Space Power Workshop 2019

Torrance Marriott Redondo Beach, CA

JUICE – Photo Voltaic Assembly (PVA) Development Results

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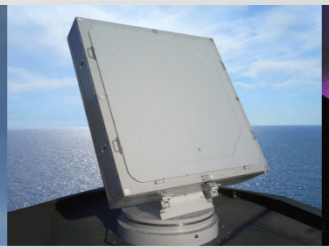
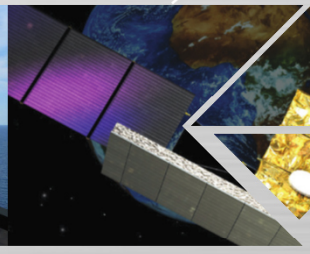

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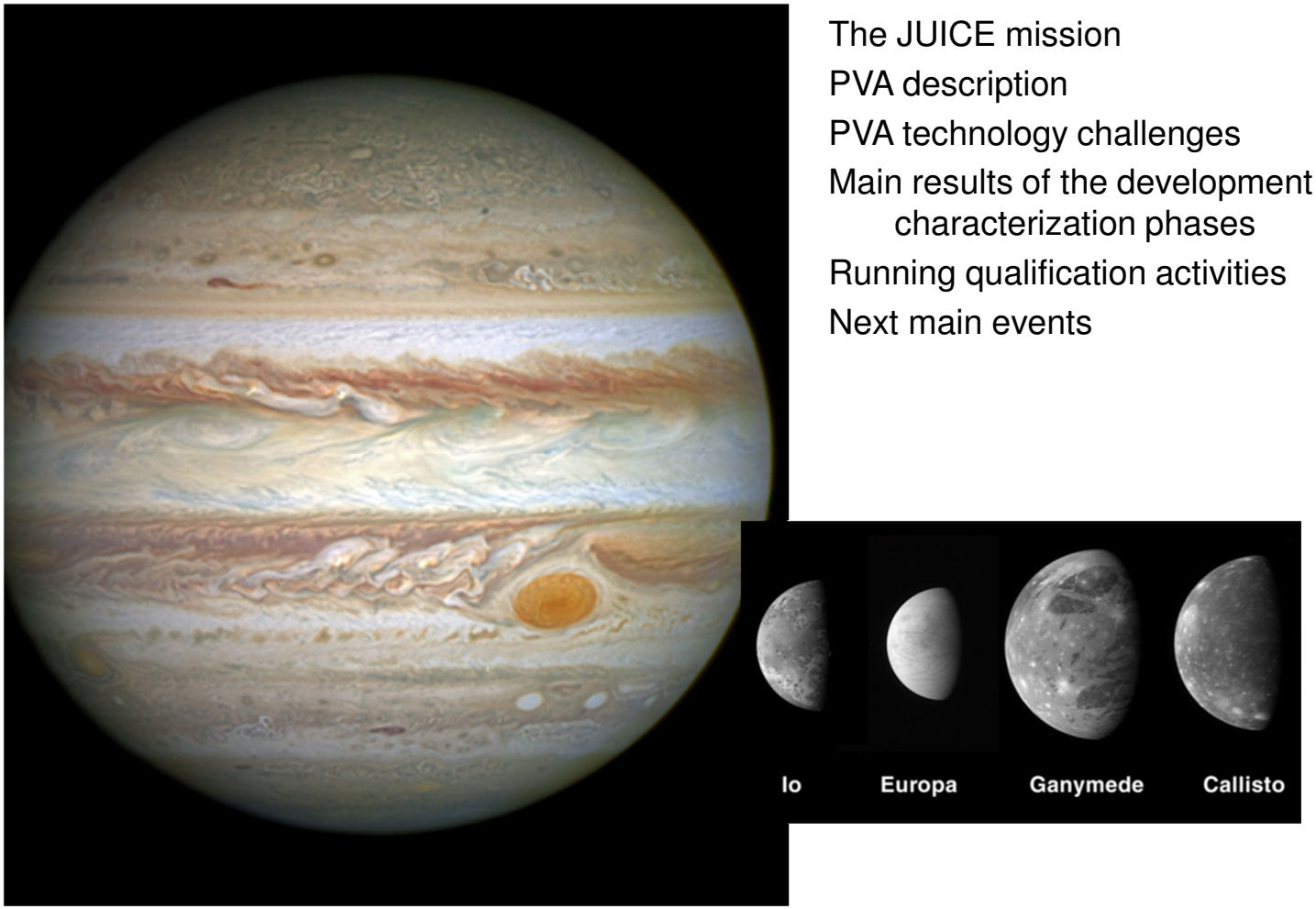
Presentation outlook



The JUICE mission

PVA description

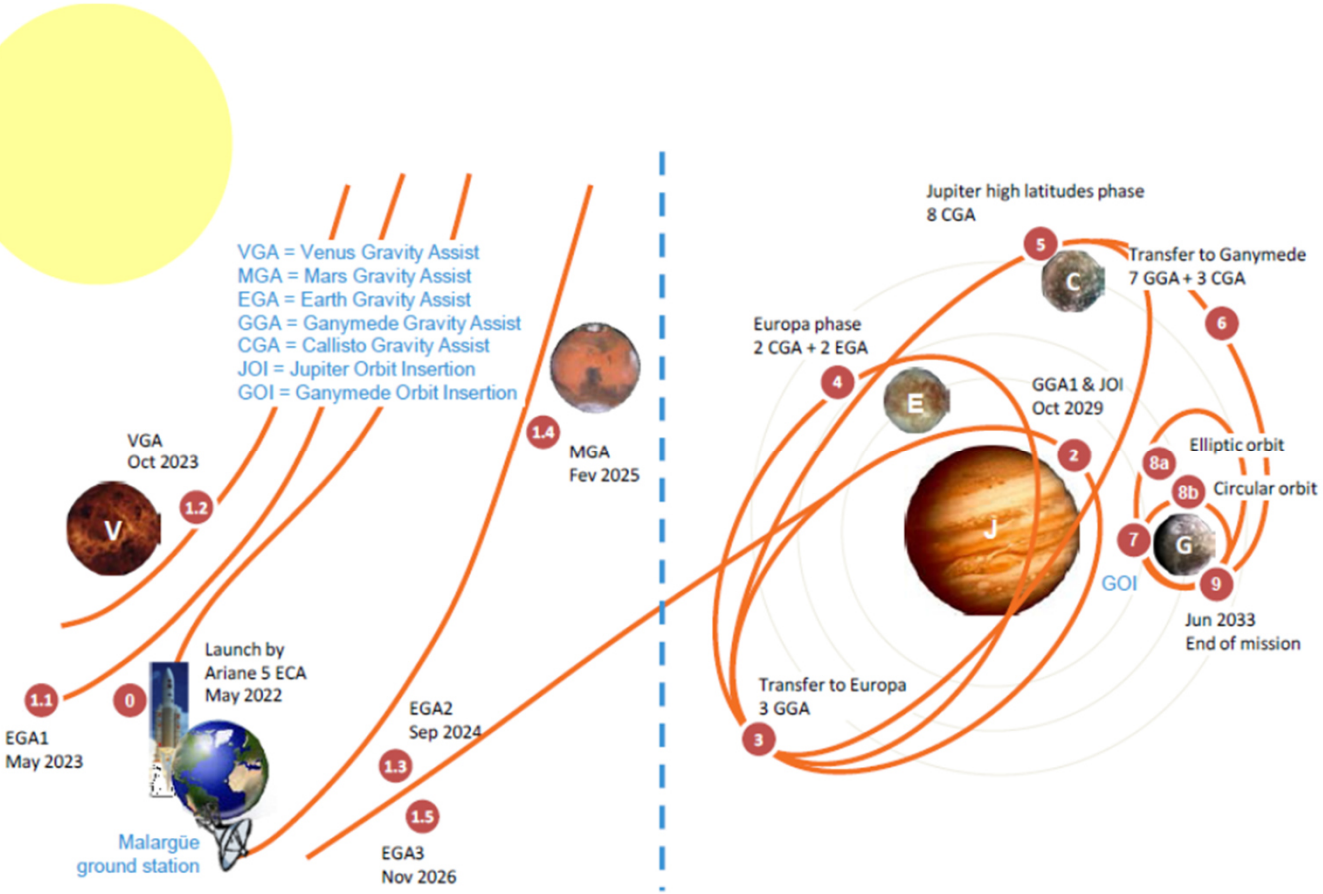
PVA technology challenges

Main results of the development / characterization phases

Running qualification activities

Next main events

The JUICE Mission



JUICE Photo Voltaic Assembly (PVA)

- Leonardo responsible for design, qualification and production of PVA for the JUICE Solar Array
- Contractual customer is Airbus DS Netherlands B.V.
- Spacecraft prime is Airbus DS SAS

- PVA Key facts
  - Largest PVA manufactured by Leonardo ever
  - 23500 solar cells installed on a total area of 80 m^2 area
  - 10 panels 3.5m x 2.5m each, ~ 30 kg mass each (including substrate)
  - 730 W developed power @ Jupiter orbit (0,37 solar constant end of life)

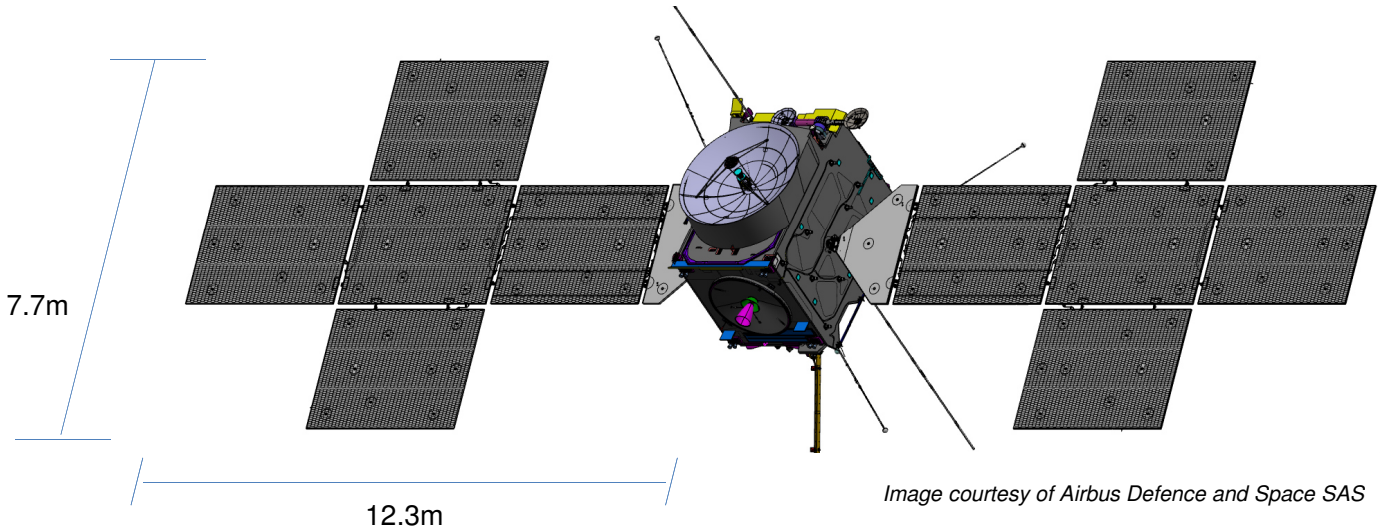


Image courtesy of Airbus Defence and Space SAS

Photo Voltaic Assembly (PVA) Technology Challenges

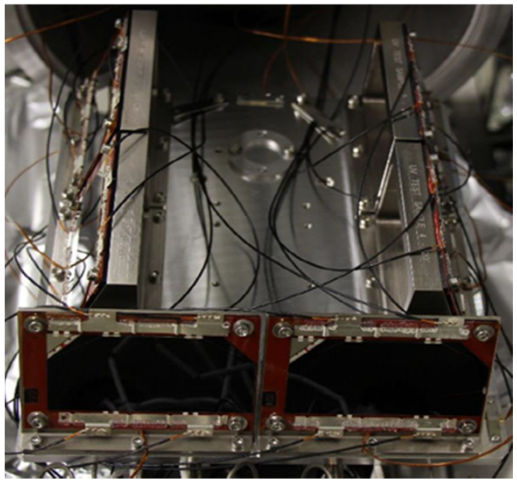
- Technological challenges
  - Low Illumination & Low Temperature operating conditions (3.7% intensity / -150C)
  - Extreme low temperature during eclipse (-235C)
  - Dedicated qualification activities at all levels of subassembly, from bare cells to PVA
  - Harsh radiation environment
  - Combination of EoL radiation and heavy mechanical loads
  - Almost no magnetic signature to be generated from the spacecraft

- Main suppliers / partners
  - AZUR Space (Germany), solar cells manufacturer
  - QioptiQ (UK), cover glasses
  - IABG (Germany), CSL (Belgium), INTA (Spain), ESA (The Netherlands) test facilities for qualification and acceptance

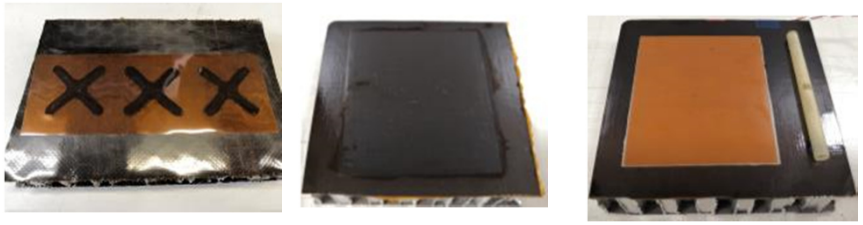
Environmental testing campaigns

In order to validate processes, components and materials used on the PVA, a remarkable number of environmental tests has been carried out by Leonardo before qualification:

- Thermal vacuum cycling tests down to -235 ° C on several SCAs and PVA coupons
- ESD tests on dedicated PVA coupons
- UV tests on SCAs at different tilted angles, representative for JUICE cruise phase in the inner solar systems
- Proton and electron irradiation on SCAs
- 3,2 Grad, 2 MeV electron irradiation on bonding samples dedicated for rear side technology development
- Materials characterization in cryogenic conditions



SCAs at tilted angles for UV exposure

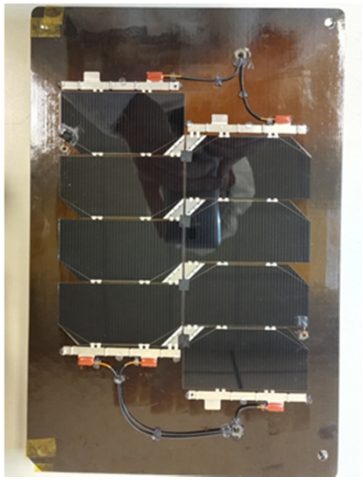


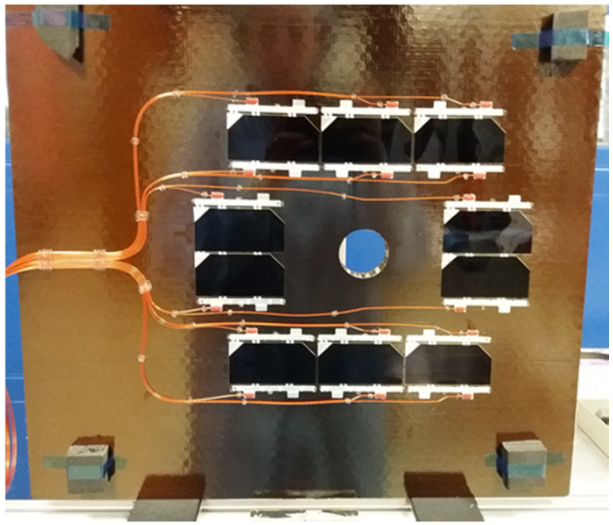
Examples of small coupons for high dose electron irradiation

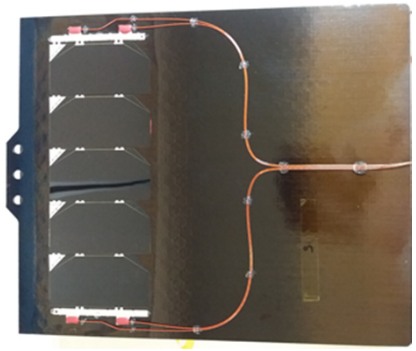
ESD and mechanical samples

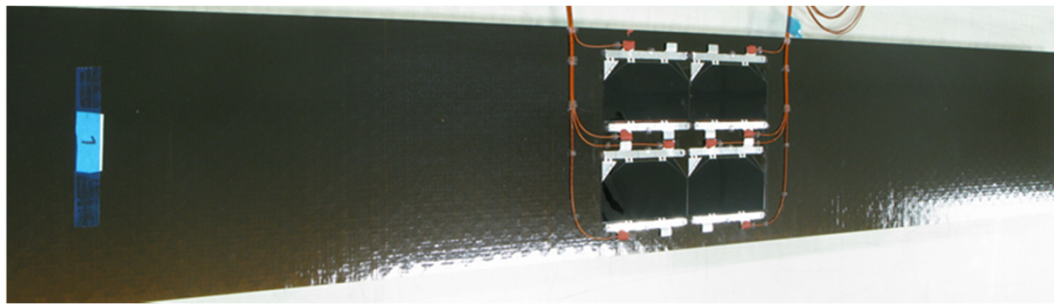
In the framework of B1 phase, several coupons have been manufactured, in order to be submitted to different environmental tests: thermal, ESD and mechanical

Examples of some of the PVA coupons manufactured during B1 phase for environmental characterization









Main results of the development / characterization phases

- Main achievements
  - Characterization tests successfully completed
  - Technological baseline + backup solution defined
  - Coverglasses qualification on going
  - Bare solar cell and by pass diode qualification on going
  - Coverglassed interconnected cell qualification on going

- Major events and Milestones
  - Intermediate Manufacturing Readiness Review for Qualification Model, end Nov. 2018
  - Baseline Design Review & Phase B1 Close Out, December 2018
  - Preliminary Design Review Co-Location, December 2018
  - Delivery of first half of FM solar cells (from manufacturer), December 2018
  - Critical Design Review Co-Location, July 2019

Cell's interconnecting technologies developed for JUICE

In order to avoid micro-cracks or shunts on solar cells, for Low Intensity operation, welding on 3 different interconnect's materials has been developed or adapted

- **Pure silver**: selected as baseline for JUICE interconnects because of its diamagnetic properties
- **Ag-plated Invar**: standard material for Leonardo, specifically adapted for JUICE as back-up
- **Ag-sputtered Molybdenum:** welding technology developed and tuned as parallel activity with respect toAg and Invar. Development now completed for thin cells, as third alternative to JUICE baseline

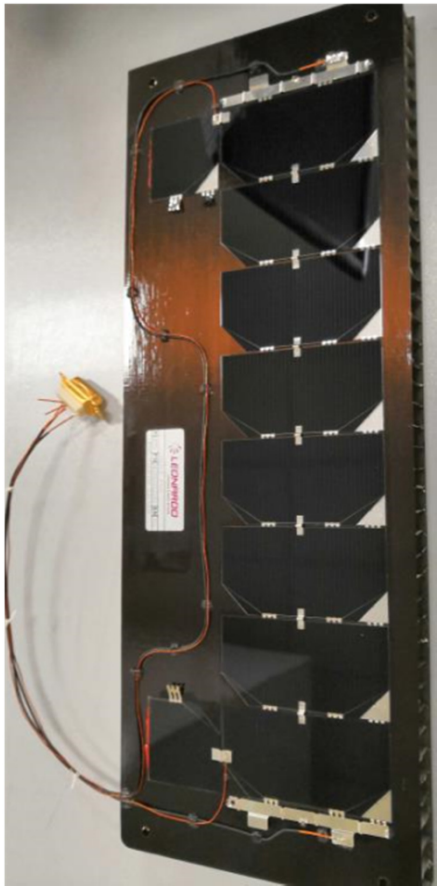
Major technological achievements

At the end of JUICE B1 phase, Leonardo has achieved the following goals:

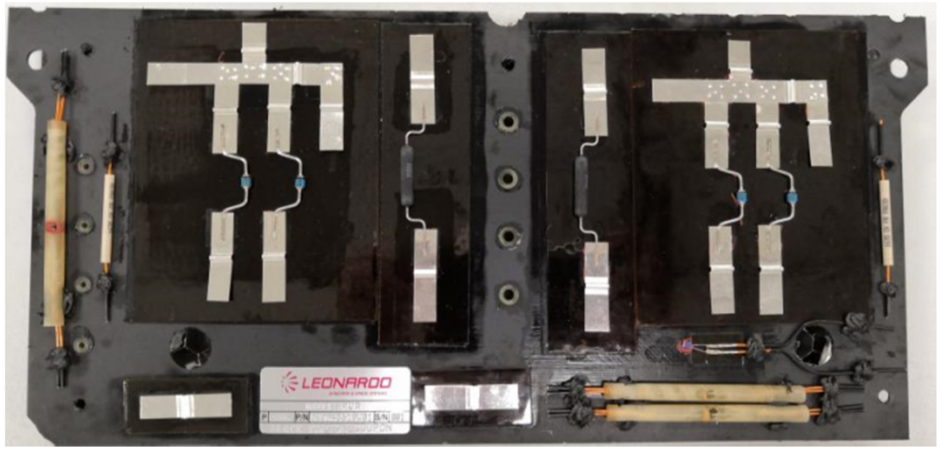
- ✓Succesful development of a baseline technology for interconnecting cells, compliant with low intensity screening
- ✓Succesful development of an innovative, large scale technology for coverglasses electrostatic grounding, able to maintain potential bias < 1 V across the PVA, once the SA will be in Jovian harsh environment
- ✓Successful identification of the technologies and materials needed to assemble harness and EEE parts of panel rear side. All solution are compliant to thermal, radiation and charging environment

Such results have been demonstrated by successful testing of several engineering coupons

Engineering coupon samples



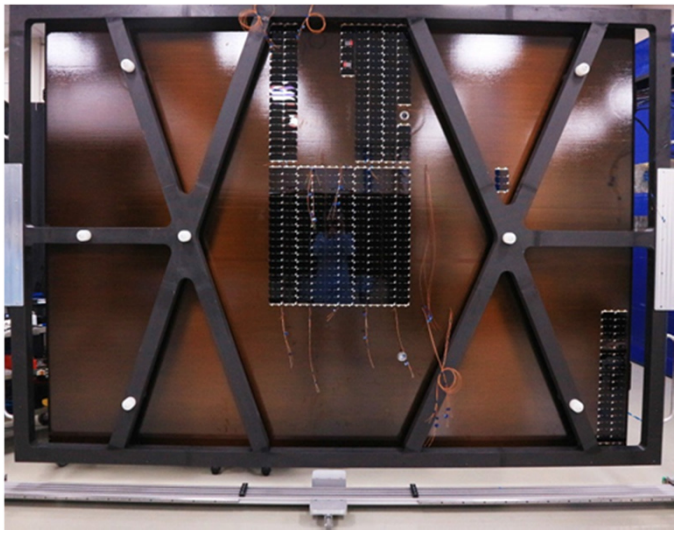
Engineering coupons have been devoted to validation of critical technologies: solar cells assemblying, coverglasses grounding network and panel rear side assemblying



Qualification Model panel

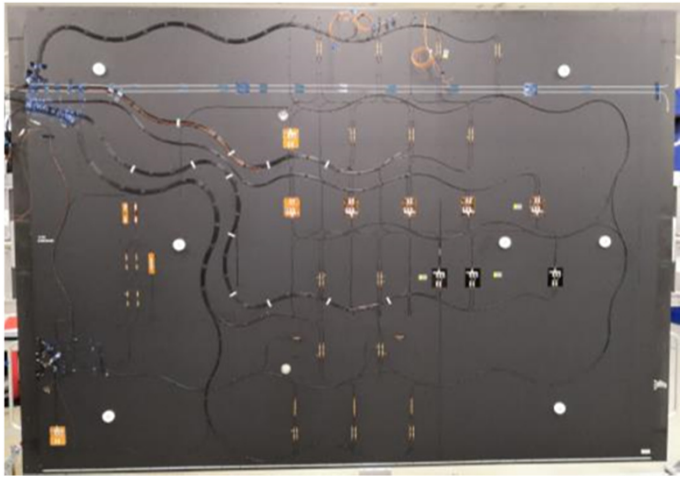
In the framework of qualification phase, a full-size representative DVT model has been built

The QM is going to be submitted to complete thermal cycling test in order to qualify both baseline and back-up technologies to be used on JUICE FM panels.



JUICE QM during manufacturing

The JUICE QM is the largest DVT panel ever built and tested by Leonardo



Qualification Model panel testing

The QM panel is going to be submitted to a challenging environmental test campaign:

High-level phases		Description
#1	**Manufacturing**	PVA assemblying
#2	**Tests at Leonardo**	Visual Inspection, electrical checks and electrical performance measurements, including Low Intensity Room Temperature characterization at panel level
#3	**Bake-out**	Maximim temperature: +127 °C
#4	**Repairing**	Mandatory repairing after bake-out
#5	**LILT BOL**	Low intensity Low Temperature measurements (**0,037 SC, T_{min}=-150 °C**) at panel level, beginning of life
#6	**Thermal cycling**	~ **200 cycles** (either in He atmosphere and vacuum) Maximum temperature: **+127 °C** Minimum Temperature: **-235 °C**
#7	**LILT EOL**	Low intensity Low Temperature measurements (**0,037 SC, T_{min}=-150 °C**) at panel level, end of life
#8	**Final tests at Leonardo**	Visual Inspection, electrical checks and electrical performance measurements, including Low Intensity Room Temperature characterization at panel level

Next main events

- Completion of the SCA TAT subgroups dedicated to thermal qualification (Q2 2019)
- Beginning of SCA production (Q2 2019)
- Starting of (P)FM cabling at bench level
- Completion of QM intermediate testing and releasing of string forming and laydown (Q3 2019)
- Start of thermal vacuum acceptance testing (Q4 2019)
- Delivery (P)FM for wing integration (end of Q2 2020)

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