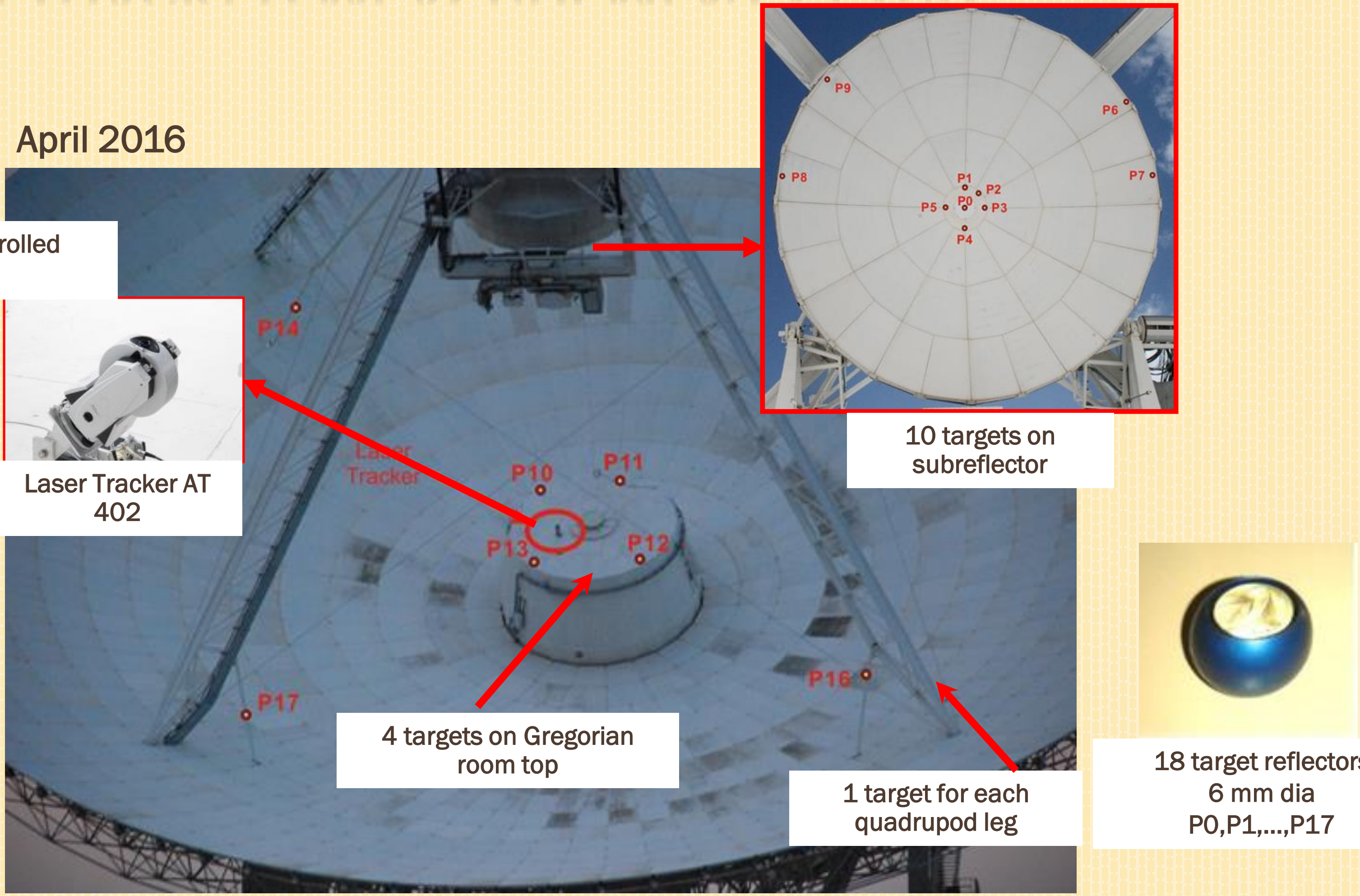
- Remotely controlled via Wireless or W-LAN connection
- digital camera, whose software is able to recognise/track the targets
- Angular accuracy: ± 15 μm + 6 μm/m
- Distance accuracy: ± 10 μm

Target reflectors Radius	Acceptance Angle	Use	cost
			€)
			€)
			€)

- Check the motions of the subreflector
- Define a procedure to build a suitable reference frame for our LT meas.
- Check the current subreflector look-up table

LASER TRACKER MEASUREMENT SETUP

April 2016



Remotely controlled by W-LAN

Laser Tracker AT 402

10 targets on subreflector

4 targets on Gregorian room top

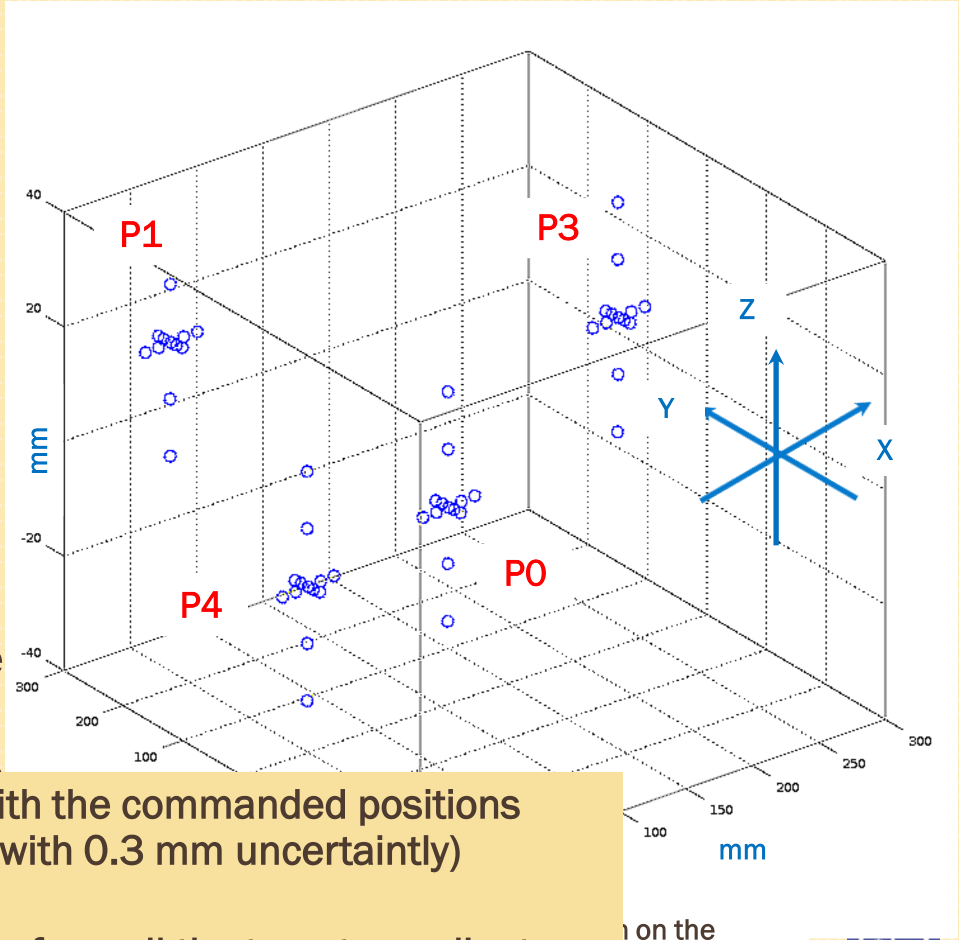
1 target for each quadrupod leg

18 target reflectors
6 mm dia
P0,P1,...,P17

SUBREFLECTOR MOTIONS AND REFERENCE FRAME

April 2016, first LT measurement

- antenna at 45° Elevation (best primary-subreflector alignment from Sigma 3D meas.)
- With LUT enabled we moved remotely the actuators by 5 steps of 10 mm in X, Y and Z direction
- Targets on the subreflector depicts **3D crosses**
- After a roto-translation the **3D crosses** were referred to the mechanical reference frame (by exploiting P0, P1, P2, P3, P4 and P5 mechanical positions as reference points)



on the
ne

1. **Targets moved consistently with the commanded positions (same axis, sign and amount with 0.3 mm uncertaintly)**
2. **Roto-translation matrix to transform all the target coordinates to the mechanical reference frame of the subreflector**

VALIDATION OF THE SUBREFL. REFERENCE FRAME

April 2016: second LT measurement

Schedule

- Measurements at 6, 15, 25, 35, 45, 55*, 65, 75, 85, 90 deg of the antenna elevation with
  - Subreflector LUT disabled (actuators parked) → OFF
  - Subreflector LUT enabled (actuator working) → ON

Data processing

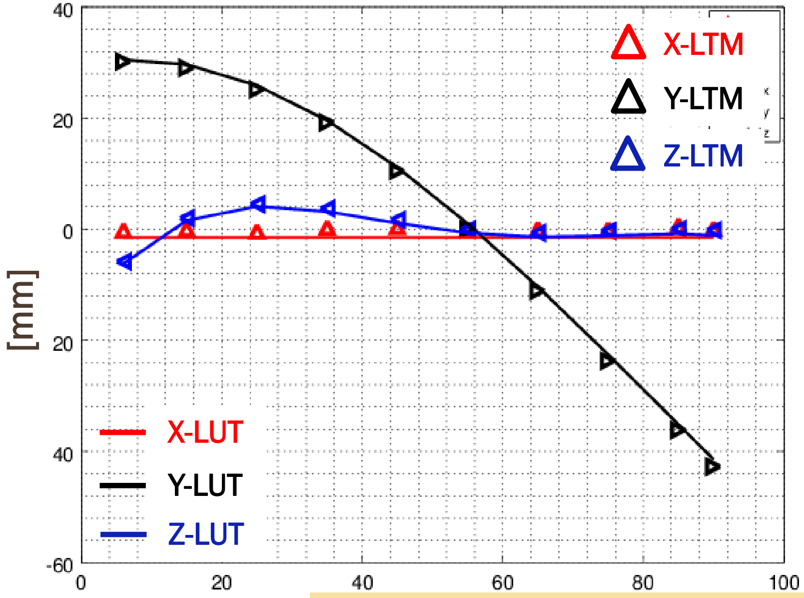
- Each dataset (one for each target on the subreflector) was roto-translated in the mechanical reference frame of the subreflector (defined before)
- Bias due to the small movements of the LT support were deleted from each dataset (bias detected thanks to the other targets)
- Reference elevation 55 deg (arbitrarly chosen as best alignment)

VALIDATION OF THE SUBREFL. REFERENCE FRAME

April 2016: second LT measurement

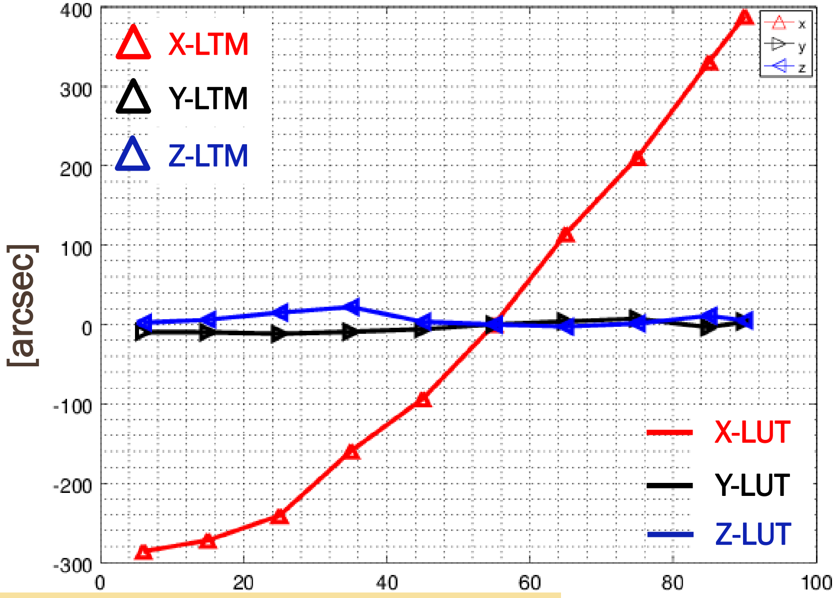
ON-OFF

Shifts



ON-OFF

Rotations



1 Subreflector motions are consistent with those commanded

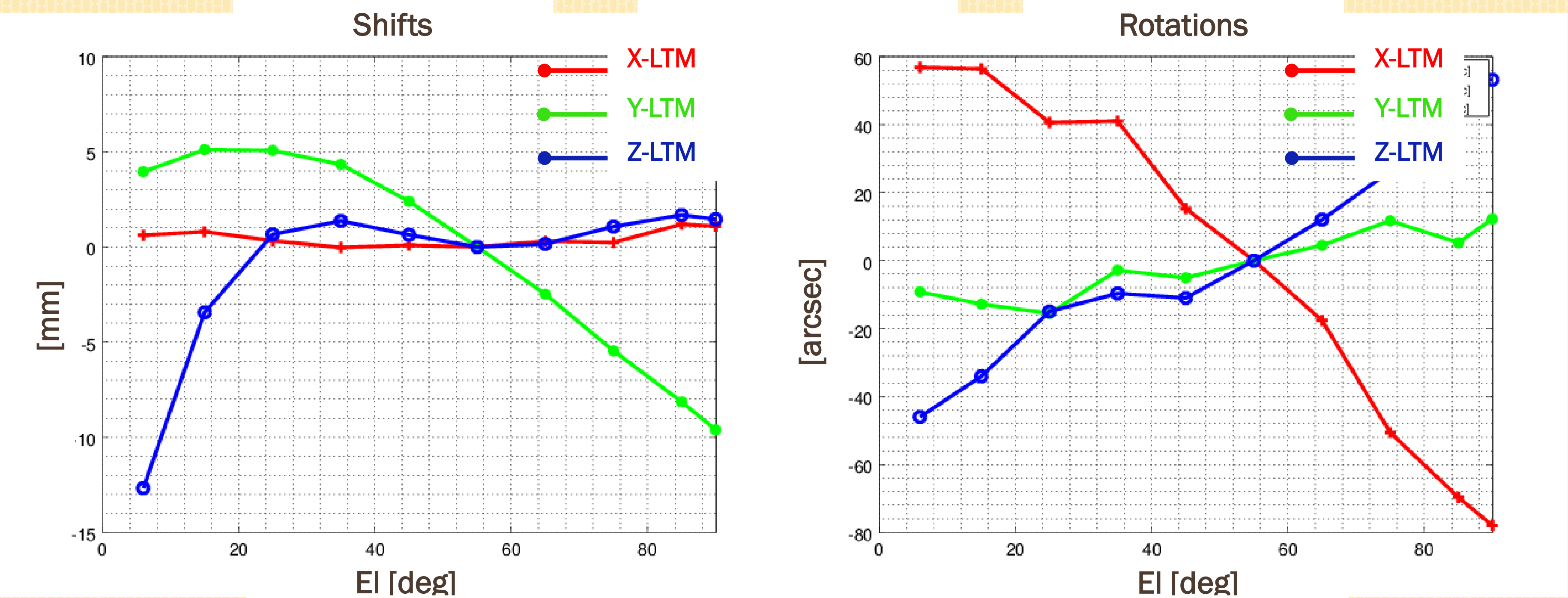
2

1. Subreflector motions are consistent with those commanded
2. Our mechanical reference frame is consistent with the reference frame of the subreflector

VALIDATION OF THE SUBREFLECTOR LUT

April 2016: second LT measurement

LUT ON



Residual misalignments w.r.t. 55° el

Y-axis shift → 5 mm @ 15° el and up -10 mm @ 90° el
Z-axis shift → Up to -3 mm @ 15°el

X-axis rotations → 56 arcsec @ 15° el, up -80 arcsec @ 90° el

Laser tracker measurement of SRT subreflector

Simulation tool
for close range photogrammetric survey

In collaboration with Prof. G. Sanna

University of Cagliari, Department of Civil, Environmental Engineering and Architecture, Italy

SIMULATION TOOL FOR PHOTOGRAMMETRY

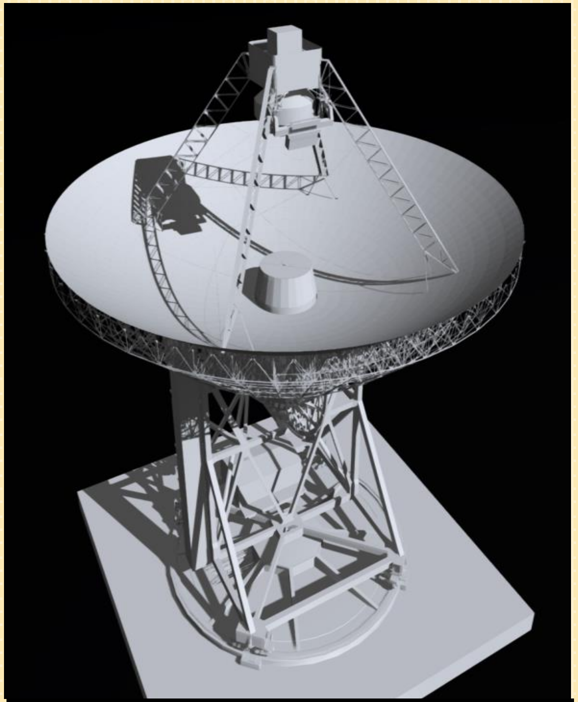
Photogrammetry surveys on large antennas are not trivial task

We have implemented a simulation pipeline (3D-models of the antenna is needed) able to:

- select the camera parameters, the image acquisition angle
- Set the crane position or a configuration of fixed camera to be installed on the antenna (on robotic sled or rail)
- evaluate different scenarios and select those providing the best measurement accuracy

In order to generate synthetic images we developed two software platform based on:

- Matlab tool
- Python-blender



3D model of SRT (320k vertices)
http://goo.gl/L1sucv

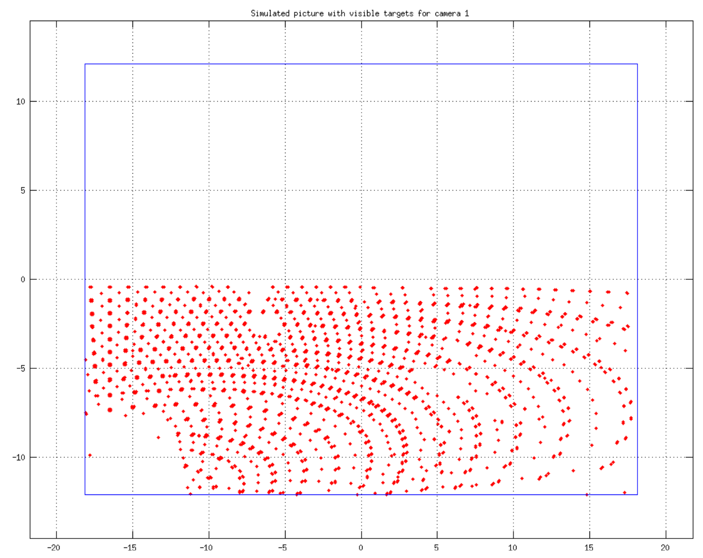
MATLAB TOOLBOX VS PYTHON BLENDER

Matlab toolbox

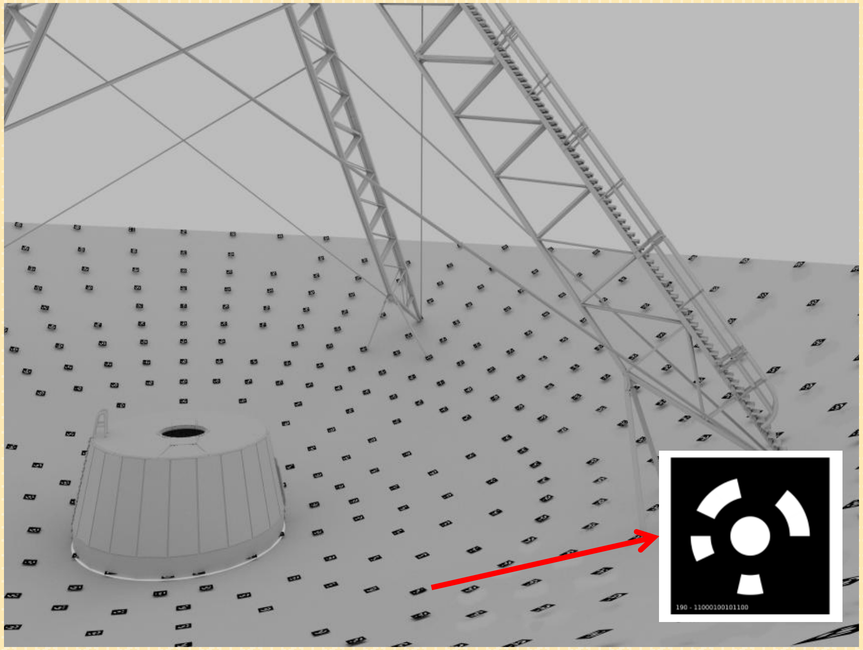
- simple 3D model (targets like point lists)
- target recognition is not required (reference points)
- fast (min) → less accurate synthetic images

Python Blender

- High resol. 3D model (targets like physical object)
- Coded target recognition (images orientation)
- slow (hr) → photorealistic images



Hidden reflector targets are masked



Matlab point lists or bender targets
are input to the bundle adjustment (MicMac, Aicon DPA pro)

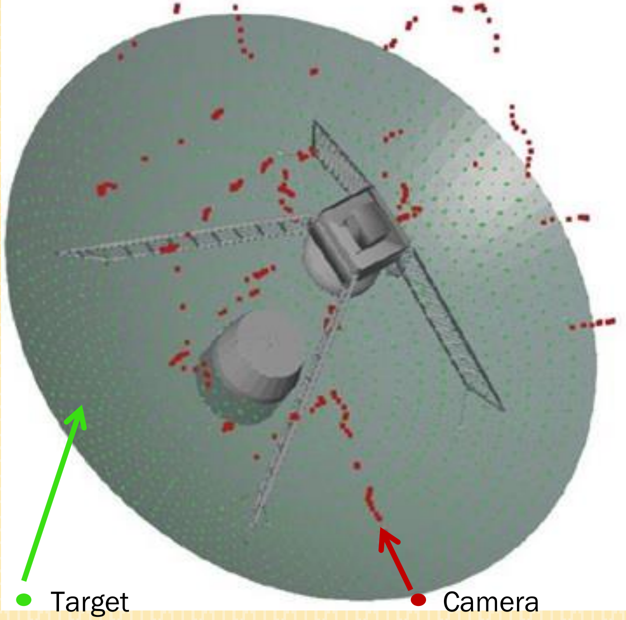
MATLAB TOOLBOX

In this preliminary study we use matlab toolbox (python bender has not tested yet) to estimate the errors in a photogrammetric survey (for example due to different camera positions or bundle adjustment engine)

We have considered two different simulated scenarios by using and ideal 3D model of SRT (without any surface deformations), but adding statistical errors.

“Scenario A”

One camera moved on the space
(“real” SRT survey Sigma 3D)

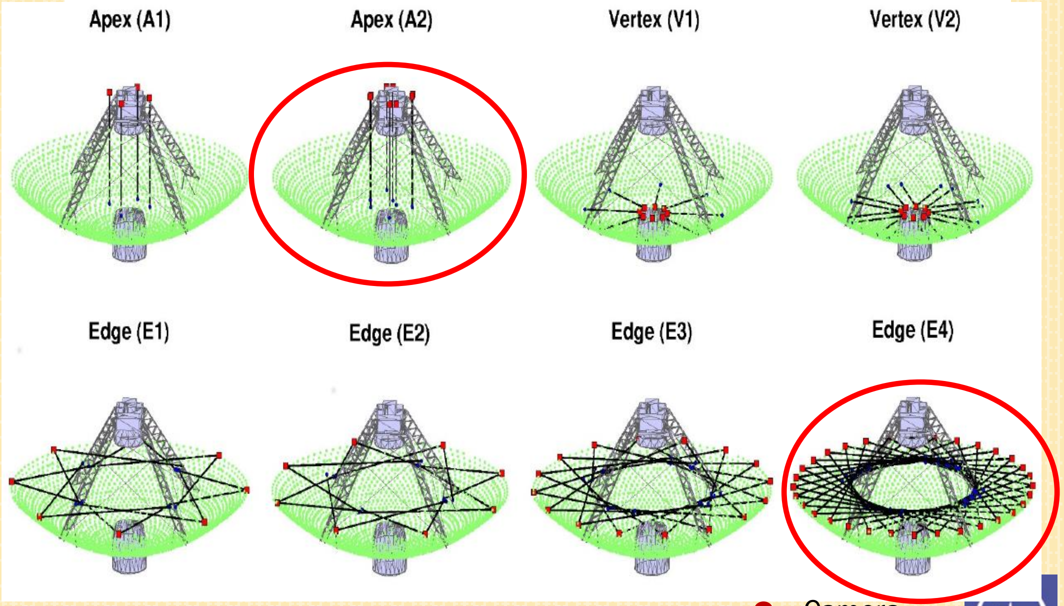


● Target positions

● Camera positions

“Scenario B”

Combinations of many camera installed on the antenna

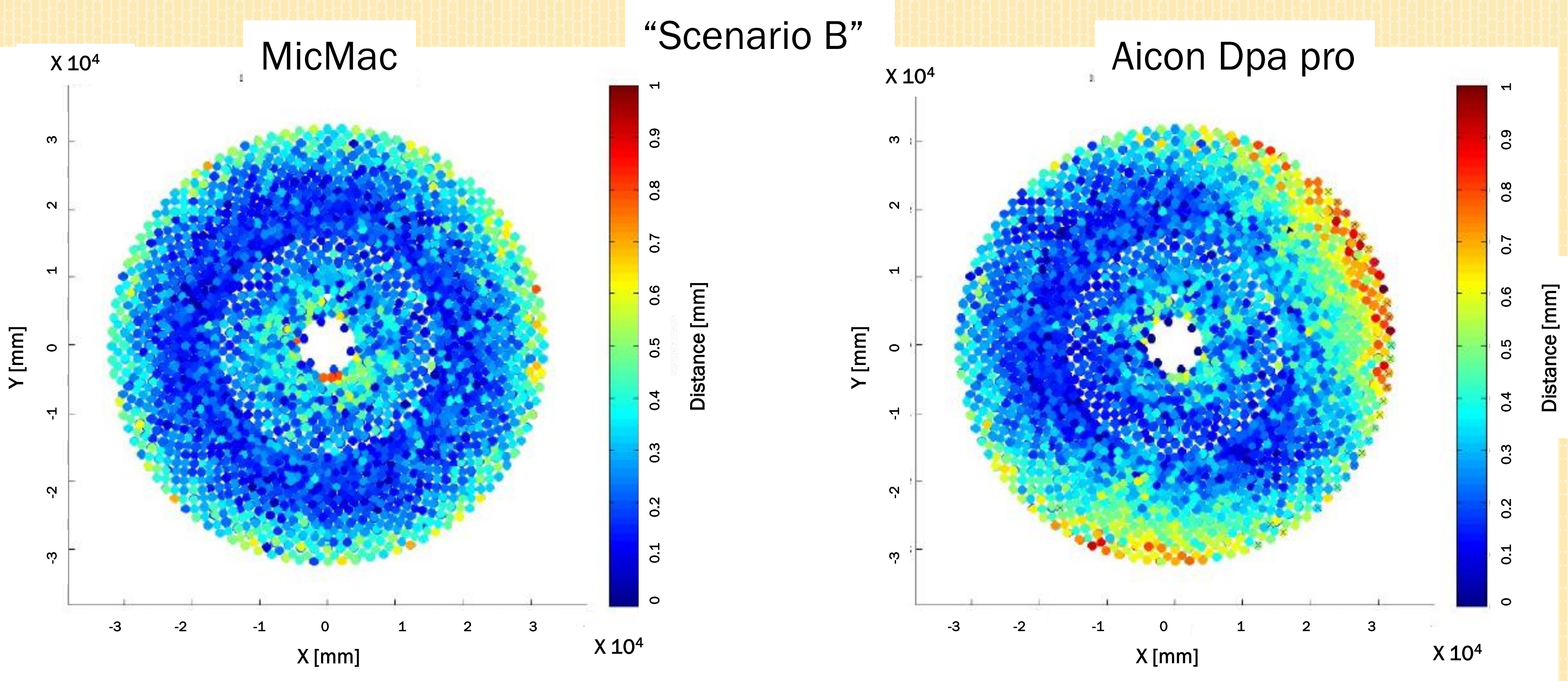


— Light of sight of the camera

● Camera

BUNDLE ADJUSTMENT ERRORS

Different bundle engines with the same input scenario (here a matlab point list of B-scenario) may give different results:



“Scenario B”

MicMac

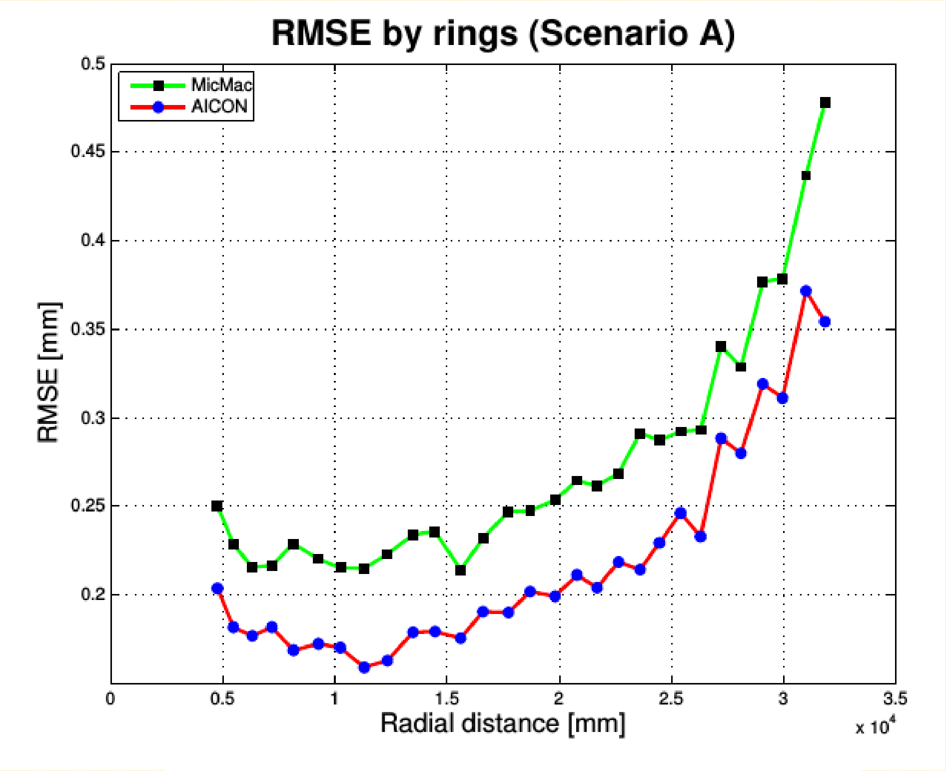
Aicon Dpa pro

Maps of error on the target positions

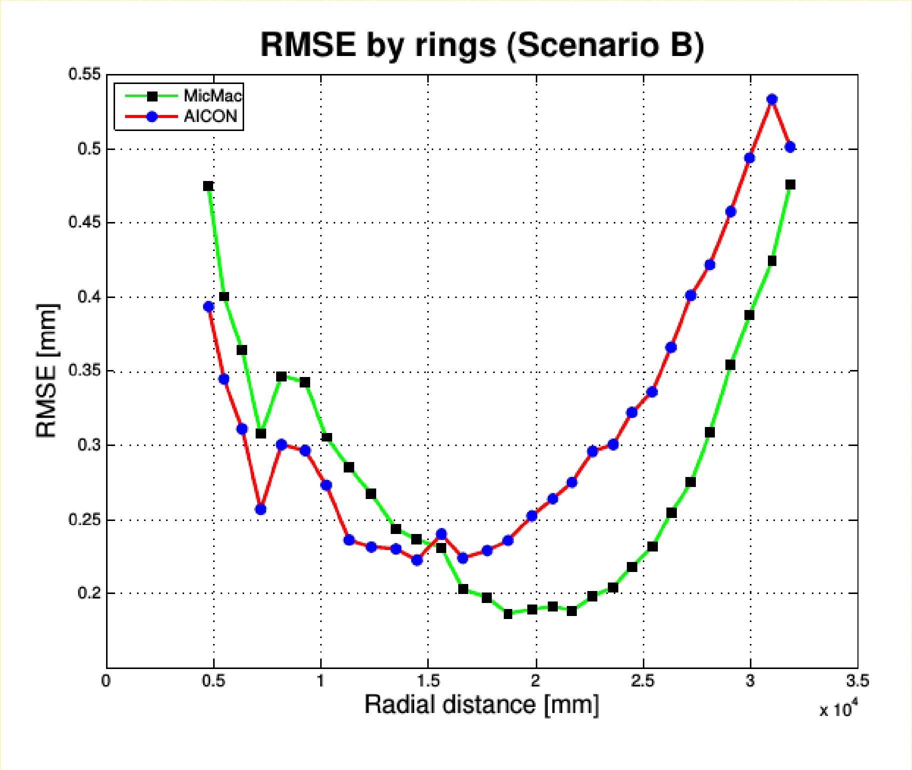
In a real photogrammetric survey this sort of errors are mixed with the surface deformations to be measured. Thus, they can not be distinguished.

EVALUATION OF SCENARIOS

A criterion to evaluate the best scenario simulated is to calculate radially the <u>averaged rms errors</u> on each sampled ring (about 2 samples for each ring)



AICON B.A: RMSE <= 0.2 mm up to 20 m



MICMAC B.A. RMSE <= 0.2 mm around 20 m

SUMMARY AND DISCUSSION

Laser tracker measurement of SRT subreflector

- Recent LT measurement shows residual misalignments of the subreflector w.r.t. 55°el
  - Y-shift 5 mm at 15° el and up to -10 mm at 90°el
  - Z-shift 3 mm at 15°
  - X-axis rotation ~56 arcsec @ 15° el, up ~ -80 arcsec @ 90° el
- New measurements have to be scheduled to:
  - figure out if such as misalignment (Y-shift at the lower and the higher elevations) can be the cause of the asymmetric features on the SRT beam at K-band frequencies
  - Create an absolute reference frame by using calibrated targets on the known points of the top of gregorian room
  - Refine the LUT so that only X-rotation and Z-shift of the subreflector are used for correcting the primary mirror rigid-body motions
  - Updating the pointing model in a such way to compensate for the Y-shift due to the primary mirror rigid-body motions

SUMMARY AND DISCUSSION

Simulation tool for close range photogrammetric survey

- Simulating a photogrammetric survey is useful to find the proper scenario which minimizes the RMS error of the measurement set, over all in a large telescopes where you need a crane or fixed camera to take a lot of pictures
- We have presented a flexible simulation tool which allows one to choise the best possible photogrammetric scenario in terms of minimum RMS error due to the meas. set-up.
- New tests are needed to validate the tool also with the open source SW platform based on Python-Blender and in other different scenarios as well

THANK YOU FOR YOUR ATTENTION

Any questions?