Mejorando el IRAM 30m para los próximos 10-15 años

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on behalf of the IRAM30m Team

Promoviendo sinergias entre grandes observatorios españoles I
23-26 de Octubre 2023, La Palma, Canarias

30-meter upgrade project

- Since its inauguration in 1984, the 30m IRAM telescope has been a leading observatory in the millimetre range (73-350 GHz) with a single mirror.
- To continue being a benchmark observatory, it requires updates to enhance its performance and improve maintainability.

30-meter upgrade project

The original goals of the project :

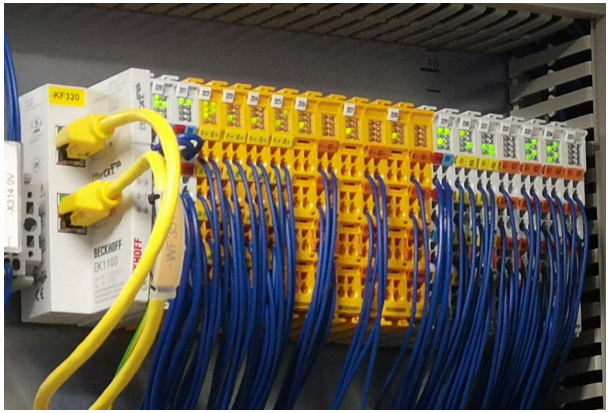
- Upgrading the **telescope servo control system** with state-of-the-art components, while retaining all functionality and enhancing performance
- **Overhaul the gearboxes** replacing deteriorating components
- Enhance observing efficiency by **upgrading the primary reflector surface, restoring the paint, and installing actuators** to improve imaging quality, aperture efficiency, and point-source sensitivity.

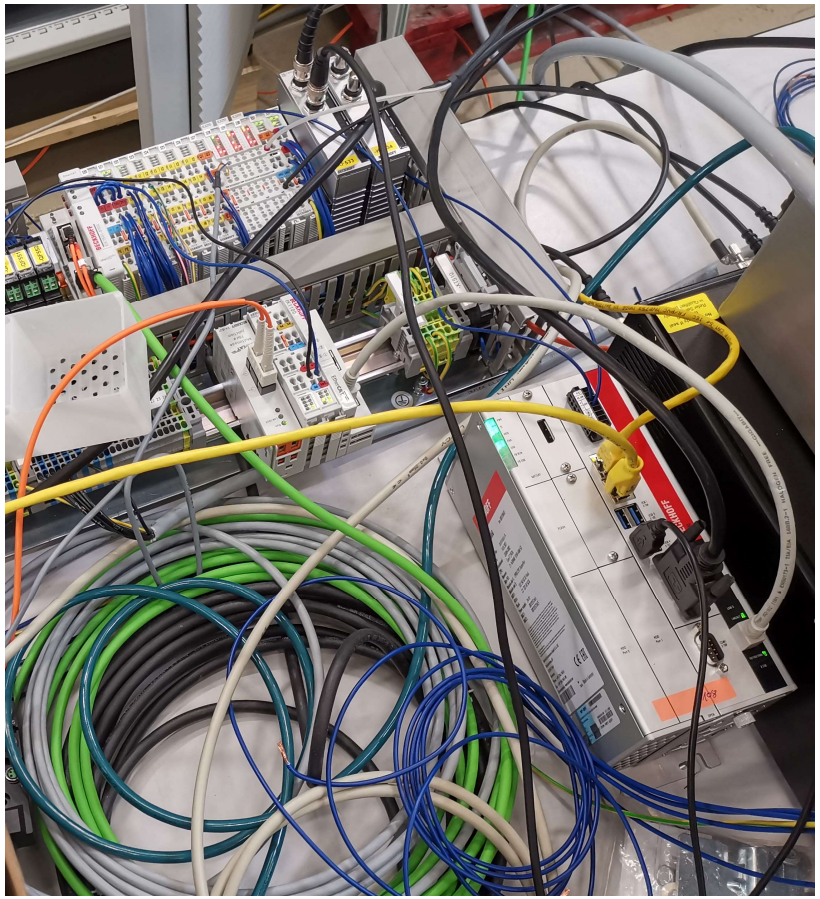
30-meter upgrade: new servo control

- Pointing and Tracking Goals:
  - **Enhance tracking accuracy** (currently very good at approximately 0.2 arcsec in slow wind conditions) at both **low and high wind speeds**.
  - **Enable faster slews and maximum tracking speed** to reduce observation overhead and expand the operational range, including additional scanning patterns.
  - **Extend the operational lifetime** by replacing obsolete components with state-of-the-art ones.
- Proposed Actions to Achieve the Goals:
  - Implement a **new servo system featuring state-of-the-art electronics with a** control loop running at significantly higher rates than the current system.
  - **Increasing the control loop bandwidth to 1 Hz** will improve tracking performance by approximately 30%.
  - Renew the **servo control system of the sub-reflector**, including the **hexapod** (with 6 spindle motors) and **wobbler** control amplifiers, to facilitate future maintenance.
  - Update and streamline the control software.
  - **Overhaul the telescope gearboxes** in parallel.

The new servo control system

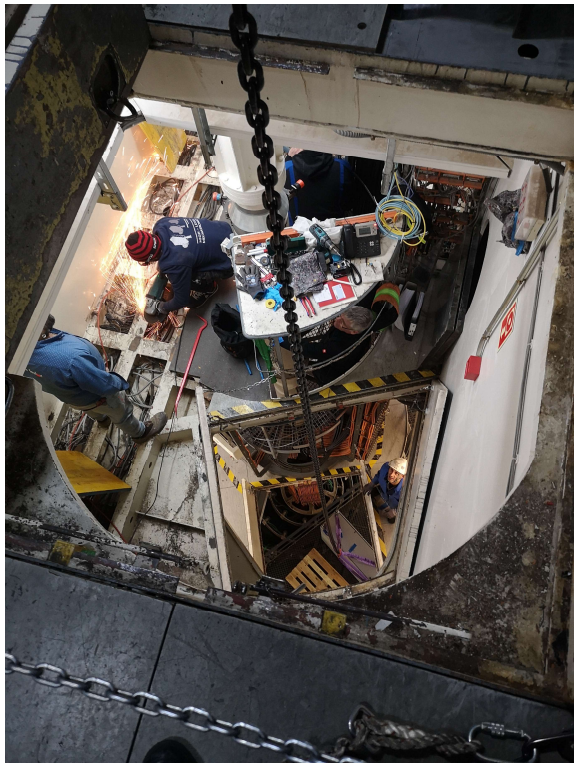
- The new servo control system is being built by the company **OHB Digital Connect GmbH** in Mainz, Germany.
- It features state-of-the art hardware and software components. All key components, including motors, amplifiers (for drives and wobbler), control computer, safety computer and many sensors are being replaced.
- A powerful **Beckhoff** industrial computer implements the Antenna Control Unit (ACU) controlling the axes and sub-reflector spindles and wobbler. It will replace the current Siemens PLCs.





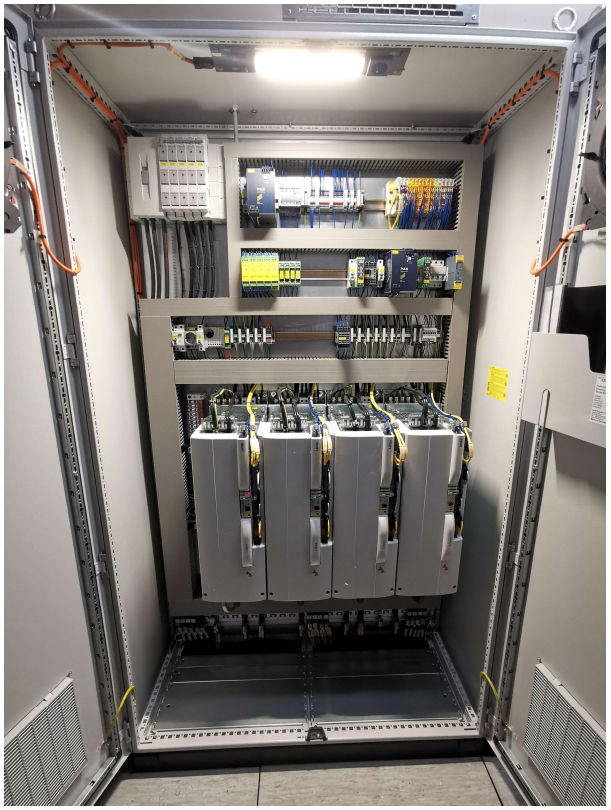
New Servo Control System Deployment

- OHB Digital Connect GmbH initiated the servo control upgrade on **February 28th, 2023.**
- The project commenced with the removal of all old cabinets and cabling, followed by the deployment of essential components, such as motors, amplifiers (for drives and wobbler), control computers, safety systems, and numerous sensors



New Servo Control System Deployment

New Cabinets Servo Control



Azimuth Control Cabinet

Elevation Control Cabinet

New Servo Control System Deployment

Hexapod/subreflector Control Cabinet

Power Control Cabinet

Main Control Cabinet

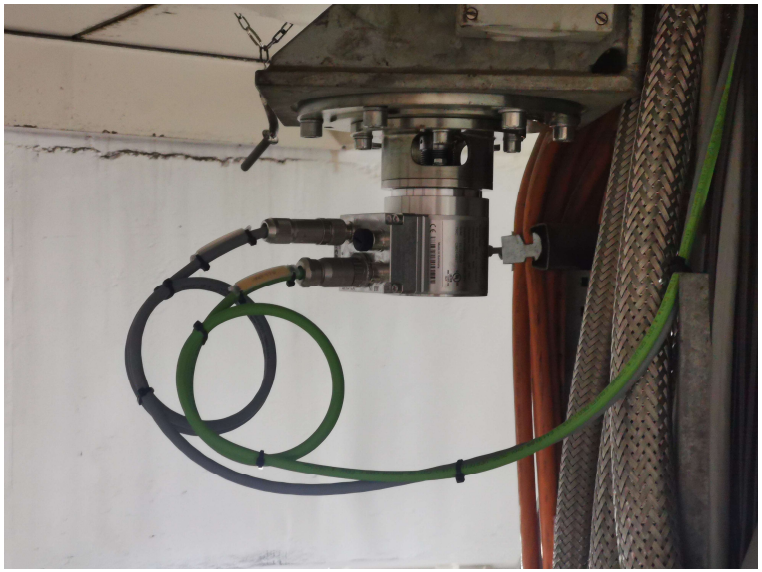
New Servo Control System Deployment

Left Elevation Motors

Right Elevation Motors

Left Azimuth Motors

New Servo Control System Deployment



Azimuth Safety Encoder

Elevation Safety Encoder

New Servo Control System Deployment

- The Secondary disassembly was done on May, 16th 2023.






New Servo Control System Deployment

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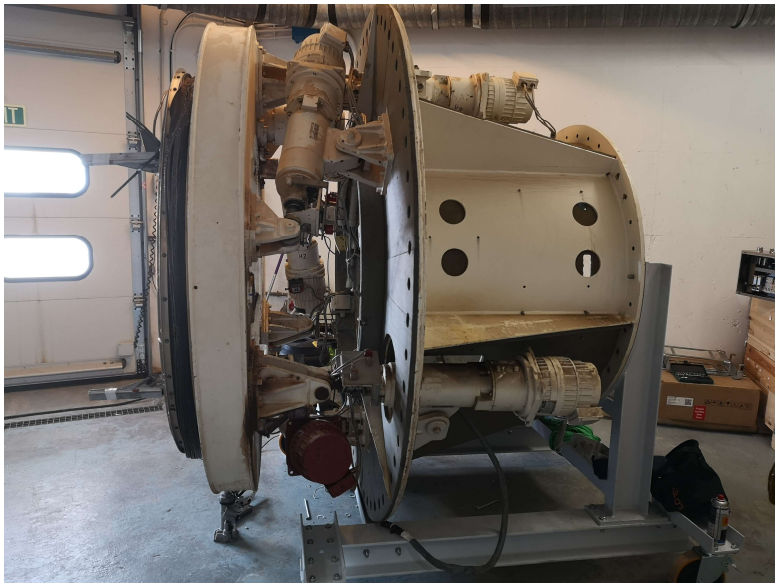
Hexapod refurbishment



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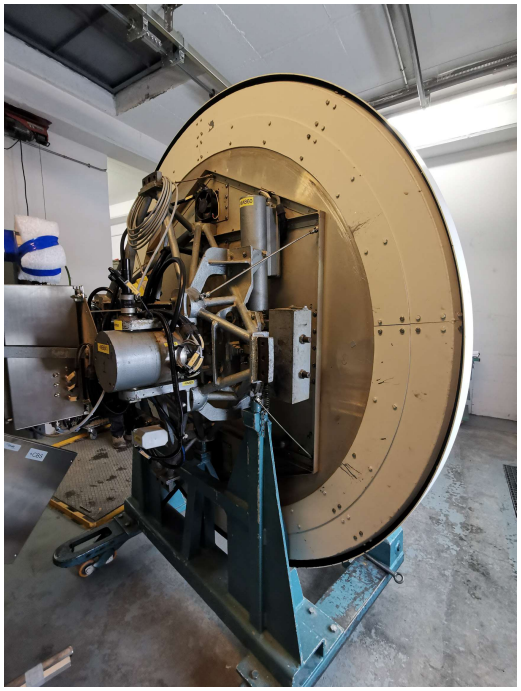
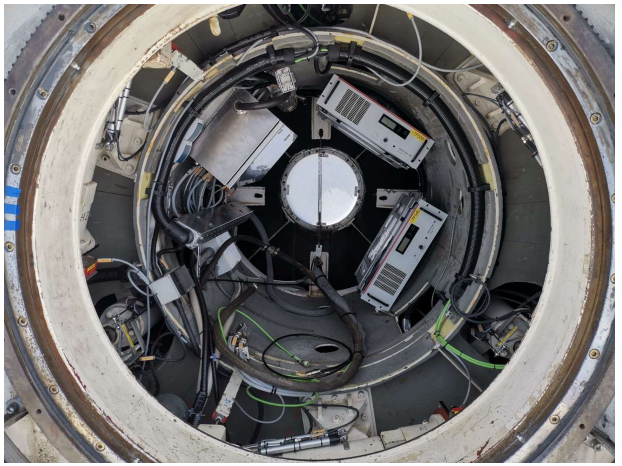
New Servo Control System Deployment

Subreflector and wobbler refurbishment





The New Servo Control System Deployment

- The hexapod was mounted after refurbishment on July 18th, while the subreflector and wobbler were reinstalled on July 25th.

Main Axis Control Issue

Since the initial tests, we have observed significant vibrations in the main axis. After ruling out gearbox-related issues, we identified that these vibrations resulted from abnormal velocity-torque control of the motors due to a wrong selection of motors and amplifiers.

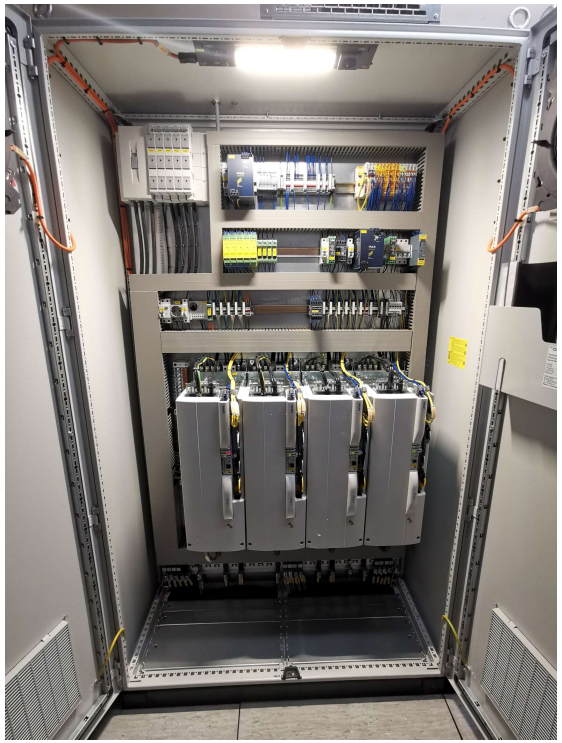
The original setup included DC motors and analog amplifiers. The new configuration features AC asynchronous motors from Lenze and digital amplifiers also from Lenze.

To address this issue, OHB has proposed two strategies:

- Replace the amplifiers with others featuring a faster control loop while retaining the existing motors.
- Replace the amplifiers with others featuring a faster control loop and change the motors by synchronous ones.

Main Axis Control Issue

The first strategy was implemented during the first week of September. The Lenze 9400 amplifiers in both azimuth and elevation were replaced with the Lenze i950 amplifiers, which are 90 times faster.



Main Axis Control Issue

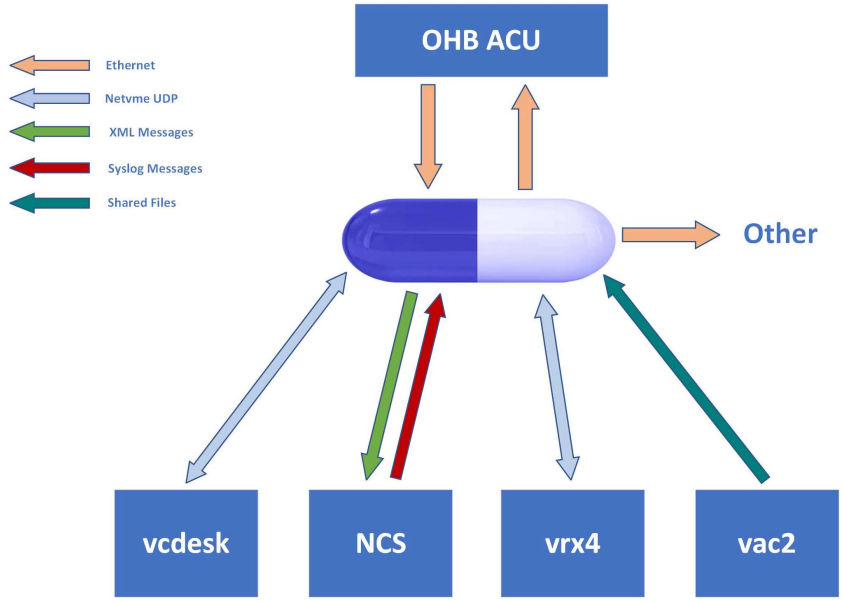
As a result, ripples in both torque and velocity have been reduced to amplitudes below 1%. However, it appears that these ripples are primarily absorbed by the high inertia of the structure and the gears but have not completely disappeared.

Throughout the last weeks, we have been conducting various tracking and operation tests to assess whether the remaining ripples impact the operation. Simultaneously, OHB in Mainz is conducting tests on synchronous motors to determine whether the ripples can be completely eliminated or further reduced.

As of now, this issue has led to a delay of more than 2 months. While the problem is not yet fully resolved, the current performance levels are sufficient to allow testing of other elements of the servo control system.

30-meter servo upgrade IRAM middleware software Development

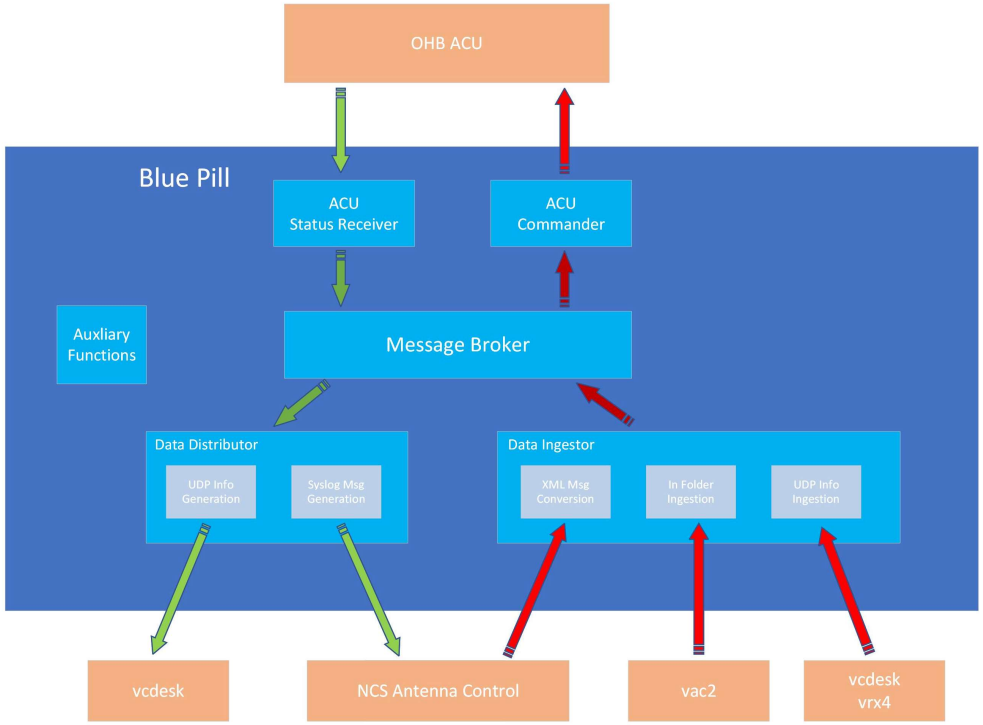
- The new OHB Antenna Control Unit (ACU) now incorporates the existing Antenna Mount Drive (AMD) functionality. To ensure seamless communication with the new system, without requiring any modification to the NCS functionality, a new software component has been developed.
- This component is responsible for transforming and translating the messages and communications currently used by the non-replaced VMEs and the NCS antenna control.
- This new software component, known as 'Blue Pill,' has been developed at the IRAM 30m facility by the computer group with the support of the telescope and astronomy groups.
- Its primary function is to emulate the I/O communications, effectively shielding the NCS from any perception of change.



Blue Pill Interface Diagram

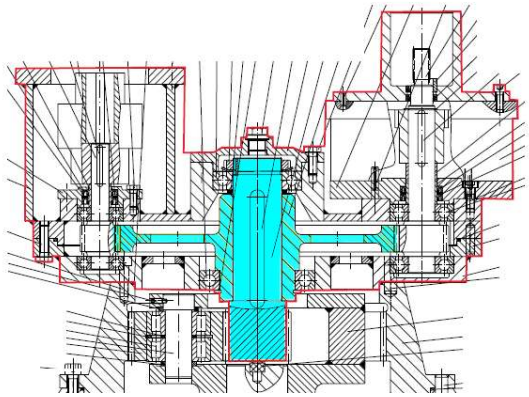
30-meter servo upgrade IRAM middleware software Development

- Internally, the 'Blue Pill' comprises a series of modules designed for the bidirectional translation and conversion of communications between the NCS and VME systems and the new ACU, facilitating command and status exchanges.
- This software is implemented in Python and operates within a separate virtual platform. As of now, the software's functionality has been successfully validated.
- Currently, ongoing efforts are focused on refining the system to ensure that all commands and information are accurately translated and converted.
- Given the evolving nature of the OHB ACU Interface, it is still necessary to adapt some of the 'Blue Pill' modules accordingly.



30-meter upgrade: gearboxes overhaul

- Performance of Az and El gearboxes are important to improve the tracking accuracy.
- Gearboxes degrade with the use.
- Periodic vibration tests shown a significant degradation of the 1st phase of all the planetary gears, mainly the Az ones.
- In the context of the servo system upgrade and the replacement of the motors, new atack spur gears have been ordered to DESCH.
- **These were delivered on July 6th, 2023 and would be installed after the new servo control system is operacional. When decided, the installation will need a downtime of 2 weeks.**



30-meter upgrade: surface improvement

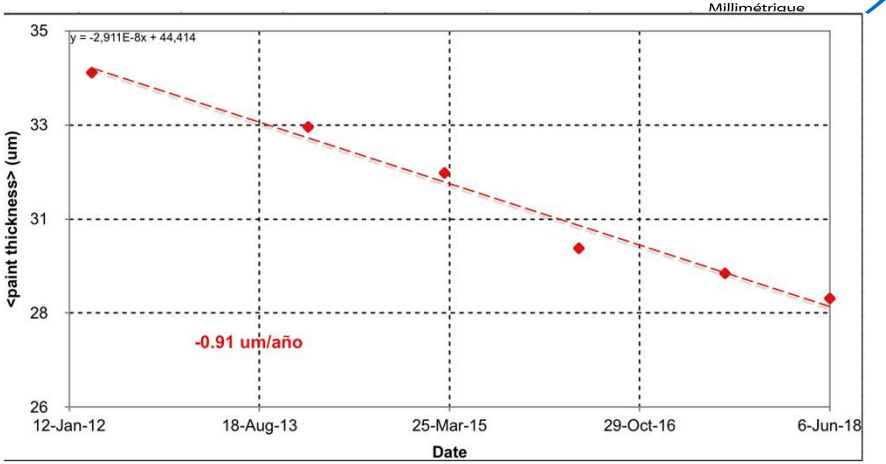
Surface improvement goals:

- Enhance the thermal behaviour of the surface and reduce the surface r.m.s. error caused by optical path differences.
- Achieve a surface r.m.s. error of 50µm at any elevation, with a goal of 40µm. This improvement will result in increased efficiency within the 1.5 to 2 at high frequency.
- Minimize the dependency of mirror efficiency on elevation, ensuring that the contribution to the r.m.s. error due to gravitational effects remains below 30 µm across the entire elevation range from 20 to 80 degrees.

Last year, OHB was commissioned to conduct a painting test and a study to assess the feasibility of these objectives.

30-meter upgrade: surface improvement

15th September, 2021

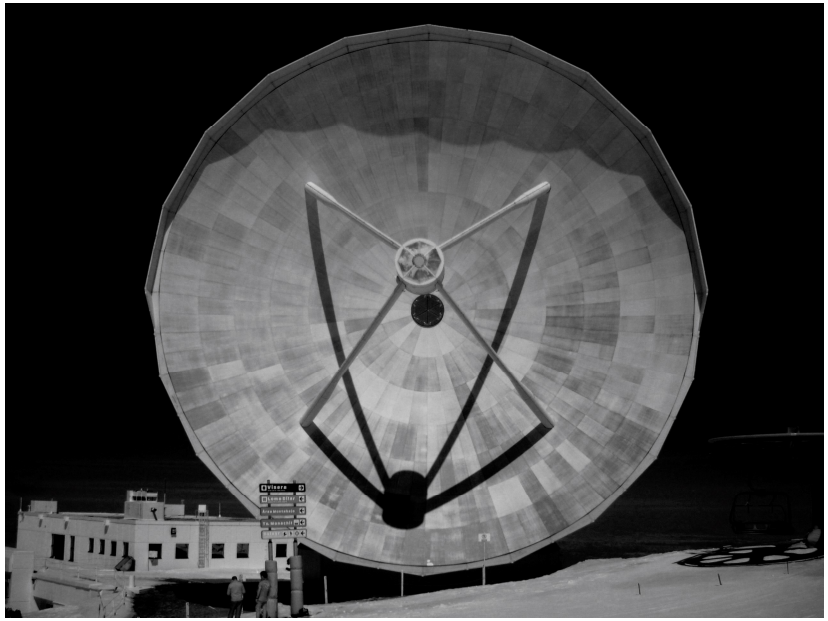


The surface TiO_2 paint has been slowly but steadily degrading over the past years, at a rate of ~1μm/year.

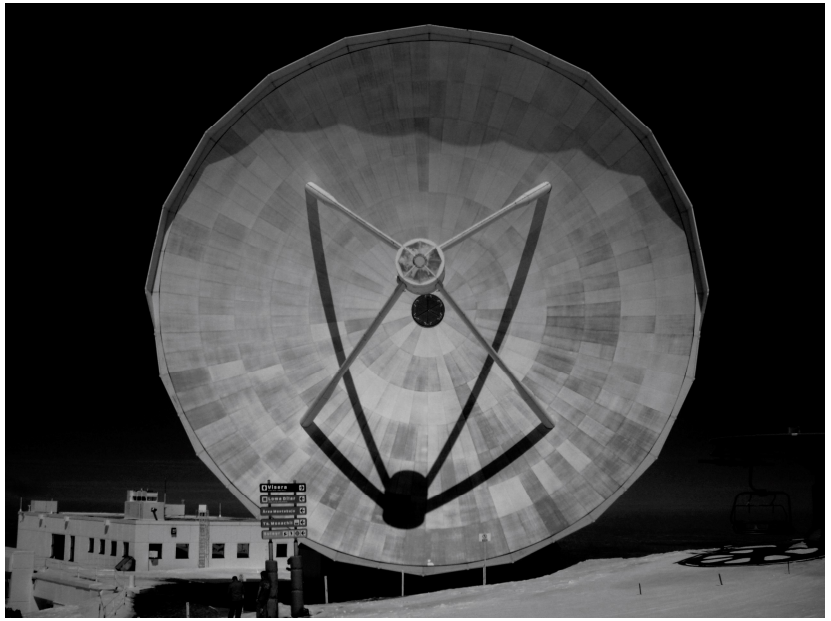
Some parts have degraded from ~50μm to 10μm thickness. The dark primer starts to show-up. This can contribute with square-add ~35-40μm to the surface r.m.s. budget.

30-meter upgrade: surface improvement

VIS



NIR



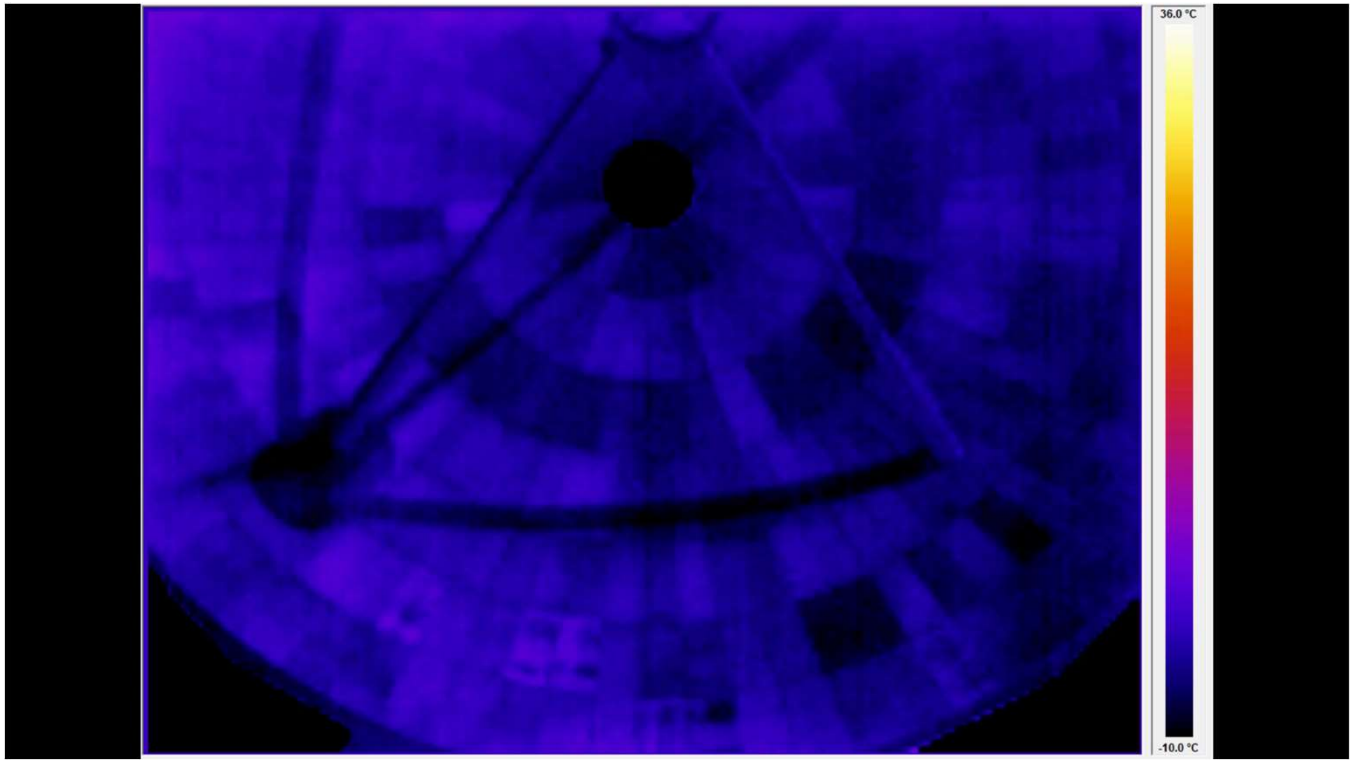
March, 23rd 2021

Due to the observed aging/weathering of the paint the following effects are observed:

- Degraded thermal performance in day time (specially critical for NIKA).
- Degraded surface rms due to uneven paint layer (day and night) and panel buckling.

Renewing the paint is likely the most urgent thing to do in order to improve the 30-meter!

30-meter upgrade: surface improvement



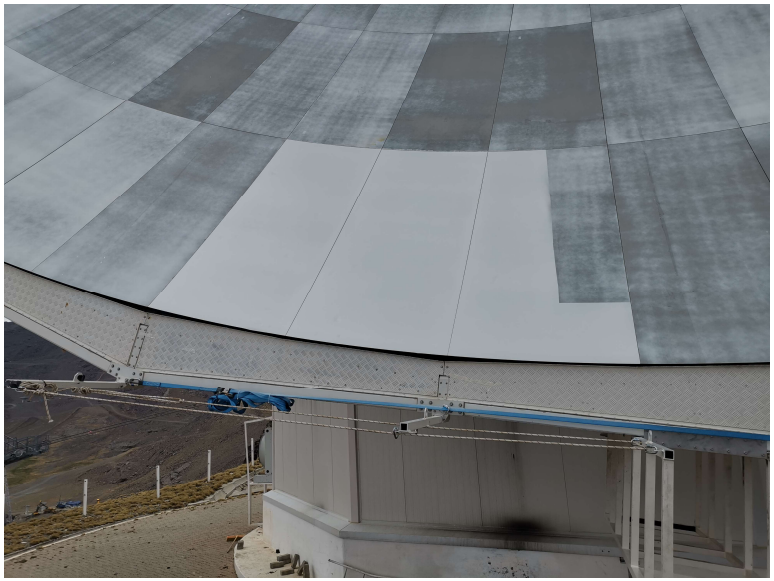
During the day adjacent pannels show temperature differences of 20 C degrees.

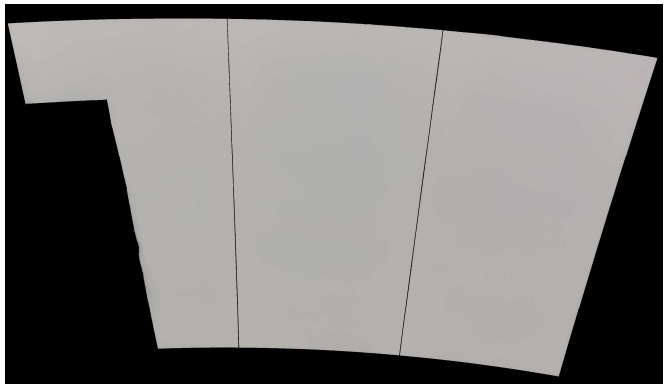
30-meter upgrade: surface upgrade testing

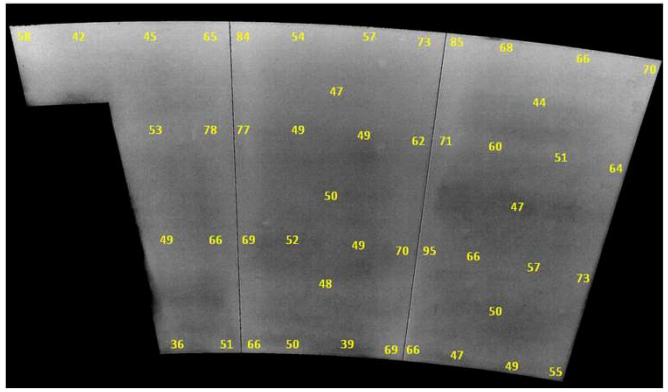
- On 2022, we carried out with our main contractor OHB a paint test campaign (laser cleaning + painting 3 panels of the external telescope ring) and the evaluation of results is in progress.
- In order to define the thickness tolerances for the cleaning and primer and topcoat application. It has required to characterise radioelectric properties of new paint samples at IRAM: dielectric constant and attenuation/losses.
- Final thickness requirement: 50 μm ±5μm peak-to-peak (cleaning: 10 μm, primer: 20 μm topcoat: 20 μm)

30-meter upgrade: surface upgrade study

Painting Test 2022







- Average of 50 μm mostly accomplished
- Margin of ±5μm peak-to-peak non achieved
- Paint application procedure to be redefined to avoid peak-to-peak margin breaking

30-meter upgrade: surface upgrade testing

iram
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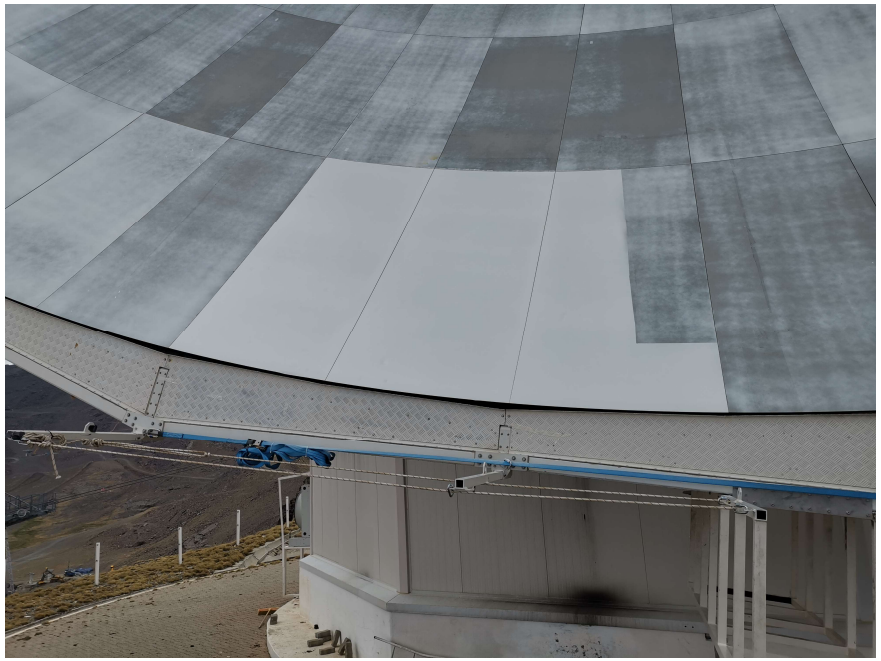
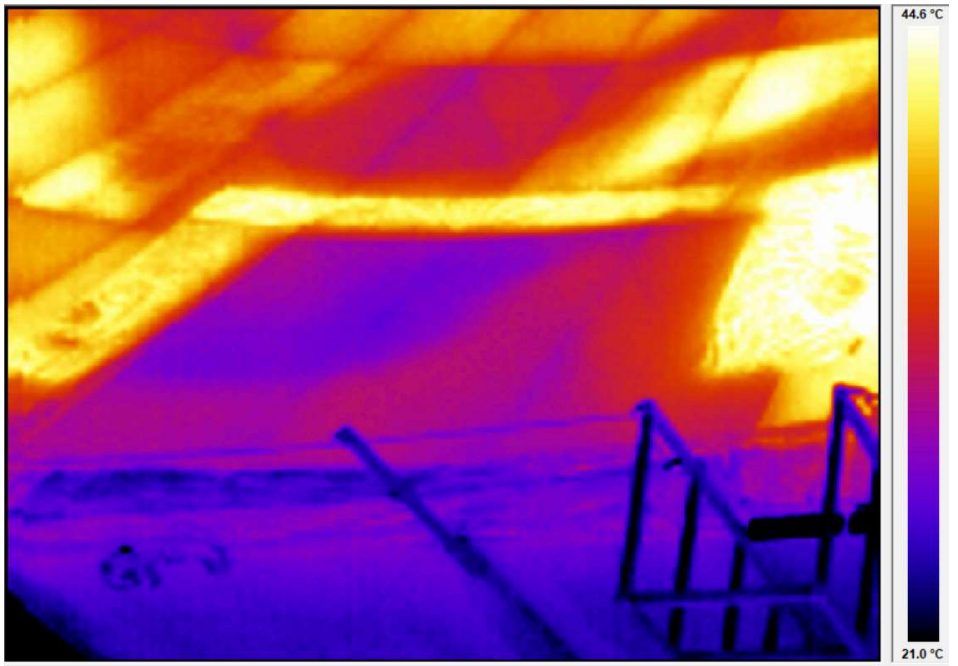
Test Results: Conclusion

- A better thermal performance is evident after the test:





30-meter upgrade: surface improvement study

After the painting test conducted at the 30m on Summer 2022 a detailed study report was delivered by OHB on May 2023. It contains the following analysis:

- **Procedures for the surface painting** tested on site on Summer 2022: cleaning, painting, safety, measurement, validation. This test was presented to SAC on 2022.
- **Paint degradation monitoring** performed both on-site at the 30m and in a laboratory at IPA Fraunhofer (accelerated aging simulation of exposure to radiation, thermal stress, etc.).
- **FE study of the telescope structure** to analyse the thermal and gravitational deformation at low and high elevations.

Paint degradation analysis

Two types of degradation analysis have been conducted:

- On-site degradation monitoring: One year after the test the painted area of the antenna shows no significant deterioration.

- Simulated environment in the laboratory: Accelerated aging tests were conducted at IPA Fraunhofer in a controlled environment simulating cycling exposure of painted samples to radiation, thermal stress, and humidity. The experiments revealed that the deterioration of the primer and paint used in the test (PercoTop by AXALTA) was not optimal. Currently, new aging experiments are underway, testing different primer and paint combinations to find the best components. Promising results have been obtained with a paint provided by MDSCC/JPL (Goldstone 7 by Triangle).

30-meter upgrade: surface upgrade study

A **Finite Element (FE) study of the telescope structure** was conducted to provide an overview of the impacts of environmental factors such as gravity, wind, and temperature on the surface deformations of the main reflector at both low and high elevations. The study aimed to assess the most effective approaches to reduce these deformations. It found that panels of ring 3 of the antenna have a significant deformation due to gravity and thermal loads.

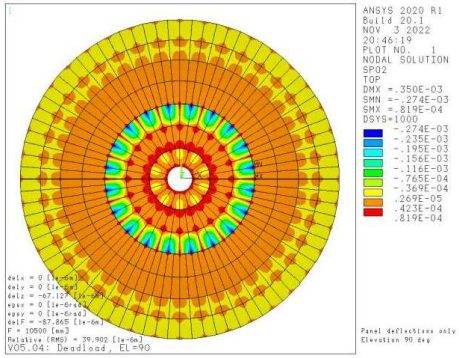


Figure 82 G3 *EL*=90° gravity: panels only 40 µm RMS

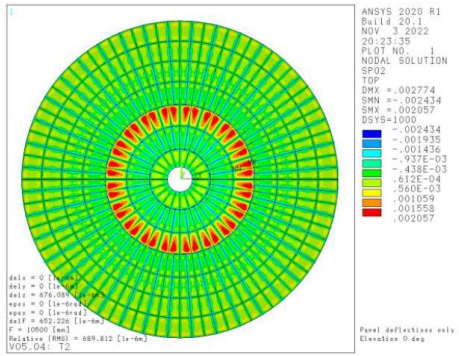
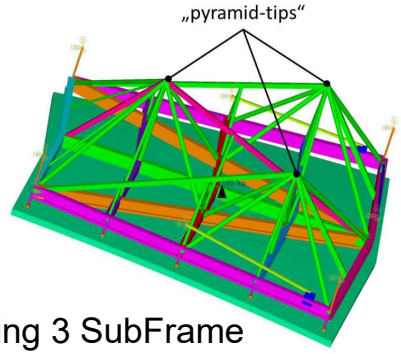
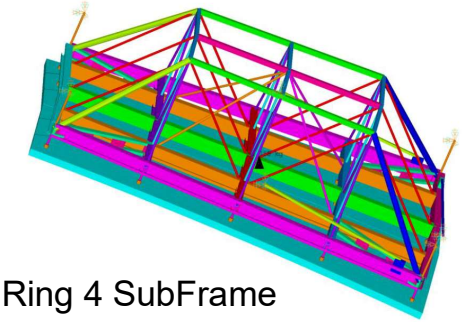


Figure 83 T2 "Winter Day" panels only 690 µm RMS



Ring 3 SubFrame



Ring 4 SubFrame

Sub-frames of ring 3 of the surface are different than the sub-frames of other rings. FE elements show that this effect can reduced after reinforcing the sub-frames connecting the free vertex.

30-meter upgrade: surface improvement study

The study resulted in the following recommendations:

- A **conservative approach is proposed for the surface painting**, involving in-situ cleaning using laser technology followed by repainting the telescope surface to meet stringent accuracy requirements. This process would be scheduled for the summer of 2024, pending the successful completion of ongoing laboratory tests. Subject to weather conditions, this process. **It will require a downtime of the 30m telescope lasting between 2 to 3 month**
- It is **discouraged to install actuators**. The effort for an integration of actuators in the BUS and to evolve the control system is extremely high compared to its expected benefits.
- To address gravitational deformation at low and high elevations, it is recommended to **reinforce the sub-frames of ring 3**. The design and composition of the reinforcement will need to be performed beforehand.


Thank you!