

TIME TO BOOST LIQUID HYDROGEN

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ARIANEGROUP

50/50

JOINT VENTURE BETWEEN AIRBUS & SAFRAN

9.000

EMPLOYEES IN FRANCE & GERMANY

ACCESS TO SPACE



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40 YEARS ARIANE.
40 YEARS HYDROGEN.



1979
ARIANE 1



1986
ARIANE 2



1984
ARIANE 3



1988
ARIANE 4



1996
ARIANE 5

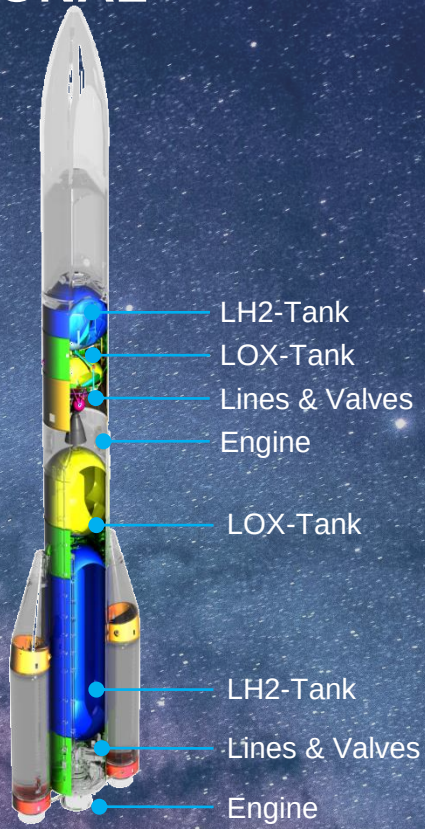


2022
ARIANE 6

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ONE ROCKET AND ITS LAUNCH PAD COMBINE ALL RELEVANT HYDROGEN COMPONENTS OF AN OPERATIONAL LH2 MOBILITY SYSTEM





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WE UNDERSTAND CRYOGENIC HYDROGEN CHALLENGES

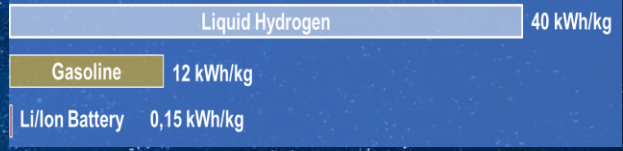


Cryogenic (-253°C)



Sloshing & thermo-dynamic control

High energy density





Small molecule, low density
→ large, tight & insulated cryogenic tanks



Thermal conditioning and tight transport
Cryogenic equipment



Combustion and transformation into mechanical power

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ARIANEGROUP: ACCELERATING THE TRANSFER TO HEAVY MOBILITY AND THE ASSOCIATED INFRASTRUCTURES

SPACE IS NOT THE LIMIT

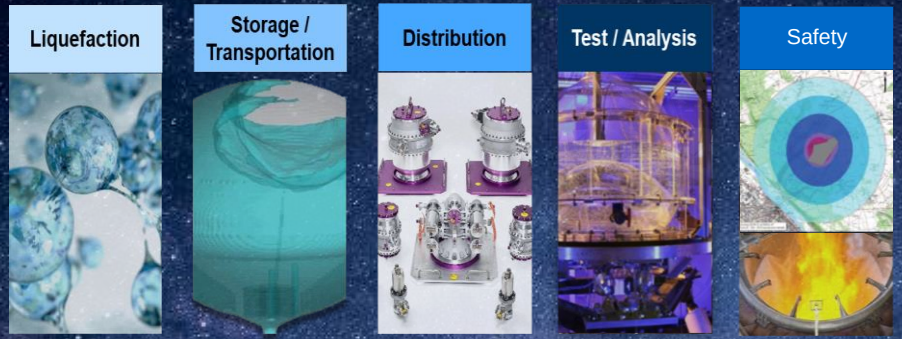


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ARIANEGROUP: A UNIQUE KNOW-HOW IN LIQUID HYDROGEN

An End-To-End system knowhow along the complete hydrogen value chain

Competencies transferable from Space



Ground infrastructures

Development of infrastructures for the management of GH2 and LH2



Equipment & Subsystem

Adaptation of equipment developed for space to heavy mobility



Services & Engineering

Hydrogen tests and material characterization for heavy mobility and engineering activities



LIQUEFACTION CONCEPT

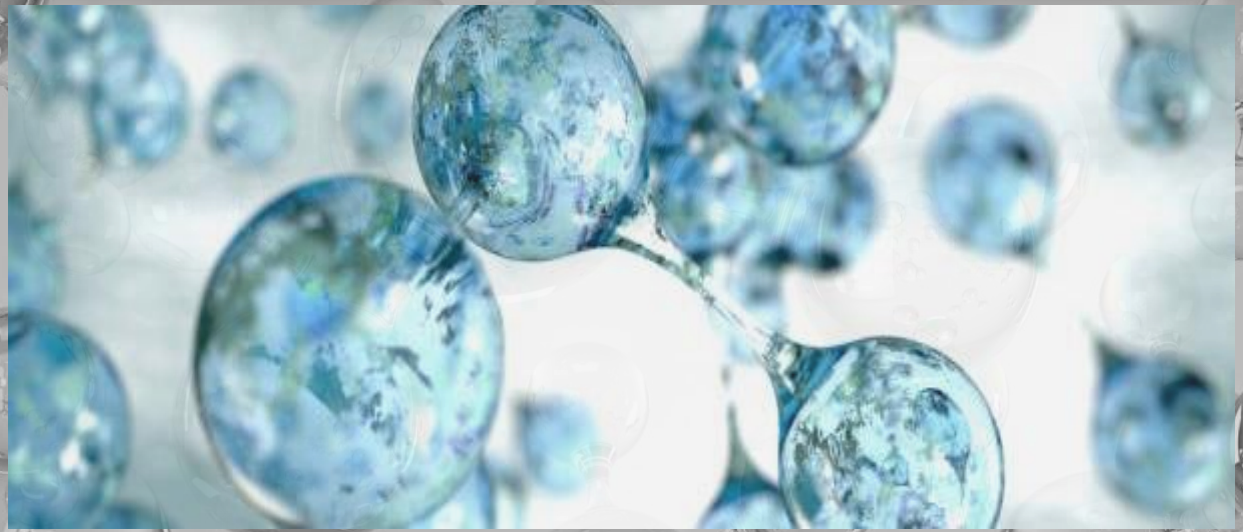
Liquefaction | Storage / Transportation | Distribution | Application | Test / Analysis

PARTNERSHIP IN KOUROU

KNOWHOW REFUELLING CRYOGENIC FLUIDS

COOPERATION WITH ENERGY PROVIDERS

LH2 PRODUCTION
SEVERAL TONS/DAY



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SYSTEM KNOWHOW – COMPLEX TANK SYSTEMS

Liquefaction | **Storage / Transportation** | Distribution | Application | Test / Analysis

LIGHTWEIGHT CRYOGENIC TANKS (CARBON FIBRE & METALLIC)

SLOSHING & FLUID CONTROL DURING TRANSPORT

AUTOMATED EXTERNAL THERMAL INSULATION

PROPULSION SYSTEM MODELLING & SIMULATION



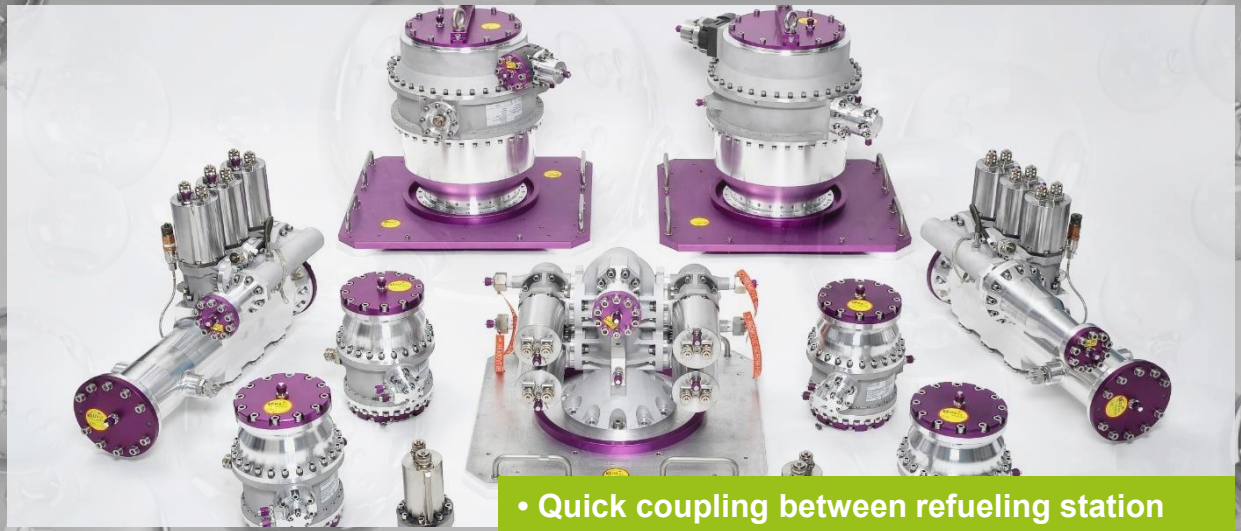
- Reduce LH2 Boil Off and recover the fatal GH2
- Analyze ROI of boil off management system
- Design the storage and distribution architecture
- Contribute to design a safe storage system
- Design the H2 fatal management systems
- Optimize fuel system footprint by design while maintaining safety requirements

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SYSTEM KNOWHOW – DISTRIBUTION & CONTROLLING

Liquefaction | Storage / Transportation | **Distribution** | Application | Test / Analysis

- ISOLATED LINES, VALVES & INJECTION SYSTEMS
- ADDITIVE MANUFACTURING 3D-PRINTING
- GASEOUS, CRYOGENIC & 2-PHASE-FLOW
- ELECTRICAL PUMPS



- **Quick coupling between refueling station and heavy truck/ship/aircraft… (including emergency release)**

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SYSTEM KNOWHOW – COMBUSTIONS SYSTEM

Liquefaction | Storage / Transportation | Distribution | **Application** | Test / Analysis

- ENGINE DEVELOPMENT & MANUFACTURING
- PHYSICAL LIMITS W.R.T. THERMAL & MECHANICAL STRESSES
- ADDITIVE MANUFACTURING 3D-PRINTING
- MATERIAL (BRITTLENESS & SEALING-CONCEPTS)



- Design and supply complete LH2 system
- Training and operation support

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TEST KNOWHOW – TEST INFRASTRUCTURE

Liquefaction | Storage / Transportation | Distribution | Application | **Test / Analysis**

HIGH PRESSURE COMBUSTION TESTS

DETAILED DATA ANALYSIS & PROCESS-CONTROLLING

FEASIBILITY STUDIES

SIMULATION & MODELLING



- **Test and qualify LH2 on board system and fuel system**
- **Risk analysis**
- **Safety analysis**
- **Define requirement for data link equipment to bunkering control command system**

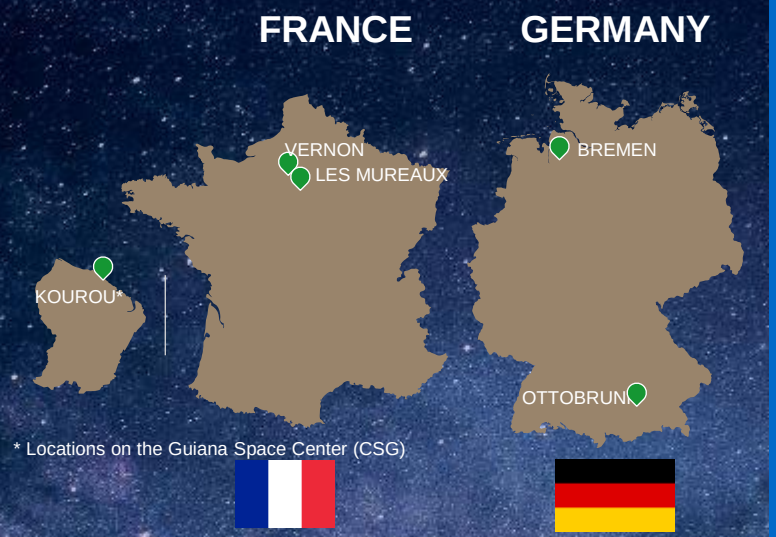
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LOCATIONS FOCUSING HYDROGEN KNOW-HOW

Vernon
Cryogenic (LH2, LOX, LHe, LN2, …) infrastructure:
- Test bench (design, operation, …),
- Cryogenic fluid management

Test campaign management
Ground-Board Connection
On board cryogenic systems inc.:
- Pump
- Feeding system
- Control, Diagnostic & Regulation System
- Auxiliary Power Unit
- Turbomachinery, …

Les Mureaux
Cryogenic infrastructure (launch pad)
Cryogenic tanks
Onboard fluid management
Launcher system, …



Bremen
Cryogenic tanks
Onboard fluid management, …

Ottobrunn
Valves
Thrust chamber
Gas generator, …

Kourou
Cryogenic fluid management
Final launcher integration

Crosscutting tools, means & services
- Technical customer support team
- Simulation tools
- Expertise on material properties in hydrogen environment with a dedicated laboratory
- Post test & post failure expertise with a dedicated team
- Metrology for on board and infrastructure measures with experience for cryogenic fluid
- 3D printing for complex metal parts
- …

TEST AREA IN NORMANDY



TEST BENCH VINCI® (PF52)

Zone K

Zone J

Zone H

Zone P

Zone G



TEST BENCH VULCAIN® (PF50)



TEST BENCH HM7 (PF41)



TEST BENCH BCLH2



HIGH PRESSURE COMBUSTION TESTS & SIMULATION MODELLING

Storage capacity LH2 > 1000 m3 = 70 Tons
Refuelling center LH2 > 4000 m3 / year
Distribution network H2 200 Bar – 80 m3 – Station 800 Bar

SEVESO site



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