Science and Technology in Italy

For the upgraded ALMA Observatory

- TECHNOLOGY DEVELOPMENT -

B23 Cartridge Prototype Final Report

Document code: iALMA-TEC-TRP-IAB-008

Version: B

Status: DRAFT

Date: 15/05/2017

Prepared by		
Name	**Organization**	**Date**
Sara Ricciardi Fabrizio Villa	INAF/IASF-Bologna INAF/IASF-Bologna	15/05/2017
Approved by		
Name	**Organization**	**Date**
Fabrizio Villa	INAF/IASF-Bologna	15/05/2017

1 Change Record

Version	Date	Affected sections	Reason
A	07/04/2017	All	Final review
B	15/05/2017	Chapter 5, first and third bullet	RID #2 RLA
B	15/05/2017	Section 8.1 added text and reference docs	RID #1 PYA
B	15/05/2017	Section 8 updated; Section 8.9, 8.10, 8.11 added.	RID #12 AGO
B	15/05/2017	Section 11 'efficiency requirements' changed to '"receiver optics aperture and polarization efficiency requirements'	RID #13 AGO
B	15/05/2017	Figure 2 (Product Tree) updated including lenses and filters units	RID # 12 AGO
B	15/05/2017	Figure 4 document tree updated (wrong document title in previous version)	For Final Review
B	15/05/2017	Changed correctly in bold the tiles of the documentation list	For final Review

2 Applicable and reference Documents

2.1 Applicable documents

[AD1] ESO/INAF Contract, Collaboration Agreement No. 64776/15/69626/HNE, 14/03/2016

[AD2] Statement of Work - Development Plan Study for ALMA Band 2+3 Prototype*Components, FEND-40.02.02.00-0023-B-SOW

[AD3] B23 Cartridge Prototype Receiver Cold Test Report, iALMA-TEC-TRP-IAB-007-A, 11/07/2017

[AD4] B23 Passive Component Final Report, iALMA-TEC-TRP-OAA-005-A, 07/04/2017

[AD5] B23 Cartridge Prototype Manufacturing and Integration Report, iALMA-TEC-TRP-IAB-010-A, 07/04/2017

[AD6] Cryogenic Test Readiness Report, iALMA-TEC-TRP-IAB-003-A, 07/04/2017

2.2 Reference documents

[RD1] iALMA Communication Management Plan, iALMA-TEC-PLA-IAB-001-A, 29/10/2015

[RD2] ALMA band 2+3 Optics Measurement Report, iALMA-TEC-TRP-ESO-001-A, 03/03/2016

[RD3] B2+3 Warm Test Baseplate Interface Control Document iALMA-TEC-ICD-IAB-001-H

[RD4] Description of Waveguides to be Produced, iALMA-TEC-TRP-IAB-005-A

[RD5] iALMA Passive Components B23 OMT Optimization, iALMA-TEC-TRP-OAA-003-B

[RD6] Report on the B23 bread-board Prototype Integration at ESO for Optical Warm Tests, iALMA-TEC-TRP-IAB-002-A, 20/01/2016

[RD7] ESO/NAOJ Cryofacility Dry Run Report iALMA-TEC-TRP-IAB-006-A

[RD8] NI-DC Voltage 2 LNA, iALMA-TEC-SPE-IAB-003-A

[RD9] ALMA Band 2+3 Optics Measurement Report, iALMA-TEC-TRP-ESO-001-A

[RD10] iALMA Cryofacility Dry Run Report, iALMA-TEC-TRP-IAB-004-A

[RD11] ALMA Band 2+3 Fore-Optics design Report, Issue 2.2, final review data pack.

[RD12] Preliminary Assessment of Reflective optics for ALMA bans 2+3, iALMA-TEC-DER-NAO-003-A, April 2016, written by NAOJ.

3 Table of content

4 Introduction and Scope

This is the final report document of the Study entitled 'DEVELOPMENT PLAN STUDY FOR ALMA BAND 2+3 PROTOTYPE COMPONENTS' for which the agreement No. 644776/15/69626/HNE was signed by ESO and INAF on 14 March 2016. This documents reports on the activity performed by INAF since the beginning of the Phase-A study started on 26 January 2015 with a meeting in ESO Garching, Germany, with the aim to setup the international collaboration (band 2+3 consortium), to agree on the content of the study and related timescale.

INAF is the Italian National Institute for Astrophysics (Istituto Nazionale di Astrofisica) composed by 19 research institutes. INAF participated to this study with the following institutions:

- **INAF/IASFbo:** Istituto di Astrofisica Spaziale e fisica cosmica (Bologna) for National management and responsibility, formal contact with ESO, project control, System engineering activity including thermal engineering, AIV.
- **INAF/OAA:** Osservatorio Astrofisico di Arcetri (Arcetri/Firenze) for design, developing and testing the Feedhorn and OMT (passive components) covering the 67-116 GHz range.
- **INAF/IAPS:** Istituto di Astrofisica e Planetologia Spaziali for manufacturing the cryostat optics for optical warm test at ESO.
- **INAF/IRA:** Istituto di Radio Astronomia (Bologna) for RF support instrumentation and electronics.

In addition, we setup collaboration with

- **UNIMI/MW:** Mechanical Workshop at Dipartimento di Fisica Università di Milano for the manufacturing of the pieces for the Band 2+3 CCA prototype
- **UNIMIB:** Dipartimento di Fisica università di Milano Bicocca for performing noise tests on INAF/JPL amplifiers at cryogenic temperature.

The international consortium as well as the master schedule is managed by ESO. INAF/IASFbo participated to the management with the system engineering activity, local management, and project control with 'lite' document configuration management.

The financial resources to carry out the work were supported by ESO within the contract above and by iALMA (progetto premiale INAF). In particular the iALMA financial resources were used to setup the dedicated laboratory (Cryowaves Lab), to support contracts for temporary staff, to anticipate the necessary budget when needed.

5 Activity Content Overview

In the framework of the ESO "Advanced Study for Upgrades of the Atacama Large Millimeter/Submillimeter Array (ALMA)" the scope of this project is the development of the components for the ALMA band 2+3 receiver cartridge.

The original content of the activity is reported in the Statement of Work [AD2] covering phase A and phase B of the Band 2+3 development study, whose goal is hereafter outlined:

i. Development of passive components (Feed horn and OMT) covering the ALMA band 2+3 (67 – 116 GHz);
ii. Development and integration of a receiver prototype for ALMA band 2+3 to characterize the optical properties and noise;
iii. Testing the receiver prototype with the aim to verify the optical performances; the tests are the following:
    a. Warm Tests (WT) whose goal to verify the optical performances of the receiver prototype.
    b. Cryogenic Test (CT) whose goals is to perform noise measurements of a breadboard Band 2+3 receiver at cryogenic temperature.

Due to the on-going activities of the international ESO-driven consortium and the bureaucratic constraints, the formal Kick-off of the project (at the contract signature by both parties ESO and INAF) was held together with the Mid Term Review.

At the Mid Term Review, we delivered our results regarding the Passive Components (i) and the activity report for setting up the Warm Tests performed at ESO (ii). We also provided an Interface Control Document [RD3] for CCA (Cold Cartridge Assembly) and we were ready to face the CCA breadboard development to be tested using the iALMA Cryofacility to evaluate the noise of the optics at cryogenic temperature.

To align the schedule of our project to the ALMA selection process and to speed up the overall Band 2+3 development, the band 2+3 consortium decided to abandon the breadboard development and to concentrate on the more ambitious goal do develop, within the 2016, a fully functional cartridge prototype. A new agreement was reached between ESO and INAF, updating the content of the activities and goals for point iii.b as follows:

- The manufacturing of the cartridge prototype was under the INAF responsibility providing also the budget required for the fabrication. The engineering design of the cartridge – based on [RD3] – was provided by ESO to INAF through the Chalmers / GARD group. The activity was limited to the manufacturing of the Cold Cartridge Assembly (CCA), being the Warm Cartridge Assembly under development by R.A.L.
- ESO provided the ALMA test cryostat to INAF/IASFbo in order to perform noise cryogenic tests in the ALMA standard configuration. As a

consequence, it was agreed by both parties to skip the upgrade of the iALMA Cryofacility to accept the CCA in order to speed up the setup of the ALMA test cryostat.

- INAF/IASFbo, with the support of ESO, performed the integration and tests of the cartridge prototype at cryogenic conditions with a bread-board downconverter provided either by ESO and INAF/IRA.

We did not make a formal change on the agreement since the change affected the technical content and activities rather than administrative content. In fact, we did not re-modulate the budget with ESO and the extra budget required to manufacture the cartridge was in charge to INAF through the National iALMA project and the phase-A funds.

6 Project management and System Engineering

The management of the B23 consortium is performed by ESO, which also led the international consortium. The activity of this study reported here was managed locally (i.e. in Italy) by INAF/IASFbo.

Although we were not bound by contract to use configuration management procedures, we decided to use a configuration management driven by the functionality and the usability. Within the iALMA project, we managed the internal (within INAF) and external (within the B23 consortium) communication through a light Configuration Management ensuring that:

- each document identifying the status of an item or an interface can be uniquely identified and related to the hardware and software;
- project documentation is received, checked, approved, recorded, and released in an orderly and consistent manner;
- a centralized archive is organized and maintained for all documentation relevant to the Project.

The details of the Configuration Management Plan are described in [RD1].

The organization chart is reported in Figure 1 together with the roles of the Institute involved in the study.

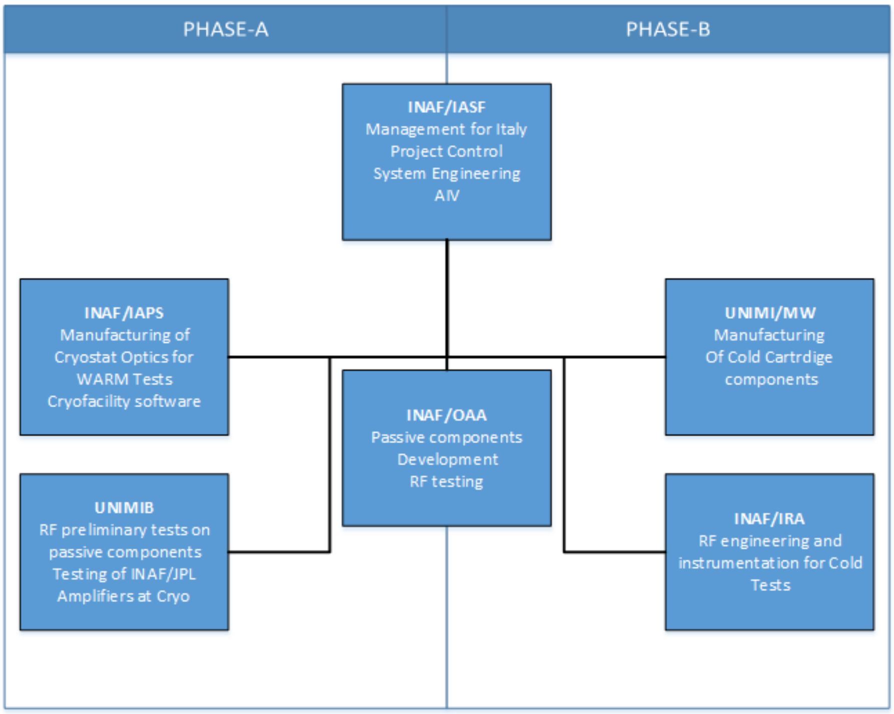


Figure 1. Organization chart for both the Phase-A and Phase-B.

To help the development during Phase-B we decided to implement a product tree (maintaining for simplicity the original part numbers of components when available) and to implement an internal 'Non Conformity Report' simplified procedure to tracks changes/non-conformities only when necessary.

As reported in Figure 2, the product tree referred to Band 2+3 Integration and test, is composed by the following products:

- The cartridge
- The ALMA Cryostat (ESO NAOJ cryostat)
- iALMA cryofacility

The 'cartridge' includes all the parts of the Cold Cartridge Assembly (CCA) and does not include the Warm Cartridge Assembly (WCA) since it is under development by R.A.L. for test purposes, instead of ALMA like WCA, we used two different bread-board down conversion unit. One of the bread-board was provided by ESO. The other one was provided by INAF/IRA (see the test report for details [AD3]). The ALMA Cryostat includes the NAOJ Cryostat as received from ESO on 24/10/2016 and all the modified flanges to adapt the cryostat to the B23 interfaces.

The 'iALMA Cryofacility' includes the large (2mx1mx1m) cryofacility to test the cartridge with a cryogenic load ranging from 4K to 300K (see paragraph 0).

During Phase-A the most important activity for System Engineering was the definition of the Interfaces. The main difficulty was the definition of the interfaces to build the Cryostat Optics for warm test according with the passive components already manufactured and the ALMA cryostat interfaces (i.e. filters and lens positions). This study was finalized in the Interface Control Document [RD3] that permitted to manufacture the Cryostat Optics.

For Phase-B, the tight schedule required to build the CCA imposed an accurate choice of the manufacturer.

To avoid to waste time finding an external provider, we decided to involve in the fabrication of all the required mechanical parts a well-known and reliable partner: the mechanical workshop of the Department of Physics of the University of Milano.

Nevertheless, all the required changes (new configuration of the cartridge to accept the LNF amplifiers, the modification of the ESO NAOJ cryostat filters and lens adapters according to the Band 2+3 ICD) required an extra effort in terms of technical resources and flexibility.

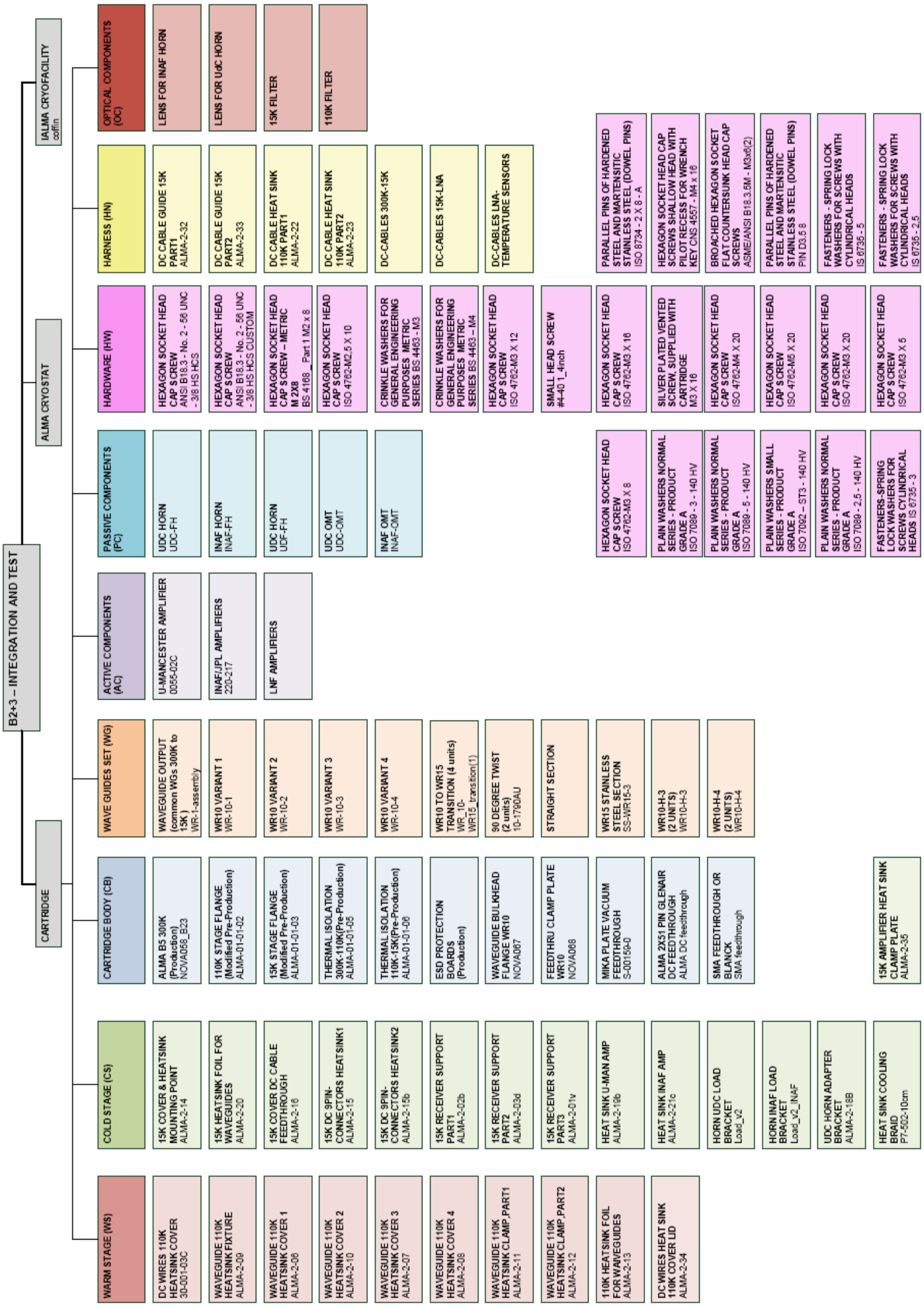


Figure 2. Detailed product tree

7 Timeline and Milestones

As described in the previous section, we redefined on the go the final goal of the phase B study. Therefore, we rescheduled the activities to push the integration of the cartridge at the end of 2016 with the goal to close the contract within spring 2017. The timescale of the study, both for Phase-A and Phase-B is reported in Figure 3 that includes the milestones and relevant activities for this INAF study.

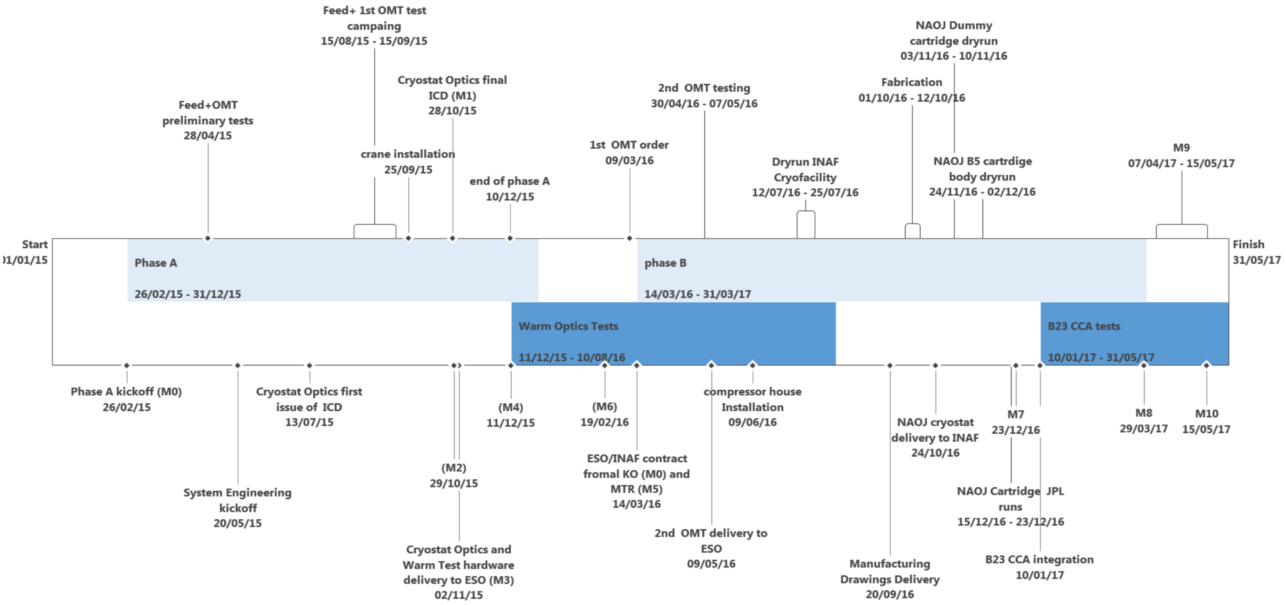


Figure 3. Timescale of the study starting from Phase A.

Regarding milestones, we highlighted the technical milestones as reported hereafter:

- Delivery of the Cryostat Optics ICD, occurred on 28/10/2015.
- Delivery of the Cryostat Optics to ESO for optics warm tests (including Feed Horn and first OMT), occurred on 02/11/2015.
- Delivery of the second OMT for optics warm tests occurred on 09/05/2016.
- Preliminary Cool down of the cartridge prototype on ESO NAOJ cryostat, ended on 23/12/2016.
- Integration of the cartridge prototype for cold tests occurred on 10/01/2017.

The following list and Table 1 reports the contractual milestones with the actual dates.

(M0) The Kick Off corresponds to the beginning of the B2+3 consortium overall activities.

(M1) the Phase-A CDR started with the System Engineering Kick Off meeting hold at INAF/IASFbo on 20/05/2015 and ended on 28/10/2015 with the finalization of the ICD.

(M2) the Hardware acceptance review corresponds with the pre-integration of the Cryostat Optics, passive components, filters and lens occurred on 28/10/2015 @ INAF/IASFbo.

(M3) The Hardware Delivery review of the Phase-A corresponds with the delivery of the Cryostat Optics to ESO occurred on 2/11/2015.

(M4) The Warm Test Readiness Review corresponds with the start of the warm test campaign occurred on 11/12/2015.

(M5) the MTR was formally held on 14/03/2016 together with the KO of this ESO / INAF agreement.

(M6) The warm test review board corresponds with the closure of the Phase-A held by teleconference on 19/02/2016.

(M7) Cryogenic Test Readiness Review occurred on 23/12/2016 after the successful testing of cryogenic Band 5 cartridge body cooled down inside the ESO NAOJ Cryostat mounted at Cryowaves Lab.

(M8) Cryogenic Test Review Board was held on 29/03/2017 with the check at warm temperature after the warmup of the cryostat. The cryogenic test campaign with the cartridge in the INAF/INAF configuration (variant 3), i.e. with the INAF horn and INAF OMT was considered completed.

Table 1. Formal Milestones with actual dates.

Contractual Milestones	**ID**	**Payment MS**	**Actual Date**
Kick off (KO)	M0	Yes	26/02/2015
Critical Design Review	M1	No	From: 20/05/2015 to: 28/10/2015
Hardware Acceptance	M2	No	29/10/2015
Hardware Delivery Review	M3	No	02/11/2015
Warm Test Readiness Review	M4	No	11/12/2015
Mid Term Review (MT)	M5	Yes	14/03/2016
Warm Test Review Board	M6	No	19/02/2016
Cryogenic Test Readiness Review	M7	No	23/12/2016
Cryogenic Test Review Board	M8	No	29/03/2017
Final Review	M9	No	From: 07/04/2017 To: 15/05/2017
Provisional Acceptance on Site (PAS)	M10	Yes	15/05/2017

8 Work package status and activity report

We report in the following paragraph (from section 8.1 to section 8.8) the main content of the work packages in relation with this contract. The numbering of the work packages follows the work breakdown structure as reported in [AD2]. For each work packages, we report the goal and the status with changes highlighted. In addition, for completeness, section 8.9, section 8.10, and section 8.11 report the main WP (not under responsibility of INAF) that were fundamental for the work done within this contract even though not formally in the SoW. For these WP INAF provided support in defining interfaces as part of the system engineering activity within the AIV WP (B23A.4.2).

8.1 Reflective Optics (B23-A.1.3)

Goal:

- Investigate warm and cold reflective optics design
- Compare with refractive optics design

Report: the activity was closed with the baseline for NAOJ and UdC to develop a refractive optics for band 2+3. Cold optics was considered an option until the demonstration that beam truncation was too high for a suitable design. The activity on cold optics, firstly started by INAF, was finalised by NAOJ. The Cold optics option was firstly proposed by INAF during the previous ESO ALMA upgrade study (Study and Development Programme for ALMA Band 2 and a Combined Band 2 and 3 Receiver System, Contract No. 43961/ESO/11/43827/ADEL). Six configurations were analysed based on 2 ellipsoidal mirror configuration. Calculations were performed using Gaussian beam propagation and full PO/PTD analysis. The field at the 15K, 110K and window stops was calculated at 67, 92.5, and 116 GHz showing that the most important disadvantage for the cold optics was the truncation of the field caused by the 15K and 110 K filter holes, being the 50 mm diameter too small. A 90mm holes in diameter was suggested to be appropriate for a possible implementation of a cold-optics scheme. Details of the study is reported in [RD11]. As already mentioned, further studies were performed by NAOJ. NAOJ demonstrated that for a cold optics option the gaussian beam propagated from secondary to the cryostat is greatly truncated by the cryostat, ruling out the possibility to implement a suitable cold optics design satisfying the ALMA optics specifications. Reflective warm optics design was then studied, as in the case of Band 3 and Band 4. In this case, the usual arrangement is to couple an ellipsoidal mirror with a flat mirror placed after the Cassegrain focus. NAOJ demonstrated that the added noise due to the losses of the warm reflective optics (two mirrors) and the cryostat window is 3.18 K @ 67 GHz, comparable with the calculated noise of the standalone lens for the baseline configuration. In the study, feed specifications to minimize truncations were derived resulting, under Gaussian propagation, a waist of 5.7mm and the horn as long as possible;

then, a first tentative optics design was addressed. Whit these specifications it carried out that a warm optics is not physically possible being the ellipsoidal mirror to be placed too close the cryostat top flange. Again, as in the case of cold optics, the only way to have a feasibility design, maintaining the truncation at acceptable levels, is to change the filter / window hole's diameters and position in the ALMA cryostat. NAOJ investigated also a mixed mirror configuration with (cold + warm) using 3 or 4 mirrors. The conclusion was that, in the first attempt, the design is feasible but the drawback is a big warm mirror (larger that the current band 3 warm mirror) and a complication of the optical layout. Based on all these reasons, the consortium decided not to dedicate additional effort on mirror optics and concentrate the activity on the development of the cartridge with lenses. In addition, it should be mentioned that ESO decided to investigate the use of Silicon lenses to reduce noise added by conventional lenses.

Status: completed

8.2 OMT (B23A.1.4)

Goal:

- Development and testing of an OMT covering the band 2+3 integrated with the Feed horn (FH).
- RF full characterization of OMT and FH over the band 2+3 at warm temperature.
- Estimation of the performances at operating temperature

Report: two models of the OMT were developed at INAF/OAA covering the entire 67-116 GHz range. The first model (OMT_v1) was built in aluminium and delivered to ESO for optical warm tests on November 2015. The second model (OMT_v2) was optimized in the design and was built in brass. It was delivered to ESO on May 2016. It was then integrated in the Cartridge for cryogenic tests. The Optimized OMT showed a return loss better than -17 dB over the entire 67-116 GHz band (see [RD5] for details) and better than -20 dB over almost the entire 50% band. The insertion loss of the OMT_v2 was improved, being the estimated added noise at cryogenic temperature of about 2 Kelvin.

Stauts: Completed

8.3 Design (B23A.4.1)

Goal:

- Contribution to the overall System Engineering activity
- CCA interface definition and maintenance
- Definition of external interfaces of CCA components

Report: A System Engineering (SE) group was setup and the system engineering KO meeting was held at INAF/IASFbo on May 2015. During the phase-A, the main activity of INAF was to develop and maintain the Interface Control Document to assure the correct development of the Cryostat Optics for warm tests. During Phase-B, we dedicated the SE activity to check the manufacturing drawings provided by Chalmers/GARD in relation with the interfaces.

Status: completed

8.4 AIV (B23A.4.2)

Goal:

- Contribution to the overall AIV activity. This includes specifically the sub packages B23A.4.2.1, B23A.4.2.2, B23A.4.2.3, B23A.4.2.4

The content of this work package changed because of the choice to develop the cartridge prototype for cold tests instead of a breadboard. The report of this activity is described in the following paragraphs, specifically the paragraphs 8.5, 8.6, 8.7, and 8.8

8.5 Test Setup (B23A.4.2.1)

Goal:

- Contribution to the design and build the test systems for WT (optical verification).
- Development of a cryostat's optics baseplate to support lens, filters, FH, OMT and supports for LNA for WT and CT.
- Design and implement test facilities for CT (cryogenic noise measurements) of a breadboard band 2/3 receiver. Test setup shall include infrared filters and a lens, at their designed physical temperatures, and may use calibration loads inside the cryogenic test facility.

Report: The design and manufacturing of the test system for warm temperature optical tests was performed by INAF with support of ESO, based on the ICD. The system was delivered to ESO and integrated on December 2015.

The baseplate for cryogenic tests, originally planned using the iALMA cryofacility (see paragraph □), was not developed since the goal changed towards the development of the entire cartridge prototype. The change in the activity resulted in the installation of the ESO NAOJ cryostat (including the vacuum system) in the INAF/IASFbo Cryowaves Laboratory and connection of the ESO cryocooler to the INAF/IASFbo compressors unit. The results of the activity was a set of cryogenic dry runs as reported in [AD6] and [RD7].

Status: completed

8.6 Auxiliary components (B23A.4.2.2)

Goal:

- Procurement of auxiliary components for receiver integration

Report: we identify as auxiliary components all the components that constitutes the cartridge apart from Feedhorn, OMT, and Low noise Amplifiers. The detailed list of components is reported in the BOM provided by Chalmers/GARD and updated according with the use of the LNF amplifiers in the cartridge (see [AD5]).

The cartridge body (including two WR10 waveguide feedthrough and cryo-harness) was provided by ESO, while all others mechanical pieces were manufactured by UNIMI/MW under the responsibility of INAF/IASFbo.

The waveguide (except the WR15 Stainless steel WG) and WR10-WR15 transitions were provided by Pasquali Microwave System (PMS). Originally planned to be manufactured by electroformation, the waveguides were manufactured by bending standard WR10 copper waveguides provided by INAF/IASFbo. Since the design of the waveguides was changed to accommodate the LNF amplifiers with manufacturing already started, this was a major risk for the schedule of the project. Details of the rational of the modified waveguide designs are reported in [RD4].

Since the WCA is still under development at R.A.L., two bread-board down conversion units were available as auxiliary components. One provided by ESO (also used during optical warm tests) and one provide by INAF/IRA.

Status: completed; at the time of the writing of this report, a set of waveguides made by electroformation is under finalization by PMS. The set will be measured @ INAF/OAA and possibly implemented into the cartridge in case the RF performances are better than the former set of waveguides.

8.7 System Assembly (B23.A.4.2.3)

Goal:

- Integration of the prototype for WT
- Integration of the prototype for CT.

Report: During phase-A, INAF successfully integrated the breadboard for Warm tests at ESO on Dec.2015 as described in [RD6]. A pair of low noise amplifiers, namely INAF/JPL were delivered together with the bias unit and commanding software [RD8]. The feed horn and two models of OMT were also delivered for optical tests. On December 2016, during the phase-B, INAF with ESO integrated @ INAF/IASFbo the Cold Cartridge Prototype Assembly at INAF on Dec 2016 [AD5].

Status: completed

8.8 System Tests (B23A.4.2.4)

Goal:

- Contribution to the WT optical performance tests @ ESO (check of the alignment and warm setup).
- Conduction and Execution of CT, noise measurements of a breadboard band 2/3 receiver at cryogenic temperature at INAF facilities and test reporting

Report: INAF supported the WT Optical tests at ESO at the beginning of the activity. The alignment was checked during the pre-integration of the Cryostat Optics @ INAF/IASFbo found a problem during the integration of the 110K filter. The filter holder was too thin to permit the integration of the correct integration of the filter. For cold tests the modified filter holder was designed by INAF/IASFbo and manufactured by ESO.

INAF and ESO conducted and executed the first campaign related to cryogenic test on the cartridge prototype with the variant 3 Configuration, i.e. with the INAF Feedhorn and INAF OMT_v2. The cartridge prototype was cooled using the ALMA test cryostat delivered by ESO [AD3].

Status: The activity is considered completed since the cold test of the variant 3 configuration of the B23 cartridge were performed. There are still test planned in the next future with other cartridge configurations: variant 1 (UdC feedhorn + UdC OMT) and possibly variant 2 and 4 (mixed INAF / UdC configurations) for which INAF will continue to provide resources and facilities.

8.9 Window and Filters (B23A.1.1)

Goal:

- to provide cryostat vacuum window (no optical power), 15K and 110K infrared filters.

Prototype lens (WP B23A1.2) will serve as vacuum window if could be designed to match ALMA optics with the existing horn designs.

Report: This WP was under the responsibility of ESO that provided the 15K and 110K filters based on IRAM design. Because of the capability to design and produce lenses covering the 67-116 GHz range, the window was not required (see WP B23A.1.2).

Status: completed

8.10 Refractive Optics (B23A.1.2)

goal:

- to provide HDPE lens (and horn). Lens to be designed to match different existing horn design(s) with ALMA optics

Report: This WP was under the responsibility of UdC that successfully manufactured the HPDE lenses based on NAOJ optical design. Two units were fabricated, one to be coupled with INAF horn and the other to be coupled with UdC horn.

Stauts: completed

8.11 MMIC (B23A.2.1)

goal:

- to design and fabricate MMIC for the first and second stage LNAs

Report: this WP was under responsibility of Uman that provided 2 LNAs units covering the 67-116 GHz frequency range.

Status: completed

9 Document tree

To provide a comprehensive view of the project and to document the overall results achieved we are presenting for this final review the following documents:

- iALMA-TEC-TRP-IAB-008-A **B23 Cartridge Prototype Final Report** (this document) as an overview of the management of the project, a wrap up of other documents, final conclusion and criticalities;
- iALMA-TEC-TRP-OAA-005-A **B23 Passive Components Final Report** as an overview of the development of Passive Component developed by INAF with final results;
- iAlMA-TEC-TRP-IAB-010-A **B23 Cartridge Prototype Manufacturing and Integration Report** as an overview of the activity of manufacturing and integration done with ESO at INAF/IASFbo for the B23 cartridge prototype;
- iALMA-TEC-TRP-IAB-003-A. **Cryogenic Test Readiness Report** as a description of the activity performed to setup the cryogenic facility for cartridge prototype testing at INAF/IASFbo;
- iALMA-TEC-TRP-IAB-007-A. **B23 Cartridge prototype receiver Cold Test Report** includes test procedures and test results on the B23 Cartridge receiver (i.e. CCA + breadboard down converter) in cold environment.

Additional documentation, although not part of the delivery for the final review, is available for reference and completeness. The detailed document tree is reported in

Figure 4.

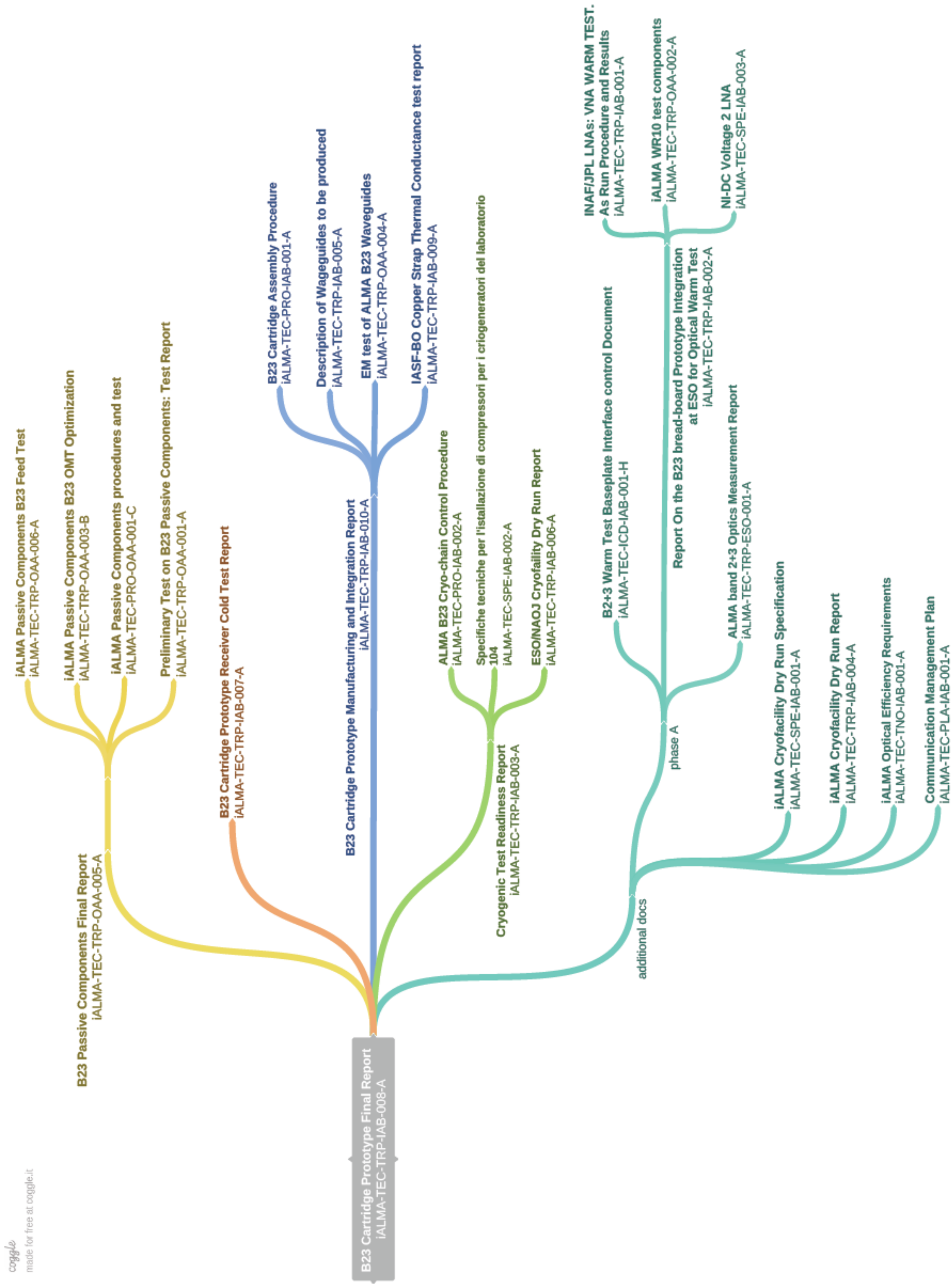
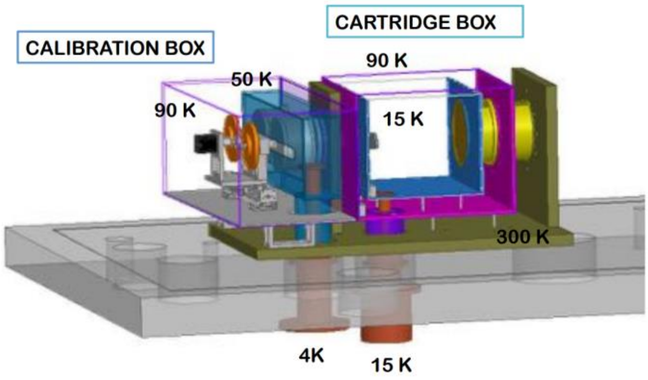


Figure 4. Document tree

10 Status of the iALMA cryofacility

Cryogenic tests were originally planned to be performed on the iALMA cryofacility. The cryofacility, whose dry test run is reported in [RD10], is installed at Cryowave Laboratory and equipped with a 4K Sumitomo SRDK-415D cold-head and a 20K Leybold RGD 5/100 cold-head. With these two coolers, it will be possible to cool down the cartridge to nominal temperature and to use the 4K cooler to refrigerate a calibrator in front of the lens.



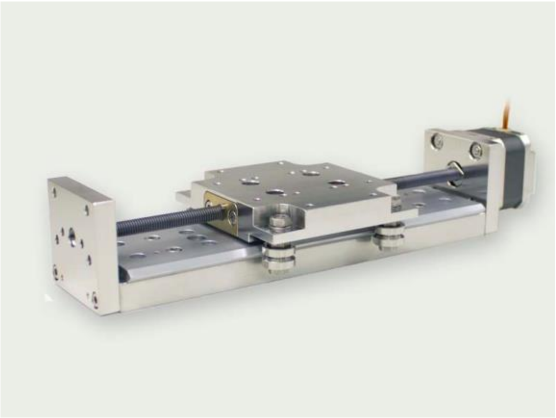


Figure 5. Left: sketch of the cartridge measurement concept inside the iALMA cryofacility. Right: cryogenic translator stage for the automatic movement of the cryogenic calibrator in front of the lens.

Two cylindrical polarized loads mounted on the Arun microelectronics Ltd TVL-150 cryogenic Translation Stage with 5µm Resolution compose the calibrator. This setup would permit to alternate in front of the B23 lens two calibrators at different temperature permitting to calibrate the cartridge in the 4K-300K temperature range, even in polarization since the loads can be rotated around the axis. The advantage of this setup is to calibrate the cartridge in a temperature range impossible with the ALMA standard cryostat. The goal is to fully explore non-idealities (even small) of the cartridge. Moreover, this setup permits, through a dedicated thermal control, a fine measurement of the susceptibilities of the various components of the cartridge.

Although as already mentioned, the upgrade of the iALMA cryofacility was not finalized during this study, the status is in a good shape since:

- Drivers, translation stage, cryogenics motors have been acquired and available.
- We acquired from R.A.L the two (110K and 15K) ALMA thermal links to mount the B23 cartridge with ALMA thermal interface.
- The cryofacility works as expected and temperature reached during dry run tests are those expected from the coolers specs.
- The calibrators are under development (RF design finalized).
- Design of the cartridge support to be finalised on the basis of the as built B23 cartridge prototype

- Interfaces with the WCA are under study. Since WCA cannot be located under vacuum, the solution is to carry out the RF signal from the CCA by using an appropriate WR10 routing interfacing a vacuum flange on the bottom of the cryofacility.

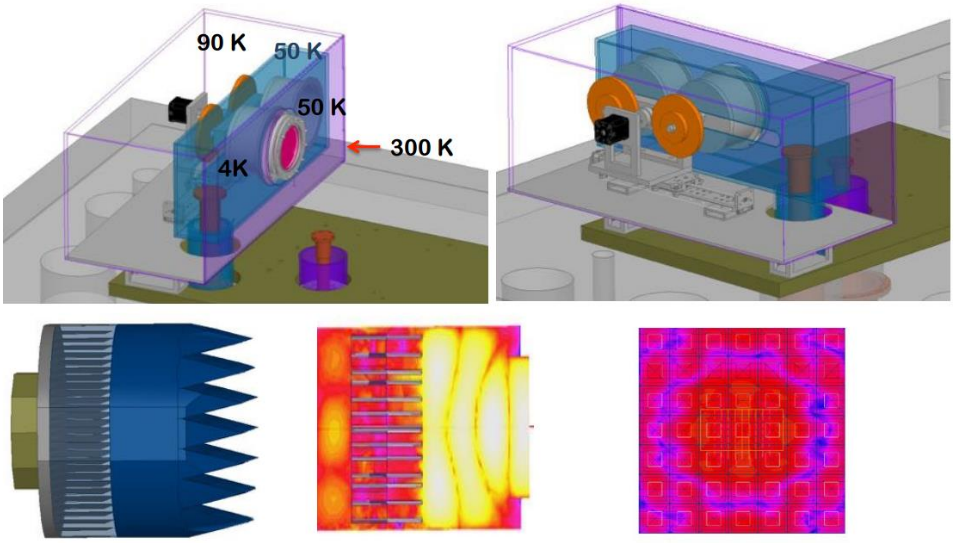


Figure 6. Detailed view of the calibrator for iALMA cryofacility composed by to polarized loads at two different temperature (ranging from 4K to 300K) that alternatively will pass in front of the lens.

The intention is to continue the work with the goal to arrive to have the system ready after the baseline tests of the other variants of the cartridge configuration.

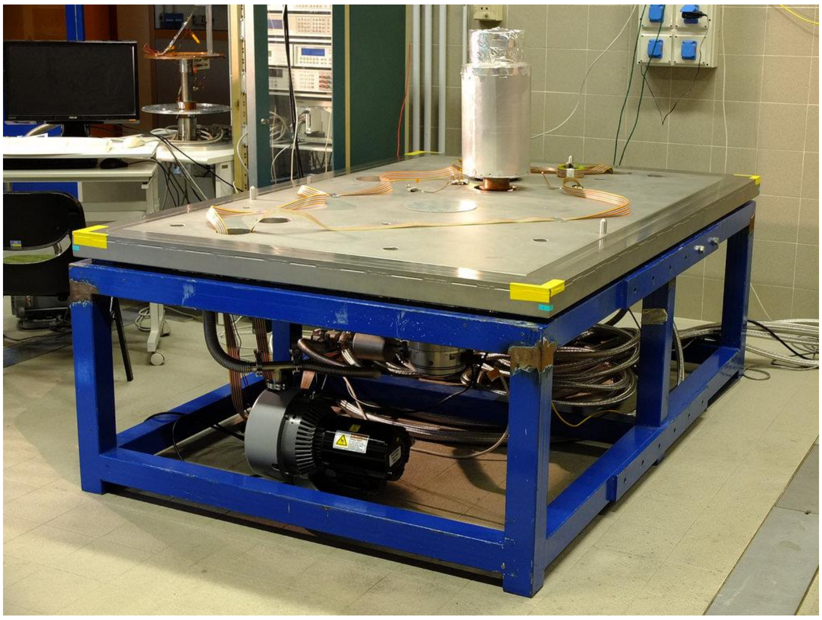


Figure 7. iALMA cryofacility.

11 Conclusions

The development of the Band 2+3 (67-116 GHz) cartridge involves the participation of an international consortium guided by ESO. Partner of the consortium are INAF (Italy), STFC/RAL and UMAN (UK), Udc (Chile), NAOJ (Japan) and Chalmers (Sweden).

The current study 'DEVELOPMENT PLAN STUDY FOR ALMA BAND 2+3 PROTOTYPE COMPONENTS' represents the experimental demonstration of the feasibility of the band 2+3 cartridge for ALMA. The Phase-A study demonstrated that the ~~Efficiency requirements~~ receiver optics aperture and polarization efficiency requirements for ALMA are satisfied over the whole bandwidth. The Phase-B study permitted to build in a very short time a fully functional CCA prototype tested at cryogenic temperature. The main output of this study is to own the capabilities in our consortium to face the thigh ALMA cartridge requirements by further optimizing the components and methods.

Next future activities based on the flexibility to mount different passive components and amplifiers, will permit to explore and further understand the behaviour and performance of the CCA to reach the adequate maturity to tackle the next steps.