The "feed indexer": lesson learnt and facilities for testing and commissioning

2019 SKA Shanghai Meeting: Concluding our Past, Realizing our Future

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  - MOSAICO: 3 – Tools for the SW tests execution automation
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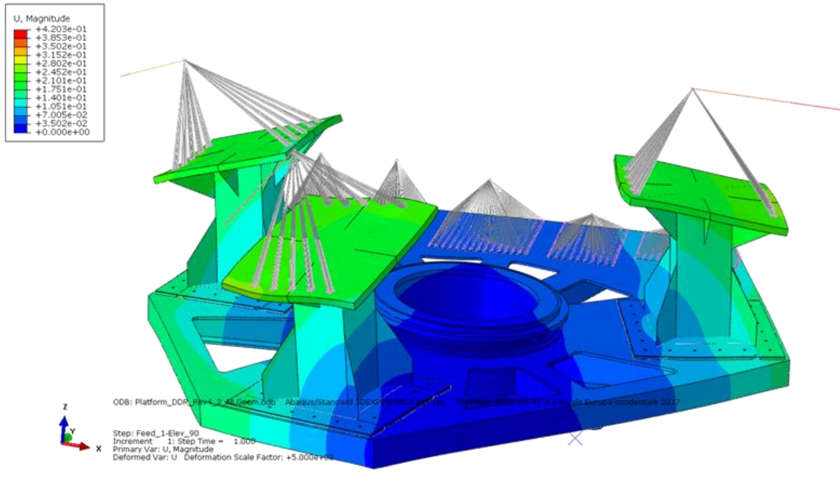
INTRODUCTION: SAM & SKA

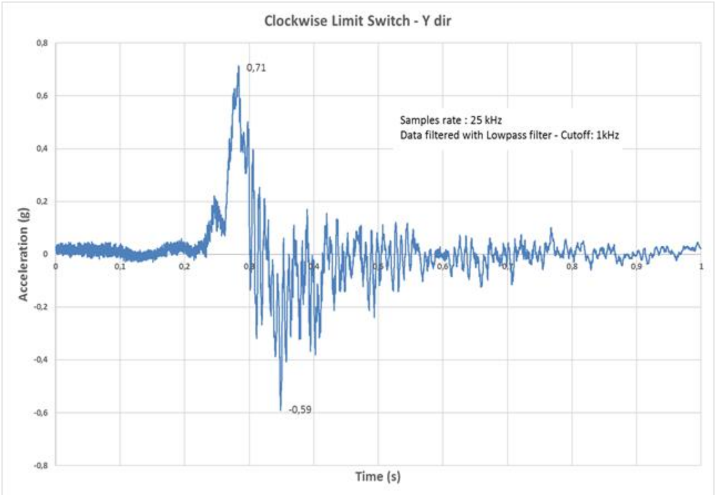


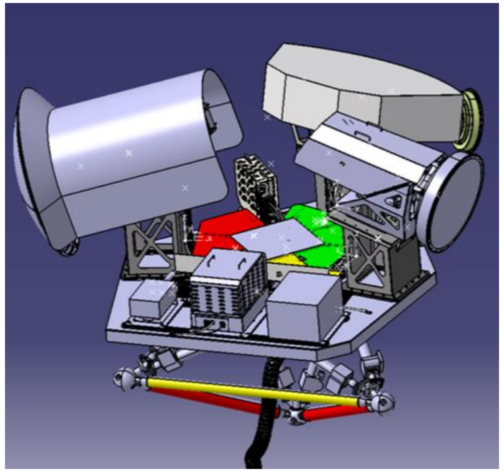
SAM is an Italian stable consortium including the companies **Euro.Soft, SRS ED and MTM-Italy**

Following activities have been carried out on **the 2 Feed Indexer Prototypes SKA-P and SKA-MPI:**

- FI Mechanical Design & FEM Analysis
- Definition of the interfaces with the antenna structure
- Control System Design, EMI-RFI Shielding, Cable Routing Des. & Test
- Maintenance Definition
- Prototype production, packaging and transportation
- Factory & field Testing & Verification

SAM participates also to the SW activities of the **«local monitoring and control» led by INAF.** The outcome was a “TANGO based” tool for the **automatic testing of LMC software**, a prototype of a possible “overall SKA SW TEST bed”, to be used during the production phase.

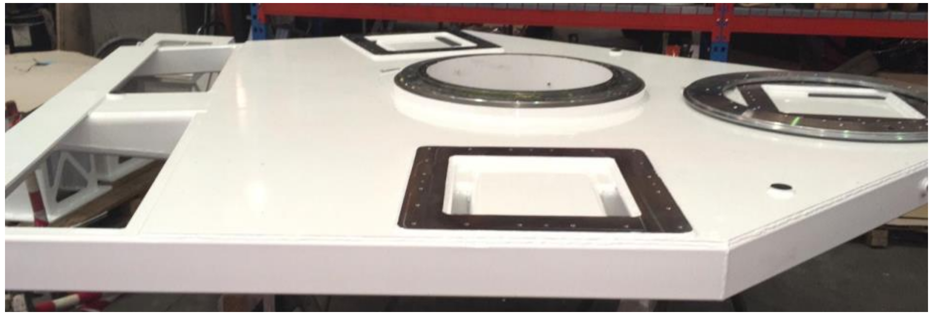




INTRODUCTION: SAM & SKA, The FEED INDEXER

From the prototypes installed in China (**SKA-P**) and South Africa (**SKA-MPI**)

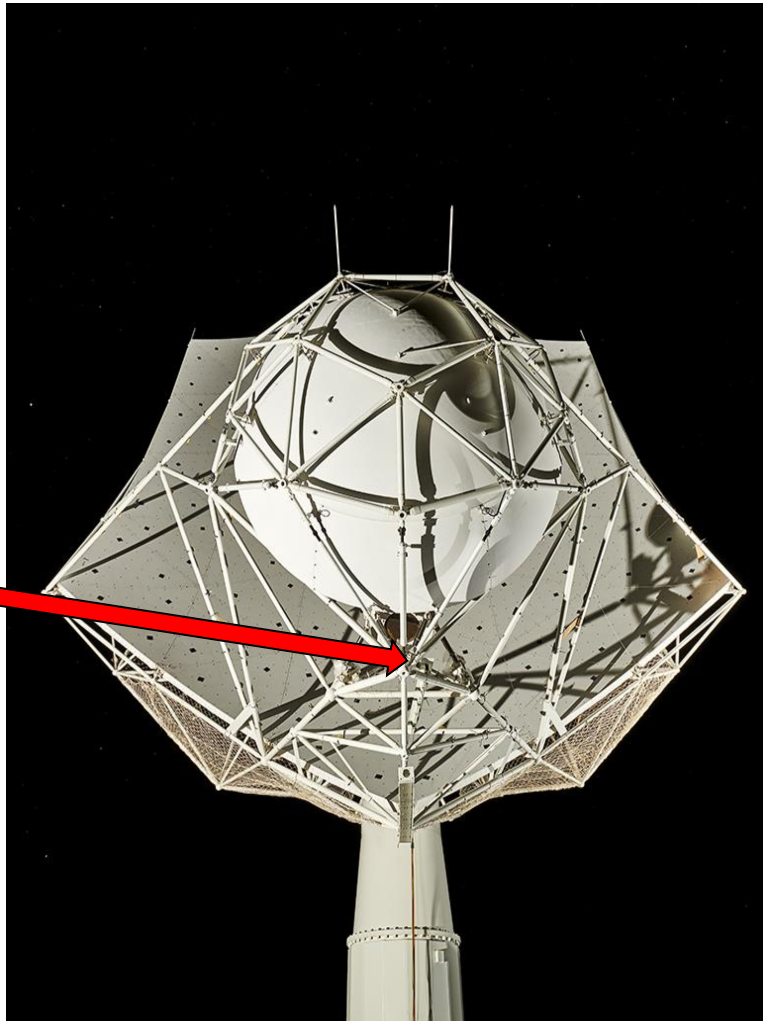
to the "**third prototype**"



INTRODUCTION: ABSTRACT

The feed indexer was designed and manufactured in Italy for both dish prototypes installed in China (**SKA-P**) and South Africa (**SKA-MPI**). A **third prototype** was developed and verified at the SAM plants in order to improve their electromechanical performances and to speed the mass production. Tools for rapid-testing and a rotation and elevation control system based on open source real-time technologies (TANGO-Linux-Ethercat) have been developed. The software architecture created for the test facility demonstrates the feasibility of an antenna control based on TANGO and therefore, completely aligned with the other SW components of SKA.

SKA-P prototype, (Shijiazhuang, China)



SKA-MPI prototype, (South Africa)

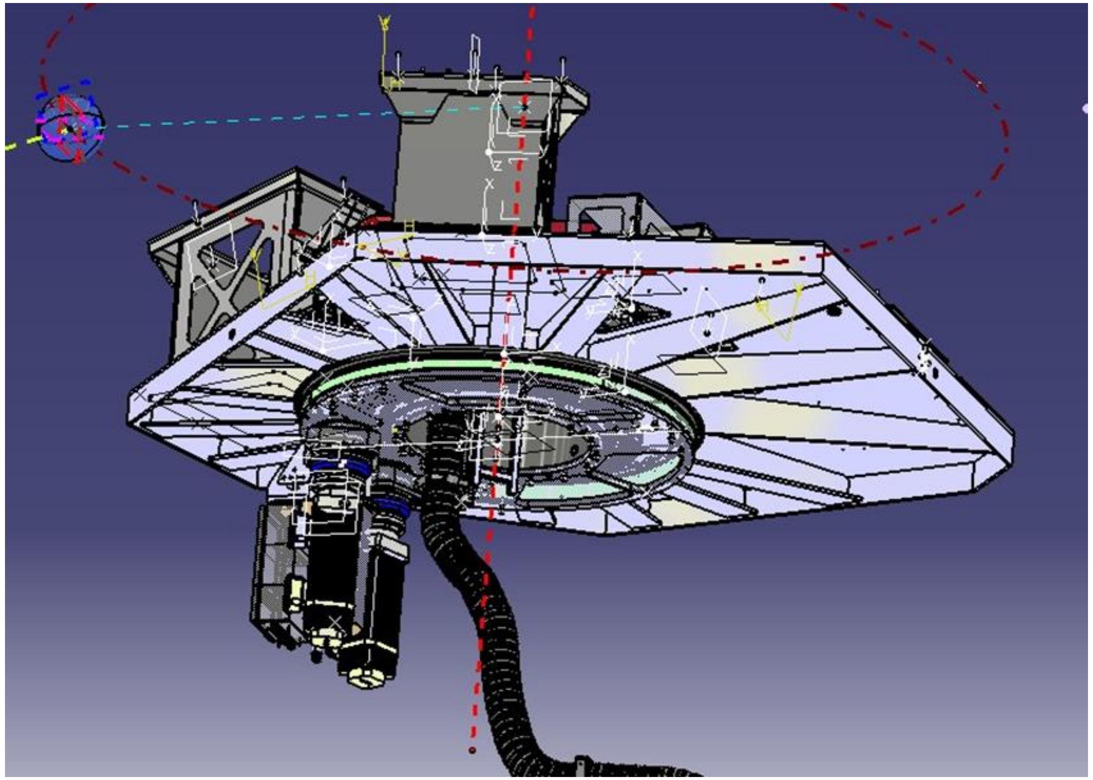
LESSON LEARNED AND ACTIONS

LESSON LEARNED	ACTIONS
• The production cost (mechanical) should be decreased • The electromechanical performances should be improved • The assembly and integration procedures should be simplified • The testing procedures (in house & on field) should be authomatized, both for the mechanical and the SW • EMI performances are a big issue: some improvement are requested • Control system should be based only on «open source» SW.	• Define, realize and test a «first production item» of Feed Indexer, optimizing the cost, improving the electromechanical performances and simplifying the assembly and integration procedures • Introduce EMI protection modifications on the motors, gearboxes and encoder-box. • Realize a set of tools able to perform authomated test procedures both for the mechanical and the SW • Define, realize and test an «open source» prototype SW architecture, based both on TANGO and on real-time SW, for the antenna control.

DEFINE, REALIZE AND TEST A «FIRST PRODUCTION ITEM» OF FEED INDEXER

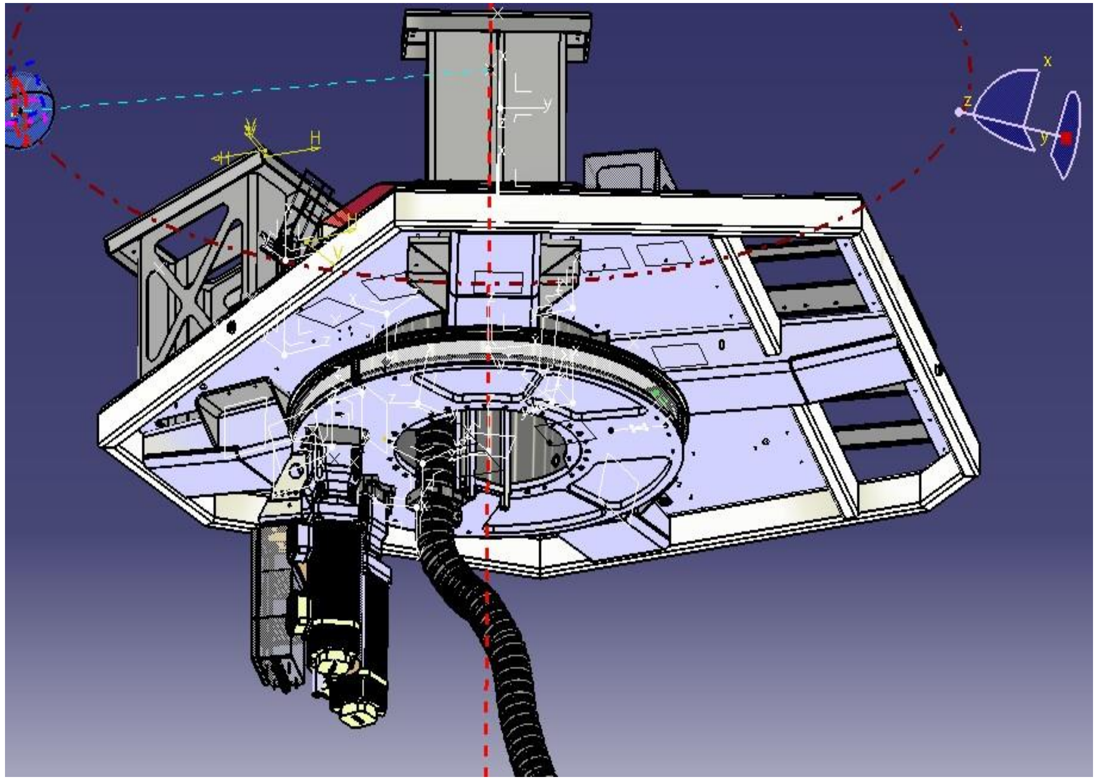
MPI & III° Prototype Platforms Comparison: The main platform has been modified in order to optimize costs and weight

MPI PROTOTYPE



Mass1317 Kg

III PROTOTYPE

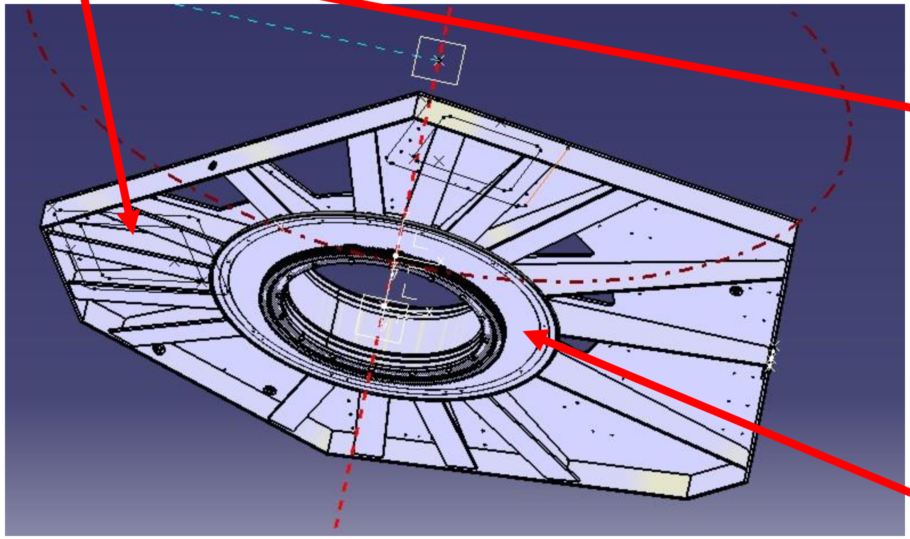


Mass1270 Kg

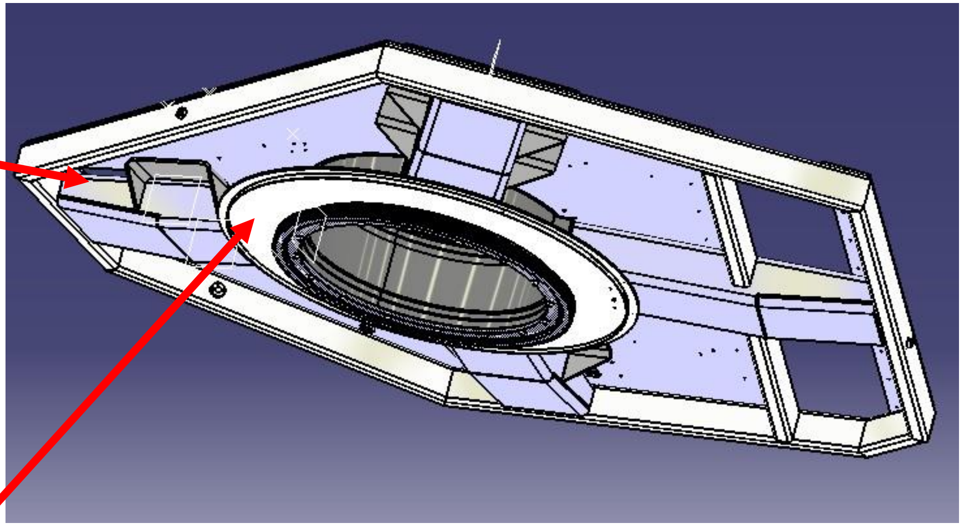
DEFINE, REALIZE AND TEST A «FIRST PRODUCTION ITEM» OF FEED INDEXER

Structural differences for the main platform; Assembly is considerably simplified, with a reduction in welds of around 30%. The new lower protection foresees the application of a thicker circular sector that supports a lip seal that closes on lateral bands placed on the motor support plate, in such a way to eliminate all the applications present on the II Prototype. This entails a reduction of details to be made and simplifies the assembly.

1) The reinforcing elements replaced with four tubular elements;



II PROTOTYPE



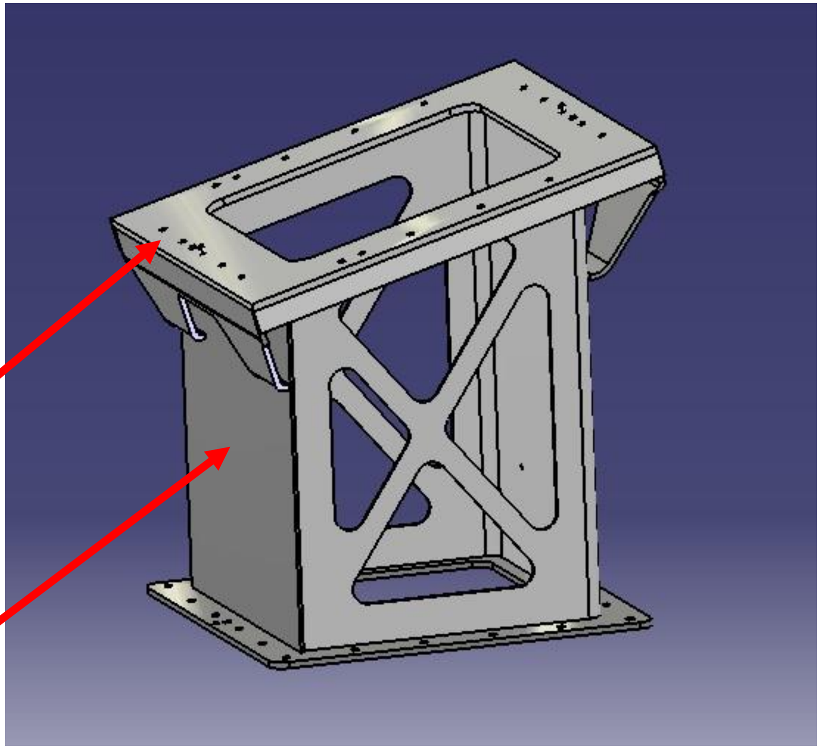
III PROTOTYPE

2) The circular sector for internal parts protection has been replaced

DEFINE, REALIZE AND TEST A «FIRST PRODUCTION ITEM» OF FEED INDEXER

Feed Supports Comparison: The main changes concern the central structure: it is composed by two C-shaped profiles (1) cut with laser and folded and the replacement of the reinforcements of the upper flange (2) with a single central reinforcement. The weight reduction is about 700 gr. (from 50 kg of the II Prot. to 49.3 kg of the 3rd Prot.) Simplification both in the assembly and in the execution of the welds

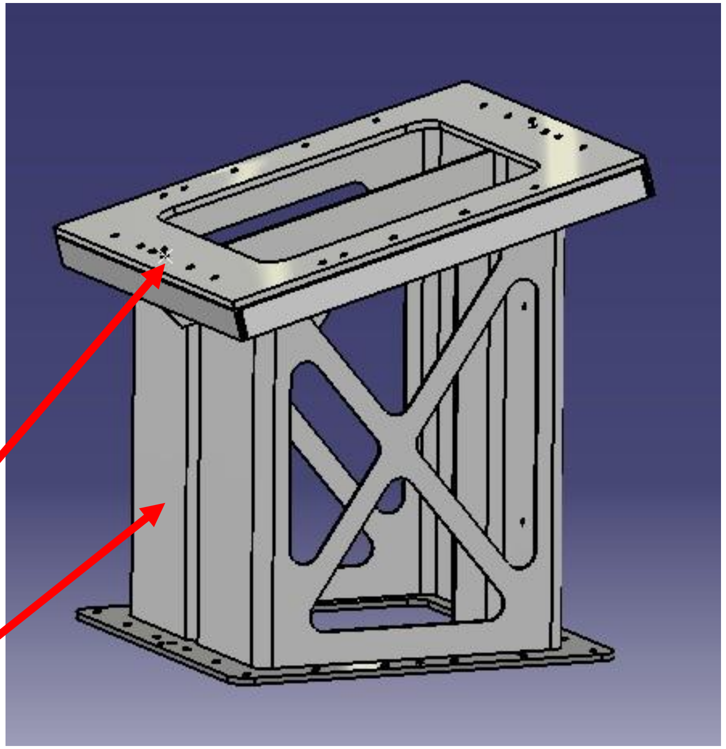
II PROTOTYPE



1

2

III PROTOTYPE



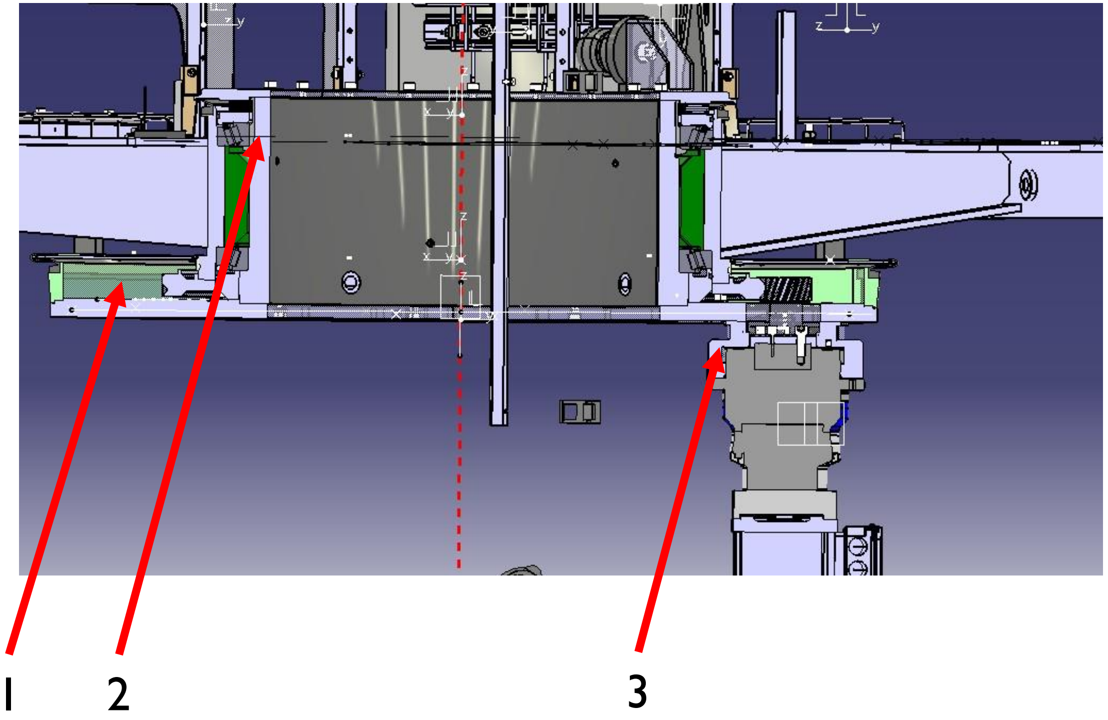
1

2

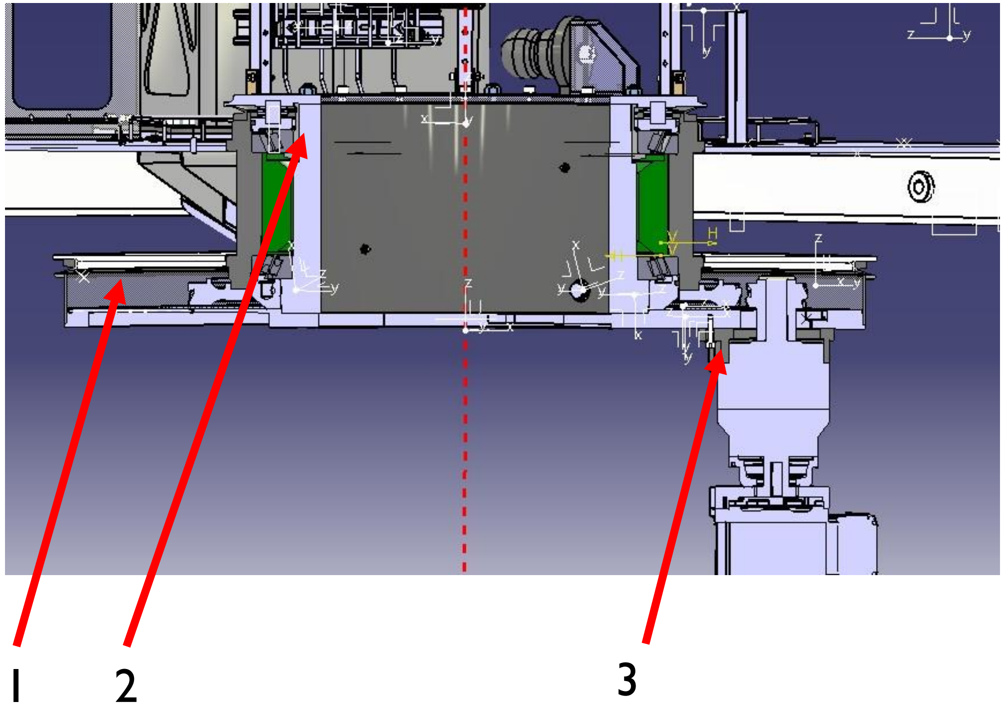
DEFINE, REALIZE AND TEST A «FIRST PRODUCTION ITEM» OF FEED INDEXER

Modifications between the II and the III Prototype; **simplification of assembly and maintenance**.

II° PROTOTYPE



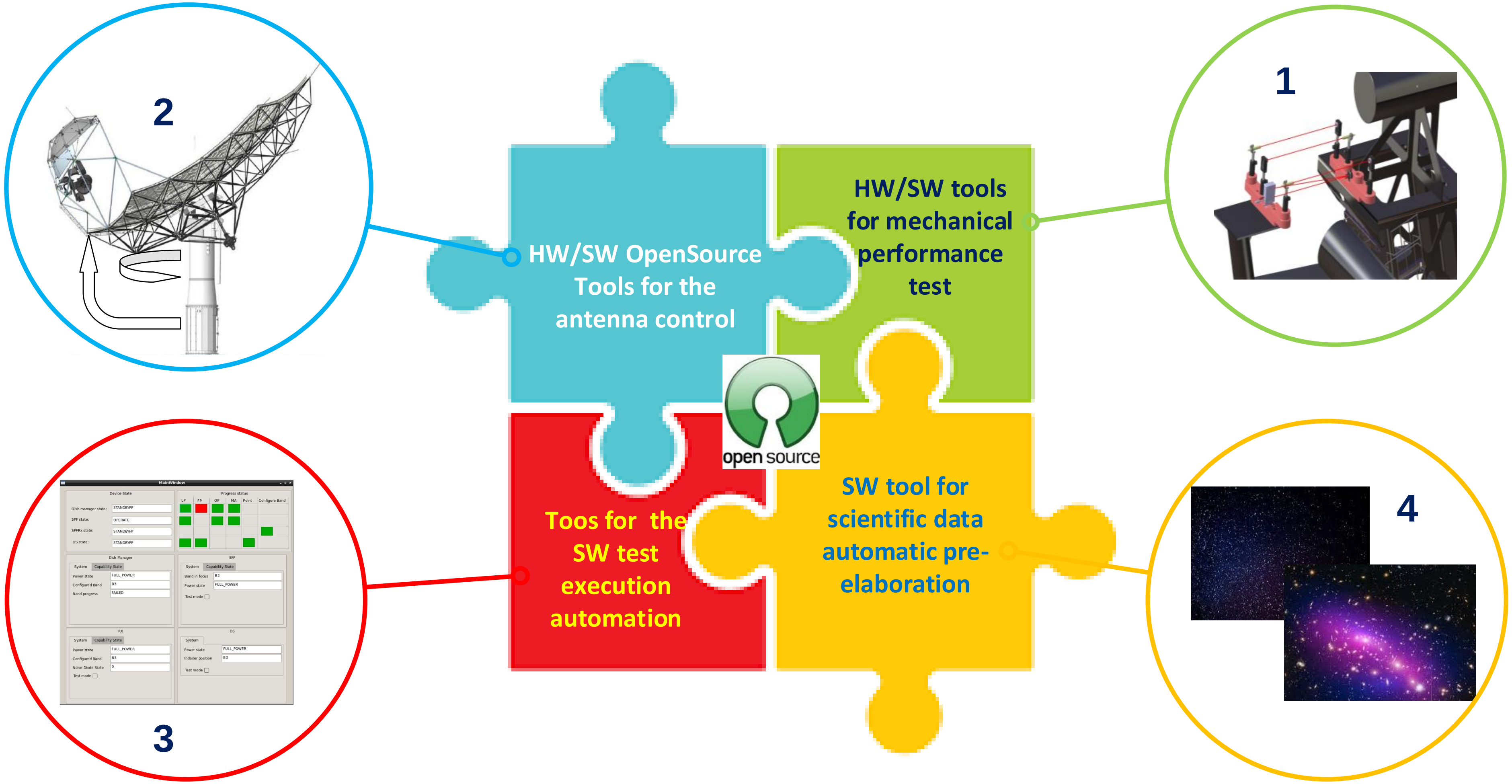
III° PROTOTYPE



1- Lateral closing bands for internal zone protection modified
2- Section of the central tube behind the bearing seat reinforced
3- Replacement of the gearboxes and modification of the related supports, simplifying the assembly

MOSAICO: A SET OF TOOLS ABLE TO PERFORM AUTOMATIC TEST PROCEDURES

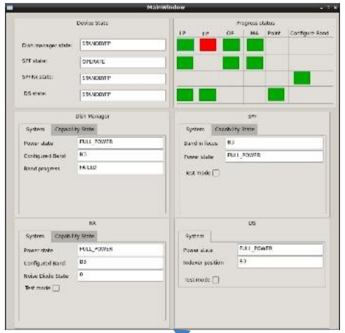
The **“MOSAICO*”** project: ongoing activities performed by SAM & INAF

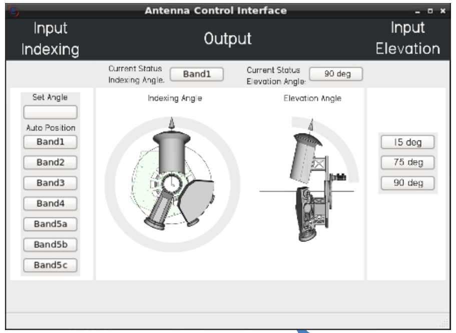


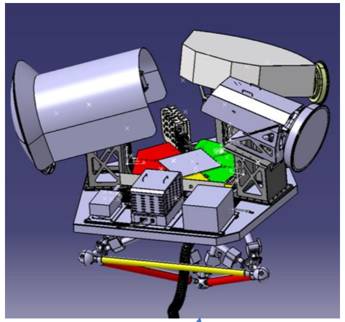
** **M**etodologie **O**pen **S**ource per l’**A**utomazione **I**ndustriale e delle procedure di **C**alc**O**lo in astrofisica*

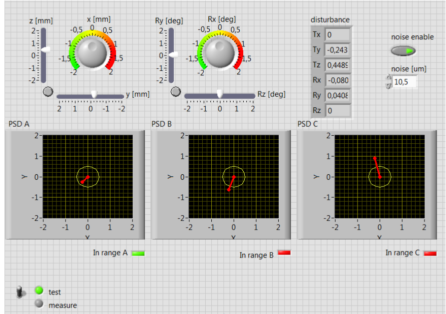
MOSAICO Facility: General Architecture

**Combinated
Test Hw/Sw & Simulation Facility
based on Linux/Tango
For SKA**









Test engine | Spreadsheet Data visualization | Scada Control | 3D viewer | Calibration Utility

bus

Library for Tango class connection | Ethercat RT network

**Software
Local Monitoring & Control
(LMC)**

**Hardware
TWO AXIS
Feed Indexer Testbed**

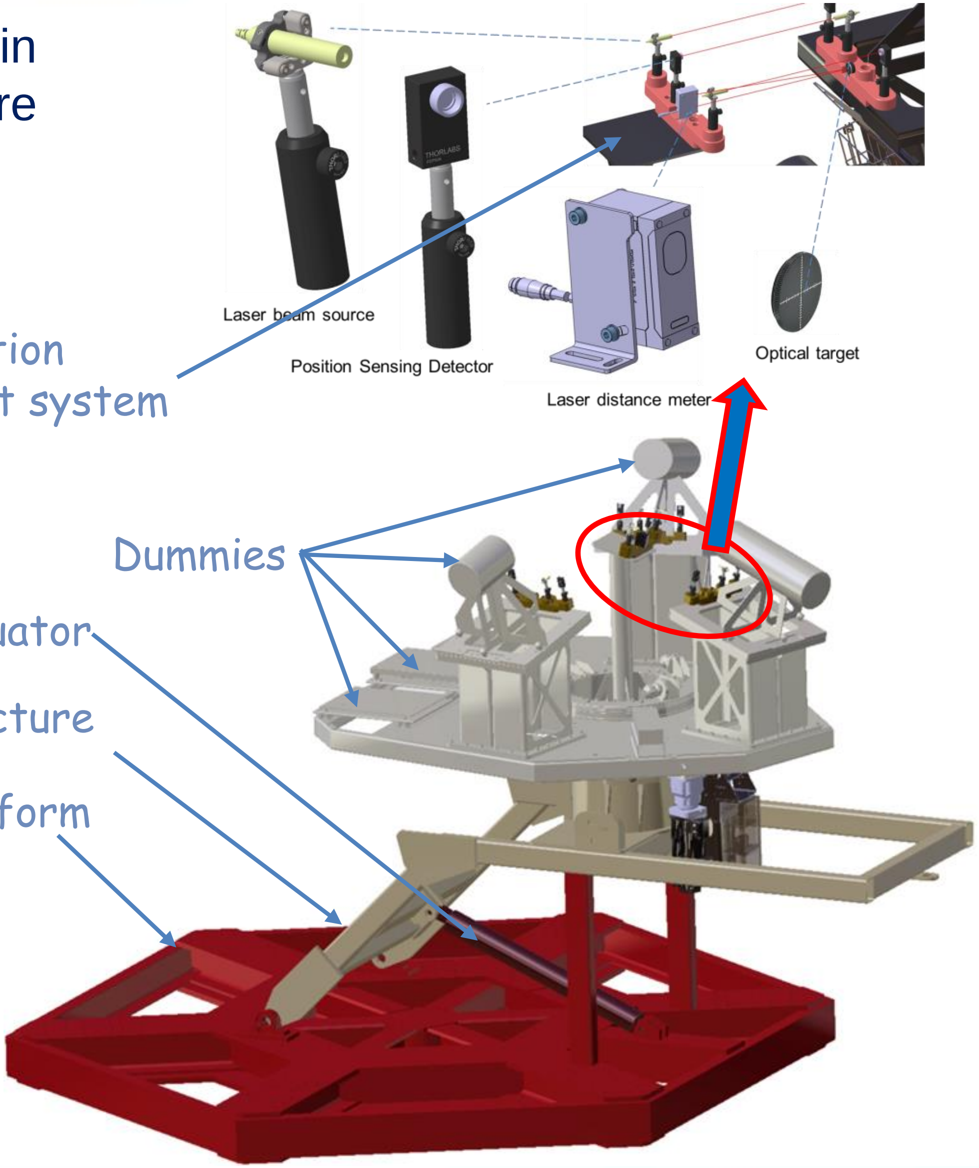
MOSAICO: 1 - HW/SW tool for mechanical performances tests

Feed Indexer **automatic testing system** assess the main requirements in automatic way at the end of the assembly line. Following requirements are addressed:

- R.FI.40, R.FI.40 - FI Build Accuracy
- R.FI.01 – Feed Index Time
- R.FI.02 – Indexing Accuracy
- R.FI.03,R.FI.04 – FI Deflection
- R.FI.37, R.FI.38, R.FI.39 FI Stability (Partial assessment)
- R.FI.09 – Limit Switches Location

The Automatic Testing System is composed by:

- Main Test Platform
- Tilting structure with software driven actuator
- Dummy Feeds and Dummy electronic equipment
- FI deformation measurement system
- Laser Targets for FI Build Accuracy measurements (to be used with Laser Tracker)
- Electric supply and Control system for FI rotation based on open source software
- Supervisor tool for the automation of the measurement phases (based on open source software)

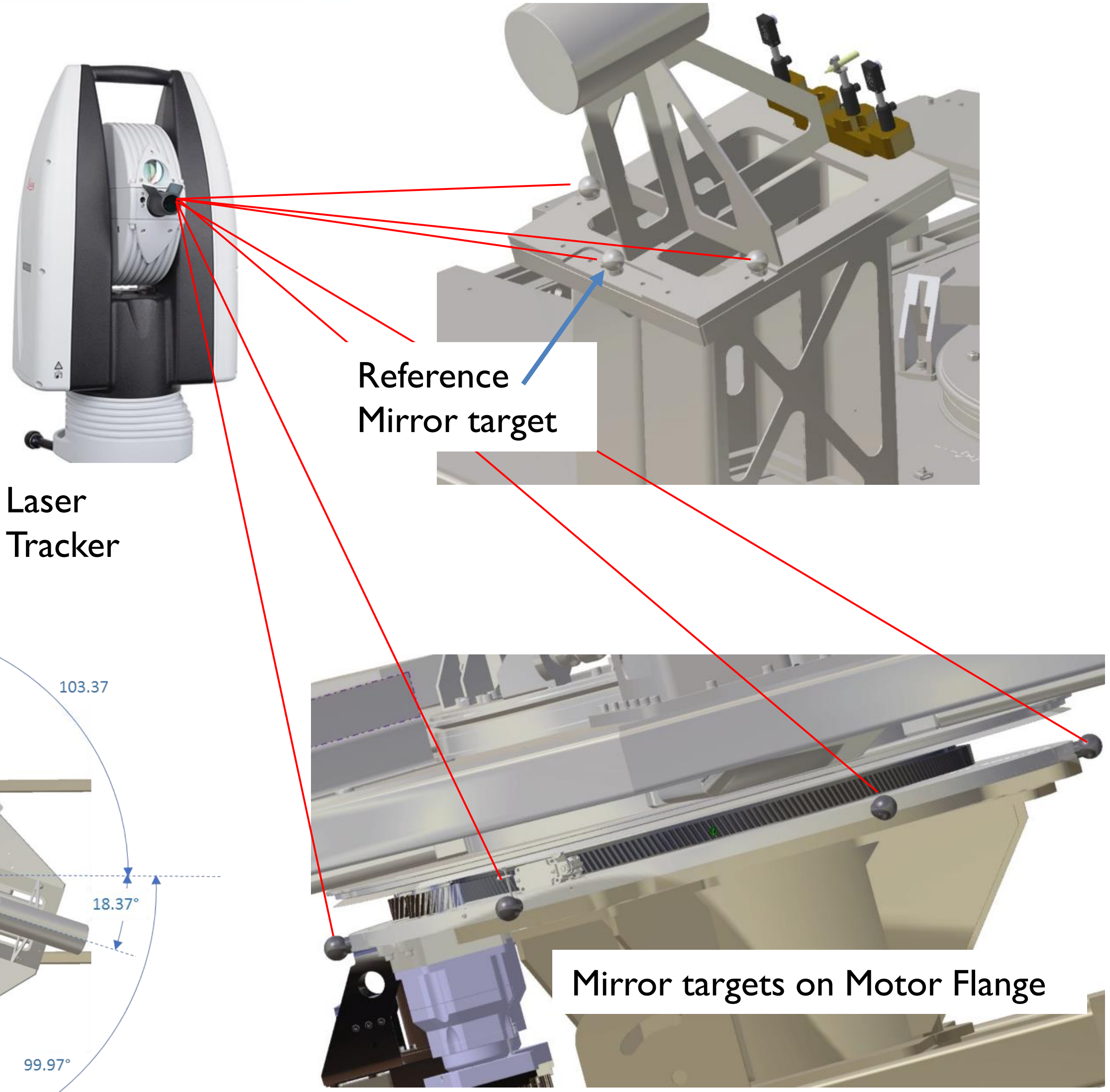


MOSAICO: 1 - HW/SW tool for mechanical performances tests

Assessment of:

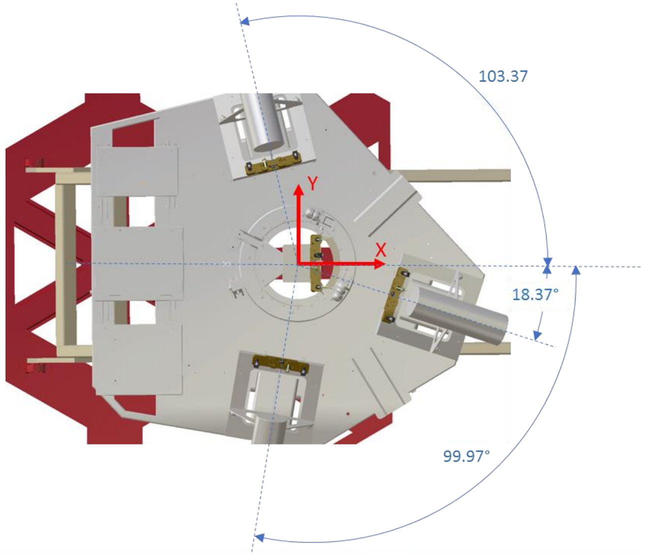
- R.FI.40, R.FI.41 - FI Build Accuracy

- Six precision holes have been machined on the Motor Flange (the interface with the Telescope Structure) in order to accept the Mirror Targets to define the Main Axes of the Feed Indexer
- Three precision holes have been machined on each Upper Plate of the Feed Supports (the interface with the Feeds) in order to accept the Mirror Targets to define the relative position of the Support Plate with respect to the main axes of the Feed Indexer
- After the measurements, the errors found for each Support Plate will be stored in the Supervisor program database for the final report issue.



This kind of test allows to reset the encoder angle corresponding to the reference position of the Feed Indexer, according to the following procedure:

1. Using the Control System for FI rotation and the Laser tracker online measures, the Reference Mirror target on the SPF345 Support is positioned on the FI X-Z Plane.
2. The Supervisor program read the Encoder present angle, set this value as Encoder Zero Position and stores it on the database.

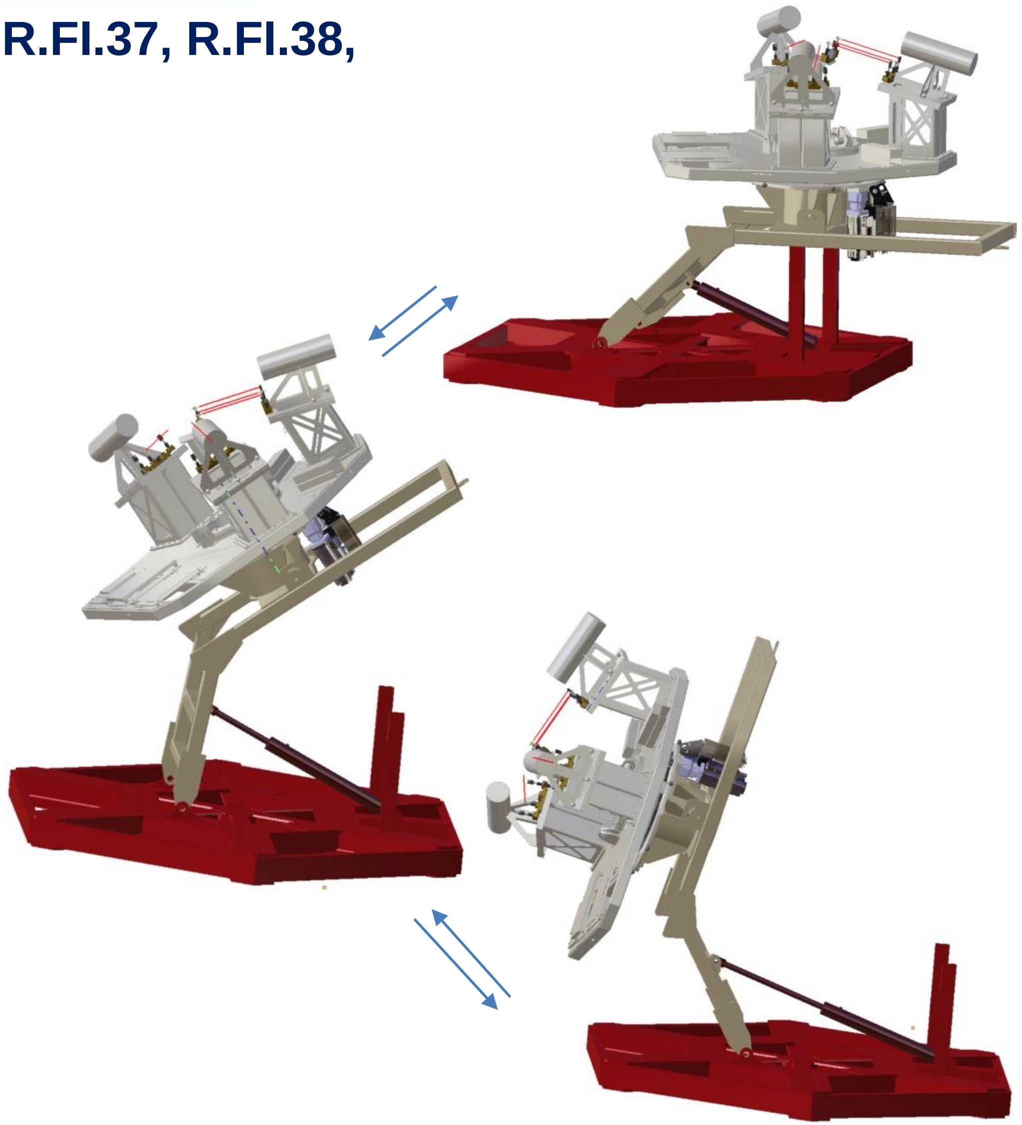


MOSAICO: 1 - HW/SW tool for mechanical performances tests

Totally Automatic Assessment of: R.FI.03,R.FI.04 – FI Deflection, R.FI.37, R.FI.38, R.FI.39 FI Stability (Partial assessment)

The test allows to assess the requirements in automatic way in order to dramatically reduce the elapsed time requested for the tests. All the measuring phases are controlled by the Supervisor program which also stores the result in the Supervisor database. The measuring phases are the following:

1. At the Elevation angle of 0° and using the Control System for FI rotation, a specific Feed is pointed on the Telescope Secondary Focus (according to the design data). The FI deformation measurements system acquires the data in this position;
2. The Elevation Actuator is actuated and the FI reaches the intermediate elevation angle (37.5°) and the FI deformation measurements system acquires the data in this new position;
3. The Elevation Actuator is actuated and the FI reaches the maximum elevation angle (75°) and the FI deformation measurements system acquires the data in this last position;
4. The Supervisor stores the data and calculates the FI deflection. Also the encoder angle is acquired and stored;
5. The previous steps are repeated several times in order to calculate the mean value and the standard deviation for the FI deflection.
6. The steps from 1 to 5 are repeated by pointing the two remaining Feeds



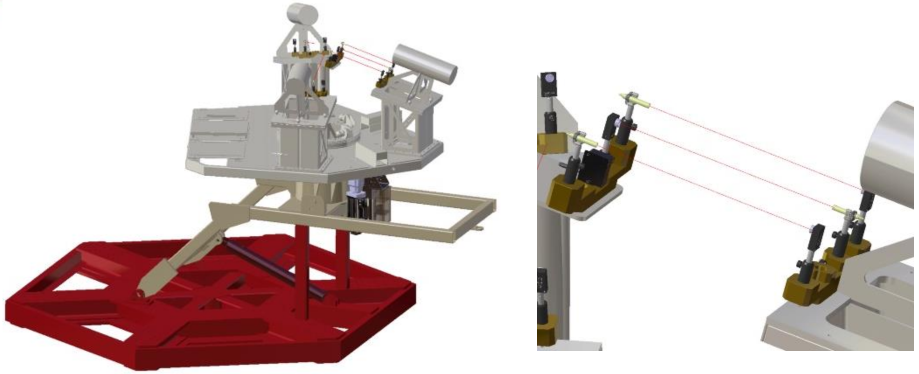
MOSAICO: 1 - HW/SW tool for mechanical performances tests

Totally Automatic Assessment of: R.FI.01 – Feed Index Time

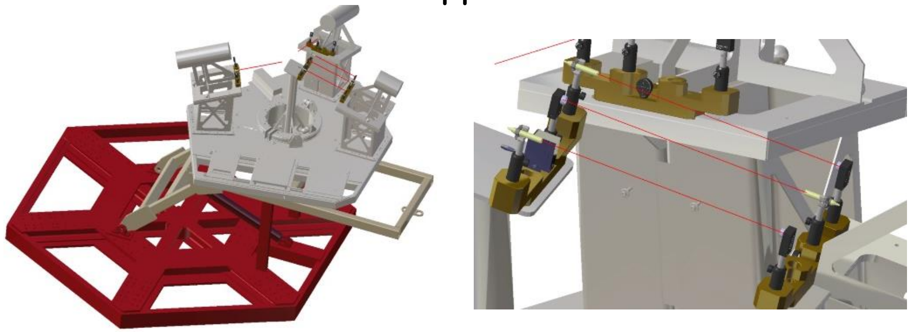
- **R.FI.02 – Indexing Accuracy**

This test allows to assess the above mentioned requirements in automatic way in order to dramatically reduce the elapsed time requested for the tests. All the measuring phases are controlled by the Supervisor program which also stores the result in the Supervisor database. The measuring phases are the following:

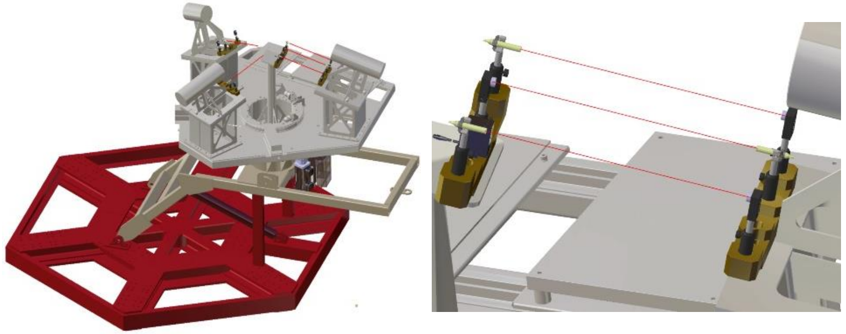
1. At the Elevation angle of 0° and using the Control System for FI rotation, the three Feed are pointed in sequence for several times. After the brake engagement the FI deformation system acquires the position of the Feed support. When the Feed support is pointed again the Supervisor acquires the new position and calculates the indexing error. At the end of the test the mean and standard deviation error for the three Feed Support is stored in the Supervisor database.
2. The step 1 is repeated for the other two elevation angles. The elevation variation is automatically managed by the Supervisor by means of the Elevation Actuator .
3. During the step 1 and 2 the Feed Index time is measured by the Control System for FI rotation and stored by Supervisor



Feed 345 Support Pointed



Feed 2 Support Pointed

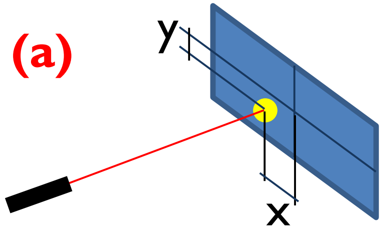


Feed 1 Support Pointed

MOSAICO: 1 - HW/SW tool for mechanical performances tests
Tools Calibration

1. The **Feed Indexer deformation measurement system is** a **simple metrology instrument**, easy to be installed and easy to be read. The positions are finely tuned in order to reset the offsets of the beams: These measures are elaborated in order to provide the repeatability error in terms of: Translations (dx, dy, dz), Rotations (rx, ry, rz)
2. The reverse process which starts from the offsets of the beam spots in respect to centers of the PSD sensors, and ends with the values of a reference systems translations and rotations, is neither simple, nor exact (many non-linearities involved).

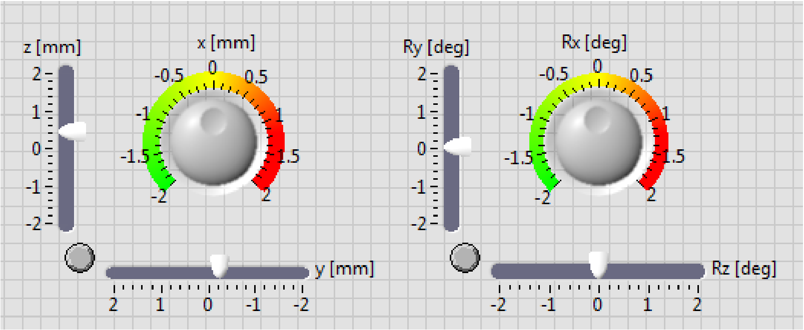
(a)

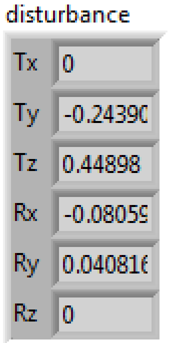


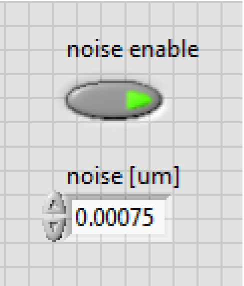
$$\begin{bmatrix} tx \\ ty \\ tz \\ rx \\ ry \\ rz \end{bmatrix}$$ (b')

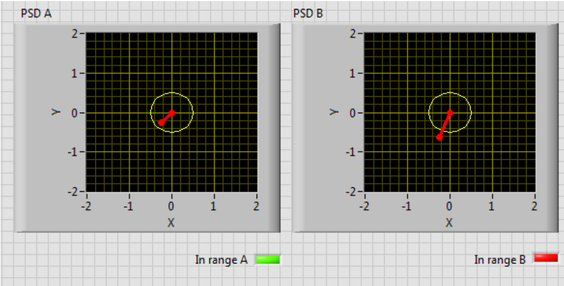
A complementary LabVIEW Tool was used to:
1. Implement a mathematical model which reproduces the exact effect of a given (b) on (a)
2. Use (a) for the (b') estimation using the reverse process
3. Compare the exact (b) with (b') , i.e. the approximate one

3. A Virtual Instruments (knobs and sliders) is used to input the "disturbance" (b) that is the offset from the theoretical position of the Feed if the entire system were rock-solid, with no backlash, or similar effects which, in reality
4. The instrument noise can be introduced as an additional effect





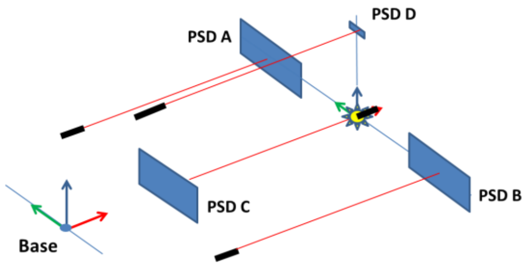




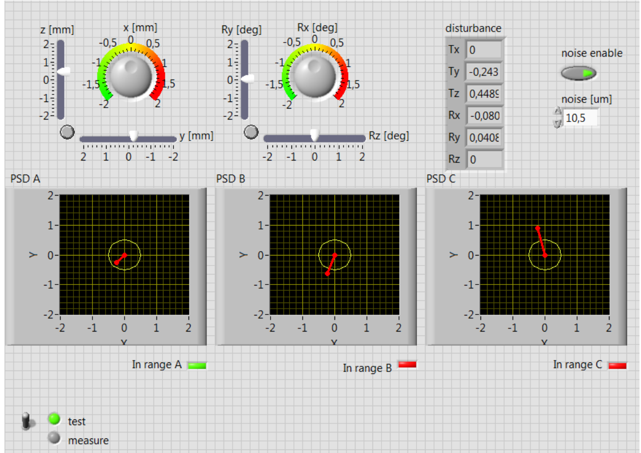
The effects of the disturbance (b) is presented as the images of the laser spots on the screen connected to the PDS

MOSAICO: 1 - HW/SW tool for mechanical performances tests
Tools Calibration

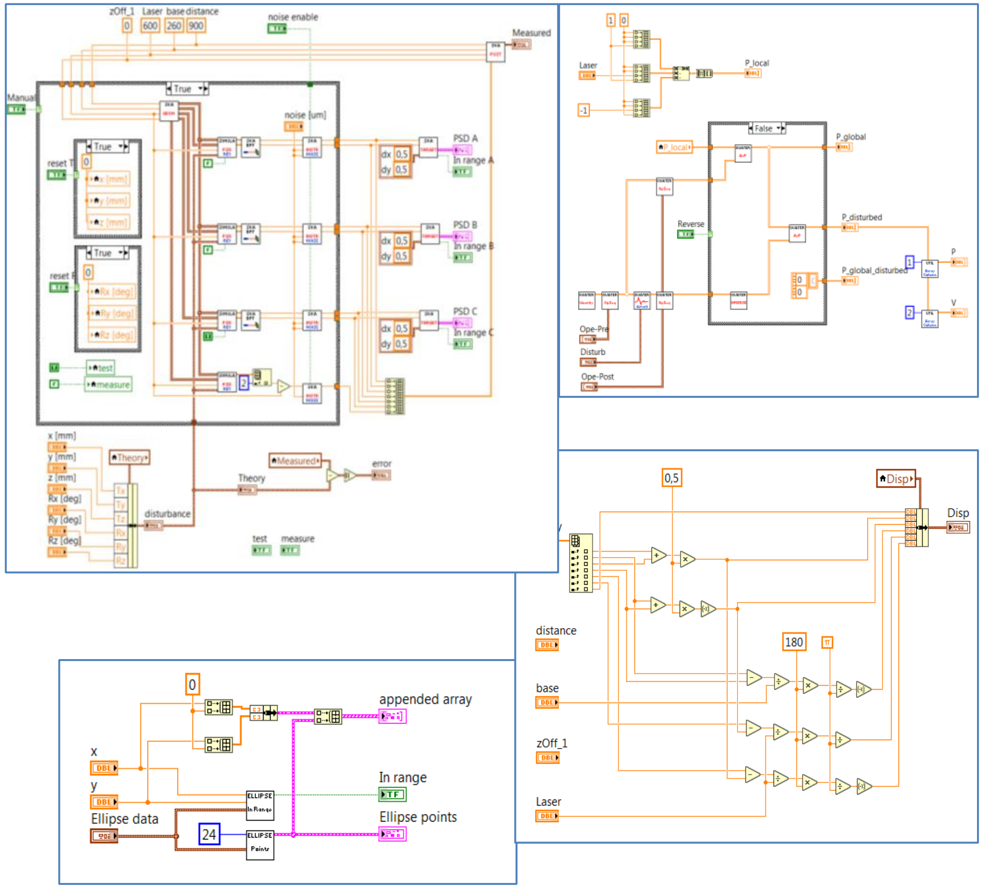
Main panel of the prototype software



Instruments scheme



Labview Block Diagrams of the prototype software



Calibration comparison

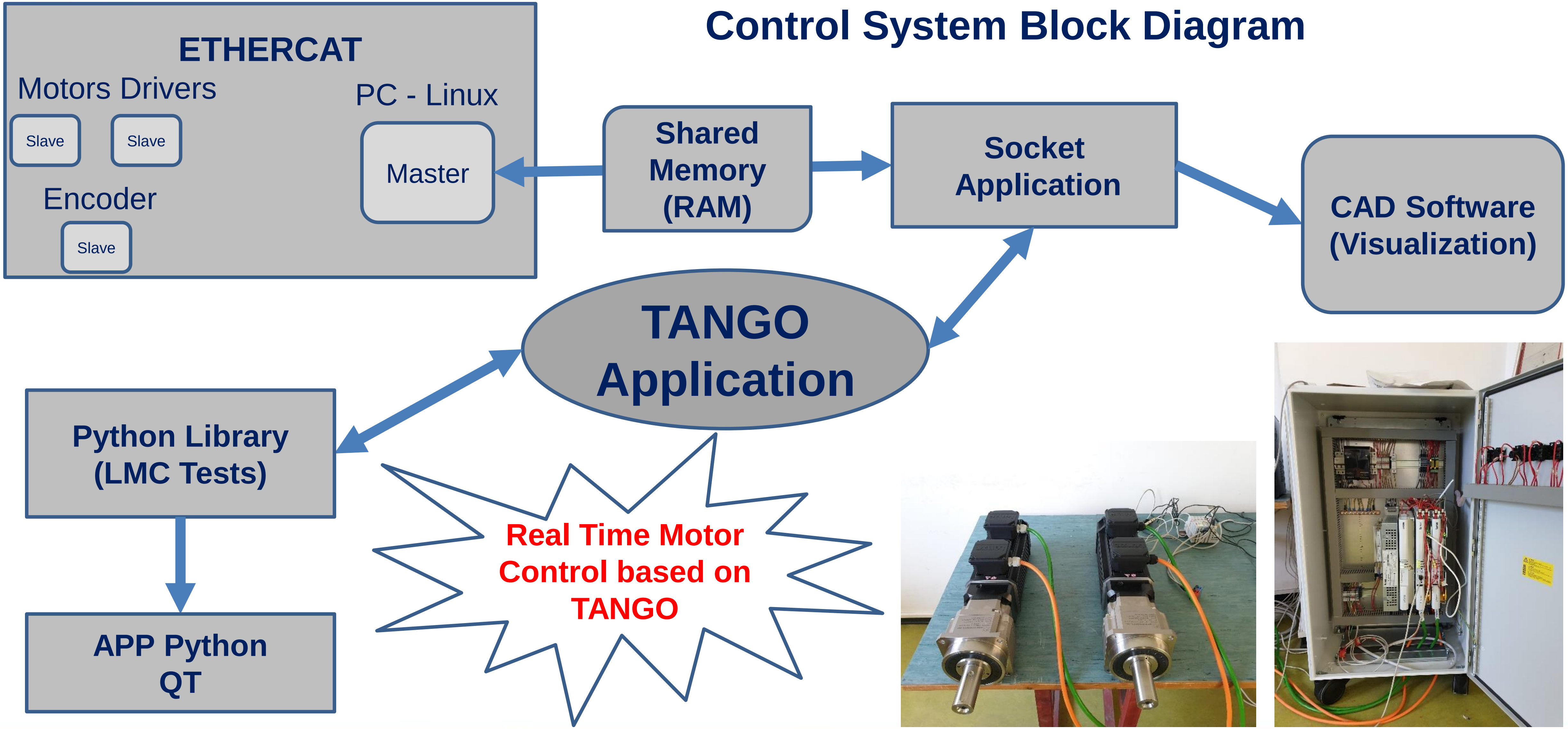
Theoretical disturbance values — Values estimated by the reverse process — error

Theory		Measured		error	
Tx	0	Tx	0.014	Tx	0.014
Ty	-0.244	Ty	-0.245	Ty	0.001
Tz	0.449	Tz	0.449	Tz	0.000
Rx	-0.081	Rx	-0.081	Rx	0.000
Ry	0.041	Ry	0.041	Ry	0.000
Rz	0	Rz	-0	Rz	0.000

Quite good

MOSAICO: 2 - HW/SW tool for “antenna testbed” control

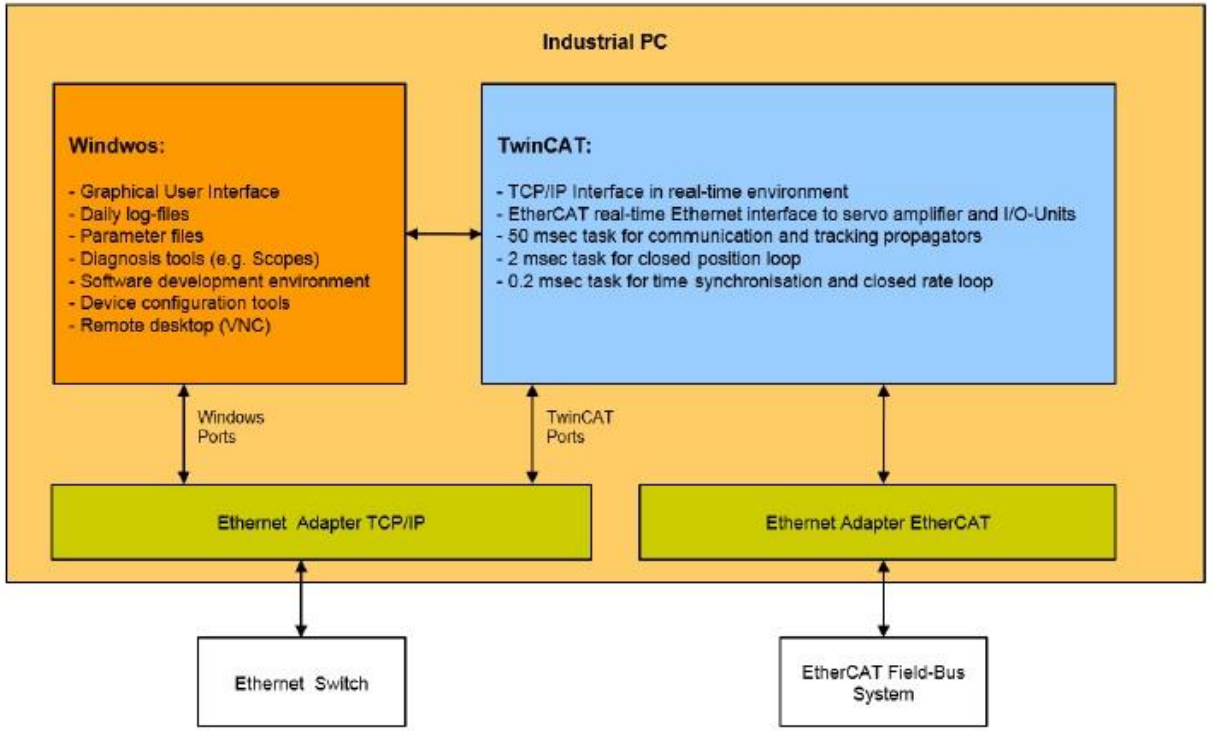
Control System Block Diagram

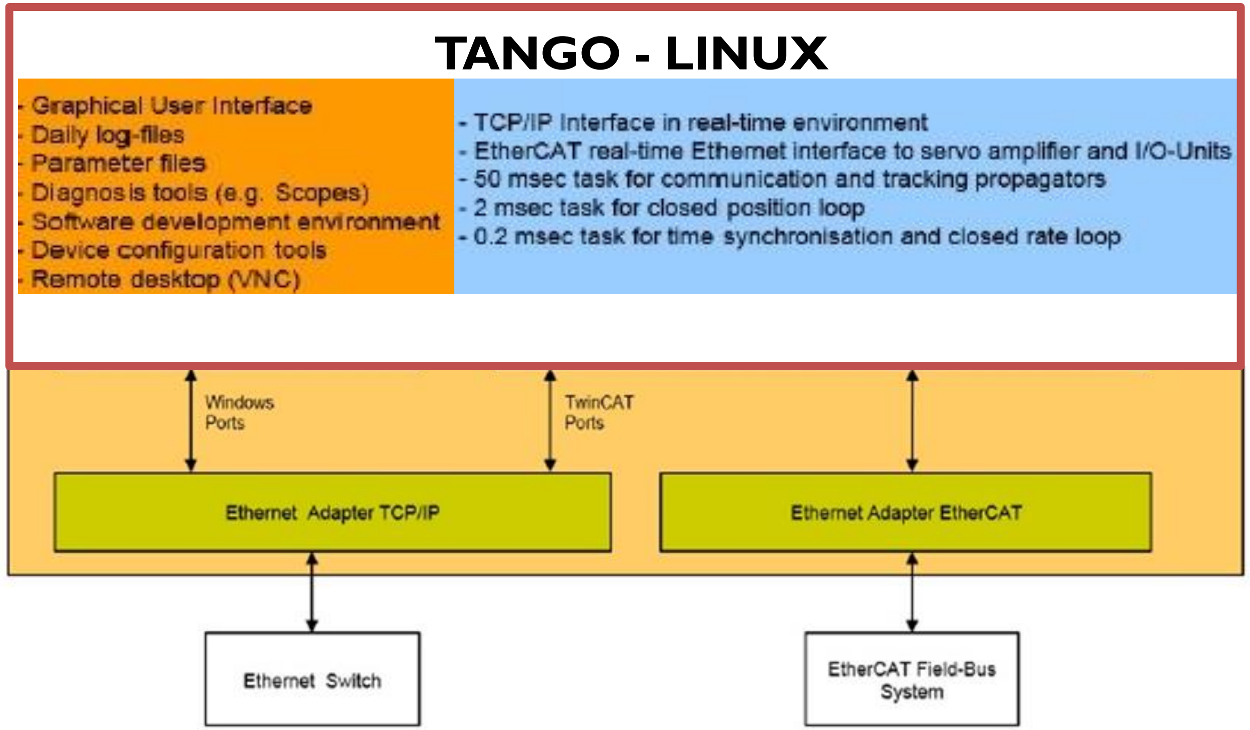


MOSAICO: 2 - HW/SW tool for "antenna testbed" control

"Testing" Control System Evolution

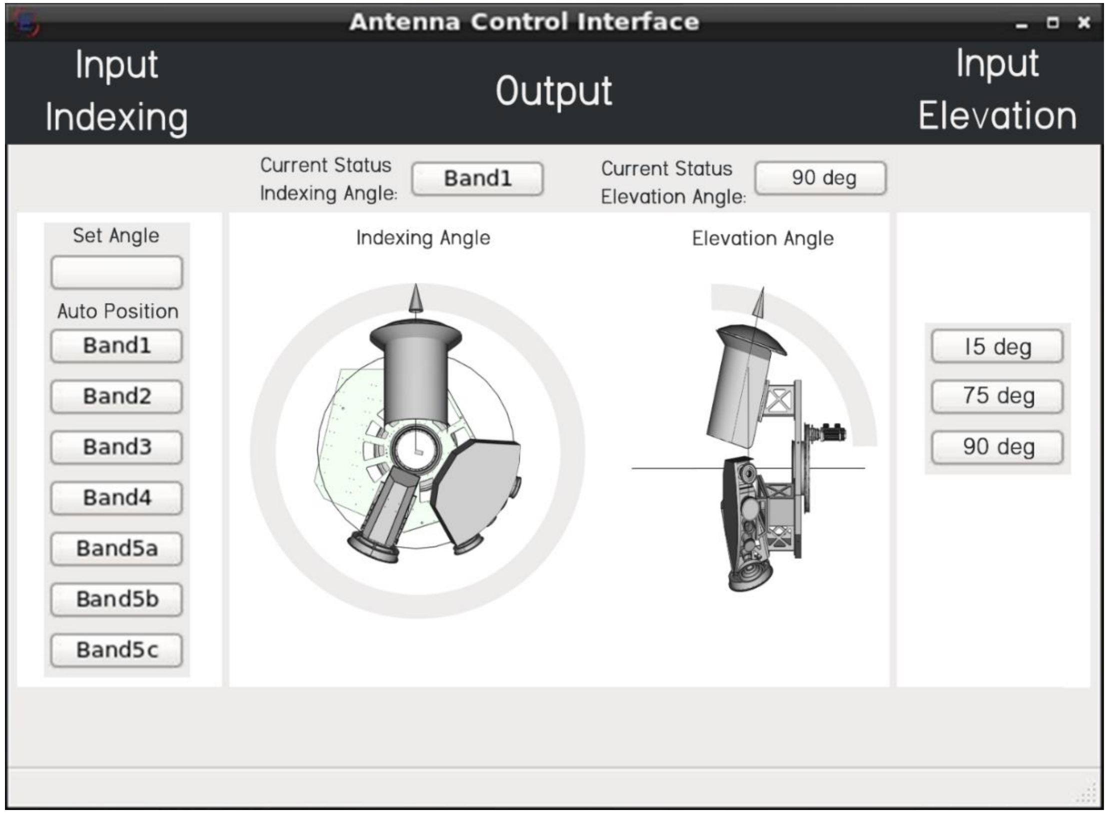
From a "proprietary architecture" → *Towards an Open Source solution*





MOSAICO: 2 - HW/SW tool for "antenna testbed" control

CTSF Facility software detail



CTSF Facility "prototype interface"

I	O.S.	Linux ubuntu open source
2	EthercatRT master	**Simple Open EtherCAT Master or SOEM developed by Open EtherCAT Society.** *"EtherCAT Master is developed starting from OCS available product. This open source product offers the possibility of adapting, through the development in C language, the acquisition of data from motors and encoder (in our specific case) and their distribution to other elements. (Such elements can be within the same server or not)"*
3	Library for Tango class connection	**Open source library for Python** *"PyTango is a python module that allows the developer to interact with Tango. Using PyTango we developed a framework which simplifies the interface with Tango"*
4	3D Viewer	**Based on FreeCAD open source** *"It is possible to show the FI positions and rotations on a CAD software. Specifically, we send data (FI rotation angles) via socket connection to FreeCad (Python function)".*
5	Scada control	We used **QT generic language** to develop the SCADA graphic interface. While the **Python** developed framework has been used to communicate (get the data / send commands) with **Tango devices** (motors, encoder, limit switches…)
6	Test engine	**Based on Jenkins and PyTest open source.** *"PyTest is a tool used to write test scripts. Jenkins is an engine to automatize the execution of the test scripts"*
7	Calibration utility	**Based on Labview**
8	Spreadsheet data visualization	**Open source spreadsheet**

MOSAICO: 3 – Tools for the SW tests execution automation

- **“Automated test” tool is a SW utility**. SAM joined the LMC team since 2017 and performed “independent automatic test” of the LMC SW (about 50% of the total test procedures)
- “Automated test” is a test that can be performed separately or within a test group directly from the command line or using an integrated test environment.
- This process involves automation of test scenarios already performed manually, **quickly, and repeatedly.**
- It may be also used to test the application from **load, performance, and stress** point of view. It increases the test **coverage**, improves **accuracy**, and saves time and money in comparison to manual testing.
- A number of “**future tools**” has been individuated:
  - **Test analysis tool** to compare tests performed on the same SW, but in different periods.
  - **MultiDISH execution** to execute the test set simultaneously on multiple DISH.LMC servers
  - **TM Emulator** to adequately simulate the request of a command by the TM towards the LMC directly in the test scripts.

MOSAICO: 3 – Tools for the SW tests execution automation

DISH

TEST SOFTWARE ARCHITECTURE

LMC TEST FRAMEWORK

- SKA TANGO LIBRARY (for the easy connection of the SKA Tango software device)
- SKA TANGO TEST LIBRARY (for the easy testing of the SKA Tango software device)

PyTango (a Tango implementation of python)

PyTest Tool (an open source python test utility)

TEST DEVELOPMENT & EXECUTION SERVER

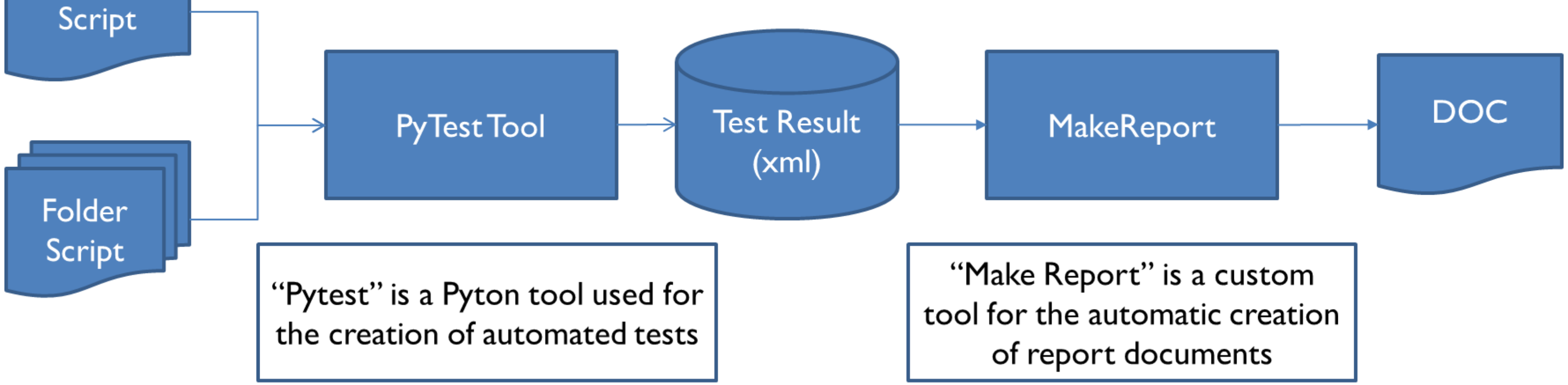
O.S. LINUX UBUNTU 16

TANGO INSTALLATION with PyTango (a Tango implementation of python)

LMC TEST FRAMEWORK

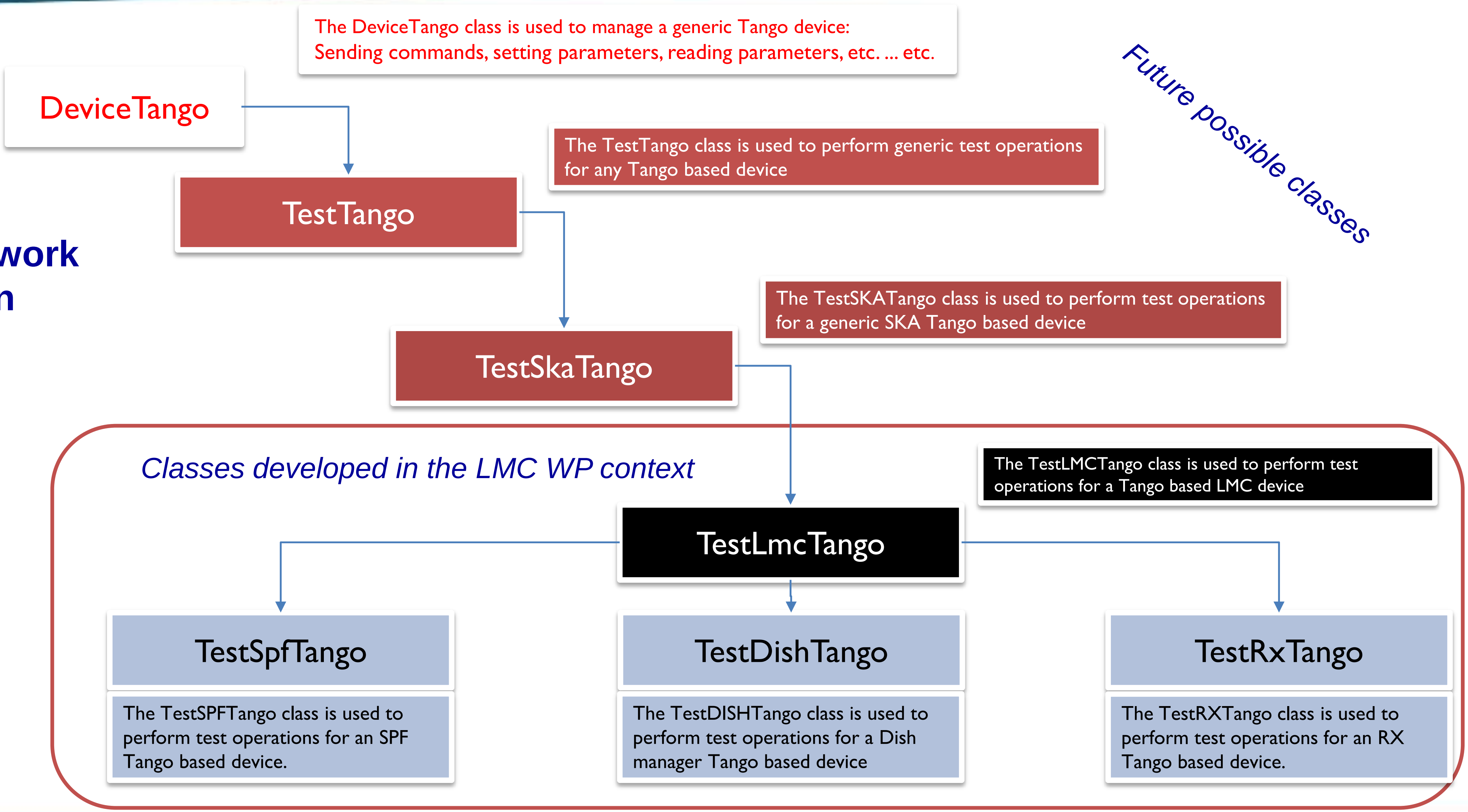
LMC TEST SCRIPT

TEST EXECUTION FLOW CHART



MOSAICO: 3 – Tools for the SW tests execution automation

Overall Framework Description

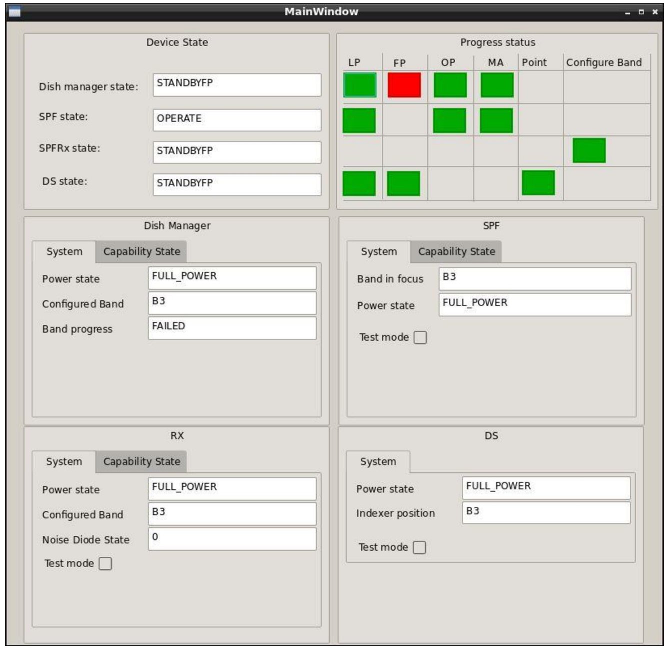


MOSAICO: 3 – Tools for the SW tests execution automation

Test Management Environment & simulation tool

A management environment facilitate the tests execution. We decided to rely to JENKINS as a management and test control environment, that allows the following functions to be performed directly from a browser:

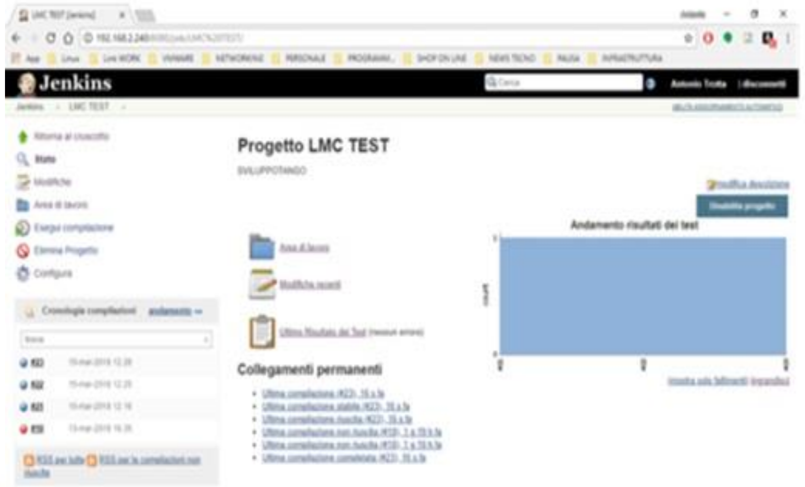
- Recover from a repository (cvs or git) the updated test scripts
- Group tests in chapters for single execution, in groups or at one time
- Summarize the tests by differentiating those passed from those not passed
- Navigate within the results of each individual test or group
- View the test report document



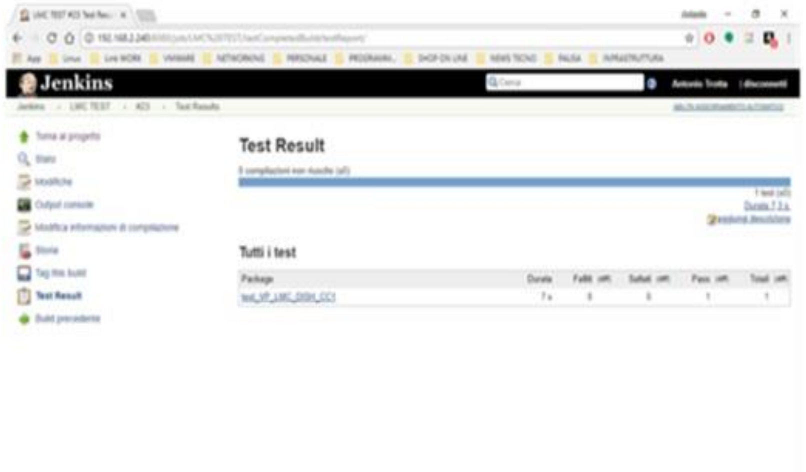
The **simulation tool** graphically display the behavior of the tested software. In the figure, the system monitoring tool used simultaneously to the execution of a test script

JENKINS TEST SUITE

MAIN PAGE PROJECT TEST



SINGLE TEST RESULT



CONCLUSIONS

THANK YOU FOR THE ATTENTION

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