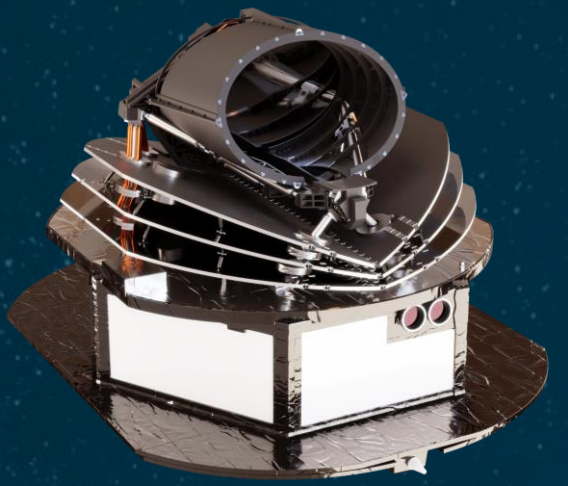

Cryogenics at ESA – Needs and Challenges

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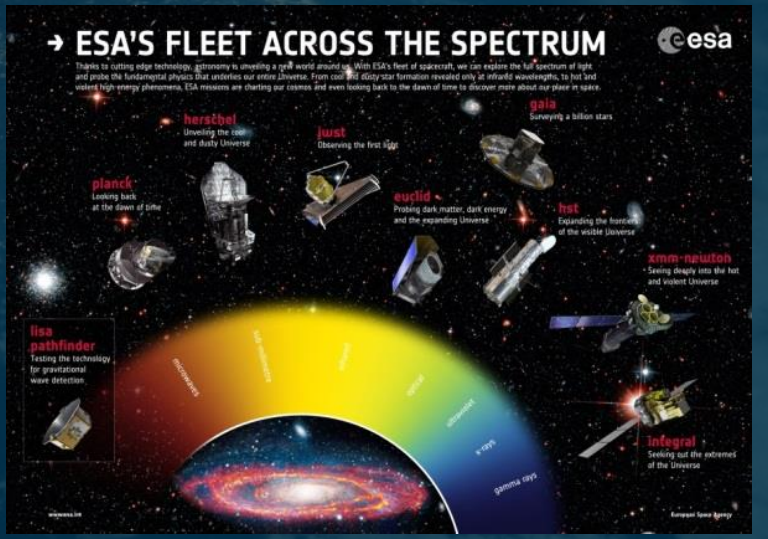
Agenda

- Introduction
- Cryogenics at ESA
  - For Spacecraft
  - For Space Transportation
  - For On-Ground testing
- How to contribute
- Conclusion

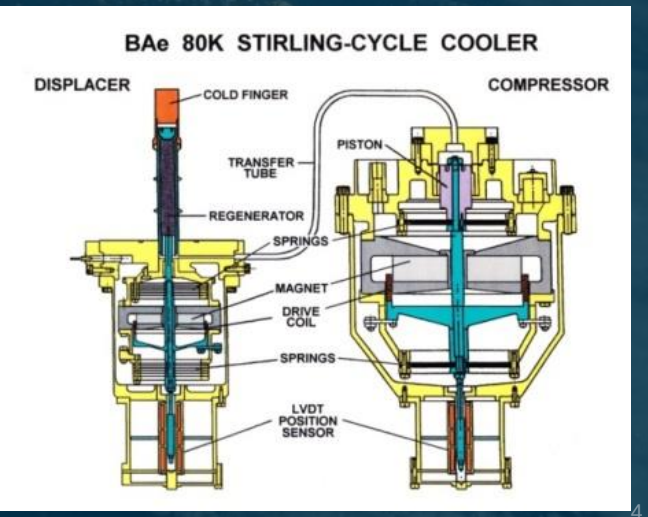
Introduction

- The main role of the European Space Agency is to ensure the development of Europe's Space capability by laying down a conjoint space programme and carrying it through.
- ESA also promotes, orientates and financially supports research and innovation that can be used for space.
- Cryogenics is an important topic in the space business:
  - Cryocooling of detectors is an enabling technology for number of missions,
  - Cryogenic fluid management is a crucial domain for launchers,
  - On-ground verifications of spacecraft require Nitrogen or Helium Thermal Vacuum facilities.



Cryogenics at ESA – for Spacecraft

- Generic need: the production and/or management of cryogenic temperature in the whole range (0.05<T<200K).
- Types of Space Coolers typically used:
  - Stirling/Pulse Tube from 120K to 15K, from 0.6kg/20W to 20kg/300W.
  - Joule-Thomson to reach 6K, 4K and 2K.
  - Specific coolers (ADR, Dilution, Sorption) for temperatures below 2K.
- Typical orders of magnitude of cooling power:
  - ~10W@120K
  - ~4W@50K
  - ~500mW@20K
  - ~40mW@4K
  - ~10mW@2K
  - ~1microW@0.05K
- The technologies used are driven by the following constraints:
  - It needs to be compact and efficient.
  - It needs to survive the launch.
  - It needs to work in microgravity environment.
  - **It needs to be reliable and cope with long lifetime requirements**.
  - It needs to be quiet (no microvibration, EM disturbances)



Cryogenics at ESA – for Spacecraft

- To coordinate developments at European level for various types of technology, ESA put in place the Harmonisation process. The harmonisation for Cryogenics and Focal Plane Cooling took place in 2019.
- Refer to https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Technology_Harmonisation for more information including how to get access to the Roadmaps.

•The Main objectives of the 2019 Roadmap:

  • Complete the portfolio of coolers, including electronics and bring them to a sufficient maturity in order to be considered in projects.

  • Prepare the upcoming “New Space” trend that will require cheaper, less reliable and potentially ‘mass produced’ coolers.

  • Foster innovation by continuing or initiating groundbreaking developments focussing on solutions that provide system level advantages (e.g.: Vibration Free Cooling, Cryogenic Heat Switches, laser cooler, enhanced architectures).

Cryogenics at ESA – for Space Transportation

- Considered Cryogenic fluid: Oxygen, Hydrogen, Methane (pure & LNG)
- Specificity: Big masses, ie: several tens if not hundreds of tons
- Topics of interest:
  - Storage: short term (a few minutes/hours), mid term (several days/weeks), Long term (several months), on ground/in orbit
  - Propellant management: Under microgravity (settlement, pumping, transfer)
  - Thermal management: thermal protection of tanks, temperature stratification (for pump cavitation), subcooling (for increased loading), chill-down of hardware

Courtesy of Arianespace

Cryogenics at ESA – for Space Transportation

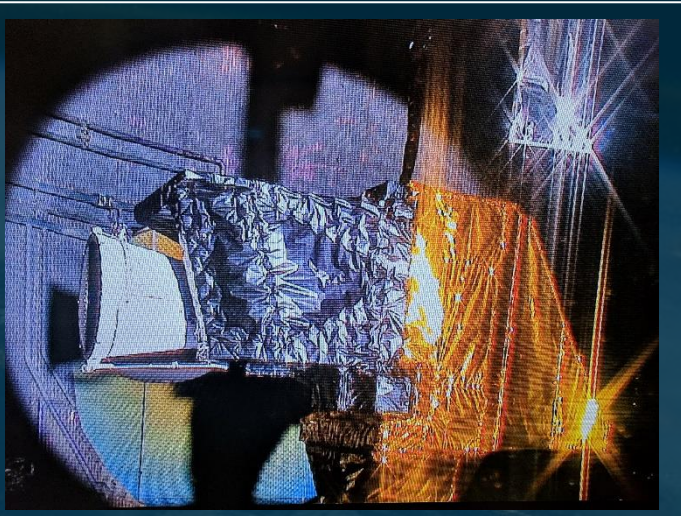
- Future trends:
  - Explore new industrialisation concepts for cryogenic “Equipped Insulated Tanks”, incl. light-weight and high performance insulated common bulkhead technologies
  - Foster the readiness level of new liquid Oxygen/Methane based “soft cryogenic” systems for towards low-cost Space Transportation applications (new rocket stages)
  - Progressing towards extended cryogenic upper stage mission flexibility by advancing propellant management under micro gravity conditions (e.g. new propellant management solutions, zero-boil-off systems, versatile thermal insulations, second life as propellant depot)

Courtesy of ArianeGroup Gmbh

Courtesy of Magna Stevr

Cryogenics at ESA – for On-Ground Testing

- Ground testing is a crucial stage of the development of spacecrafts (no maintenance up there).
- Space environment characterized by extreme thermal environment and vacuum (cf. Gaetan Piret presentation for vacuum technology) → **Thermal Vacuum Tests** (at Spacecraft, Instrument or Sub-system levels) are indispensable for the validation of space technology.
- Multiple space companies or institutes have thermal vacuum space facilities of different size and temperature range capabilities: Primes (TAS, ADS, OHB etc.), testing centers (Intespace, IABG, CSL etc), subsystem providers.
- At ESTEC, ~5 labs have thermal vacuum chambers.



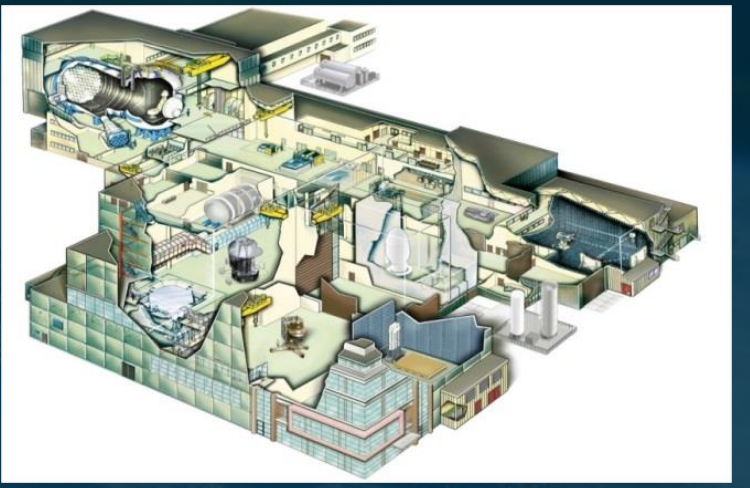
MTG-I STM Satellite in the LSS

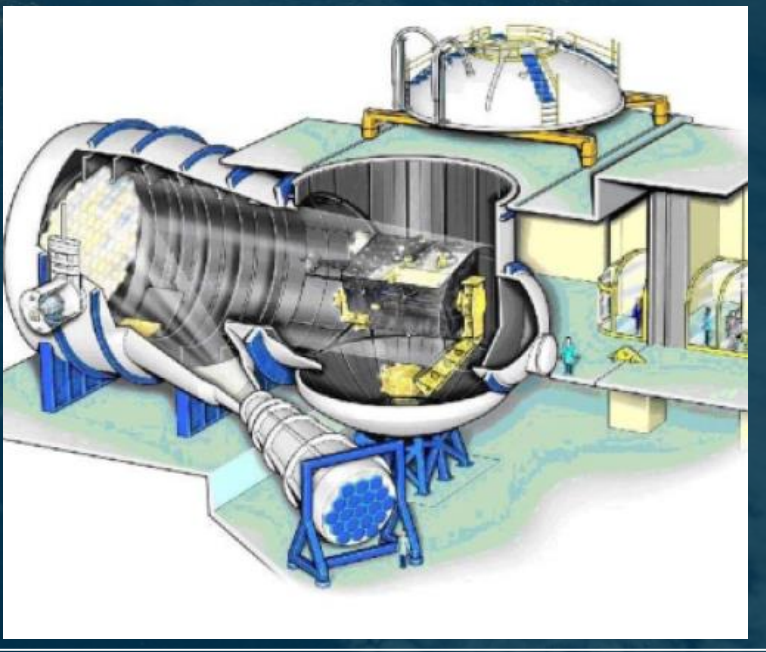
Mechanical System Laboratory at ESTEC

Cryogenics at ESA – for On-Ground Testing

- Example - Test Centre at ESTEC, 3 TVAC facilities:

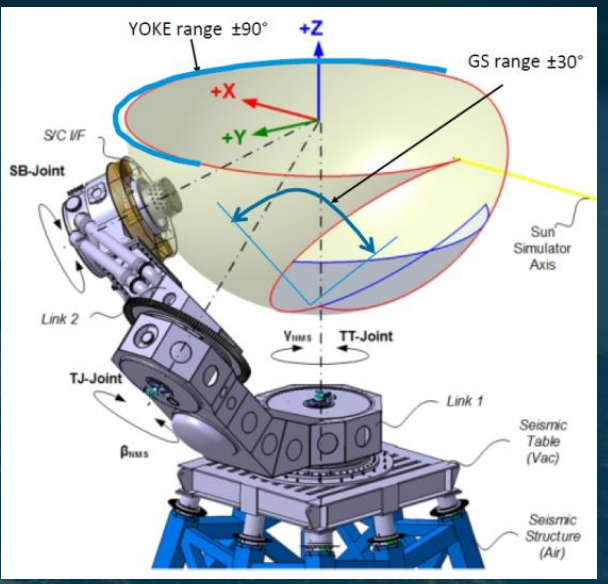
	Large Space Simulator	Phenix	VTC 1.5
Chamber volume	2300m^3	160m^3	11m^3
Shrouds temperature range	100 K-350 K	100 K-350 K	100 K-393 K
Dissipation in LN2 mode	170kW	30kW	10kW
Dissipation in GN2 mode	10kW	0.6kW per shroud (6)	1kW

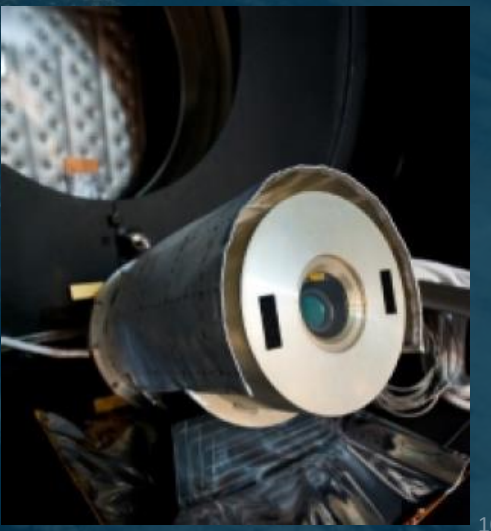




Cryogenics at ESA – for On-Ground Testing

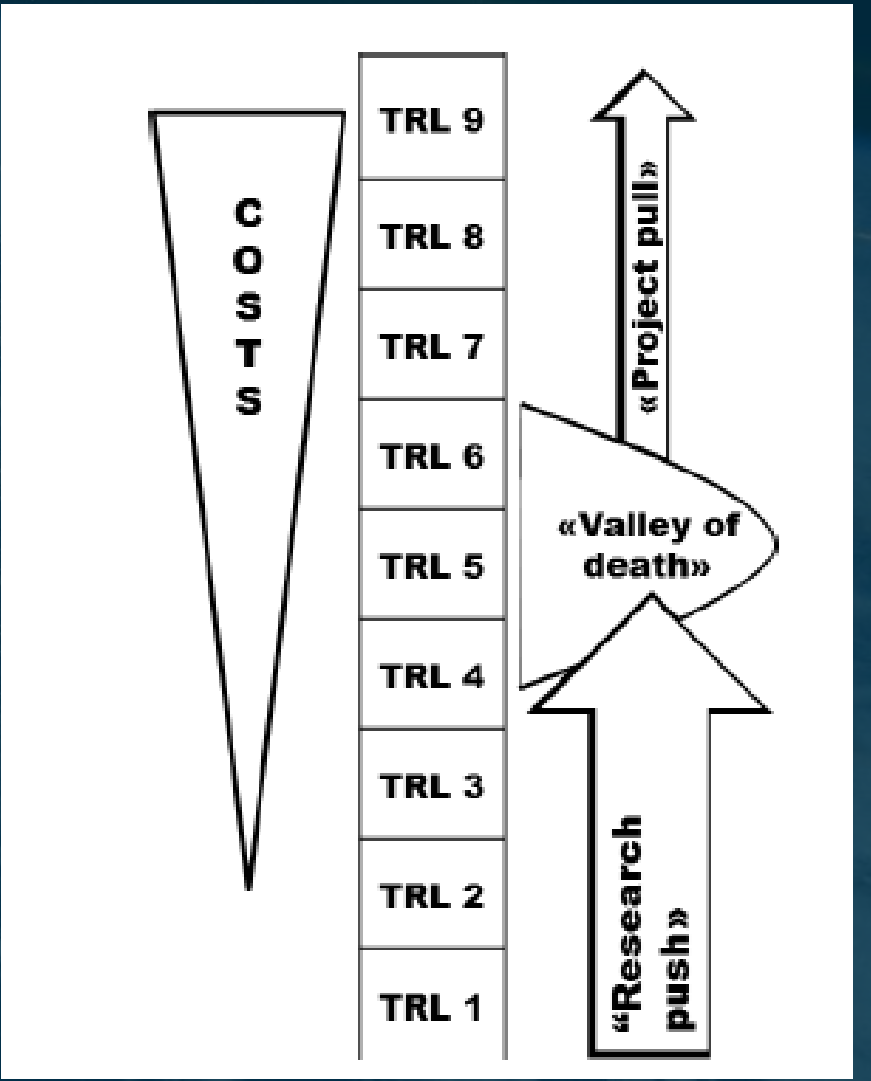
- Topic of Interest for Cryogenics in Space ground testing:
  - Motion System that includes cryogenic joints
  - Cryogenic (non intrusive) thermography
  - If LN2 is sufficient for most of the spacecraft testing, sometime missions need a lower sink temperature:
    - He shrouds, open/close loop.
    - Active coolers with efficient broad area cooling.





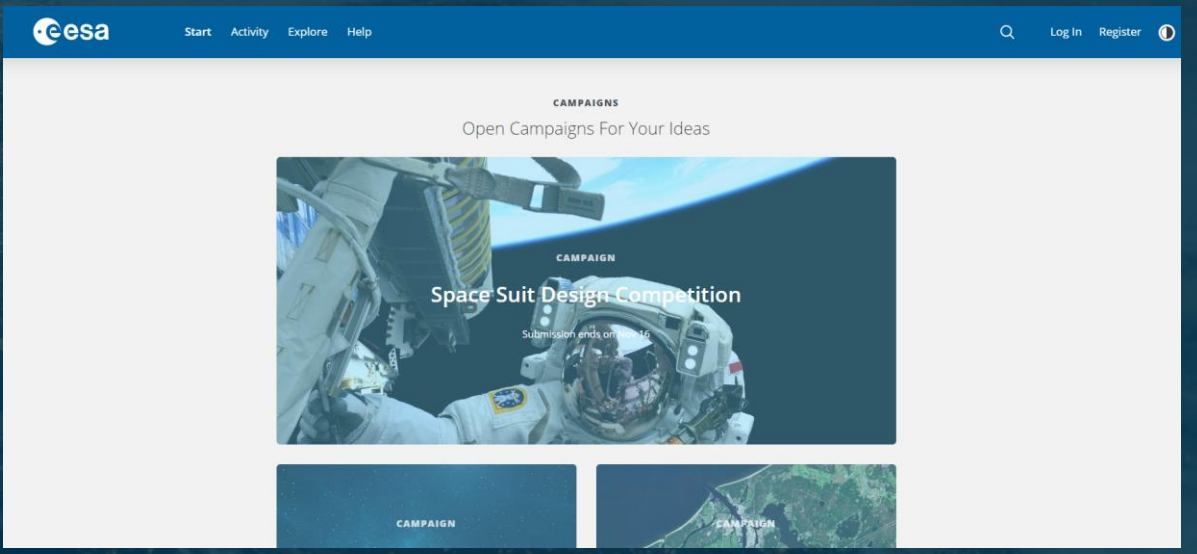
How to Contribute

- ESA supports developments from the very first idea (low TRL) to the qualification into a product (TRL9).
- Range of development tools depending on the type of activity/TRL:
  - To reach TRL4:
    - Generic Technology Development Element (TDE), or Service Domain specific Technologic Development Activity (e.g. CTP, EOEP): ESA proposed, open competition.
    - Bottom-up proposals: now channelled through the Open Space Innovation Platform (cf. next slide).
  - To go beyond TRL4:
    - General Support Technology Program (GSTP): member state support.
    - Picked up by a project or a service domain
- **Check ESA-STAR (http://doing-business.sso.esa.int) for the invitations to tender and other useful information about doing business with ESA**



How to Contribute

- Since the 2019, the Open Space Innovation Platform hosts a permanent call for innovative space ideas (https://ideas.esa.int/).
- It covers the following types of activities:
  - PhD and Post-Doc sponsoring (30kEUR per year).
  - Early system studies (~ 50kEUR)
  - Proof of concept and breadboarding (from 90kEUR to 250kEUR or more – with co-financing)
- Process:
  - Simple and high level online form.
  - Evaluation every months
  - Second step depends on the type of programme you fit into (co-sponsored research or early technology development).



Conclusion

- Cryogenic for space is difficult to compare to ‘Big Science’ Cryogenics, but some challenges overlap:
  - Vibration Reduction.
  - Remote Cooling.
  - Long Lifetime.
  - Cryogenic Fluids Handling.
- The European Space Agency encourages innovative collaboration and synergies between different fields.
- 3 different domains can attract different actors:
  - Spacecraft Cryogenics for innovative, sophisticated and relatively compact coolers or integration solutions.
    - Approximate budget: ~ 1.2MEUR/year
  - Space Transportation for fluid management and larger volumes
    - Approximate budget: ~ 5MEUR/year
  - On-ground Testing for more classical lab-based solutions.
    - Approximate budget: ~ 2.5MEUR/year (investments and running costs)

Final Word

- If you are interested in Space Cryogenics, do not hesitate to sign-up for the 8th European Space Cryogenics Workshop!
- It will take place from the 05/06/23 to the 07/06/23 in ESTEC (Noordwijk, NL)
- Check https://atpi.eventsair.com/QuickEventWebsitePortal/8th-european-space-cryogenic-workshop/2020 for more information or get in touch with Moritz Branco (Moritz.branco@esa.int) or me (Thierry.Tirolien@esa.int).