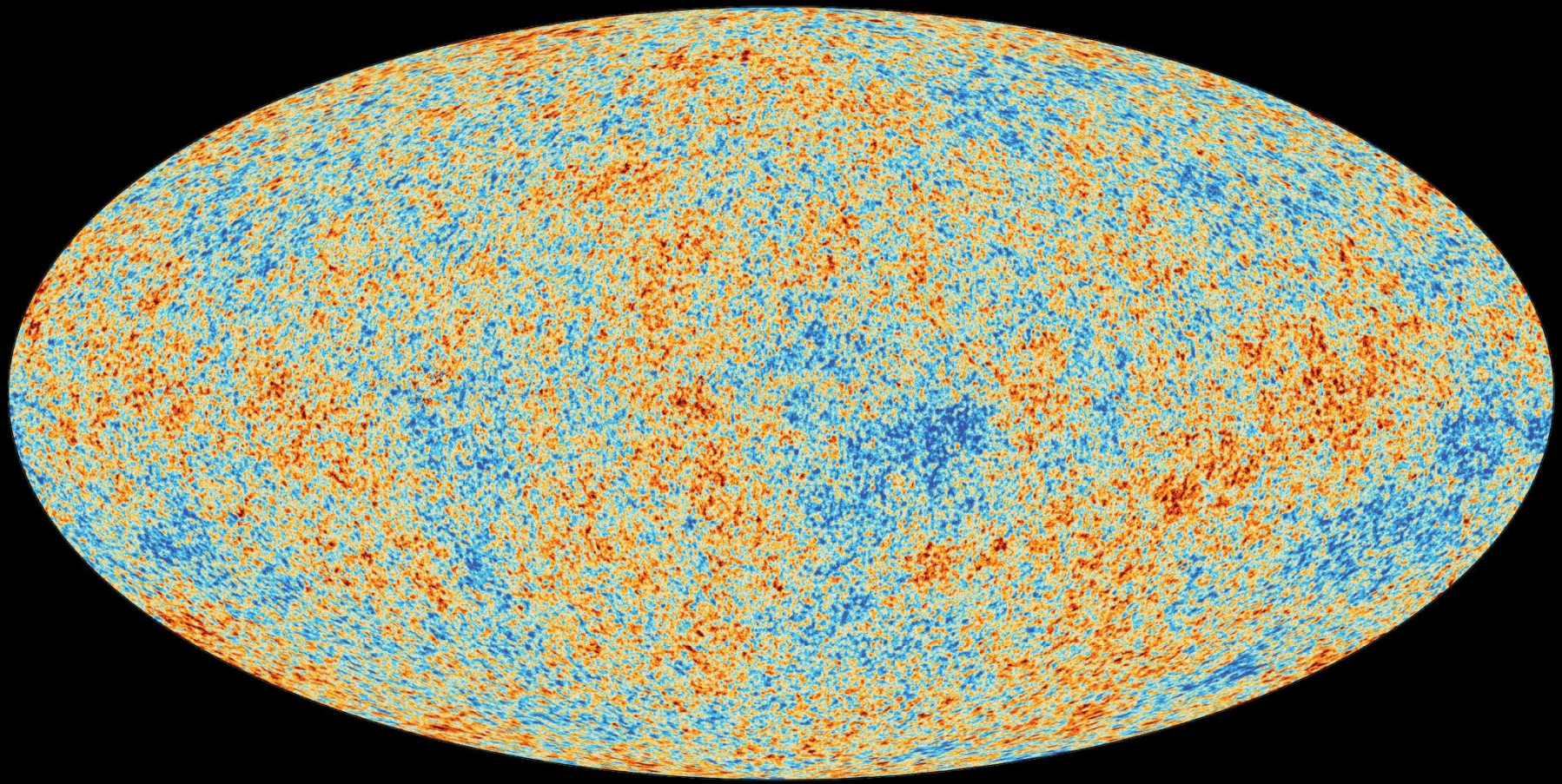
# → THE COSMIC MICROWAVE BACKGROUND

Planck Legacy Release 2018

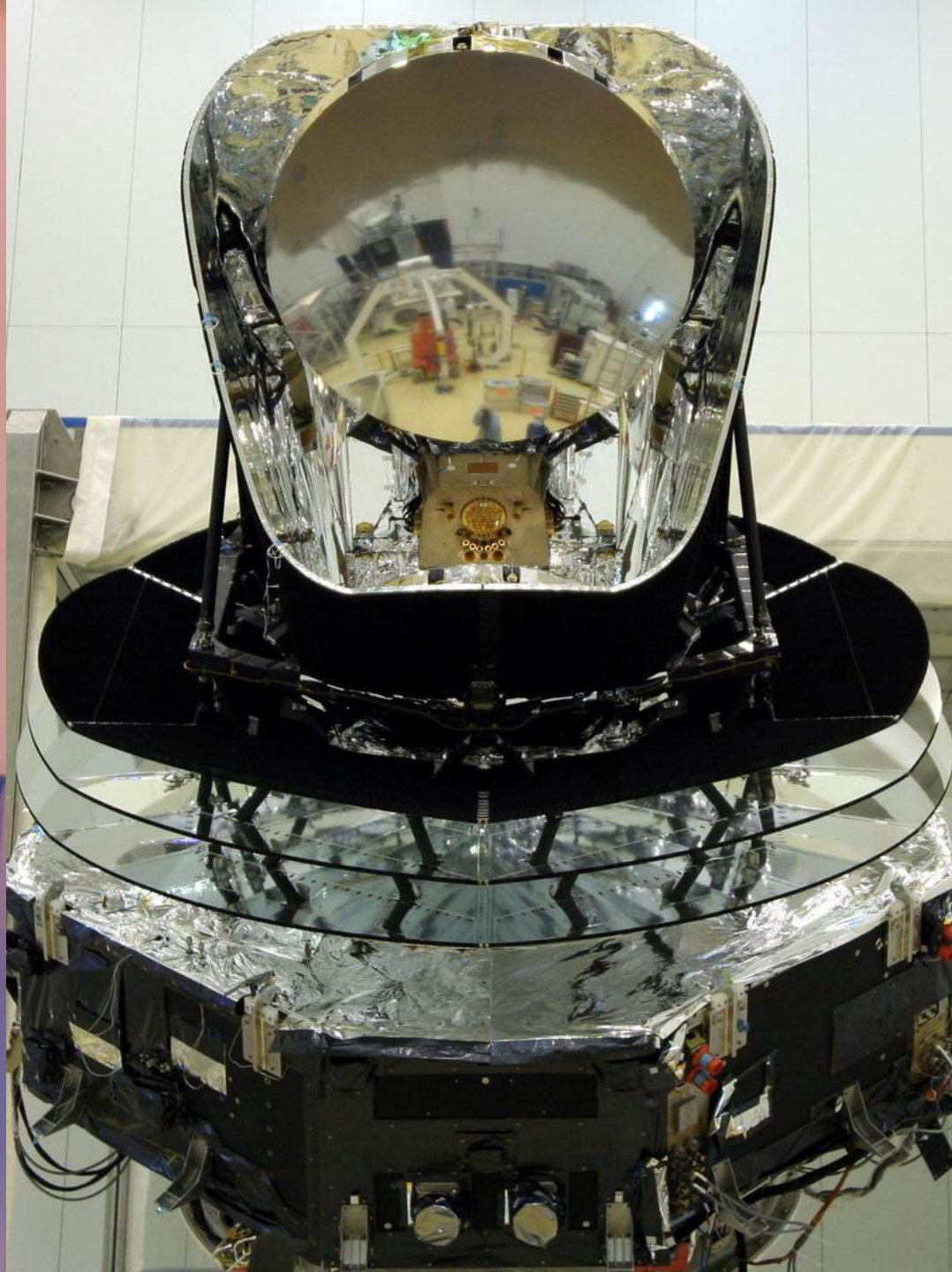


*Credit: ESA/Planck Collaboration*

www.esa.int

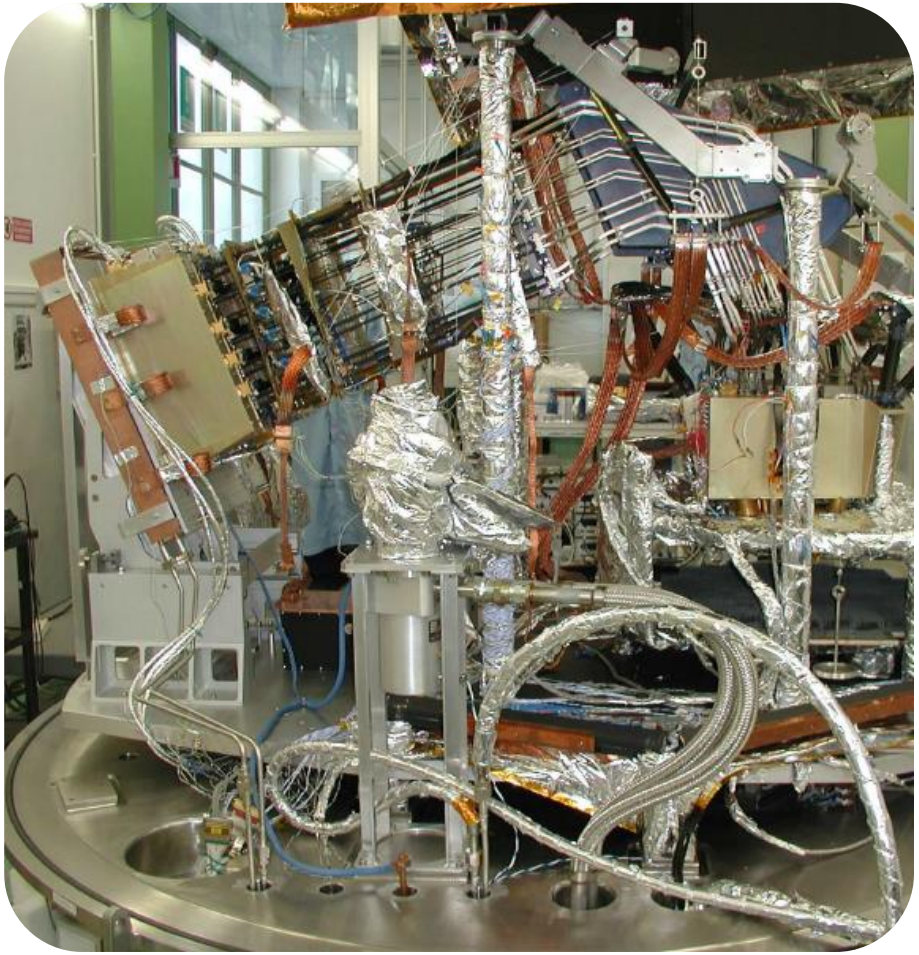
European Space Agency


esa
esa
CNES
CNES
©2009 ESA-CNES-ARIANESPACE / Optique Video du CSG - P. BAUDON



# Low Frequency Instrument

Cryowaves
è Bologna



# Planck heritage: Expertise 1/2

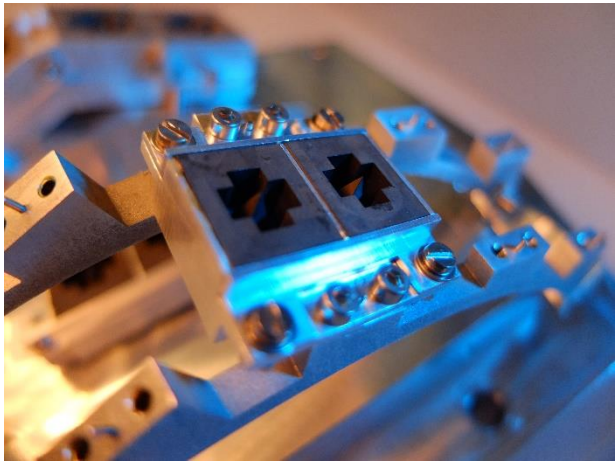
Cryowaves è Bologna

- **Project System team (system engineering)**
  - Low Frequency Instrument
  - Satellite interfaces
  - NASA/JPL Sorption cooler
- **Test and Verification**
  - Radiometer Chain Assembly Test Campaign
  - Radiometer Array Assembly test Campaign
  - System level test  (Instrument and Satellite level)
- **Instrument operation team**
  - Flight test and calibration campaign
  - first light
  - Support in data analysis
- **Sorption Cooler System Operation Manager**
- **Calibration and Perfromance Verification (CPV) Phase Manager**

# Planck heritage: Expertise 2/2

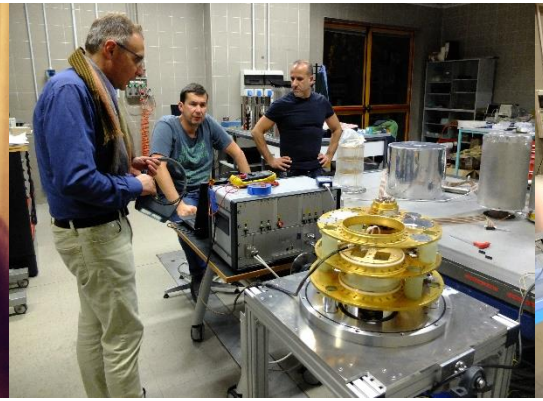
Cryowaves è Bologna

- **Cryogenics**
  - dev. of Sorption cooler of Planck, cryo-chain of Planck, 4K reference load
- **Thermal engineering**
- **RF/microwave engineering**
  - passive components, calibrators, EM analysis,
  - amplifiers and radiometer optimization
- **Telescope engineering**
  - from design to qualification
  - Full Electromagnetic analysis of telescope
- **4K reference load full development**
- **Sorpiton cooler development @ NASA/JPL**
- **full development of the calibrator for system level tests**
- **Data analysis, pipeline development, software development**
  - Foreground component separation
- **Outreach**

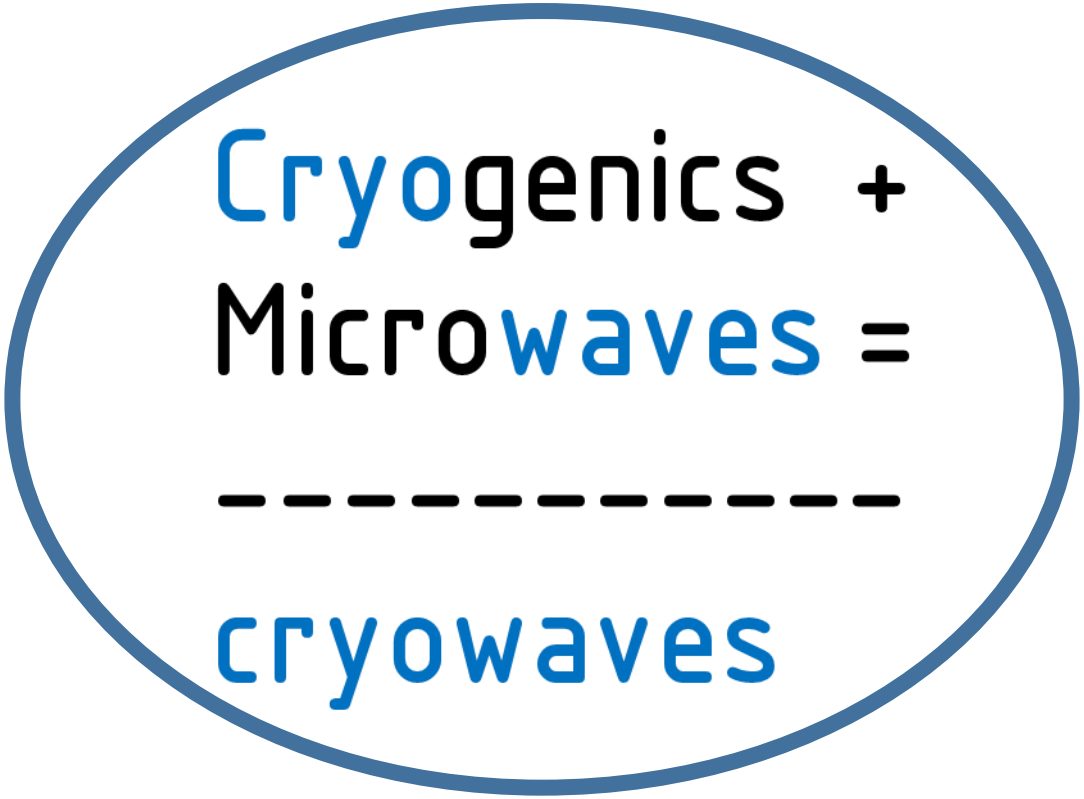


**to gather competence, skills and experiences to approach all the phases of a large project (space-born and ground-based), from the conceptual design phase to the commissioning and observations.**

Cryowaves
è Bologna



## A reference laboratory for AIV / AIT activities (Assembly Integration and Verification and Test)



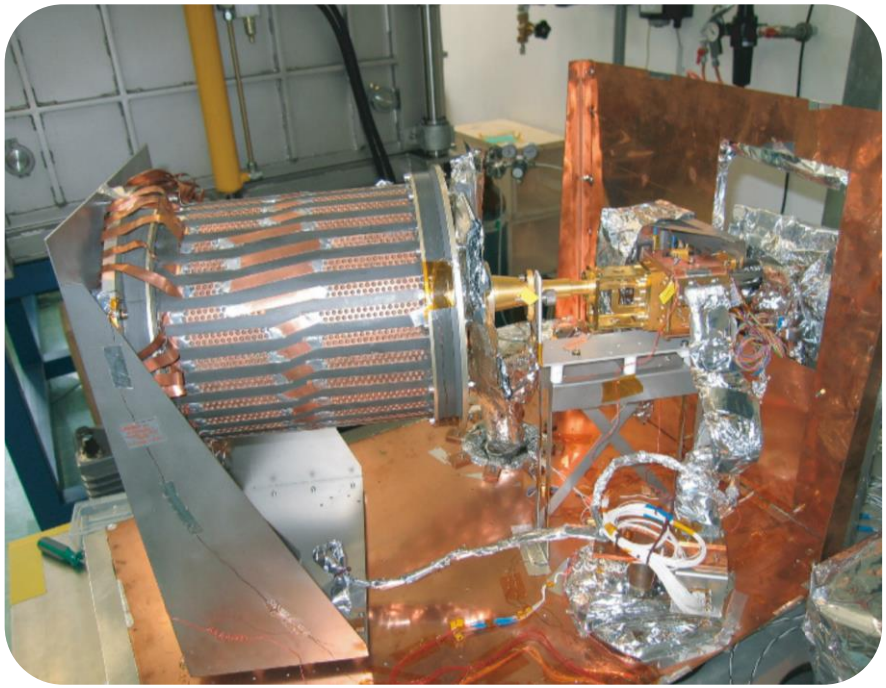

Cryowaves
**è Bologna**

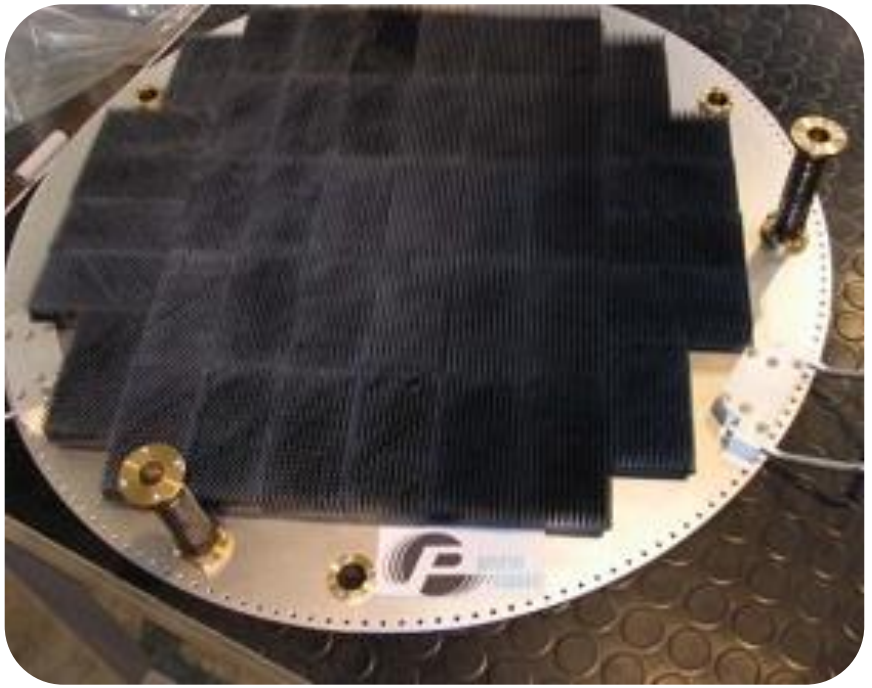
**cryogenics and microwave technologies are tightly related one to each other**

**we can refer to cryowaves technologies, a science and technology branch mainly focused to develop technologies and facilities to build and operate wideband high performance radio, microwave, and mm-wave receivers and antennas to be operated in cryogenic environment**

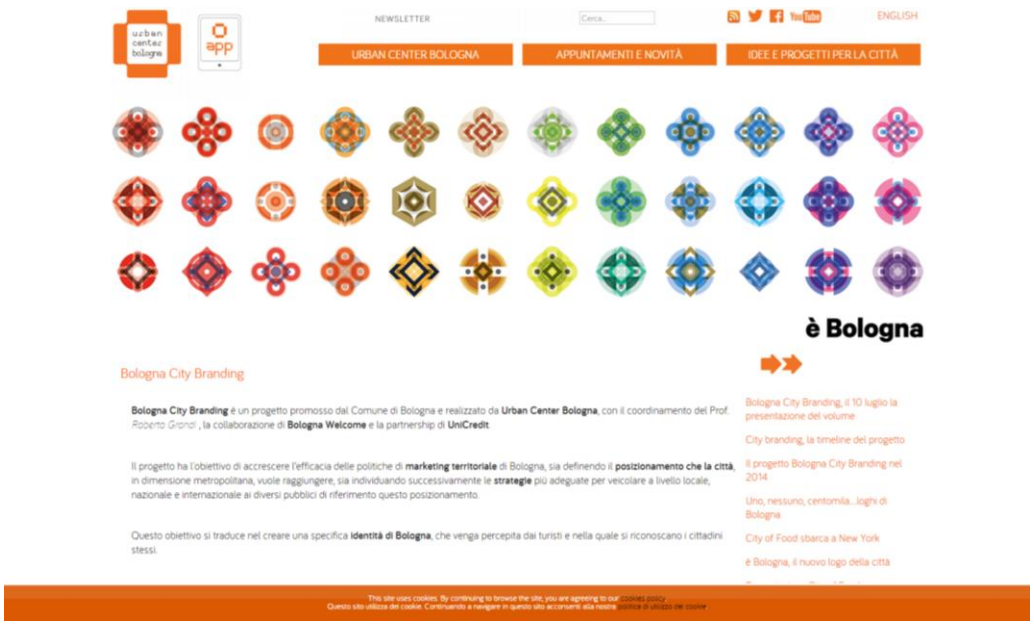
# State of the art in calibrators development

Cryowaves
è Bologna





Cryowaves
**è Bologna**



# the cryowaves experience

Onde millimetriche a temperature criogeniche

Viaggio illustrato dagli Appennini alle Ande

attraversando lo spazio profondo

**OAS-days 17-18 Dec 2018 presented by F. Villa**

INAF

Cryowaves
è Bologna

# Cryowaves personnel

Cryowaves è Bologna

## Expertise mainly in experimental Physics

**A.Derosa** (Technician): Mechanical Engineering

**F.Cuttaia** (Senior researcher): RF engineering / AIV

**G.Morgante** (Researcher): Thermal Engineering

**S.Ricciardi** (Researcher): Outreach, Science, Project Control

**M.Sandri** (Tecnologa): Outreach, Optics, S/W

**M.Terenzi** (Researcher): Thermal Engineering

**F.Villa** (Senior researcher): PM, RF engineering, Optics

**S.Mariotti** (Technician, IRA): RF technical support

# Competences on Instruments & experiments

Cryowaves è Bologna

- **Management of projects**
  - Program Management, System engineering, Product assurance, AIV/AIT ECSS standards and best practices.
- **Technical expertise on**
  - Cryogenics, Thermal engineering (cryostat and cooler design)
  - Microwave, mm-wavelength and RF components design and opt.
  - Low Noise Amplifier optimization
  - Electromagnetic analysis and Opt. on passive components, antennas and telescopes
  - Calibrator's development
- **Design, development, integration, qualification, testing and calibration of microwave and mm-wave instruments and telescopes in cryogenic environment**
- **Data analysis, pipeline and software development**
- **Coding and Tinkering**


Cryowaves
**è Bologna**


Linde

# Cryo-vacuum facilities

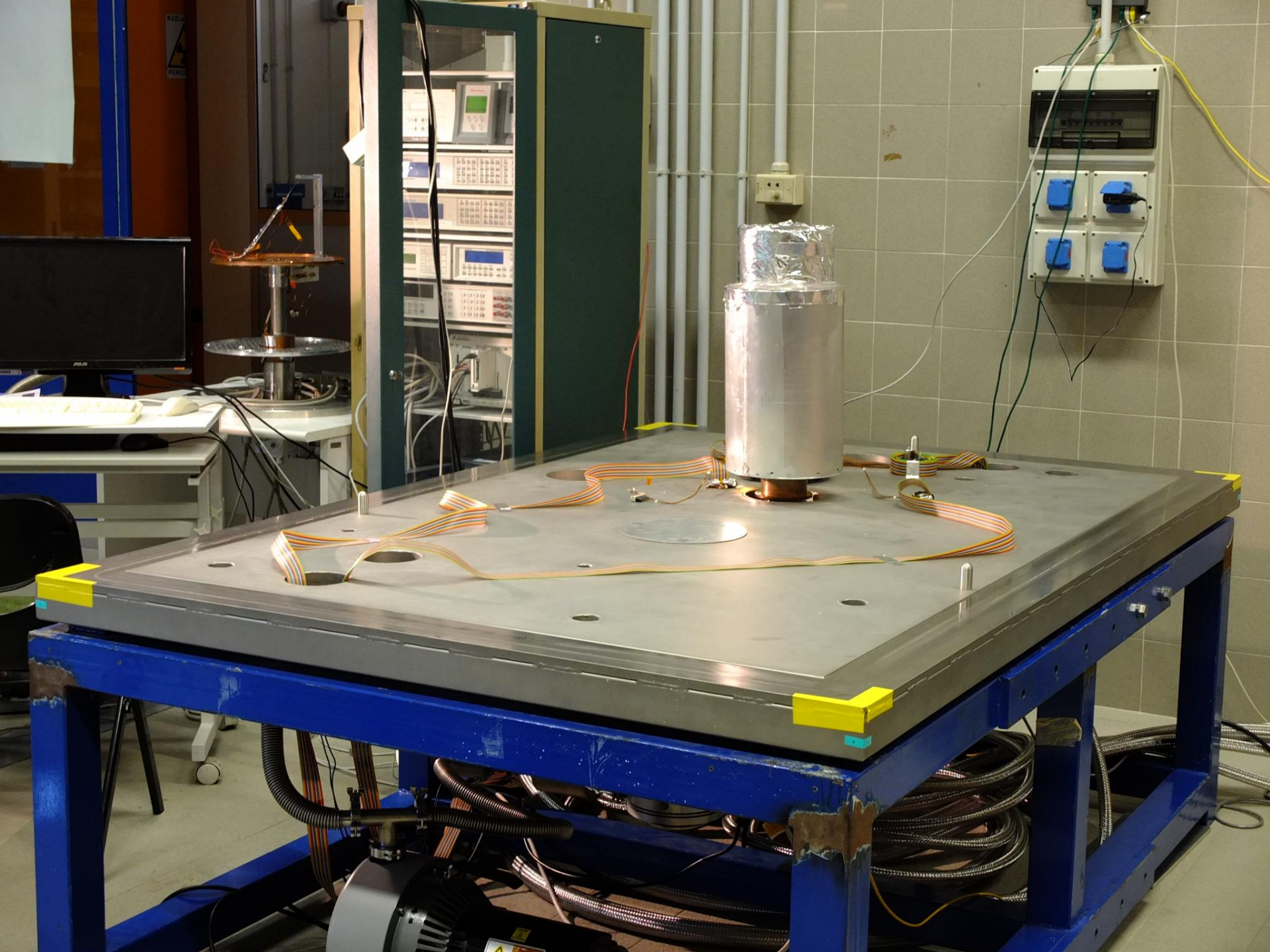
Cryowaves è Bologna

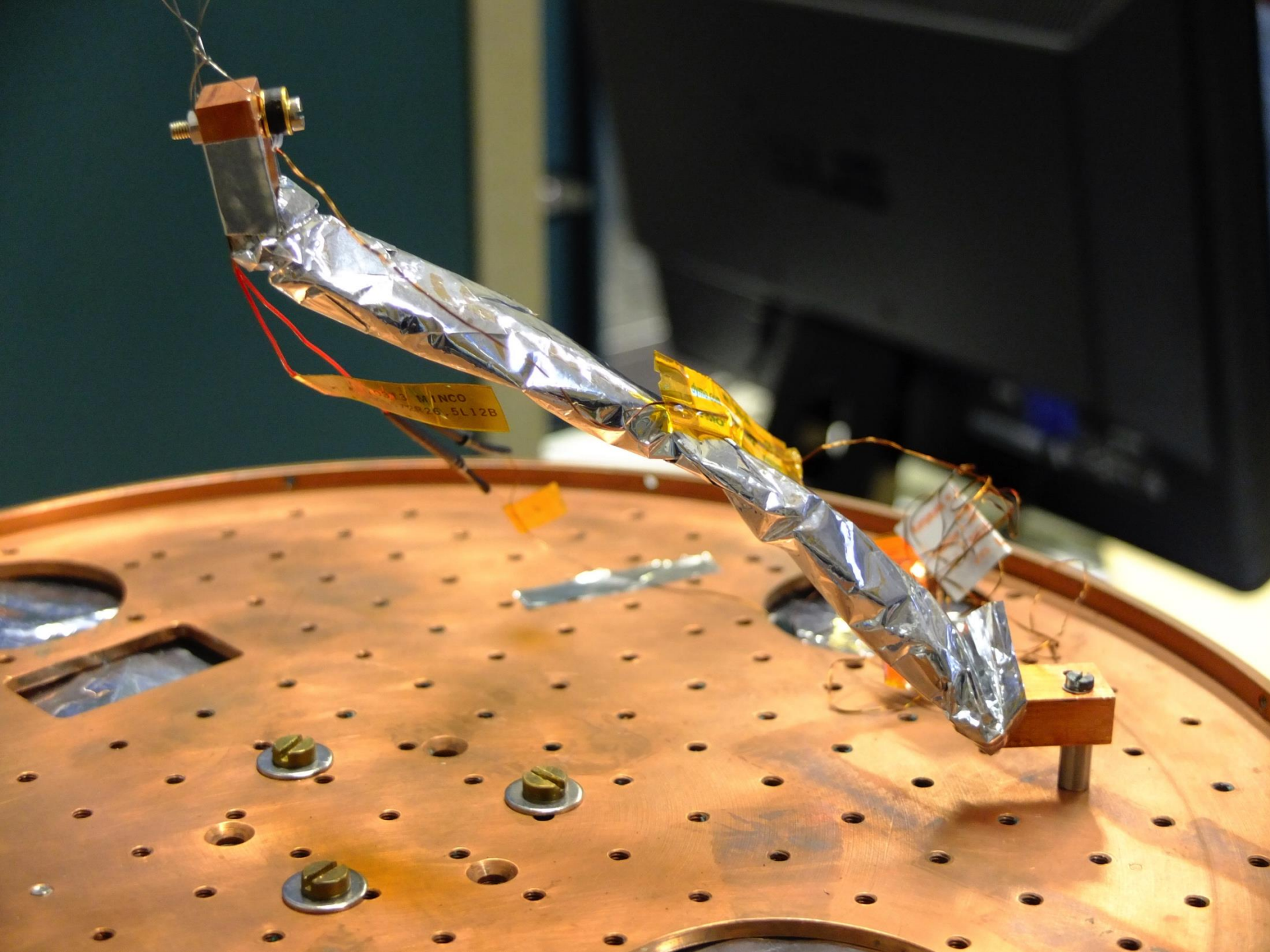
- **Compressors house.** Dedicated house to protect compressors. The house permits to connect 4 compressors working at the same time, cooled with air or water. An automatic chiller refrigerates the water in a closed cycle.
- **Leak detector.** VS PD03 Dry leak detector with dry pump combination.
- **Vacuum instrumentation** and several lake shore instruments, pressure probes, etc. are available as support for facilities.

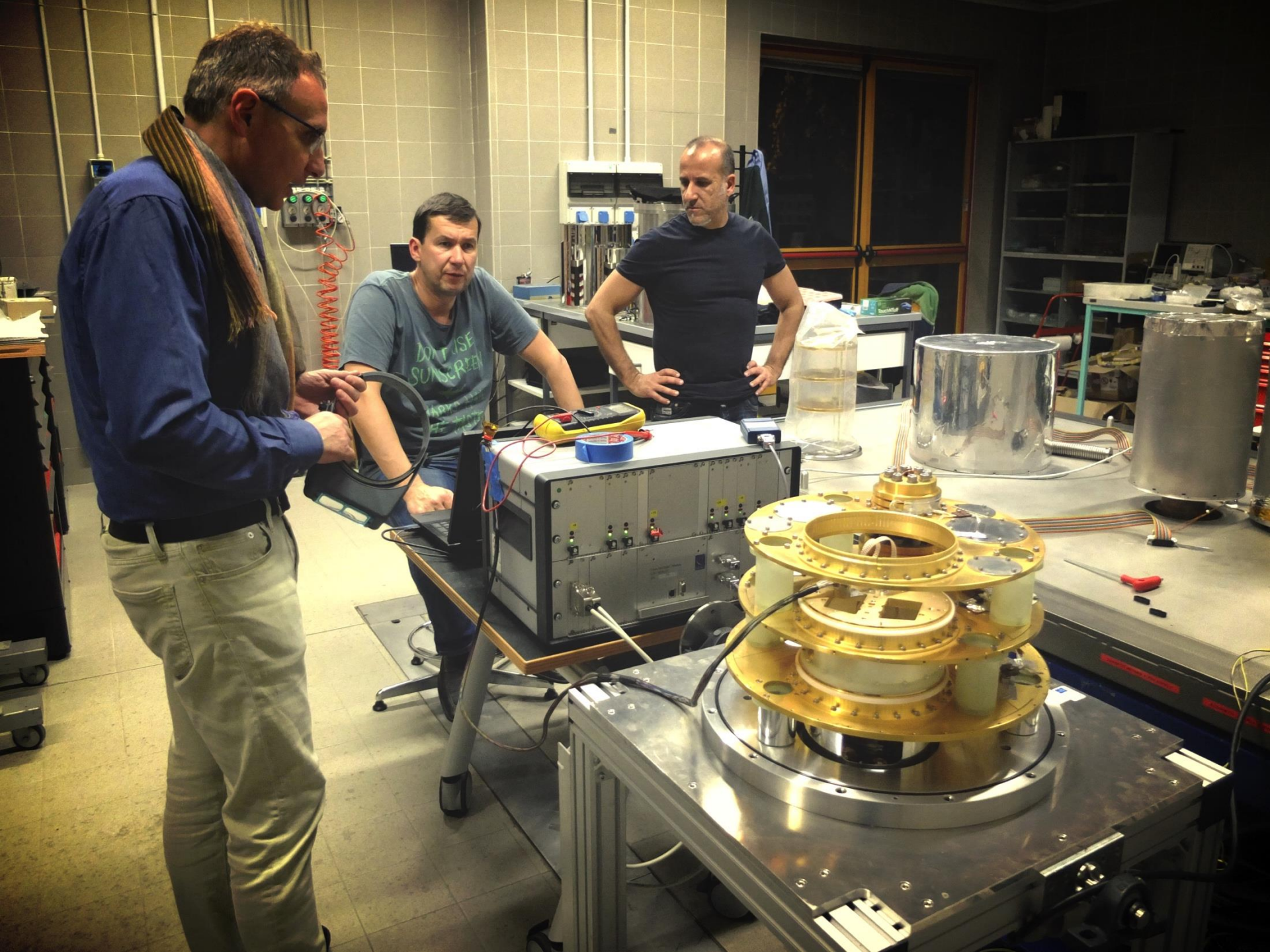
# Cryo-vacuum facilities

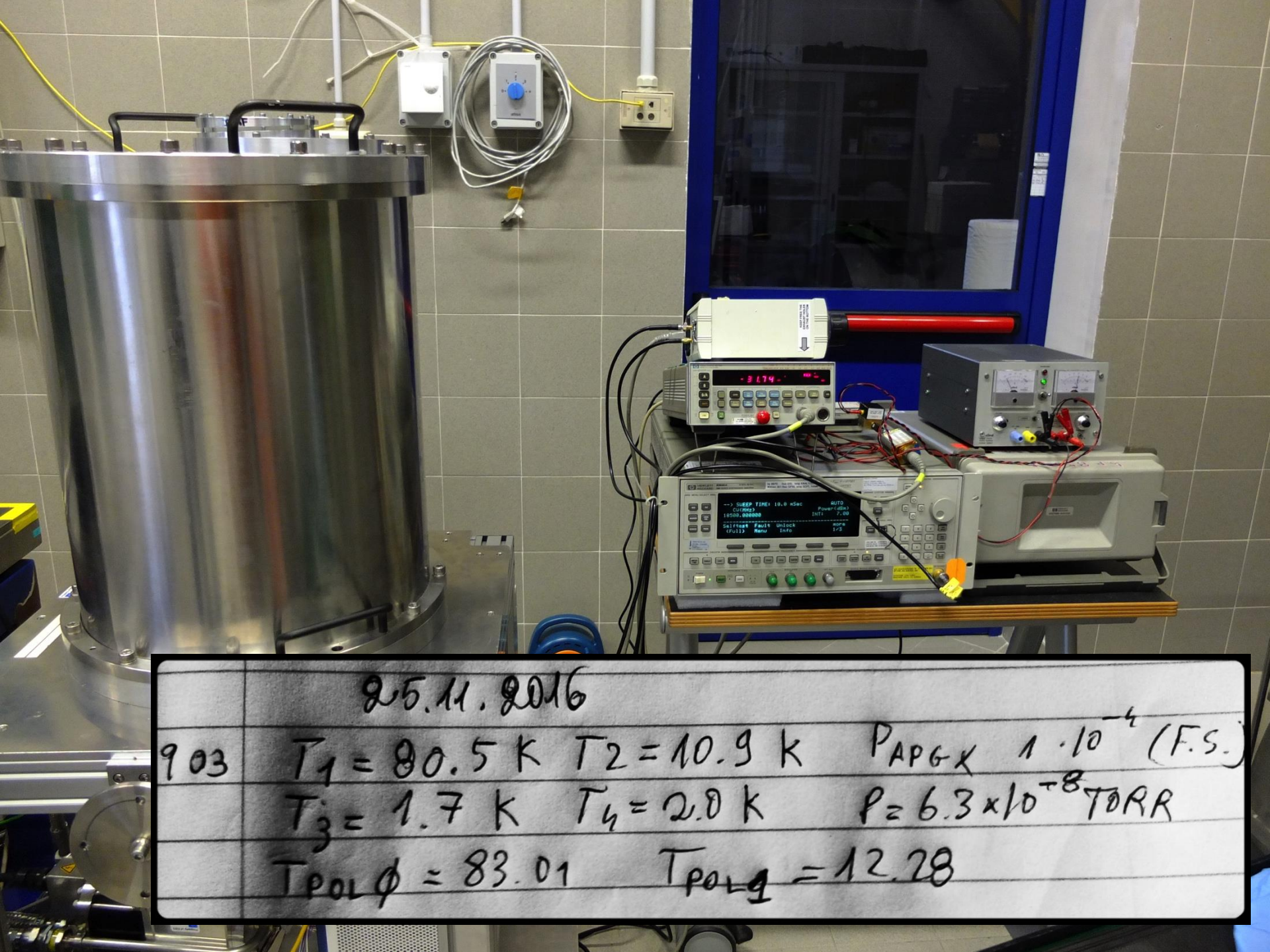
Cryowaves è Bologna

- **The 'coffin'.** the most important instrumentation for dimensions. A 1m x 2m in size x 1 m in high cryofacility with configurable thermal interfaces to cooling instrumentations down to 4 K.
- **The 'blue barrel'.** A small cryofacility (4K) to test components such as passive components at cryogenic temperature, or to measure thermal properties of materials and pieces.
- **ALMA test Cryostat.** At present Cryowaves lab is hosting the NAOJ ALMA test cryostat to test the ALMA band 2 (+3) receiver prototype.
- **LSPE / STRIP cryostat**




MINCO




25.11.2016
903 $T_1 = 80.5\ K$ $T_2 = 10.9\ K$ $P_{APGX}\ 1 \cdot 10^{-4}$ (F.S.)
$T_3 = 1.7\ K$ $T_4 = 2.0\ K$ $P = 6.3 \times 10^{-8}$ TORR
$T_{POL}\phi = 83.01$ $T_{POL\,1} = 12.28$


WARNING
Sudden Pressure Release
Protect Yourself and Others

# Microwave Facilities

Cryowaves è Bologna

- **Scalar network analyzer** 10 MHz - 100 GHz Agilent tech. 8757D + sweeper and WG setup
- **Wideband Peak Power meter.** Anritsu ML2487 A (100 KHz - 65GHz) equipped with standard diode sensor MA2475D 10 MHz- 50 GHz
- **BIAS Supply and data Acquisition system.** NI PXI System with 2 units NI PXIE-4140 4-CHANNEL SMU to provide 8-channel supply for LNAs biases. NI PXIe-6361, X Series DAQ (16 AI, 24 DIO, 2 AO) providing 16 analog input channels and 24 Input/Output channels.
- **3D Printer.** Additive 3D printer with printing area of 300X450X235 mm.

# Software Facilities

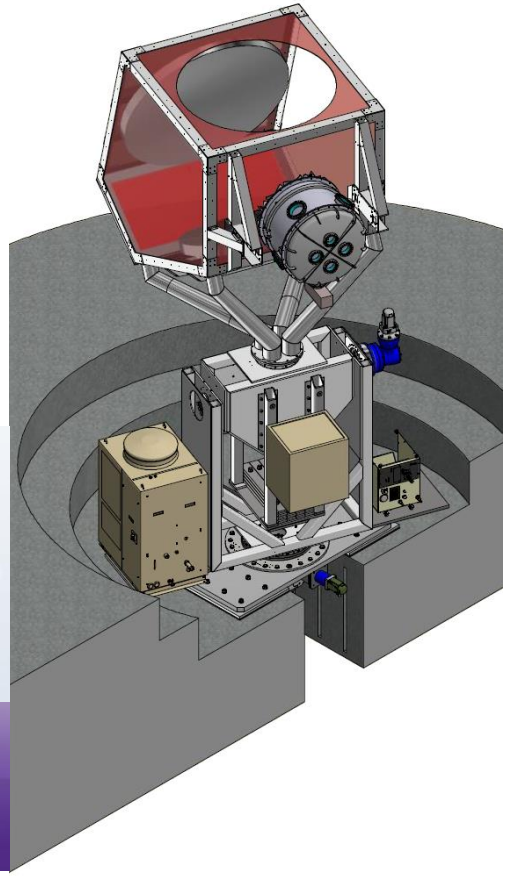
Cryowaves è Bologna

- **GRASP**. (www.ticra.com) GRASP with mrGTD and QUAST add-ons, is the most complete and precise tool to analyze reflector antennas. Version updated until 31/01/2018.
- **SRSR-D**. Software to analyze symmetry of revolution structures like corrugated horns, lenses and reflectors. Up to date version.
- **Ansys HFSS suite**. (http://www.ansys.com) High Frequency Electromagnetic Field Simulation is the industry standard for simulating 3-D, full-wave, electromagnetic fields. Up to date version, now acquired and maintained by INAF ITC.
- **ESATAN TMS**. (www.esatan-tms.com) Thermal analysis software with thermalXL plugin. Up to date version.
- **National Instrument Labview.** (www.ni.com). Software to control lab instruments and data acquisition. Up to date version.

# Cryowaves projects

Cryowaves
è Bologna

- ALMA band 2(+3)
- LSPE / STRIP (G. Morgante talk)
- LiteBird (G. Morgante talk)
- Athena X-IFU filters
- Development of Calibrators

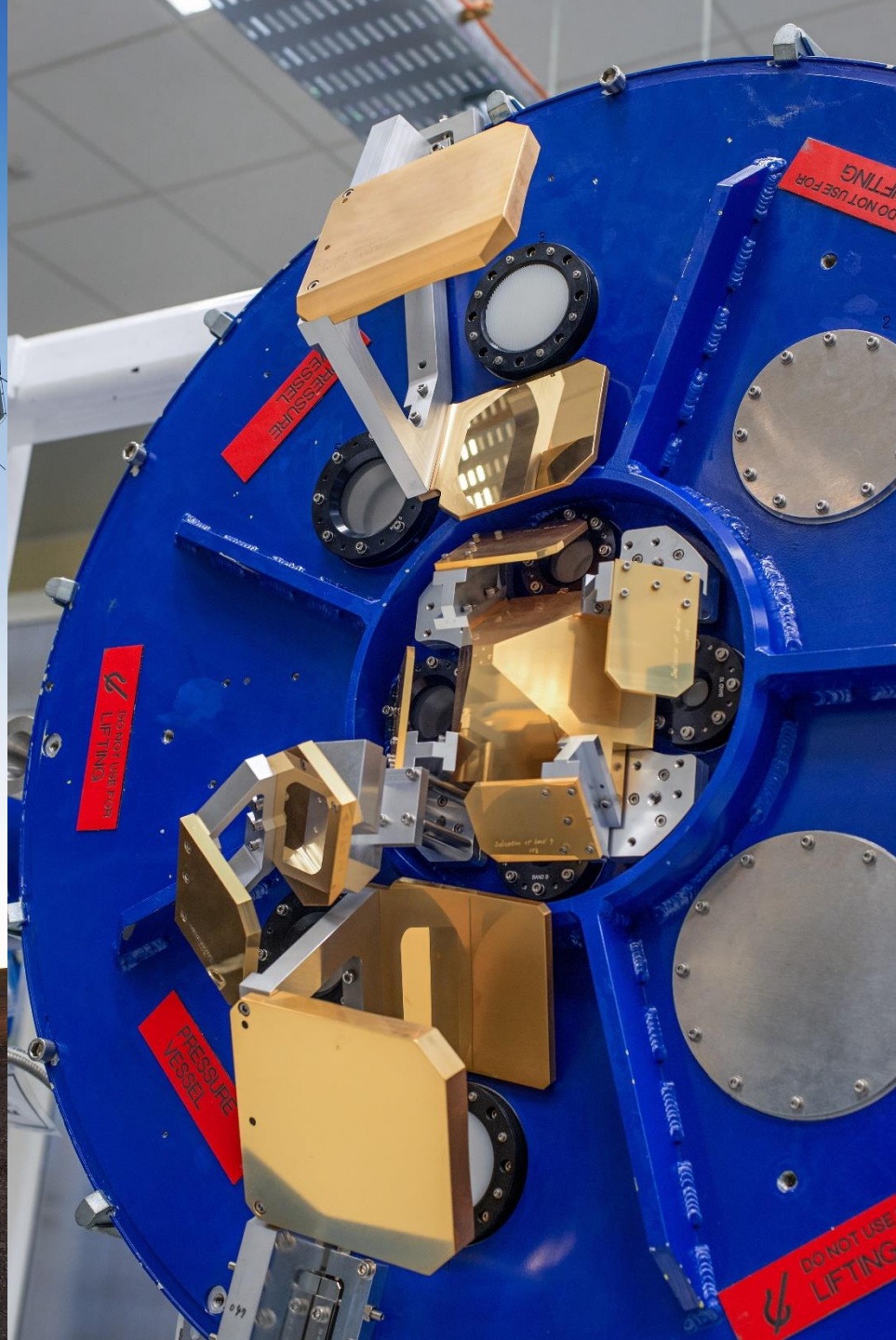


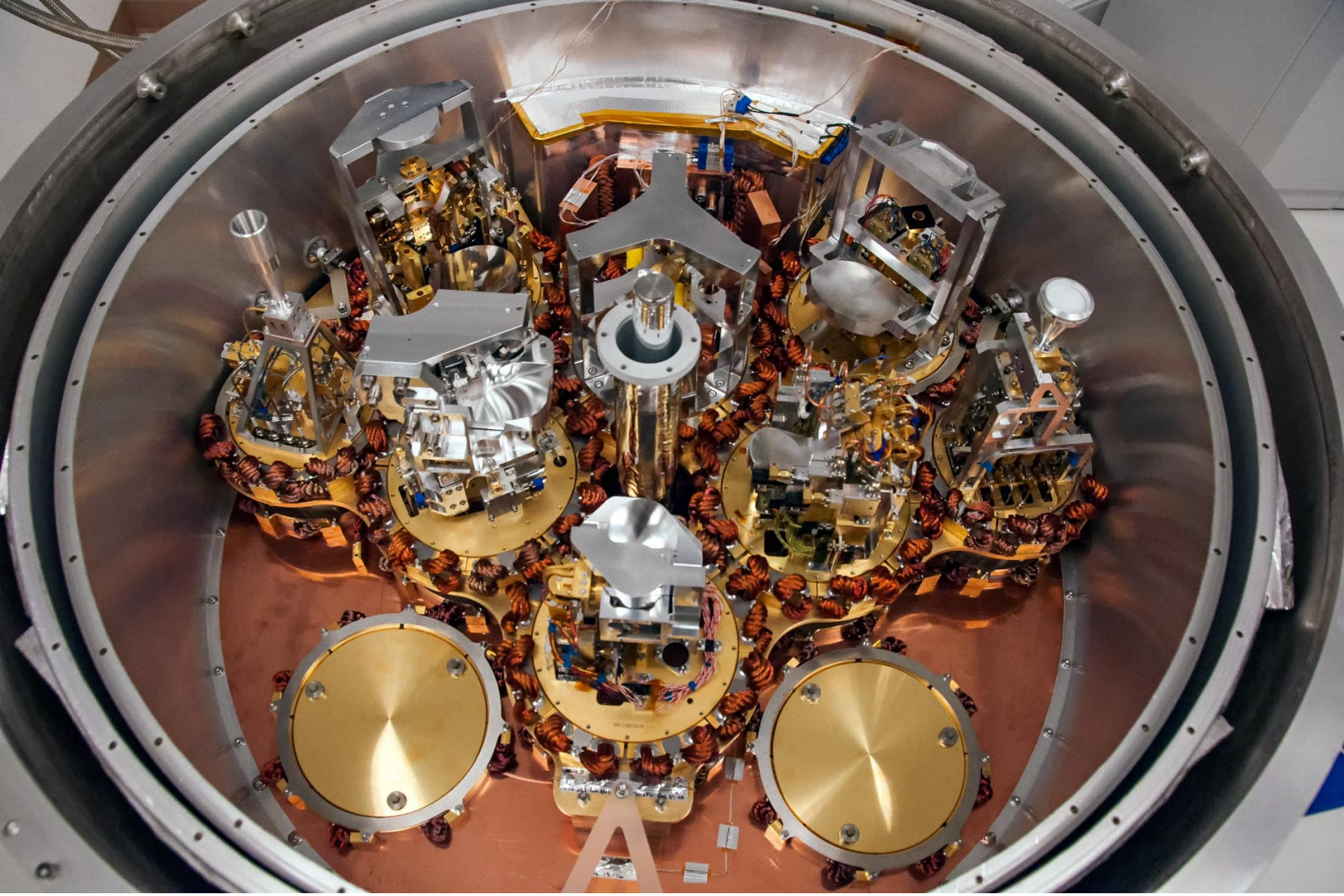
ALMA

IFU
ATHENA X-ray Integral Field Unit

LiteBIRD
Lite (Light) satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection


DV-05


PRESSURE VESSEL
DO NOT USE FOR LIFTING
PRESSURE VESSEL
DO NOT USE FOR LIFTING



**Frequency bands of receivers:** When it has all 10 bands incorporated, ALMA will measure signals from 8.6 mm to 0.32 mm. the following table shows the specifications of the bands astronomers will be able to use for their observations with ALMA (available from Cycle 5, in construction, and under development):

Cryowaves
**è Bologna**

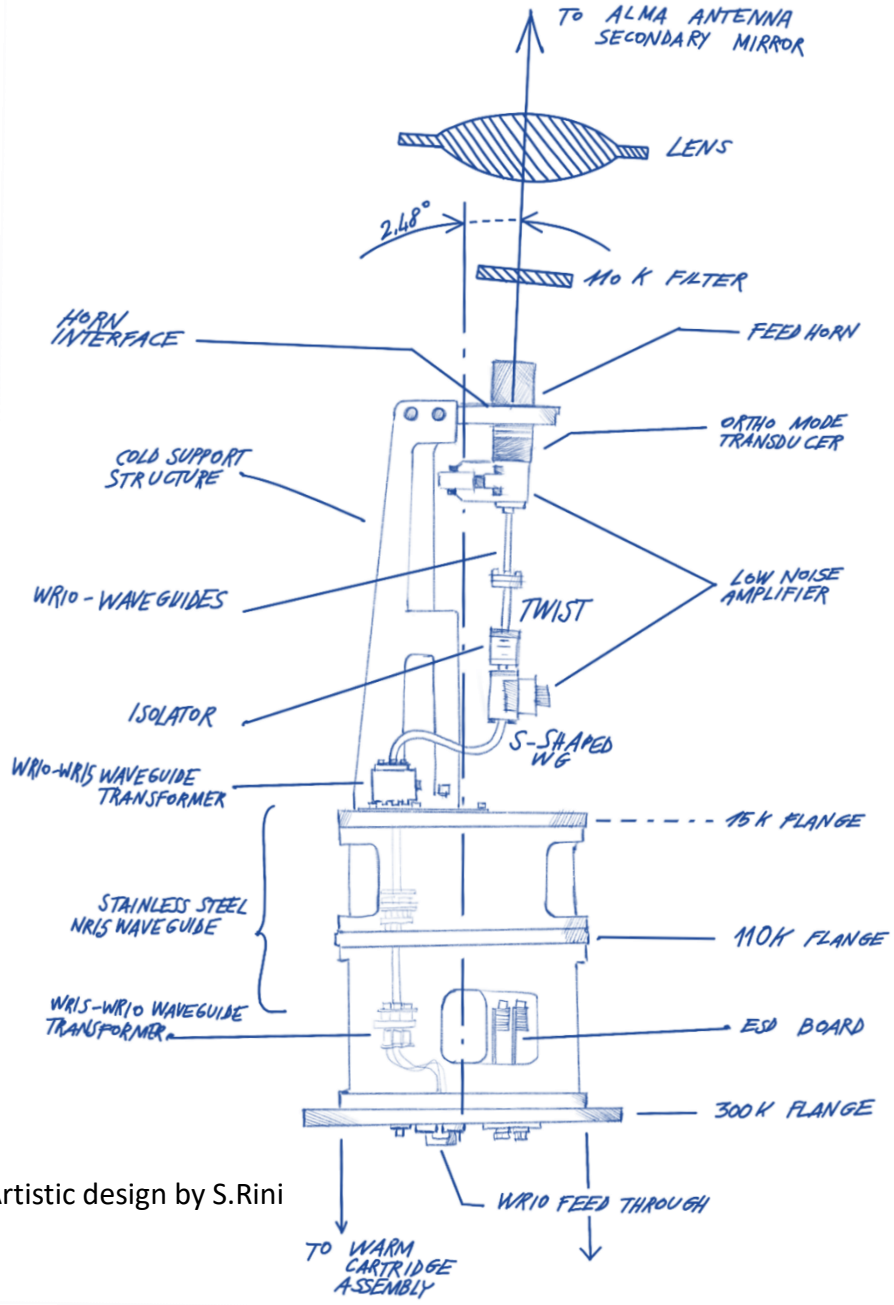
| Band | Wavelength (mm) | Frequency (GHz) |
|---|---|---|
| 1 | 8,6 – 6 | 35 – 50 |
| 2 | 4,6 – 3,3 | 65 – 90 |
| 3 | 3,6 – 2,6 | 84 – 116 |
| 4 | 2,4 – 1,8 | 125 – 163 |
| 5 | 1,8 – 1,4 | 163 – 211 |
| 6 | 1,4 – 1,1 | 211 – 275 |
| 7 | 1,1 – 0,8 | 275 – 373 |
| 8 | 0,8 – 0,6 | 385 – 500 |
| 9 | 0,5 – 0,4 | 602 – 720 |
| 10 | 0,4 – 0,3 | 787 – 950 |

During Cycle O and Cycle 1, the antennas were outfitted with four bands: Band 3, Band 6, Band 7, and Band 9. Two more were added in Cycle 2: Band 4 and Band 8. Band 10 was added in Cycle 3 and 4.

# ESO ALMA upgrades

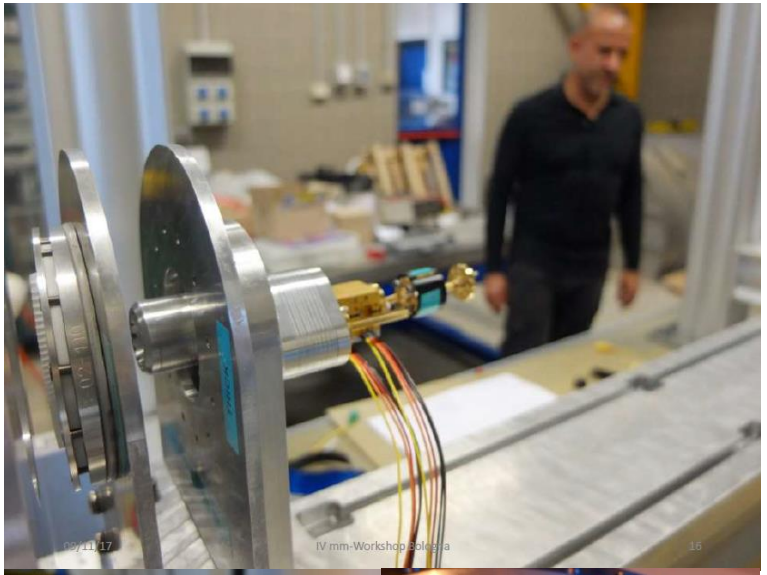
Cryowaves è Bologna

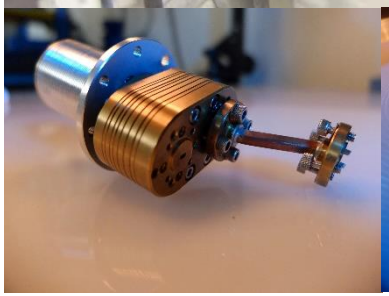
- **2012 collaboration setup to study the feasibility of the band 2 (67-90 GHz) and possibly the band 2+3 (67-116 GHz) for ALMA**
  - INAF (I), RAL (UK), U-MAN (UK), IRAM (F)
- **Output: band 2+3 optics could be feasible, green light to go ahead with further studies**
- **2015 ESO started to guide an international consortium to focus on the extreme large detector**
  - ESO, INAF, U-MAN and RAL, NAOJ, U-CHILE
  - Goal to demonstrate the technology to reach the optical requirements (efficiencies) for ALMA
- **Output: optical train (Lens+filters+FH+OMT) within ALMA requirement**

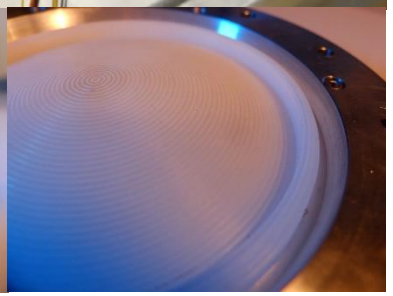



Artistic design by S.Rini

Cryowaves
**è Bologna**







# Full functional prototype

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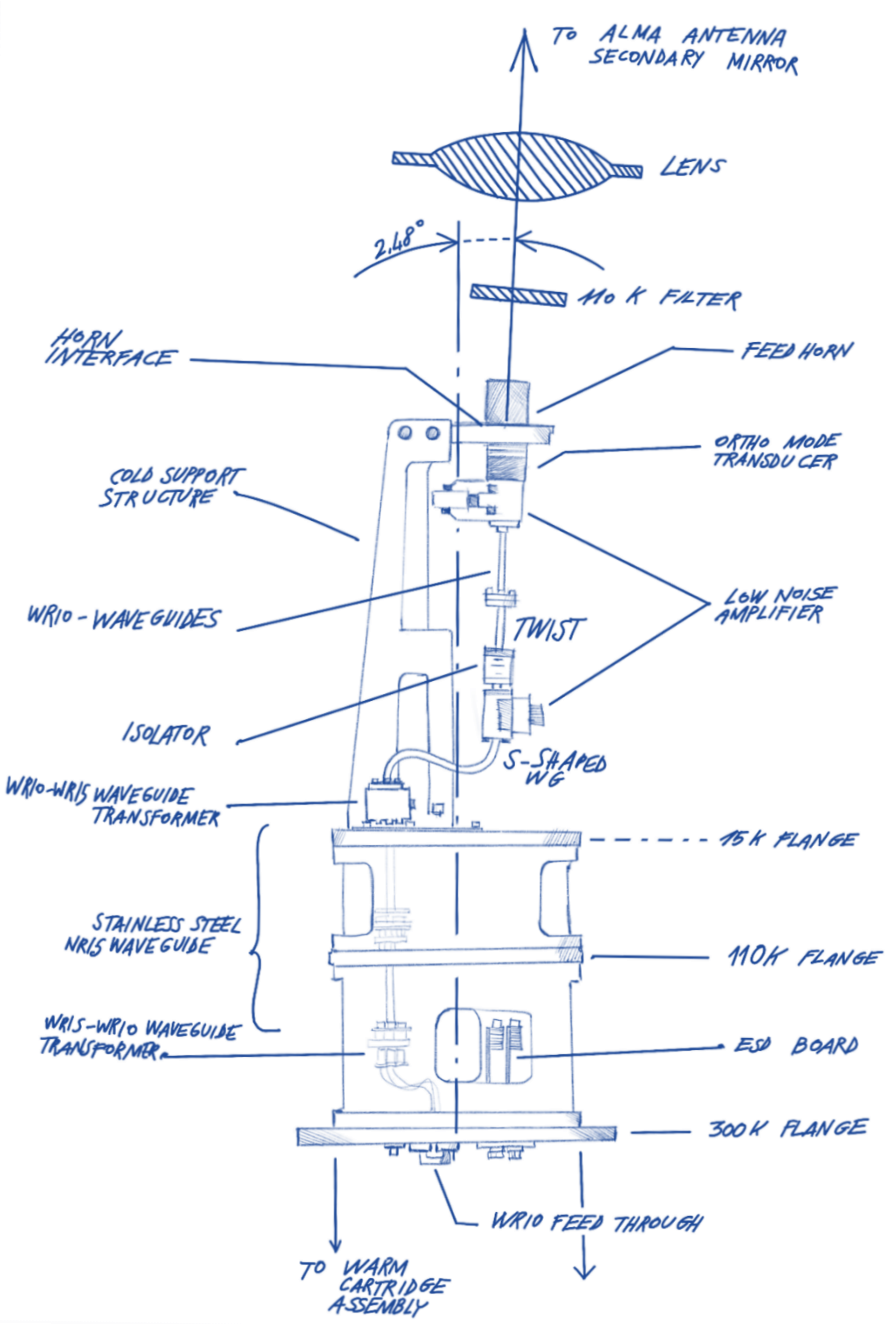
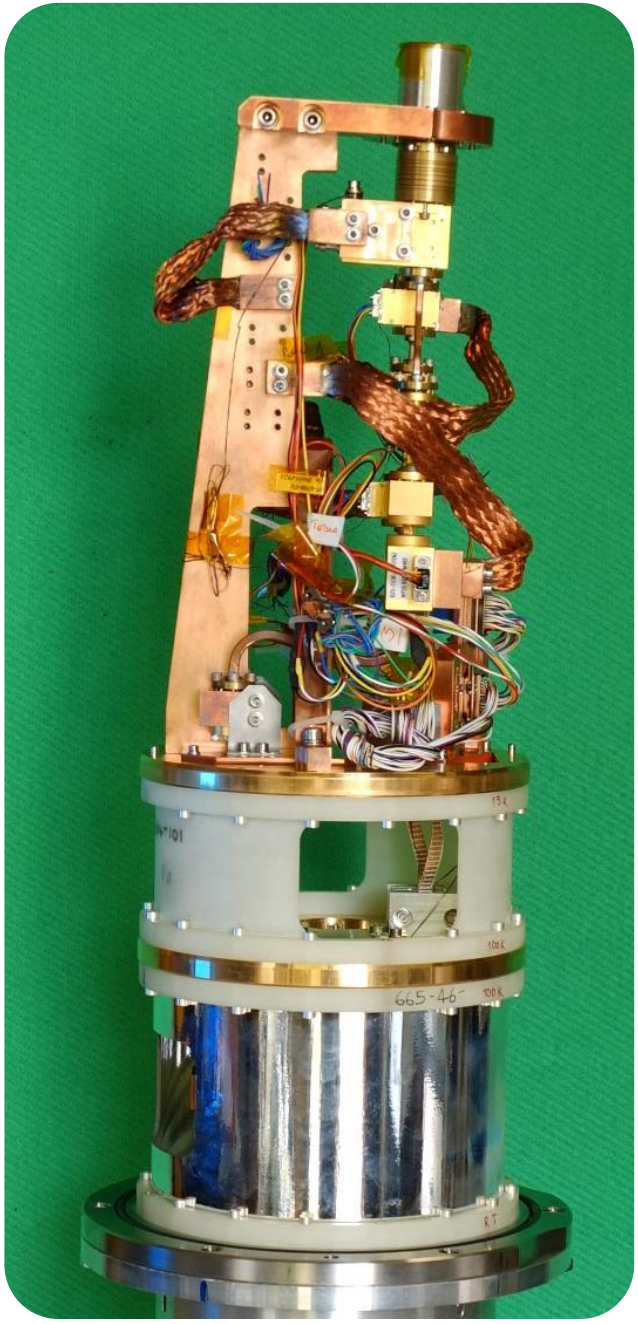
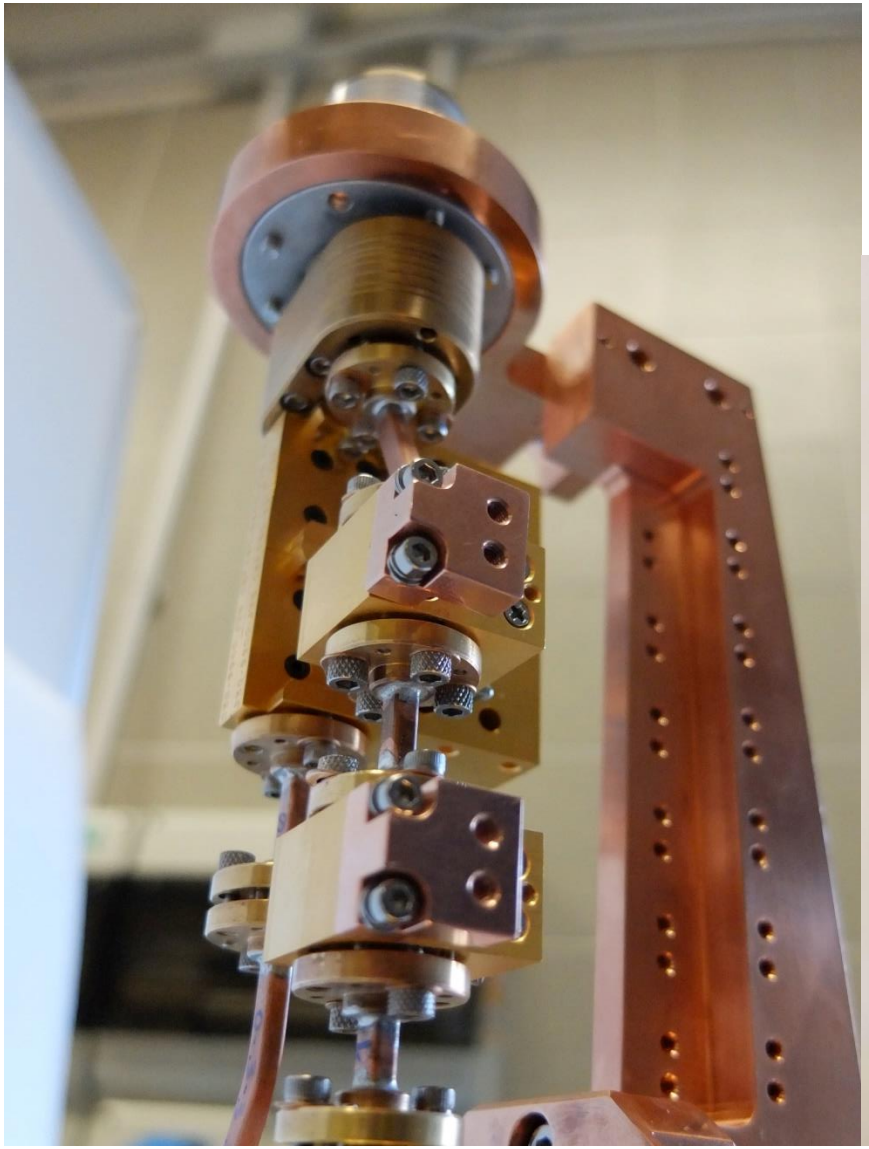
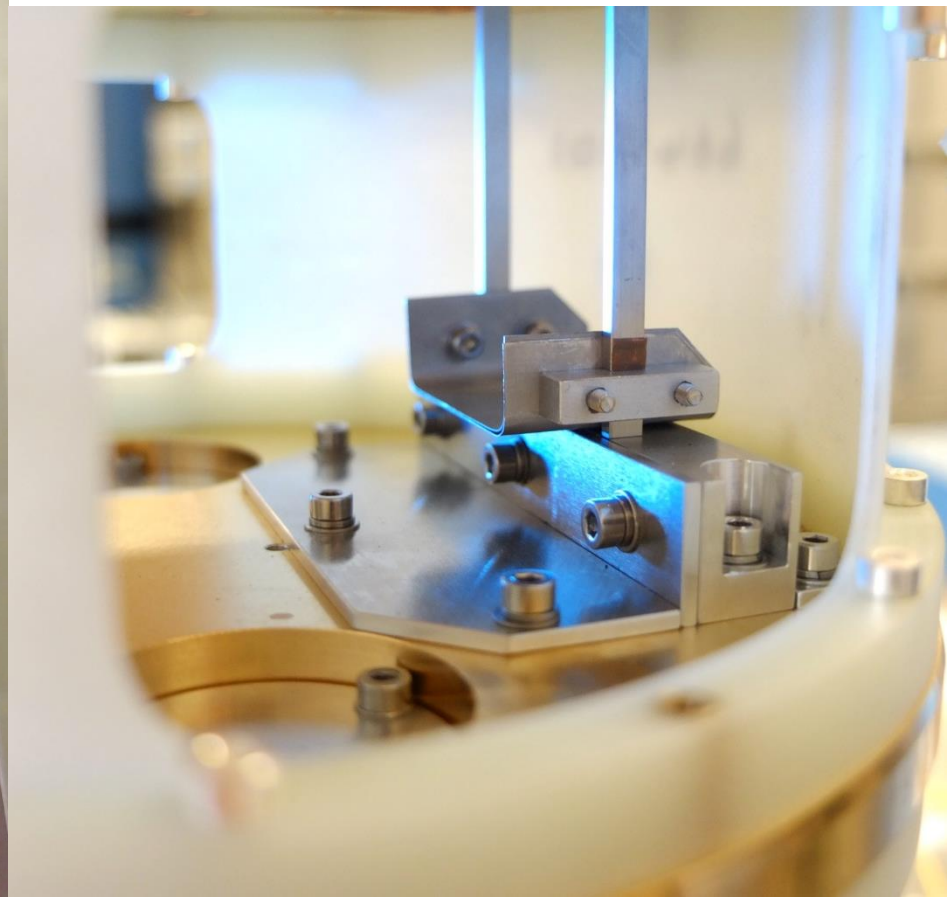
- Developed by the consortium
- Mechanical Design by GARD, Chalmers University using Band 5 spares (Sept 2016)
- Manufactured in 2 months  by the Workshop at Univ. of Milano, Physics dept. (Oct – Nov 2016)
- Assembled and tested at INAF cryowaves lab (Jan – May 2017)
- Presented by the consortium to the ALMA Preliminary Design Review, Nov. 2017


TO ALMA ANTENNA SECONDARY MIRROR
LENS
2.48°
110 K FILTER
HORN INTERFACE
FEED HORN
ORTHO MODE TRANSDUCER
COLD SUPPORT STRUCTURE
LOW NOISE AMPLIFIER
WR10 - WAVEGUIDES
TWIST
ISOLATOR
S-SHAPED WG
WR10-WR15 WAVEGUIDE TRANSFORMER
15 K FLANGE
STAINLESS STEEL WR15 WAVEGUIDE
110K FLANGE
WR15-WR10 WAVEGUIDE TRANSFORMER
ESD BOARD
300 K FLANGE
WR10 FEED THROUGH
TO WARM CARTRIDGE ASSEMBLY



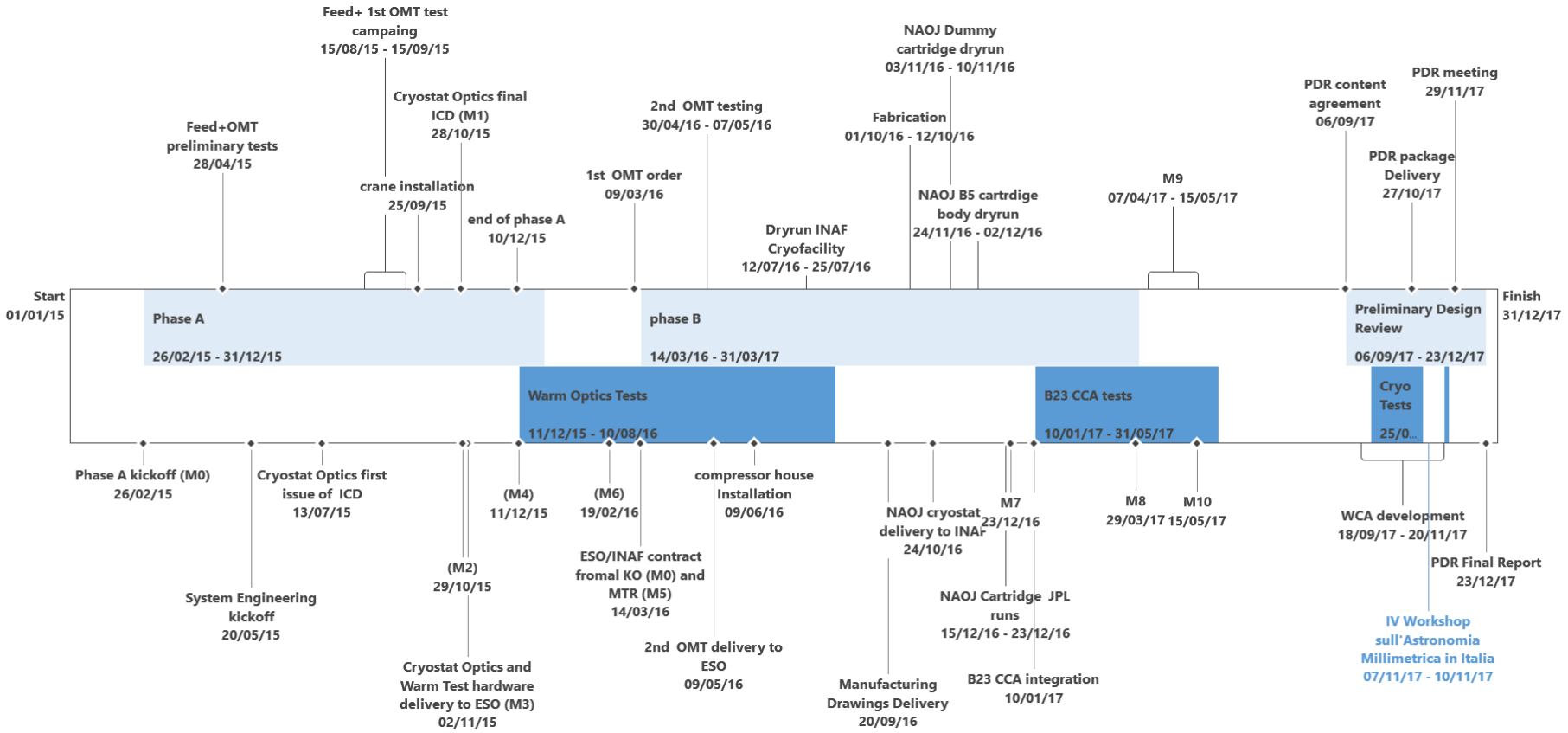




Cryowaves
**è Bologna**

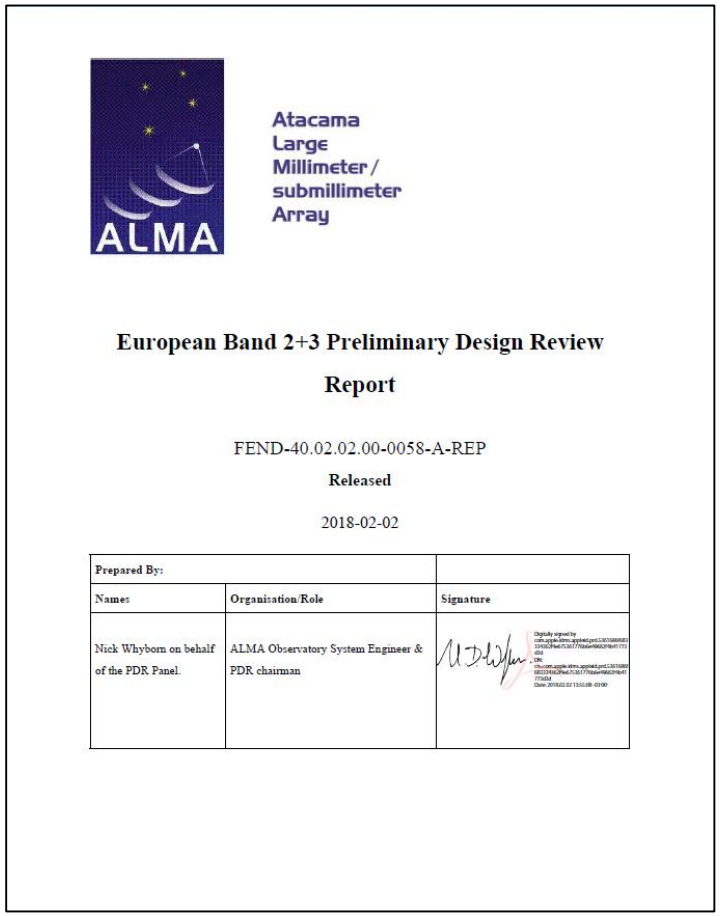
# early phases up to PDR

Cryowaves è Bologna



# PDR Report 2017

Cryowaves è Bologna



Atacama Large Millimeter / submillimeter Array

**European Band 2+3 Preliminary Design Review Report**

FEND-40.02.02.00-0058-A-REP

**Released**

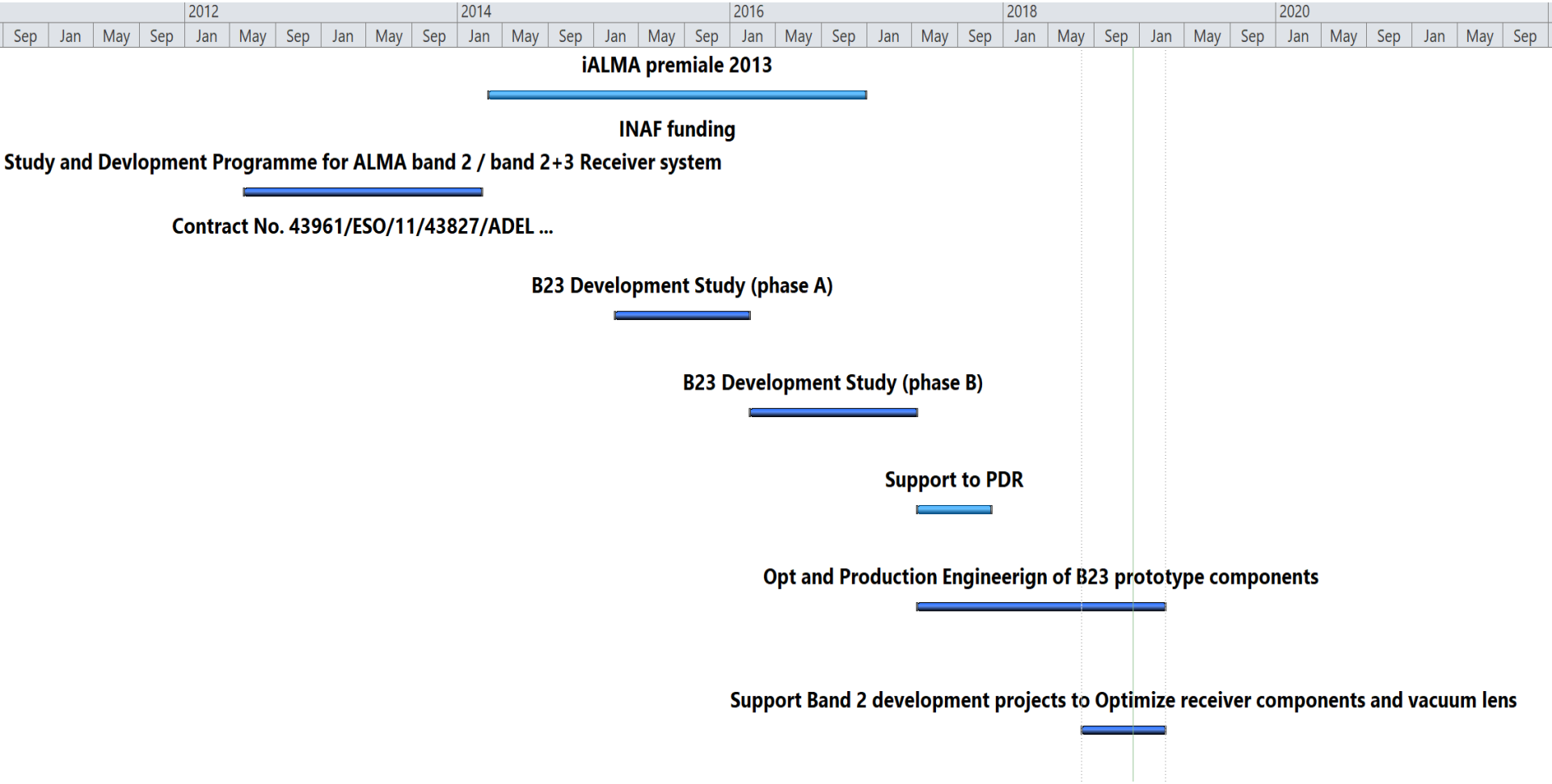
2018-02-02

| **Prepared By:** | | |
|---|---|---|
| **Names** | **Organisation/Role** | **Signature** |
| Nick Whyborn on behalf of the PDR Panel. | ALMA Observatory System Engineer & PDR chairman | |

> **The panel were impressed by the extensive work done** by the Band 2+3 team in preparation for this review **and the excellent results reported**. A high degree of cooperation and a good atmosphere among the team members from the different groups was evident during the meeting. The panel appreciate the thorough and complete documentation provided for review by the Band 2+3 team, the rapid responses given to the RIDs raised, and the open discussion of issues during the meeting.

# contracts & agreements

Cryowaves
è Bologna



**INAF/OAA-Arcetri**

FH and OMT design
and Manufacturing
RF tests and
Analysis
Science

**INAF/IAPS-Rome**

Cryo Control
Software
Optics Test bench

**INAF/IASF-Bologna**

System Design
SE + AIV
Cryogenics
WCA Development
Calibration
Project Control

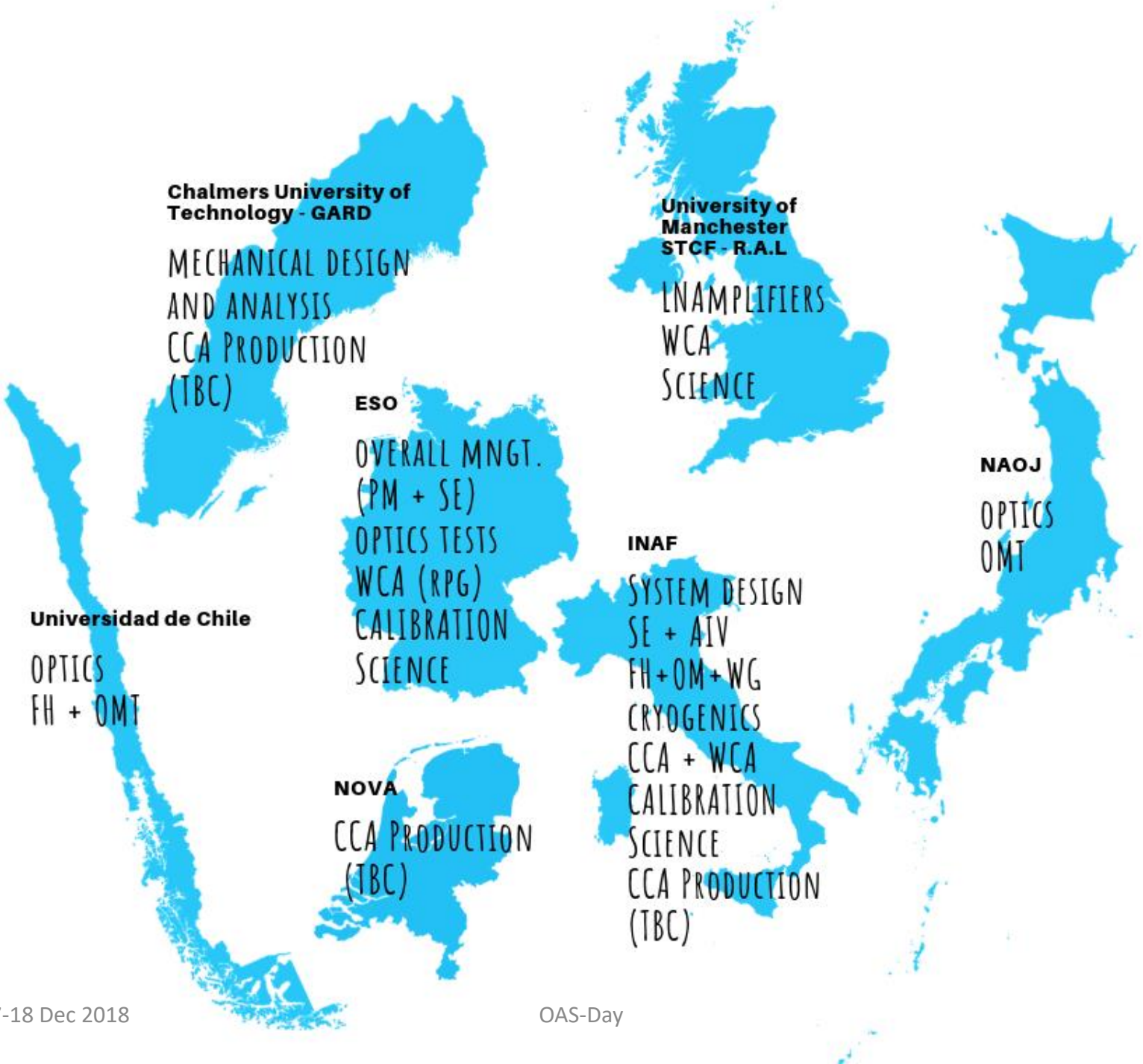
**INAF/IRA-Bologna**

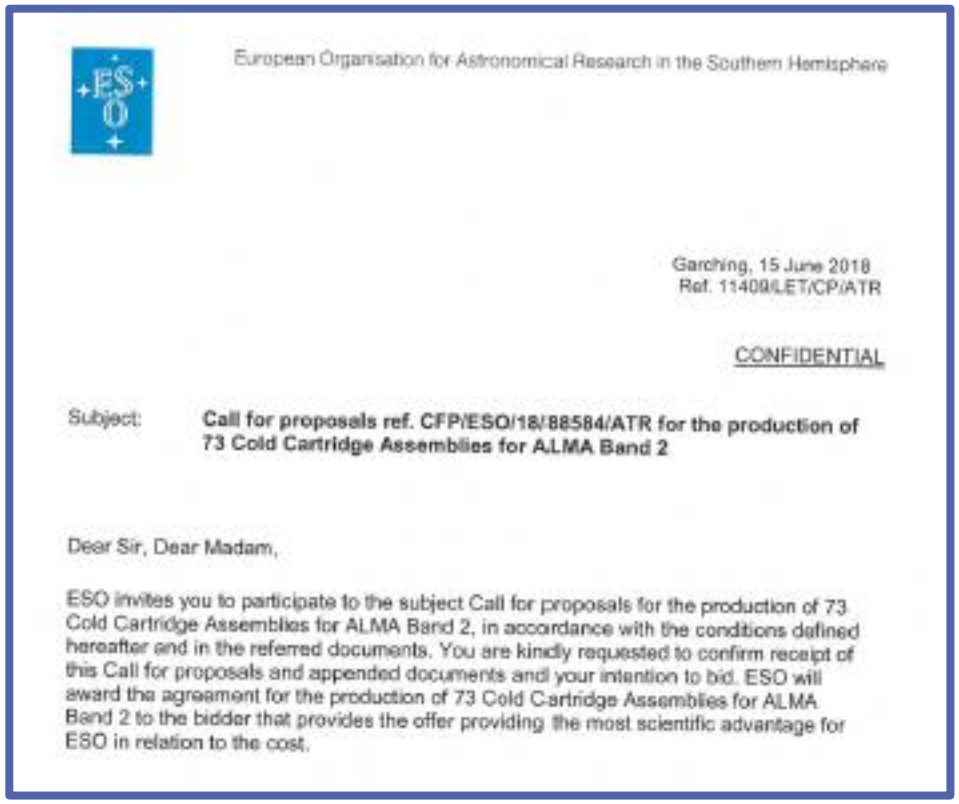
RF engineering and
Instrumentation

**MW-UNIMI**

CCA Manufacturing


Chalmers University of Technology - GARD
MECHANICAL DESIGN AND ANALYSIS
University of Manchester STCF - R.A.L
LNAMPLIFIERS
WCA
SCIENCE
ESO
OVERALL MNGT. (PM + SE)
OPTICS TESTS
WCA (RPG)
CALIBRATION
SCIENCE
INAF
SYSTEM DESIGN
SE + AIV
FH+OM+WG
CRYOGENICS
CCA + WCA
CALIBRATION
SCIENCE
NAOJ
OPTICS
OMT
Universidad de Chile
OPTICS
FH + OMT


Chalmers University of Technology - GARD
MECHANICAL DESIGN
AND ANALYSIS
CCA PRODUCTION
(TBC)
University of Manchester
STCF - R.A.L
LNAMPLIFIERS
WCA
SCIENCE
ESO
OVERALL MNGT.
(PM + SE)
OPTICS TESTS
WCA (RPG)
CALIBRATION
SCIENCE
NAOJ
OPTICS
OMT
INAF
SYSTEM DESIGN
SE + AIV
FH+OM+WG
CRYOGENICS
CCA + WCA
CALIBRATION
SCIENCE
CCA PRODUCTION
(TBC)
Universidad de Chile
OPTICS
FH + OMT
NOVA
CCA PRODUCTION
(TBC)



European Organisation for Astronomical Research in the Southern Hemisphere

Garching, 15 June 2018
Ref. 11409/LET/CP/ATR

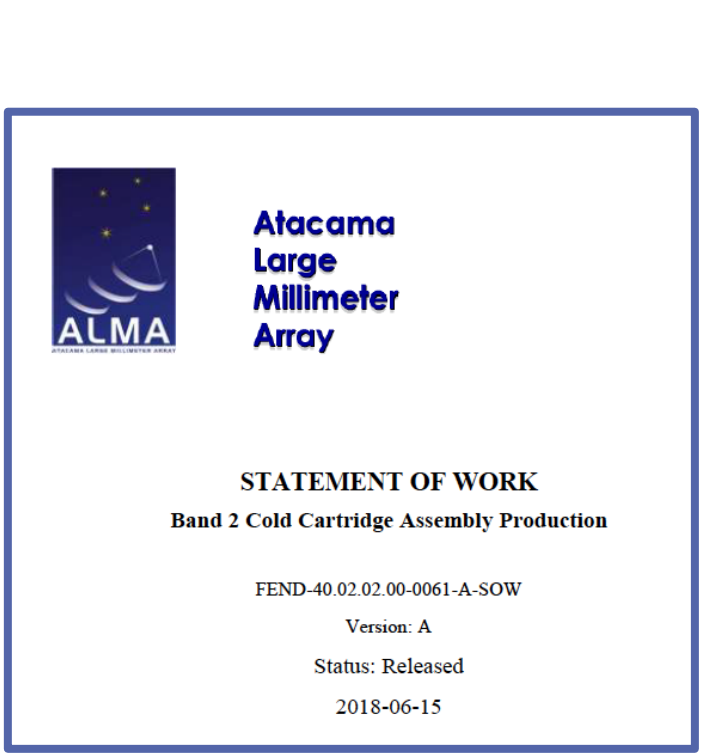
CONFIDENTIAL

Subject: **Call for proposals ref. CFP/ESO/18/88584/ATR for the production of 73 Cold Cartridge Assemblies for ALMA Band 2**

Dear Sir, Dear Madam,

ESO invites you to participate to the subject Call for proposals for the production of 73 Cold Cartridge Assemblies for ALMA Band 2, in accordance with the conditions defined hereafter and in the referred documents. You are kindly requested to confirm receipt of this Call for proposals and appended documents and your intention to bid. ESO will award the agreement for the production of 73 Cold Cartridge Assemblies for ALMA Band 2 to the bidder that provides the offer providing the most scientific advantage for ESO in relation to the cost.

Cryowaves
**è Bologna**



Atacama Large Millimeter Array

**STATEMENT OF WORK**

**Band 2 Cold Cartridge Assembly Production**

FEND-40.02.02.00-0061-A-SOW

Version: A

Status: Released

2018-06-15

# Consortium setup

NOVA (NL)
GARD Univ. of Chalmers (S)
INAF OAS and OAA (I)

Table 1 Band 2 CCA Delivery Schedule

| Milestones | Date |
|---|---|
| Kick-off (KO) | 2019-02-01 |
| Completion of Band 2 CCA unit #1 | 2020-02-01 |
| Band 2 CCA CDR – Delivery of review data package | 2020-04-01 |
| Band 2 CCA CDR – Meeting | 2020-06-01 |
| Band 2 CCA CDR – Completion | 2020-07-01 |
| Completion of Band 2 CCA unit #2-6 | 2021-03-01 |
| Band 2 CCA and WCA (combined) Gate Review | 2021-06-01 |
| Band 2 CCA MRR – Delivery of review data package | 2021-08-01 |
| Band 2 CCA MRR – Meeting | 2021-10-01 |
| Band 2 CCA MRR – Completion | 2021-11-01 |
| Band 2 CCA unit #7-10, Provisional Acceptance on-Site (PAS) | 2022-06-01 |
| Band 2 CCA unit #11-20, Provisional Acceptance on-Site (PAS) | 2022-08-01 |
| Band 2 CCA unit #21-30, Provisional Acceptance on-Site (PAS) | 2022-10-01 |
| Band 2 CCA unit #31-40, Provisional Acceptance on-Site (PAS) | 2022-12-01 |
| Band 2 CCA units #41 - 50, Provisional Acceptance on-Site (PAS) | 2023-02-01 |
| Band 2 CCA units #51-60, Provisional Acceptance on-Site (PAS) | 2023-04-01 |
| Band 2 CCA units #61-73, Provisional Acceptance on-Site (PAS) | 2023-06-01 |
| Band 2 CCA spare parts | 2023-06-01 |

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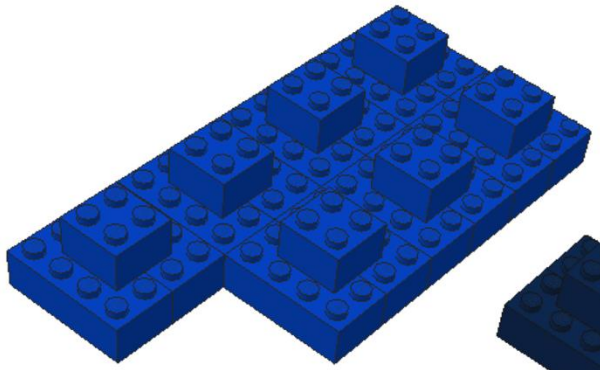
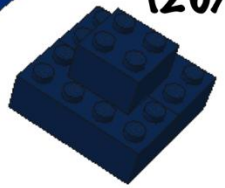
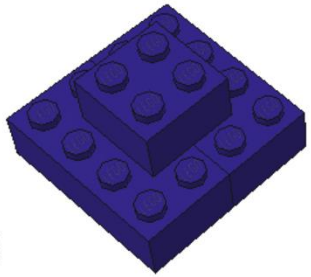
ESO band 2 / band 2+3
Feasibility Study
(7/6/12 - 7/3/14)

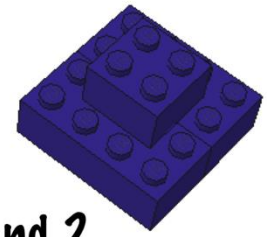
iALMA premiale INAF
25/3/14 -



ESO band 2+3
Prototype development
(26/2/2015 - 15/5/2017)







ESO band 2
optimization project
(31/7/2018 - )

ESO band 2+3
Passive components
Production Engineering
Study
(16/5/2017 - )



Band 2
73 receivers
CCA production
(under negotiation
2019 / 2023)

# Brochure INAF on iALMA

Cryowaves
è Bologna

## iALMA Scienza e tecnologia per ALMA

**Osservare l'universo oscuro per svelare l'origine del Cosmo e della Vita**

**Observing the Dark Universe to unveil the Origins of the Universe and Life**

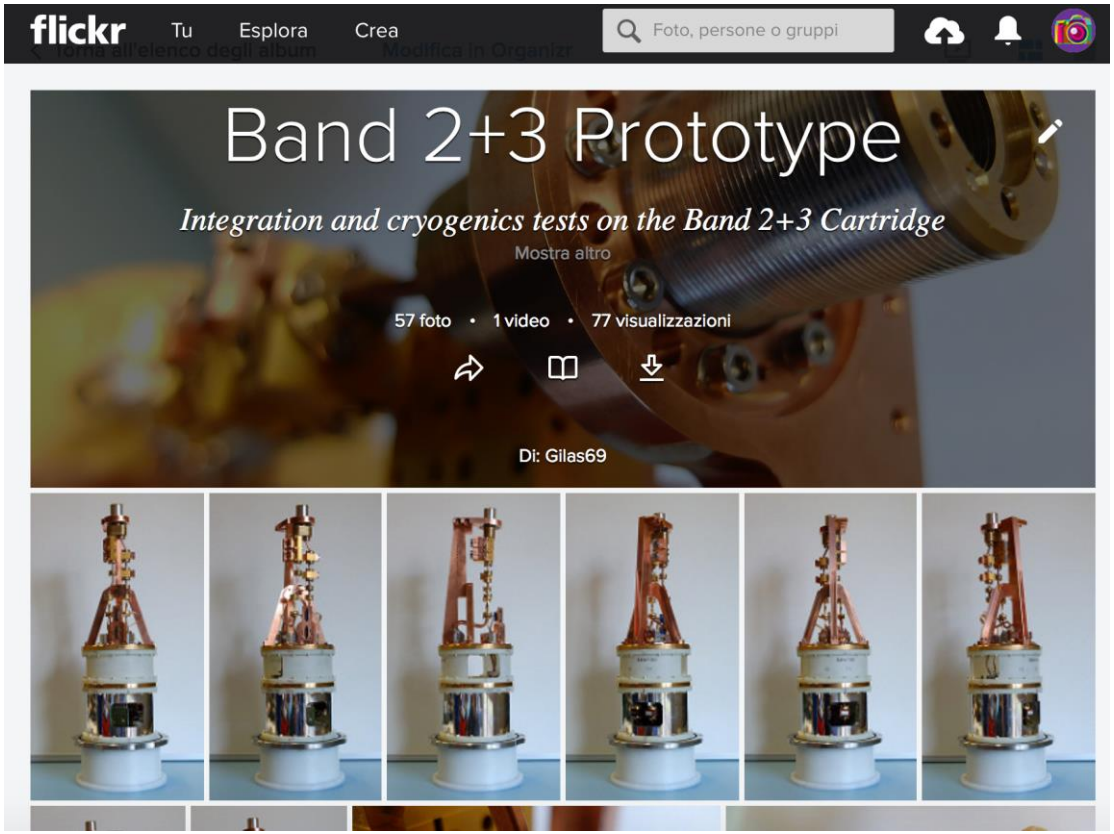
Funded by iALMA through MediaINAF

Out on Feb 2019

# ALMA Band 2 Photo album

Cryowaves
è Bologna

https://www.flickr.com/photos/gilas69/sets/72157677037620172



# Criticalities

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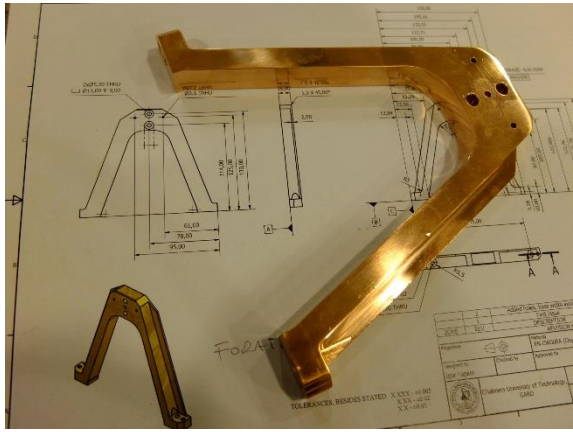
- **Access to the Mechanical Workshop and or find a quick way to fabricate mechanical pieces and prototypes**
  - Availability and access to basic tools and hardware
  - Technicians
- **Software maintenance**
- **Upgrade of Lab instrumentation**
  - Vector Network Analyzer up to 70 (116) GHz
- **Upgrade of laboratory environment**
  - Pressurize the laboratory
  - Clean the ducts for helium flex-lines
  - Controlled access to Laboratory for cleanliness
- **beginning of 2019 start to upgrade facilities and instrumentations to face the CDR of ALMA Band 2 (in case of funding for production)**



# ALMA B2 perspectives

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- Jan-Feb 2019 Continue the work on prototype demonstrator to consolidate the development of components and lens
- April 2019 ALMA board will decide the production (CCA+WCA)
- May 2019 (if approved) Kick of Meeting of Band2 CCA production up to 2023/2024
- Scientific interest in OAS for Band 2 observations

# Cryowaves perspectives

Cryowaves è Bologna

- Consolidate the laboratory facilities, expertise at international level
- ‘third parties’ activities  to fund lab running costs and to continuously upgrade the instrumentation
- Competences for industrial grade work
  - Mechanical engineer, electronic engineer
- Continue the partnership with high tech industries
- To have students working on experimental physics and engineering

# ATHENA X-IFU

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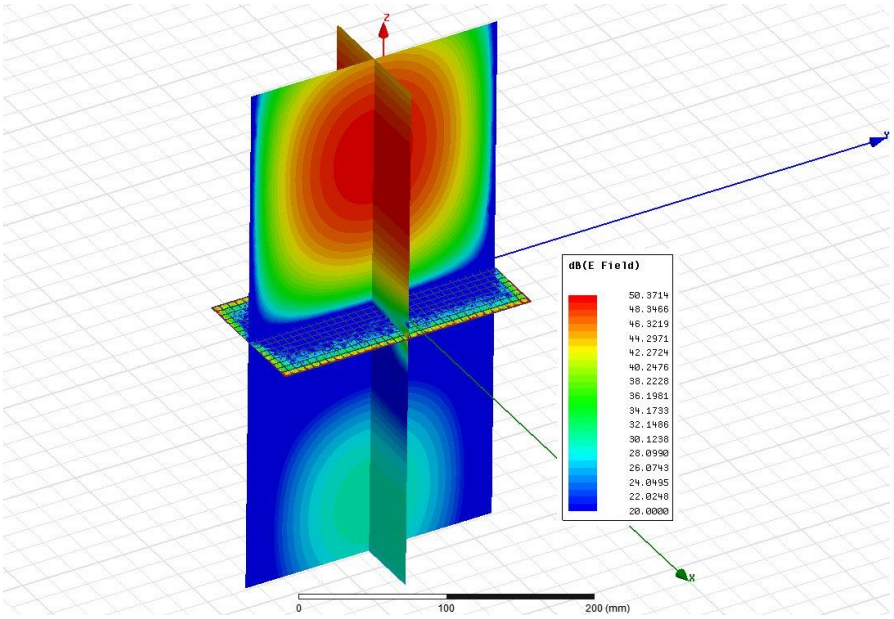
è Bologna




**to provide, with some of the X-IFU filters proper Radio Frequency shielding in the frequency range of the satellite telemetry. Measurement and modeling at cryowaves lab.**

**Athena X-IFU thermal filters development status towards the end of the instrument phase-A**

Marco Barbera[*a,b], Ugo Lo Cicero[b,a], Luisa Sciortino[a], Fabio D'Anca[c], Giuseppe Lo Cicero[a], Giancarlo Parodi[d], Salvatore Sciortino[b], Gregor Rauw[e], Graziella Branduardi-Raymont[f], Salvatore Varisco[b], Salvatore Ferruggia Bonura[a,b], Alfonso Collura[b], Roberto Candia[b], Gaspare Di Cicca[b], Paolo Giglio[g], Antonino Buttacavoli[a,b], Francesco Cuttaia[h], Fabrizio Villa[h], Massimo Cappi[i], Thien Lam-Trong[i], Jean Michel Mesnager[i], Philippe Peille[i], Roland Den Hartog[l], Jan-Willem Den Herder[l], Brian Jackson[l], Didier Barret[m], Luigi Piro[n]

# VERIFICATION VALIDATION & TESTING

Cryowaves
è Bologna

## *Verification Validation and Testing: Passion and Deployment challenges in the Italian Eco-System*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Tetra Pak Packaging Solution
Modena Italy

Luca Stringhetti
SKA HQ
SKA Organization
Macclesfield, Great Britain

# Tinkering with the Universe

Cryowaves
è Bologna

## Applicare il **Tinkering** alla didattica e divulgazione delle STEAM (Science Technology, Engineer, Art, Mathematics) in campo Astrofisico

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**they are playing seriously**

**they are focus**

**they get frustrated**

**they get excited**

**they feel they are in power**

**they get engaged**

**they feel they belong to STEM**

**super inclusive**
**(every kids feel they can play)**

# definition of thinkering

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**Ricciardi's definition**
**inspired by the tinkering studio**
**San Francisco Exploratorium**

**UNO SFORZO UMANO PROFONDO**
**BASATO SULL'ESPERIENZA DIRETTA**
**(LA CONOSCENZA È COSTRUITA MENTRE UN OGGETTO FISICO PRENDE FORMA)**

**NON UN CURRICULUM DEFINITO**
**50% GIOCO 50%RICERCA**
**NON È LINEARE ( MA) CUMULATIVO**

learning happen more efficiently if the learner is engaged in building some physical object.

# Collaborazioni in corso

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- IC12+IC3 bologna
- convenzione Istituzione bologna musei (Museo del Patrimonio Industriale)
- collaborazione UNIBO (Dipartimento di Psicologia)
- collaborazione Università' di Urbino (Dipartimento di Studi Umanistici)
- Cineteca di Bologna
- Associazione Hamelin
- Accademia di Belle Arti di Bologna

**Representing the Universe: a Hands on Challenge**
S.Varano, S.Ricciardi
Proc. of the Communicating Astronomy with the Public March 2018 in Fukuoka, Japan

Cryowaves è Bologna

**Tinkering with the Universe: a primary school project**
S.Ricciardi, F.Villa, S.Rini
Proc. of the Communicating Astronomy with the Public March 2018 in Fukuoka, Japan

**Officina degli Errori: a Tinkering Experience in an Informal Environment**
S.Ricciardi, F.Villa, S.Rini, M.Boni, S.Venturi, A.Bugini, M.Masini
Proceedings International conference New Perspective in Science Education, 2018 in Firenze

**Il tinkering va al umseo**
S.Ricciardi, F.Villa, S.Rini
per la rivista Scuola Officina set-dic 2018

**Tinkering, la coraggiosa arte di sbagliare incontra un museo civico**
S.Ricciardi, F.Villa, S.Rini
contributo al libro CCC - Citta' come cultura- Fondazione MAXXI Roma, in press

**Tinkering, ovvero la coraggiosa arte di sbagliare**
S.Ricciardi
Blog topipittori