



Space Technologies & Products Handbook

Engineering & Technologies

2025

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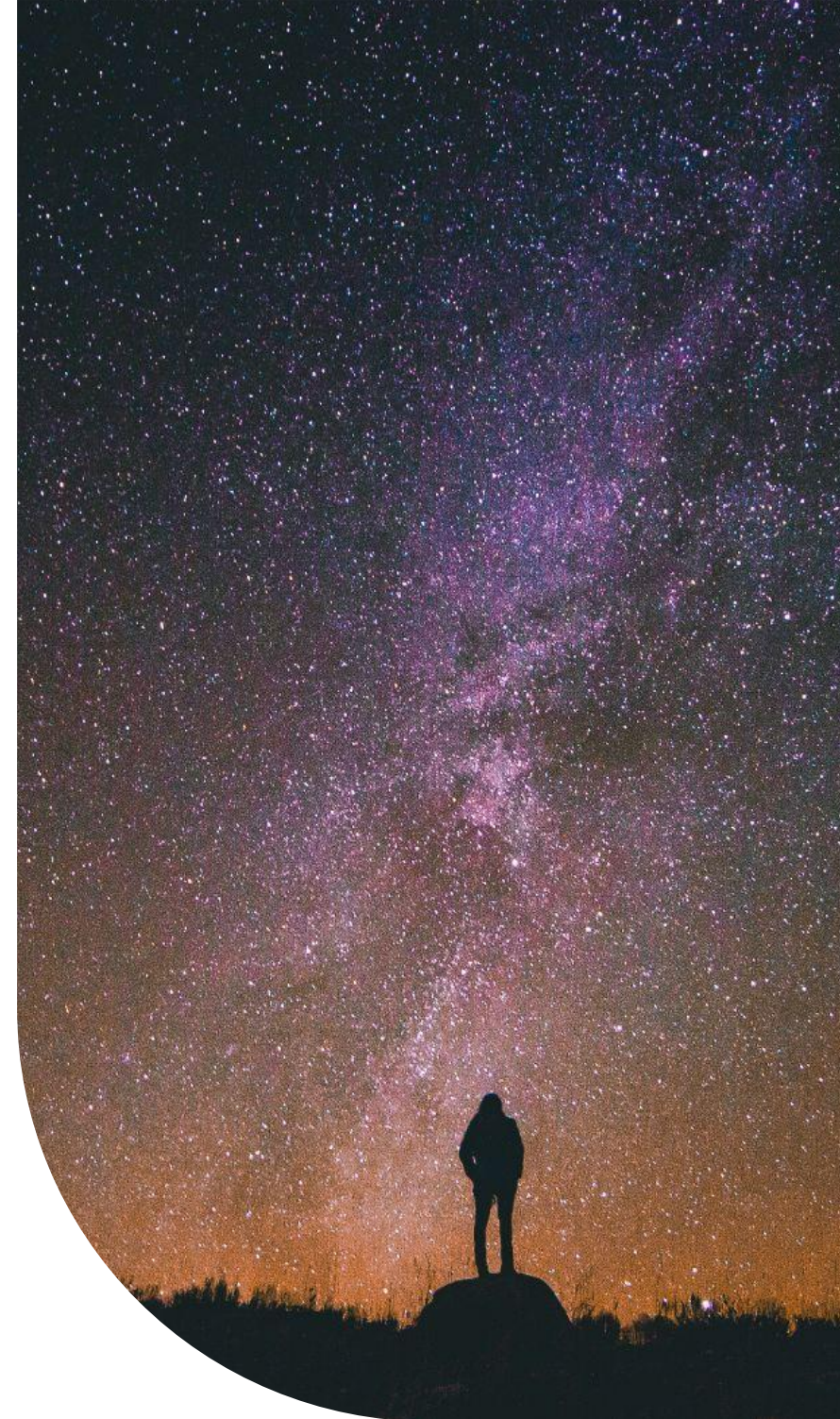
Active cooling

Gas management

Energy management

Ground systems

Technology development competences





Space @ Air Liquide advanced Technologies

Your space partner for on-ground & on-board cryogenics so as gas management systems

A partner in the space adventure for 60 years, we began supporting the Ariane program in the early 1970s, designing and manufacturing over 770 tanks to date.

Our expertise also extends to launch pad infrastructure, on-board cryogenics for satellites, and ground test equipment for launchers and satellites.

Today, for Ariane 6, Air Liquide is the design authority and in charge of the production of various cryogenic equipment, and is responsible for the development of tanks for VEGA-E.

Our teams are also innovating in the field of space exploration, developing energy production and storage technologies, as well as air purification equipment, to support future projects and missions, notably to the Moon and then to Mars.



Air Liquide advanced
Technologies



Created in 1962
as a R&D center
for low temperatures
in Grenoble, France



**Innovative technologies
for gas and cryogenics**



- **1,250+ people**
- **~300m€ sales**
- **40+ patent/year**



- **Engineering offices**
- **Production and
aftersales warehouses**
- **Test center areas**

We are committed to safety for all those we work with



We are working towards **zero accidents** at all our sites and those of our subcontractors and customers



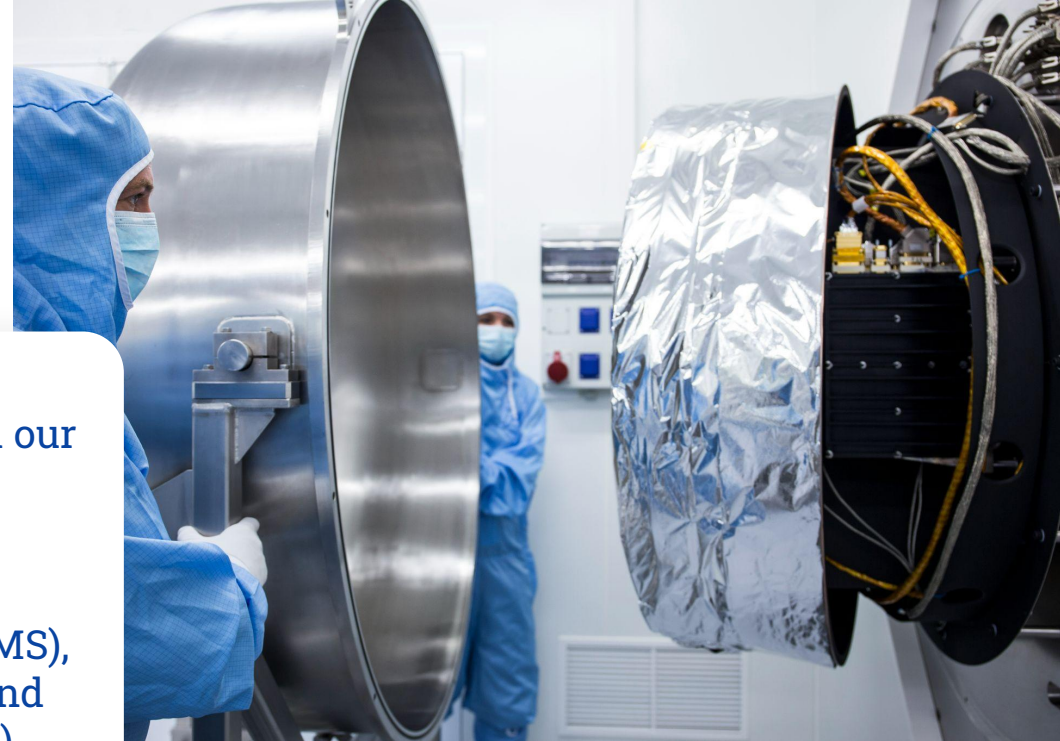
Using our **Industrial Management System (IMS)**, we rigorously assess everything we design and operate (from one component to a whole unit)

- Ensuring safe, reliable operation whilst minimizing risk and environmental impact



We **share our safety experience** with our subcontractors and customers to raise awareness of gas risk management

- Workforce training on using our products safely
- Supply of personal protective equipment (PPE)
- On-site safety coordination



Launchers cryogenic equipment & technologies



Launchers

Cryogenics tanks, cryogenic lines, cryogenic fluid simulation and behavior

Launchers cryogenic equipment & technologies

Application

LH₂, LOx or LCH₄ tank for launchers using cryogenic propulsion

Size

Depending on launcher program

Key points

More than 800 cryotanks for flight models

LCH₄ tank development

Insulated & equipped cryogenic tanks

Description

Cryogenic tank capable of storing and managing LH₂, LOx or LCH₄ during all the launch phases. The tanks can be equipped with external and internal insulation as well as equipment such as anti-Vortex, baffles, anti-sloshing, level gauges, pressure and thermal sensors.

Technology

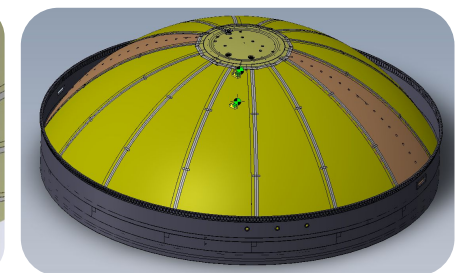
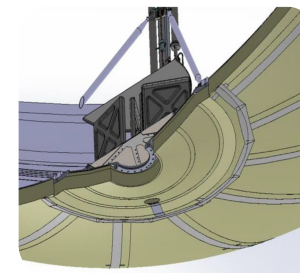
The tanks are made of aluminum and TIG welded, internal equipment are bounded or screwed.

Manufacturing capacities

AL-aT can manufacture tanks up to 4m diameter and 10m length.

References

- Manufactured and delivered all the LOx/LH₂ tanks up to Ariane 5 (included)
- Design authority for Ariane 6
- Development of the cryogenic tank (LOx/LCH₄) for the upper stage of next launcher generation





Application

LOx tanks pressurization



Size

166kg of LHe
1 to 20 BarA



Key points

119 flight models (03/25)

SSHeL - Liquid Helium Sub System

(Sous-Système Hélium Liquide)

Description

LHe storage (166 Kg of LHe), equipped with level, thermal and pressure sensors, relief and check valves, feeding and degassing valves. This tank is used to pressurize LOx tank, control LOx flowrate and minimize thermal residual.

Technology

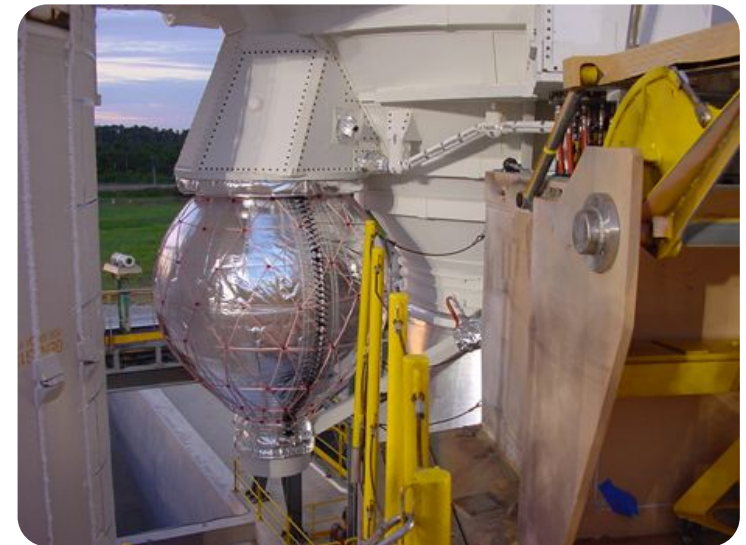
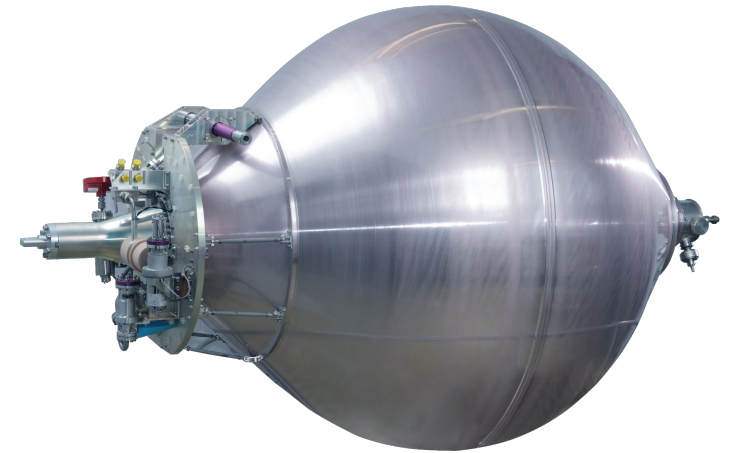
Aluminium double wall vacuum insulated.

Manufacturing capacities

Air Liquide has developed and manufactured this tank for the Ariane 5 program. It is still manufactured at AL-aT facilities for the Ariane 6 program.

References

- All the tanks up to Ariane 5 (included)
- Ariane 6 program





Application

Anti-vortex, anti-sloshing devices, anti-wetting devices



Key points

Calculation
Design
Optimization

Propellant management device

Description

Design, qualification, cleaning, assembly and control of all internal LOx, LH₂ and LCH₄ tank equipment (anti sloshing, anti vortex, anti wetting, level gauges, equipped covers and liquid collectors, including filtering and pass through connectors).

Technology

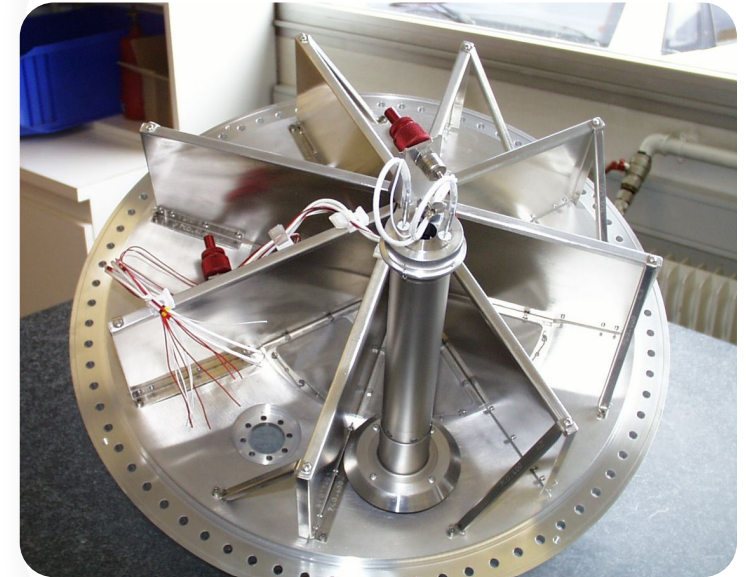
Design and qualification option covers mechanical, thermal and functional (fluid dynamics) aspects.
Equipment are mainly made of aluminum parts, assembled by rivets or bolts.

Manufacturing capacities

Cleanroom ISO07 (surface >450m²) for space launcher equipment manufacturing, assembly and cleaning.

References

- All Ariane launchers from Ariane 1 to Ariane 6
- Vega-E



 **Application**
LH₂, LOx or LCH₄ tanks

 **Key points**
Bonded or
projected
insulation
All LH₂ & LOx
tanks of Ariane 5
are covered with
insulation

Insulation for tanks and cryogenic lines

Description

Insulation is made of material that could be bounded or sprayed onto the tank and lines surfaces. It could also be on internal surfaces in case of common bulkhead and internal line.

Technology

- Injected or sprayed foam
- Multi-layer insulation
- Open foams

Manufacturing capacities

Air Liquide procures the raw materials and then integrates this material onto the surfaces.

References

- All the Ariane tanks up to Ariane 6 (included)
- HX CNES demonstrator
- CNES Cryofenix launcher
- Vega-E upper tank (in development)



Application
LH₂, LOx or LCH₄ tanks

Size

- Short sensor: 200 mm measurement range
- Long sensor: 464 mm measurement range

Key points

- Used in all Ariane 5 tanks
- New Glenn LH₂ & LOx tanks

Level gauges for cryogenic tanks

Description

Level gauges are used to measure and monitor the liquid level in the tanks.

They are used during ground operations, to ensure that the required propellant loaded mass is well on board the launcher.

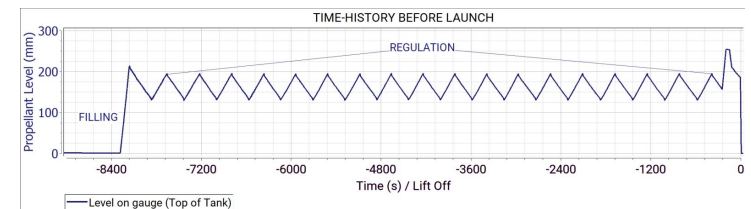
They are also used during flight to monitor tank draining and to implement engine shut down criteria.

Technology

Electrical capacity measurement. Whether the sensor is full of gas or full of liquid, the electrical capacity between the two sensor elements is different. The electrical capacity is linearly proportional to the liquid level.

References

- All Ariane launchers from Ariane 1 to Ariane 6
- Rocket Lab Electron
- AVIO Vega-E
- MaiaSpace



 **Application**
Cryogenic launchers

 **Size**

- From 1 to 6 meter long
- From 20 to 185 millimeters in diameter

 **Key points**
150 references for Ariane 6

Cryogenic lines

Description

The cryogenic lines are used to connect the tanks to the thrusters and the filling ports.

Technology

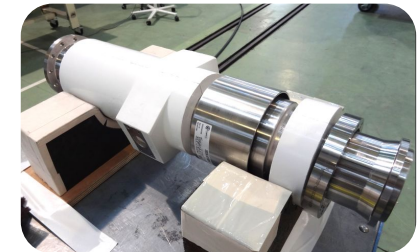
Cryogenic lines are made of aluminum or stainless steel depending on the mechanical constraints. They are isolated either with double wall and vacuum architecture, with insulation sprayed on, with injected foam, Multi Layer Insulation, etc.

Manufacturing capacities

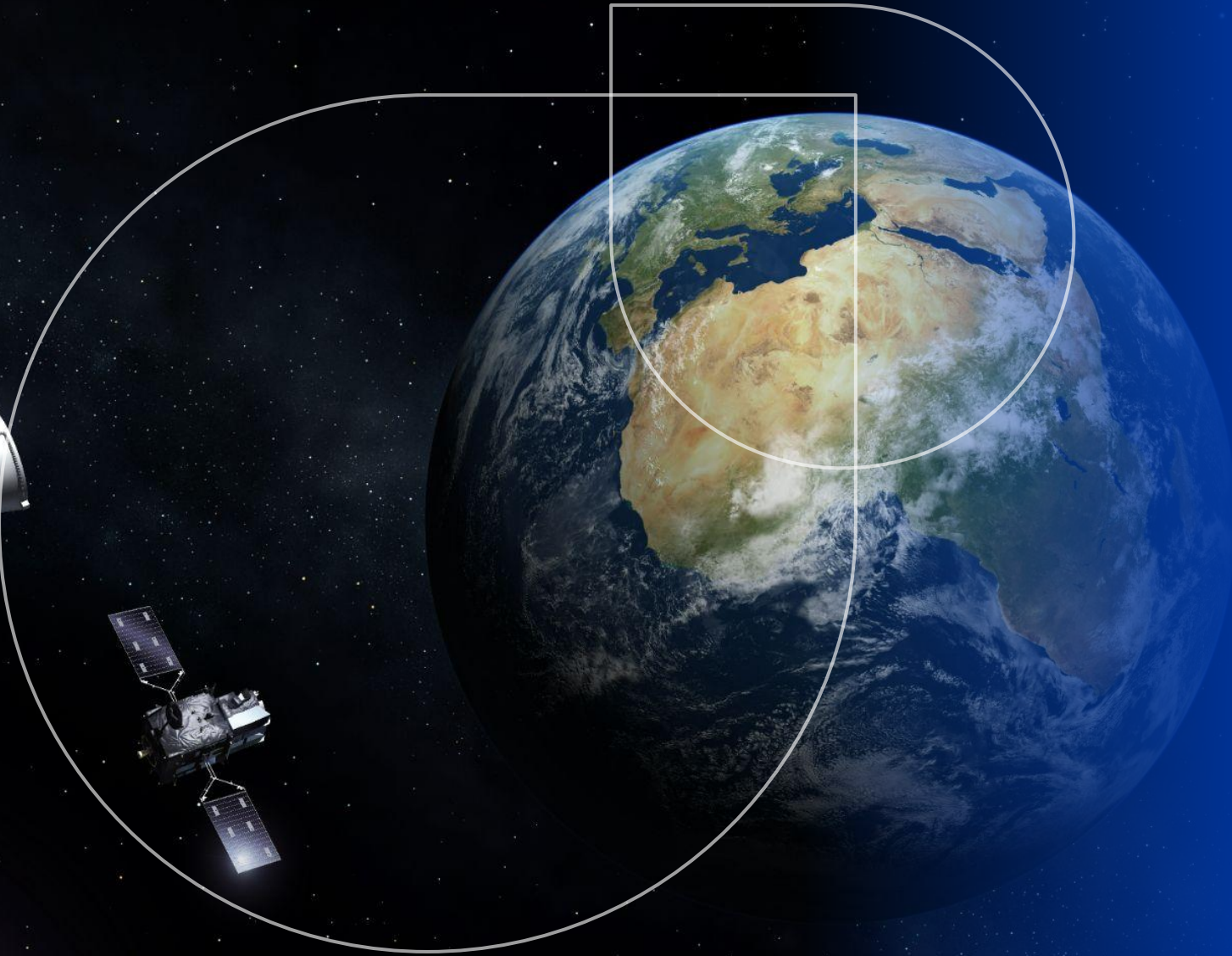
AL-aT can manufacture, proof pressure test, control and clean all the cryogenic lines, all length from 6 mm until 200 mm in diameter.

References

Most of the cryogenic lines for Ariane 6 launcher.



Active cooling



Cryocoolers

Pulse tube, dilution, cryostat, laser cooling, Turbo-Brayton



Application

Earth observation missions (military or civil) in the IR wavelength



Mass

15kg



Key points

TRL 9:

- Nb of delivered units; 24
- Nb of units in orbit: 8
- Nb of units in production: 4

3 W@ 50K with 160W elec (Begin Of Life)

LPTC: Large Pulse Tube Cryocooler

Description

LPTC (Large Pulse Tube Cryocooler) is a cooler based on the stirling thermodynamic cycle and capable of providing cold (down to 50K) to cool down detectors. It offers high reliability (15 years life time without maintenance) and low vibrations.

Technology

This cooler is based on the pulse tube technology developed during the last 25 years at Air Liquide. It is composed of a linear compressor generating a pressure wave that oscillates inside a cold finger to generate cold at one of its end (the heat is extracted at the other end).

LPTC is a split configuration: the cold finger is connected to the compressor by a pipe, allowing a versatile accommodation on board the satellite.

Manufacturing capacities

AL-aT develops the cold finger internally and has all the means to assemble internally this cooler (clean room ISO 5 and test benches). Compressor and electronics are procured from external suppliers.

References

Cooler mounted on the French national program, MTG and MetopSG missions.





Application

Earth observation missions (military or civil) in the IR wavelength



Mass

11 kg without electronics



Key points

- Engineering model
- 6 W@ 50K with 300W CPA power

LPTC-NG: Large Pulse Tube Cryocooler Next Generation

Description

LPTC NG, standing for Large Pulse Tube Cryocooler Next Generation, is a cooler based on the Stirling thermodynamic cycle and capable of providing cold (down to 50K) to cool down detectors. It offers high reliability (15 years life time without maintenance) and low vibrations. Compared to its previous model (LPTC), this version is more powerful (up to 300W compressor power) and therefore offers higher cold power.

Technology

This cooler is based on the pulse tube technology developed during the last 25 years at Air Liquide. It is composed of a linear compressor generating a pressure wave that oscillates inside a cold finger to generate cold at one of its end (the heat is extracted at the other end).

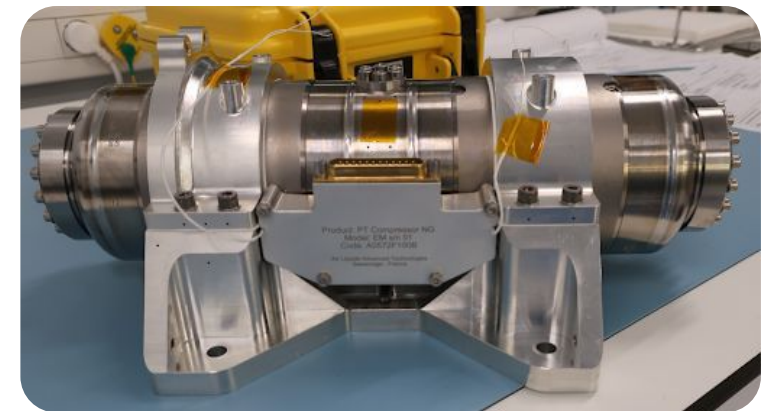
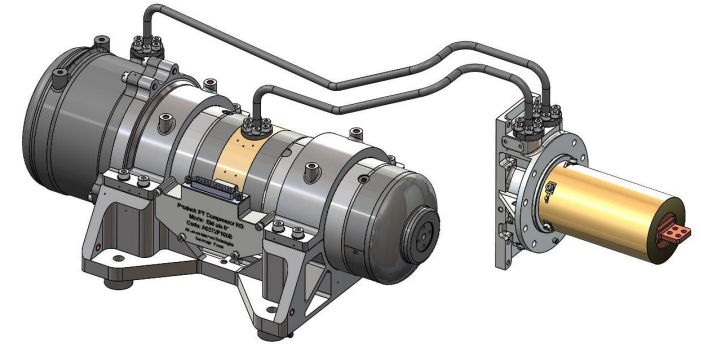
This system integrates new improvement especially with a compressor developed internally.

Manufacturing capacities

AL-aT develops the cold finger internally has all the means to assemble internally this cooler (clean room ISO 5 and test benches). Compressor and electronics are procured from external suppliers.

References

No references yet as it is a new development.



HiPTC: High Power Pulse Tube Cryocooler



Application

Space science observation



Mass

34kg



Key points

- TRL 5
- 480 mW @ 15K and 2W @ 80K

Description

Intercepted pulse tube cryocooler capable of providing 480 mW @ 15K for the cold stage and 2W @ 80K for the middle stage. These values are raw performances at beginning of life (BoL). The electrical power required is around 300W at compressors level.

Technology

This cooler is based on the pulse tube technology already developed by Air Liquide for the LPTC. The HiPTC is fitted with a double stage cold finger coupled with a linear compressor generating a pressure wave, and an active phase shifter to induce a phase shift in the pressure wave.

Manufacturing capacities

AL-aT can assemble and test this product thanks to its internal means (clean rooms, test benches, etc.)

References

- Development for ESA
- Cold finger was developed in collaboration with the CEA.



Active cooling

Application
120K cooling applications

Size
A few centimeters long for the optical head

Key points

- TRL3
- 0.3W @ 120K

Laser cooling

Description

This system provides cold (up to 120K) by using a laser that impacts a specific crystal. Compared to conventional coolers, this system is vibration-free and offer very high reliability since there is no mechanical part moving.

Technology

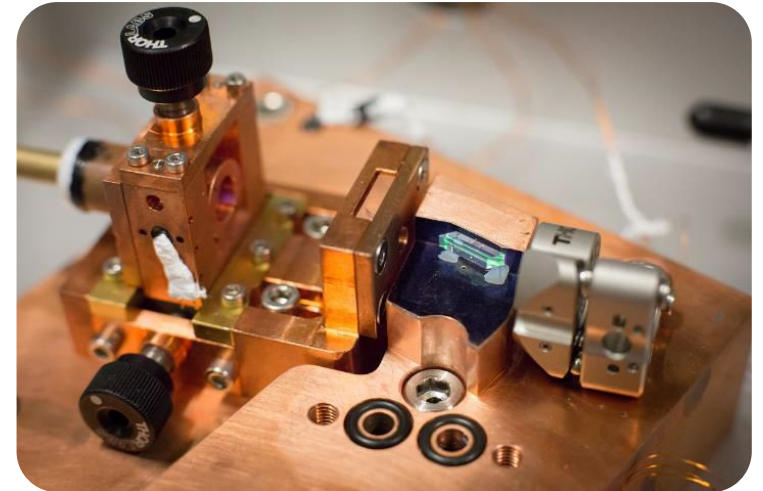
This technology is based on the anti-Stokes shift: a specific crystal is illuminated by a laser source at a specific wavelength. A fluorescence appears in the crystal. The light emitted by the crystal is more powerful than the light coming from the laser: the crystal cools down.

Manufacturing capacities

Air Liquide has some key capabilities and means to produce such a system: especially an ISO 5 clean room. However, some subsystems will have to be procured from external suppliers such as the laser source or crystal.

References

New development.



MELFI - Minus Eighty Laboratory Freezer for ISS - Reverse Turbo-Brayton

Application
Biological sample cooling

Size
TBD

- Key points**
- TRL 9 (TRL4 if new order)
 - 11.2024: in operation in the ISS since 2006
 - 100 W@ -80°C with 900W electrical power

Description

MELFI: Minus Eighty Laboratory Freezer for ISS. It is a space cooler that provides 100W of cold at -80°C in order to store biological samples. This cooler has been developed for the ISS under ESA contract.

Technology

The “Turbo-Brayton” technology consists of having on the same rotating machinery: a centrifugal compressor, a high speed motor, a centripetal turbine (expansion work recovery) mounted on aerodynamic gas bearings.

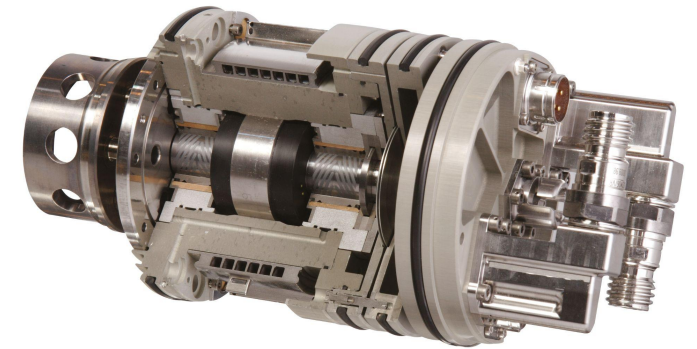
Manufacturing capacities

AL-aT has manufactured and tested all the coolers internally.

References

3 machines delivered to NASA plus 2 spares.

1 flight unit (FU1) installed on July 19, 2006; FU2 on October 2009; FU3 on December 2010. 48 years of cumulative and continuous operation by January 2025.



Ultra-cold systems for astronomical satellites

Application

Observation of Universe Cosmic Microwave Background and galaxies formation in the far IR domain



Mass

< 10 kg dilution
< 150 kg He cryostat



Key points

- 0,6 μ W@ 0,1K
- 10-6 K max fluctuations
- Superfluid He @1,6 K, 4 K & 9 K
- 10-6 max leakage

Description

In May 2009, Ariane 5 launched the PLANCK and HERSCHEL satellites built by ESA, the former to study the early ages of the Universe and the latter to understand the formation of galaxies. While PLANCK-HFI instrument was cooled down to 0,1 Kelvin by a dilution refrigerator, all instruments aboard HERSCHEL were cooled down between 1.6K and 9K by a superfluid Helium cryostat. AL-aT provided both cooling systems, which remained operational 2.5 years for PLANCK and 3.5 years for HERSCHEL.

Technology

This dilution cooler uses a He^4/He^3 isotope mixture cooled to 4 K, which is then pumped by the outer space vacuum, through a 20 μ m capillary heat exchanger. A complex gas management platform was also built by AL-aT.

The superfluid cryostat contains 2400 liters of liquid He^4 . It is pumped by the outer space vacuum, thus reaching a superfluid state at 1.6 K.

Manufacturing capacities

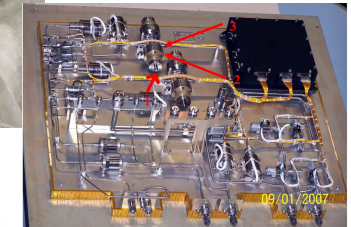
Complete design and qualification of the dilution freezer with its gas management system, superfluid cryostat and optical bench, thermal links and 3 vapor-cooled shields.

References

Successfully flown at the second Lagrangian point of the Earth-Sun system



Dilution refrigerator



Gas management plate



Superfluid Helium tank



Superfluid thermal links

Gas management



Gas management systems

Launcher pressure regulators, electric propulsion, scientific missions

Application
Tank pressurization and gas regulation

Size

- GPR-S: 114mm x 113mm x 87mm
- GPR-M: 216mm x 235mm x 75mm
- GPR-L (Platine): 374mm x 289mm x 254mm
- GPR-L: 180mm x 204mm x 79mm

Key points

- GPR-S: TRL 6
- GPR-M: TRL 7
- GPR-L (platine): TRL 9
- GPR-L: TRL 9

Gas pressure regulators

Description

Our mechanical gas pressure regulator product line is fitted on the propulsion line of a launcher. It is placed between the He HP tank and the propellant LP tanks. The goal of these products is to ensure a good pressurization of the tank.

Technology

Mechanical Gas Pressure Regulator technology. Regulation in single (GPR-S) or dual stage (GPR-M + GPR-L + PRHe). In addition to the pressure regulator, PRHe is composed of a filter, a pressure transducer and check/relief valves.

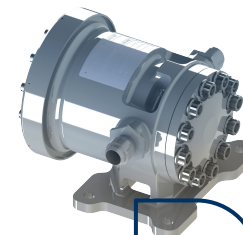
Manufacturing capacities

33 per year in cleanroom.

References

Blue Origin, ArianeGroup (Ariane 5 and Ariane 6), Avio

Small launchers, satellites



GPR-S

Super heavy launcher

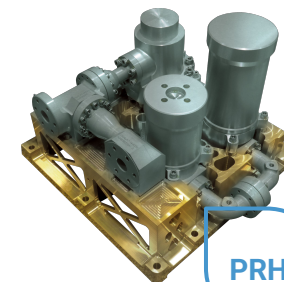


GPR-L

Kick-stage / heavy launcher



GPR-M



PRHe

	GPR-S	GPR-M	GPR-L / PRHe
Stage	Single stage	Double stage	Double stage
Mass flow rate	4g/s	22.5g/s (6.5g/s to 29g/s)	0.5g/s to 170g/s
Upstream pressure	31.4 ± 0.6 bar	20.74 ± 0.65 bar	41 to 49 barA
Mass	< 1.7kg	< 5kg	< 9kg / < 19kg

Application

Loading Carts for Electric Propulsion satellite gas loading

Key points

CE/ASME

- Operating simplicity / easy to operate
- Good transportability / easy to move
- Easy to maintain
- High level of purity
- Minimum loss of gas during the filling
- Mass filling accuracy

Loading carts

Description

Product dedicated to EP propellant satellite loading (in Xe and/or Kr).

A small loading cart is dedicated to low flow rate (1g/s) and to load LEO/MEO satellites (<100kg per satellite).

The large loading cart is dedicated to high flow rate ~10 to 15 g/s and to load GEO satellites (>100kg per satellite).

Technology

The small loading cart is based on three modules: the first one is the gas management module, then a membrane compressor and a vacuum and analysis module.

The large loading cart is based on a cryogenic compressor (fully integrated). This product was developed by the past (>15yr ago) and some further development activities needs to be done before another production batch.

Manufacturing capacities

Up to 10 per year.

References

Airbus OneWeb, SITAEL



Application

Gaseous chromatography for scientific missions

Size

- MLV: 2cm x 1cm x 1cm
- Equipped sphere: 7cm in diameter

Key points

- TRL7
- Operating media: He
- Internal/external Leakage: 10⁻⁷ mbar/L.s GHe
- Response time: 20s
- Electrical consumption: 3W

Scientific missions regulation kit

Description

Scientific missions generally need having several analysis systems based on a Gas Chromatograph (GC) coupled with a mass spectrometer (LD-GC-MS), to search for and identify a wide range of organic compounds and potential biosignatures in atmospheric and soil samples.

The equipped sphere allows to feed the whole instrument with GHe. The MLV aims to direct the flow of helium into the lines of the equipment.

Technology

200g titanium micro-sphere for inert gas (He, Xe, Kr, Ar) storage associated with a thermal valve.

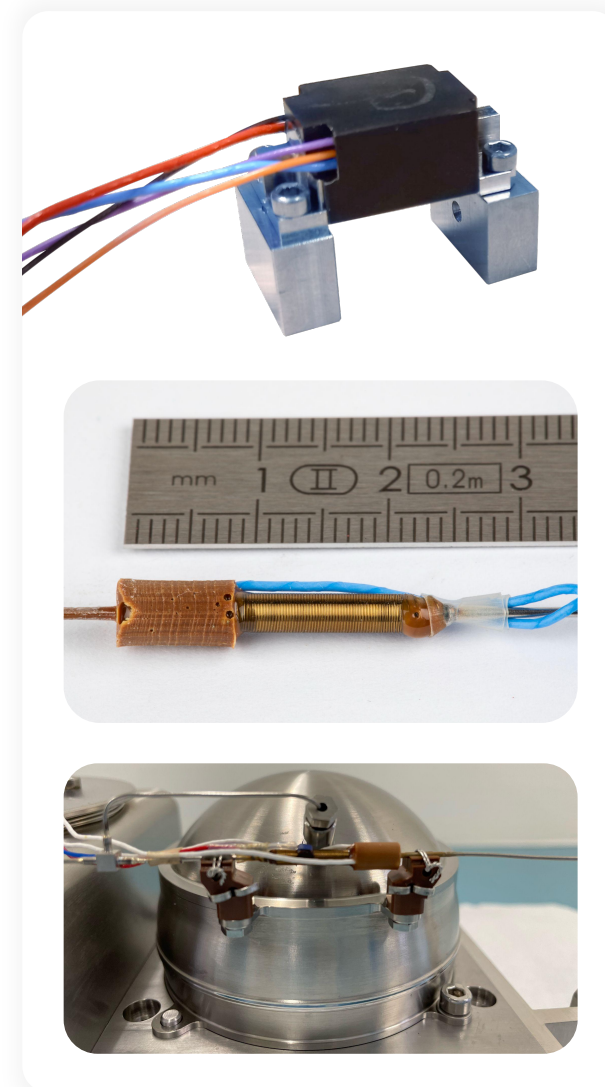
Miniature latching valve is He compatible operating with current (on/off) magnetic latching valve to regulate He flow (100mL/min)

Manufacturing capacities

NA, some units per years.

References

- MLV valve developed with the ExoMars mission for the MOMA (gaseous chromatography) in 2016.
- DragonFly mission (currently in production) in partnership with CNES/LATMO (application for gaseous chromatography).



Krypton and Xenon propellants

Application
Electric propulsion satellites, lab testings

Size
From small cylinder (0,4L equivalent water) to large ones (50L e.w) and even to bundles for Kr

Key points
TRL7

- Operating media: He
- Internal/external Leakage: 10-7 mbar/L.s GHe
- Response time: 20s
- Electrical consumption: 3W

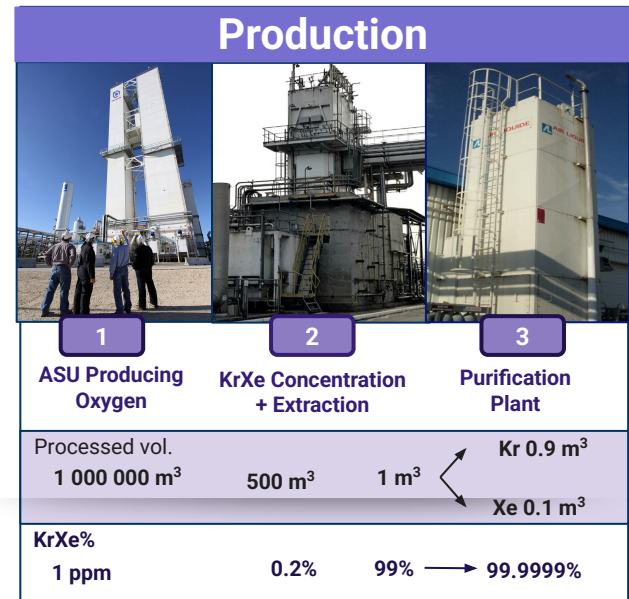
Description

Kr and Xe are used as propellants for small to large satellites and are extremely rare gases.

KrXe sourcing

KrXe are extracted together from very large oxygen ASUs and go through several steps before being delivered to customers with the requested grades of purity.

Due to its international geographical footprint Air Liquide has a multi-countries sourcing relying on Air Liquide ASUs worldwide + 2 purification plants, one in France and the other one in South Korea. This management of the entire supply chain allows Air Liquide to provide large volumes and ensure a seamless experience for its customers



Energy management



Fuel cell systems, RFCS

PEM (Proton-Exchange Membrane) fuel cell stack C50

Application
Primary source of energy

Size
20 x 15 x 10cm

Key points
TRL5 (ongoing development)

Electrical power ranging from 200 W to 6 kW

Description

Carbon stack, 50 cm², 0.2 to 6 kW
Dual oxygen/air – stationary & light mobility

Technology

Proton-Exchange Membrane (PEM)

Manufacturing capacities

Stack assembly

References

CNES



Configuration

# of cells	Air		Oxygen	
	10	60	10	60
Power (kW)	1	4	1	5
Voltage (V)	6	36	6	36
Volume (L)	1.28	2.82	1.28	2.82
Weight (kg)	1.42	3.03	1.42	3.03
Width x height (mm)	180 x 76			
Length (mm)	94	206	94	206
Cell pitch (mm)	2.25			

Calculated with cell volume only (0.65 V, 1 barg, air stoich 1.5, 65°C, 40% RH).

Application
Lunar night survival

Size
Contact us

Key points
TRL5 (ongoing development)

130W electric output energy

Regenerative Fuel Cell System

Description

RFCS (Regenerative Fuel Cell System) is a promising solution for energy storage and heat generation during lunar night survival. It offers high specific energy density, produces heat as a byproduct, and can be integrated with life support and resource utilization systems. RFCS is seen as a key enabling technology for lunar and Martian exploration, offering advantages over traditional batteries and serving as a potential alternative to nuclear reactors.

Technology

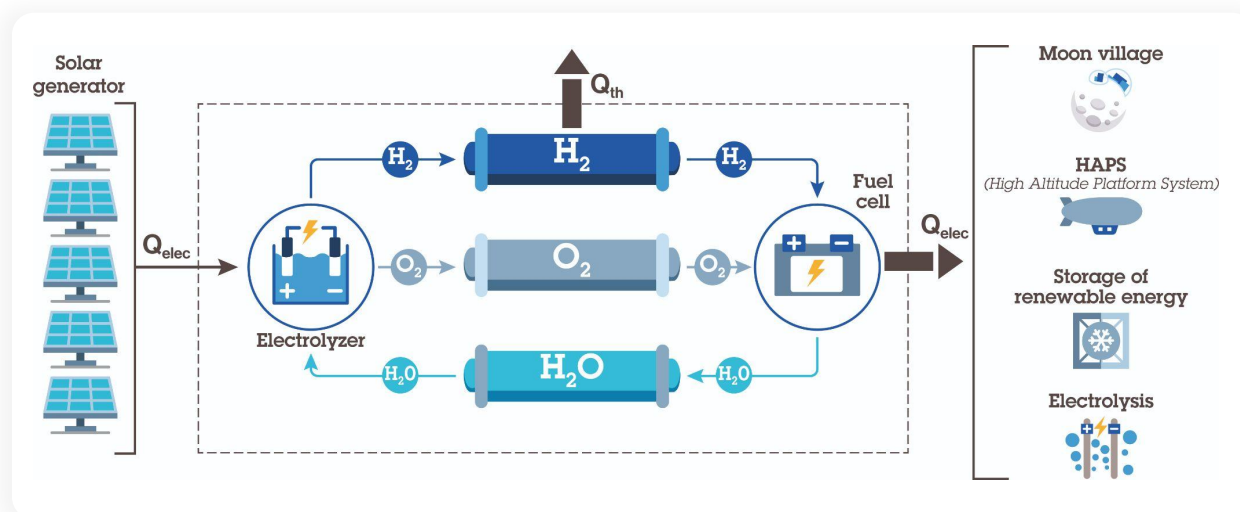
RFCS technology works by using a closed-loop process of water electrolysis and fuel cell energy generation. During lunar day, an electrolyzer splits water into hydrogen and oxygen using solar energy. During lunar night, a fuel cell recombines the stored gases, producing electricity and heat.

Manufacturing capacities

AL-aT key competencies are focused on the fuel cell and system integration.

References

CNES, ESA



Ground systems



Launchpads

Hydrogen, oxygen and helium liquefier

Application

Launchpad for launcher propellant production

Key points

Decades of experience and a proven track record in delivering H₂ and He liquefiers, and Air Separation Units.

Description

Liquefiers for storage or recovery systems.

Technology

- Hydrogen liquefaction plant up to 50 tpd
- Methane / biogas standard liquefier
- Air separation units for LO_x / LIN production
- Utilities: Liquid Helium, Helium, Nitrogen, air

Manufacturing capacities

COTS equipment or tailor-made.



Application
Launchpad facilities

Key points
Decades of experience and a proven track record in delivering launchpad systems.

- Last in date, ELA4:
- 2km of cryogenic distribution lines
 - More than 500 components
 - More than 100 interfaces with storage tanks, launcher and utilities

Description

- Production and delivery of fluids (LIN, GN2, GHe, air) and propellants (LH₂, LOx)
- Design, manufacturing of cryogenic lines for launchpads
- Exploitation and maintenance of cryogenic assets

Technology

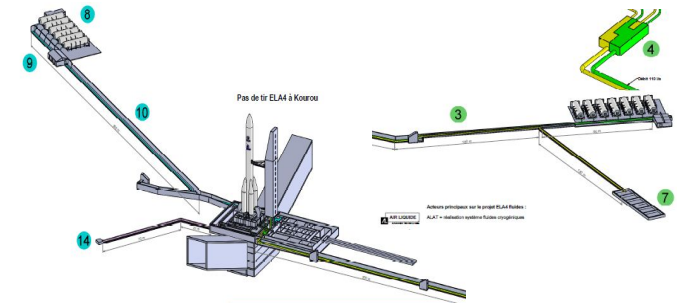
- He boil-off recovery system of LHe fixed storage tank
- All cryogenic and gas ground support equipment
- Safety of operators and equipment during launching campaigns
- Contribute to campaign duration optimization
- Maximize yearly launch rate
- Reduction of maintenance time
- Efficiency of propellant supply chain
- Draining and refilling capability for launch abort
- Reduction of propellant losses from production to launch sequence

Manufacturing capacities

On demand product specifically developed for customers.

References

- Ariane Group, CNES, NASA, JAXA
- Ariane 6 (ELA 4)



Competences

A large industrial facility, possibly a research or production plant, is shown in a grassy field. The facility features a prominent tall, multi-level metal structure with a complex network of stairs and walkways. To the right, there is a smaller structure with a tall, narrow chimney-like element. In the background, a rainbow arches across the sky, and mountains are visible under a blue sky with white clouds. A large white circle is overlaid on the image, partially obscuring the sky and the rainbow.

Technology development
competences



Maturity

60 years of Cryogenic test experience



Application

Liquid and gaseous He, H₂, O₂, N₂, CH₄



Capacity

~30 people

Test center

Description

A 3-hectare test area is located on ALaT site to support developments. It offers many possibilities:

- Large on-site LH₂ storage capacity. If needed, multiple LH₂ trailers operation authorization.
- Liquid H₂ test and qualification areas (pumps, couplings, breakaway, liquid dispensers, ...)
- Gaseous H₂ test and qualification area (medium and high pressure compressors, complete HRS)
- Cryogenic mechanical lab to study material behaviour under cryogenic hydrogen atmosphere. Traction test up to 250 kN can be proposed
- Electrochemistry lab dedicated to fuel cells and electrolysis tests
- HRS component qualification

Main features

- A specialized technical team of 30 people is dedicated to the operation of this test area



Technology development competences



Maturity

From TRL1 to TRL3



Application

Space, Energy, Aeronautic, H2,...



Certification

Prototyping only



Capacity

- Machining
- Design
- 3D printing
- Electronics
- System Engineering

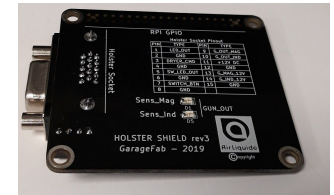
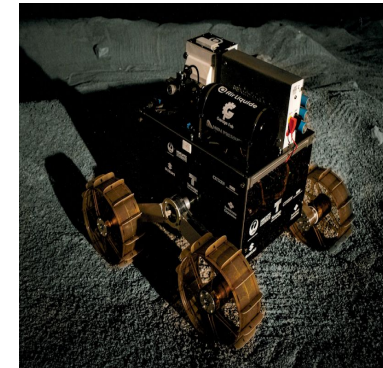
Garage Fab

Description/Competencies

Team and resources dedicated for prototyping any part or complete systems. Our competencies: creativity, system engineering, CAD, mechanics, welding, composite materials, machining, 3D printing, electronics, programming (embedded and softwares), virtual reality simulations.

Resources

- Machining: drilling, milling, CNC machining, 2 lathes, 3D printing (9 FDM, 3 SLA), laser cutting (wood, PMMA), water cutting...
- Welding: 2 TIG, 1 MIG
- Electronic: infrared reflow oven, 2 soldering stations
- Virtual Reality: 2 VR headsets for development and simulation meetings
- Team: 3 dedicated engineers
- Workshop: 380m²



Design Thinking



Empathize



Define



Ideate



Prototype



Test





Application

Cryogenics (He, H₂, air and rare gases), mobility, space, biogas



Key points

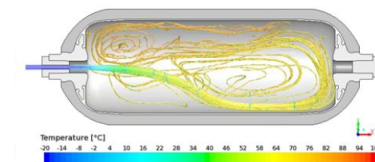
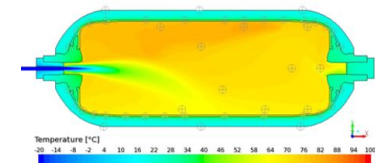
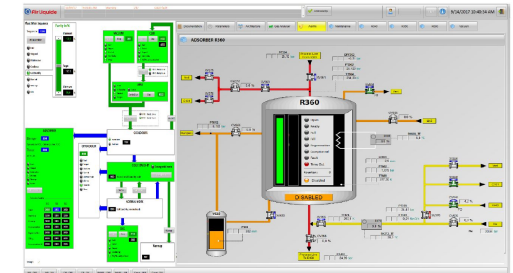
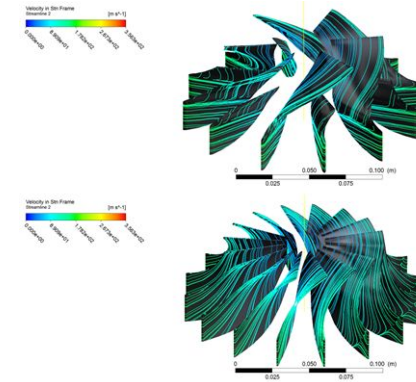
- From TRL1 to TRL9
- 50 engineers and technicians

Description

Since our advanced products and technologies demand a broad range of competencies, skills, and expertise, we have a dedicated department to support project and product engineering and management.

Main features

- **Process calculation:** we handle both steady and transient state calculations using tools like ASPEN HYSYS, ECOSIMPRO, EDR, and SIMULIS.
- **Computational Fluid Dynamics (CFD):** our CFD capabilities range from 0D to 3D, covering steady and transient analysis. We utilize Ansys Fluent and CFX, OpenFoam, TurboGrid, Icem/Meshing, BladeGen, DesignModeler, Vista TF/RTD, and custom scripting with Excel, VBA, Python, Fortran, C, and C++. Our simulations are correlated with 30 years of cryogenic test data.
- **Design and mechanical calculation:** we employ Solidworks, Draftsight, ShemPID, and FEA for design and mechanical calculations, adhering to worldwide construction codes (including EU, US, KR, CN, and JP).
- **Command control:** our expertise includes Siemens automation TIA Portal for control, safety, and WINCC systems.
- **Expertise:** we possess deep knowledge in materials, welding engineering, and regulatory compliance.





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