Graphene Loop Heat Pipes for Thermal Control in Space Missions

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LEONARDO
AIRBORNE & SPACE SYSTEMS

Our Business

Leonardo is a global company in the high technology sector, and is one of the key actors in Aerospace, Defence and Security worldwide. We operate through:

DIVISIONS

- **Helicopters**
- **Aircraft**
- **Aerostructures**
- **Airborne & Space Systems**
- **Land & Naval Defence Electronics**
- **Defence Systems**
- **Security & Information Systems**

SUBSIDIARIES AND JOINT VENTURES

- **DRS Technologies** (100% Leonardo)
- **Telespazio** (67% Leonardo and 33% Thales)
- **Thales Alenia Space** (67% Thales and 33% Leonardo)
- **MBDA** (37.5% BAE Systems, 37.5% Airbus Group, 25% Leonardo)
- **ATR** (50% Leonardo and 50% Airbus Group)

AIRBORNE & SPACE SYSTEMS

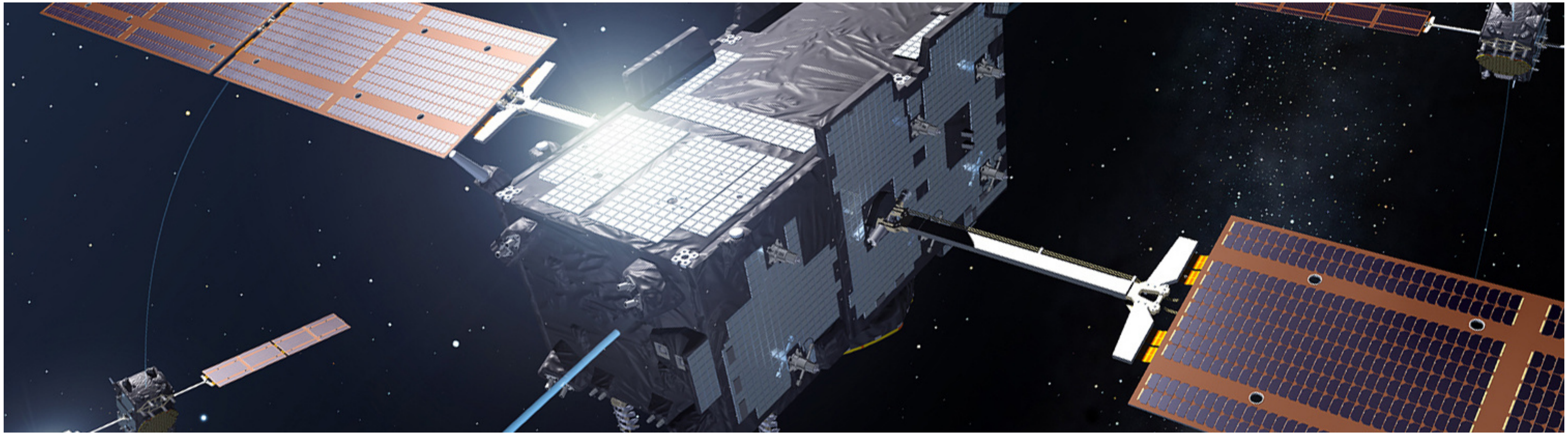
The **Airborne & Space Systems Division's** wide range of products and solutions includes:

- **integrated mission systems** (such as ATOS-Airborne Tactical Observation and Surveillance, for manned platforms).
- **radars and sensors** (such as the multi-mode Seaspray radars family, based on AESA technology (Active Electronically Scanned Array) and the Gabbiano radar family, based on advanced mechanically scanning array antenna.
- **electronic warfare systems**
- **aerial target systems**
- **simulation systems**
- **on-board avionics** and **CNI**
- **remotely piloted aircraft systems** (Falco), also offered through full service contracts.
- **space systems that include sensors, mission payloads and advanced robotic systems.**
- **ISTAR** solutions (Intelligence, Surveillance, Target Acquisition & Reconnaissance), based on integrated and agnostic architectures.

SPACE SOLUTIONS

SPACE MANUFACTURING

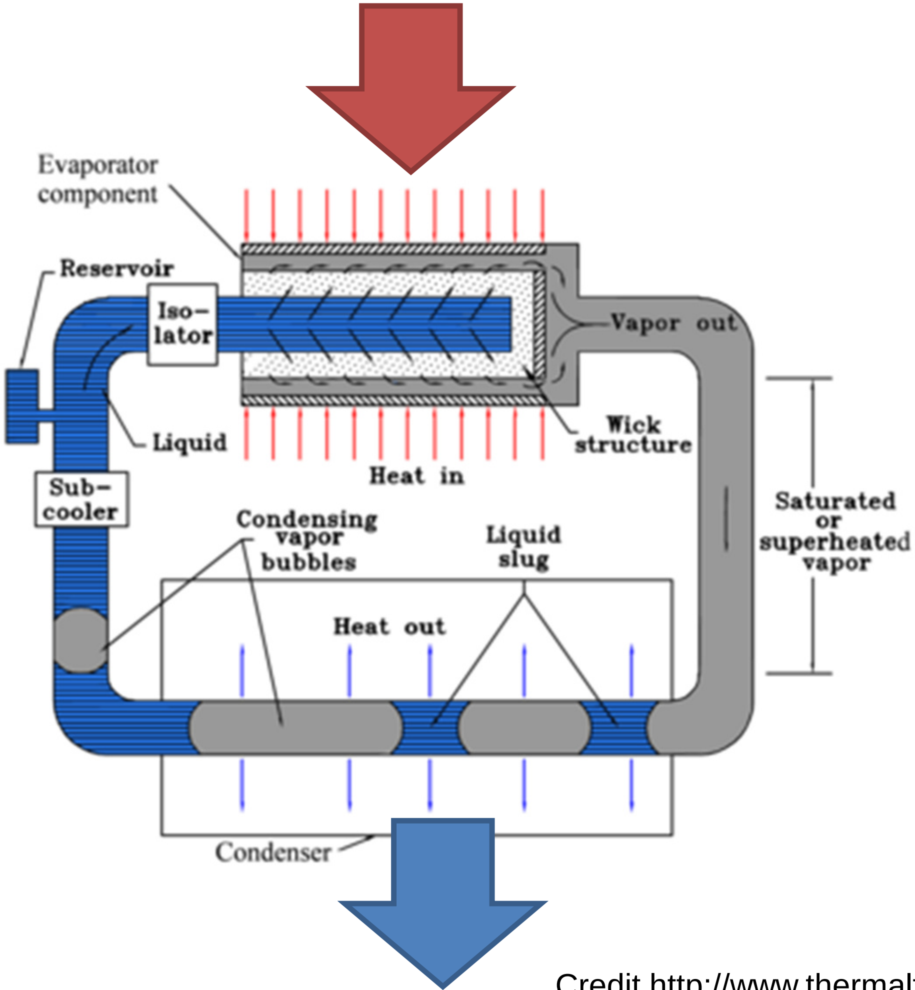
SATELLITE SYSTEMS | GROUND SEGMENT | SPACE INFRASTRUCTURES | SATELLITE EQUIPMENT & PAYLOADS



SPACE SERVICES

GEO INFORMATION | SATELLITE SYSTEMS & APPLICATIONS | SATELLITE OPERATIONS | SATCOM

Loop Heat Pipes

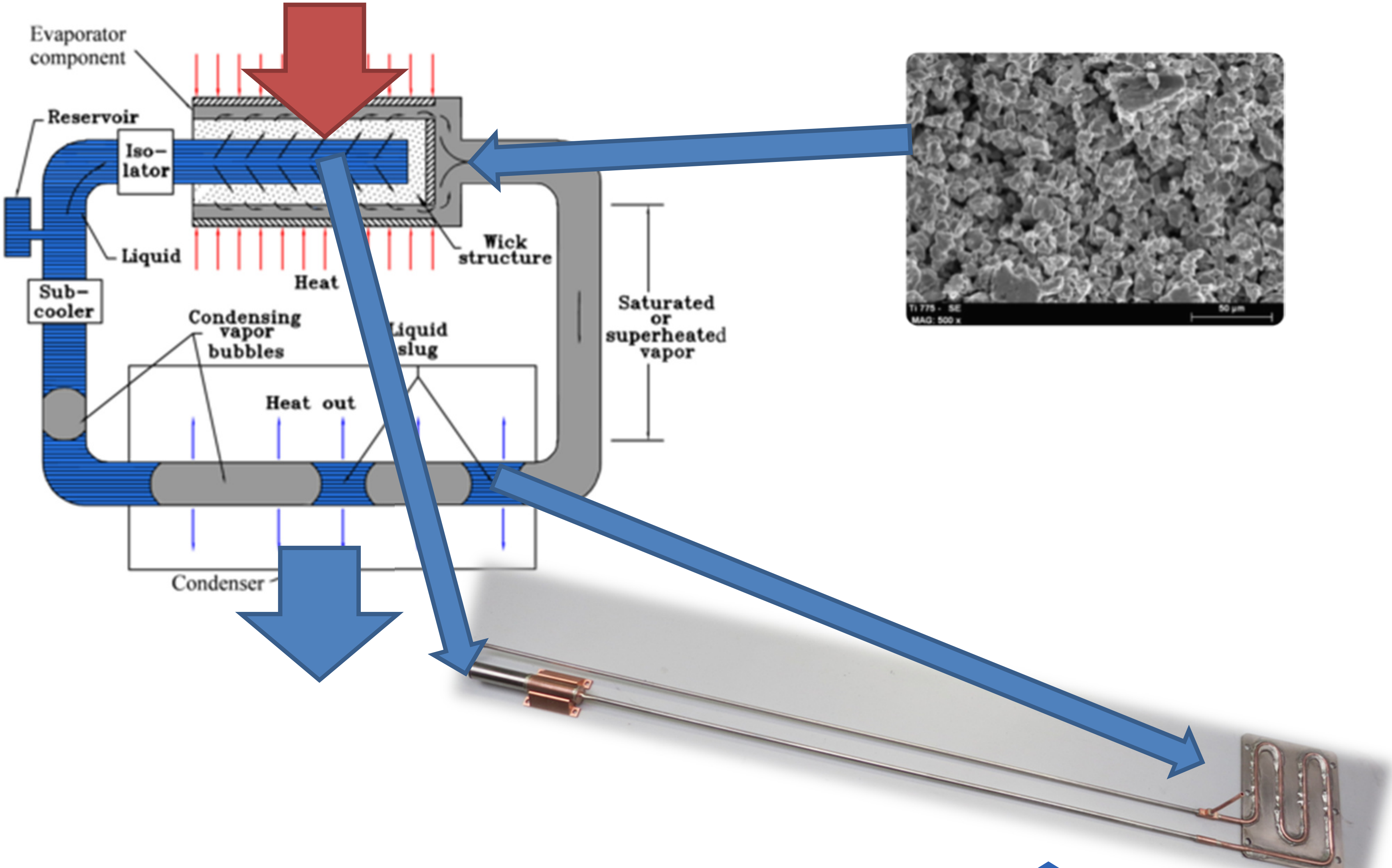


Credit NASA

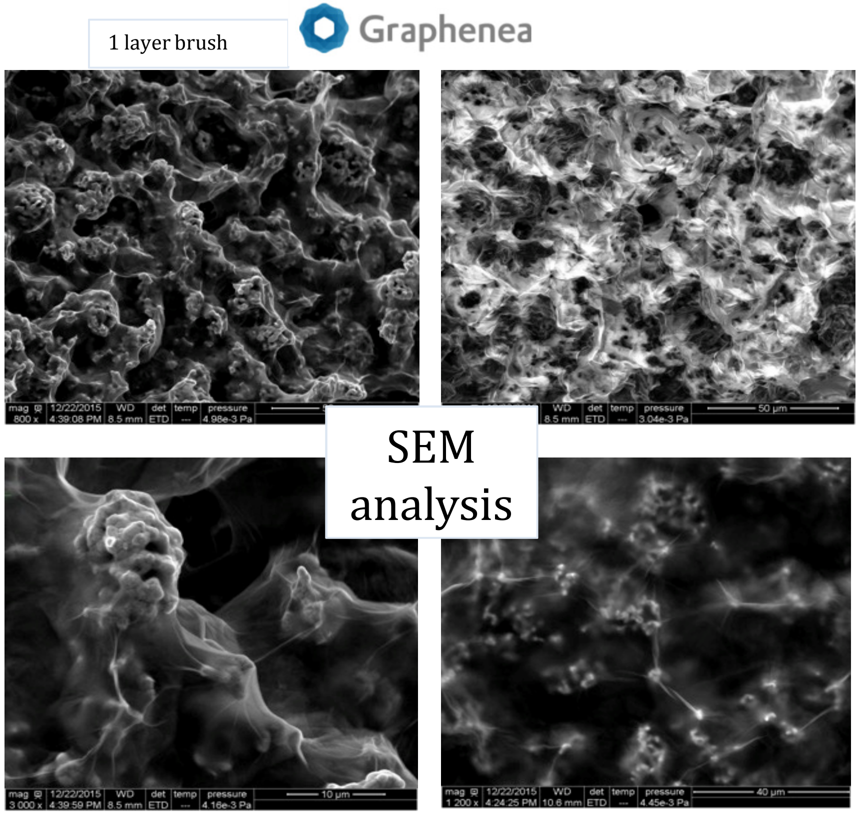
Credit http://www.thermalfluidscentral.org

LHP demonstrator (0.5 m long)

LHP in space: a first demonstrator (2015-16)

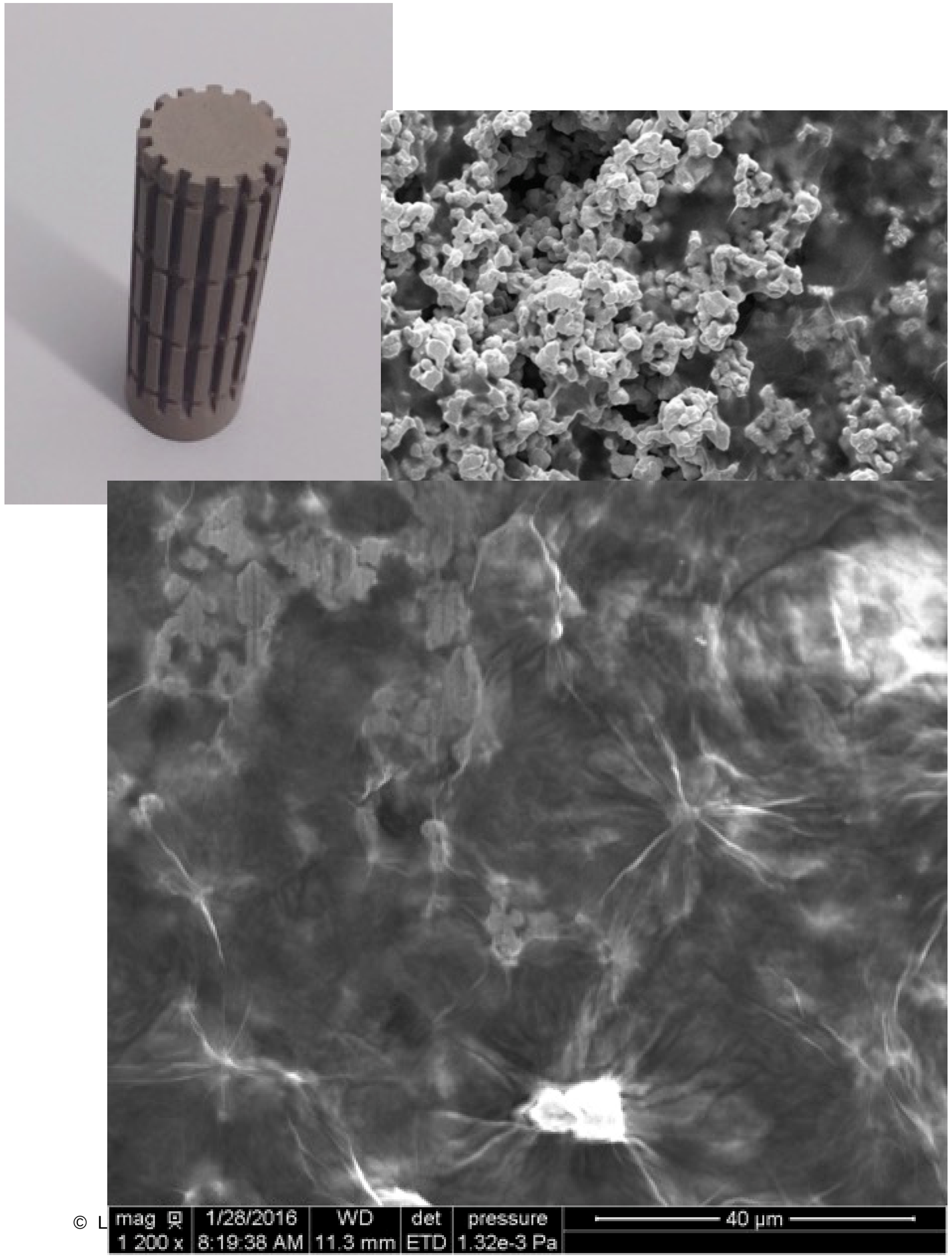


Ni wick coating with GO



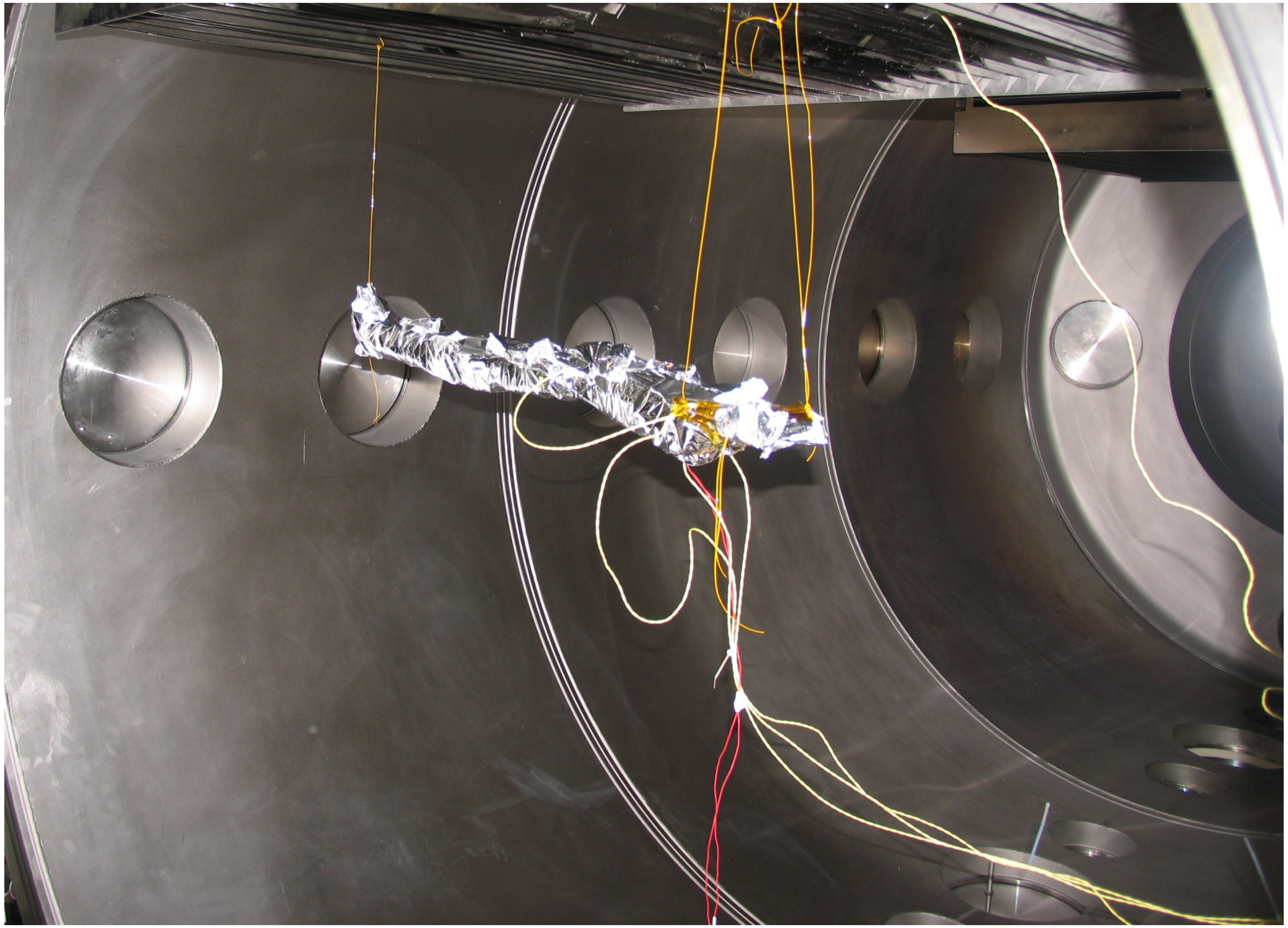
PROPERTIES

Wettability, thermal conductivity, porosity of Graphene play a role in the capillary action enhancement

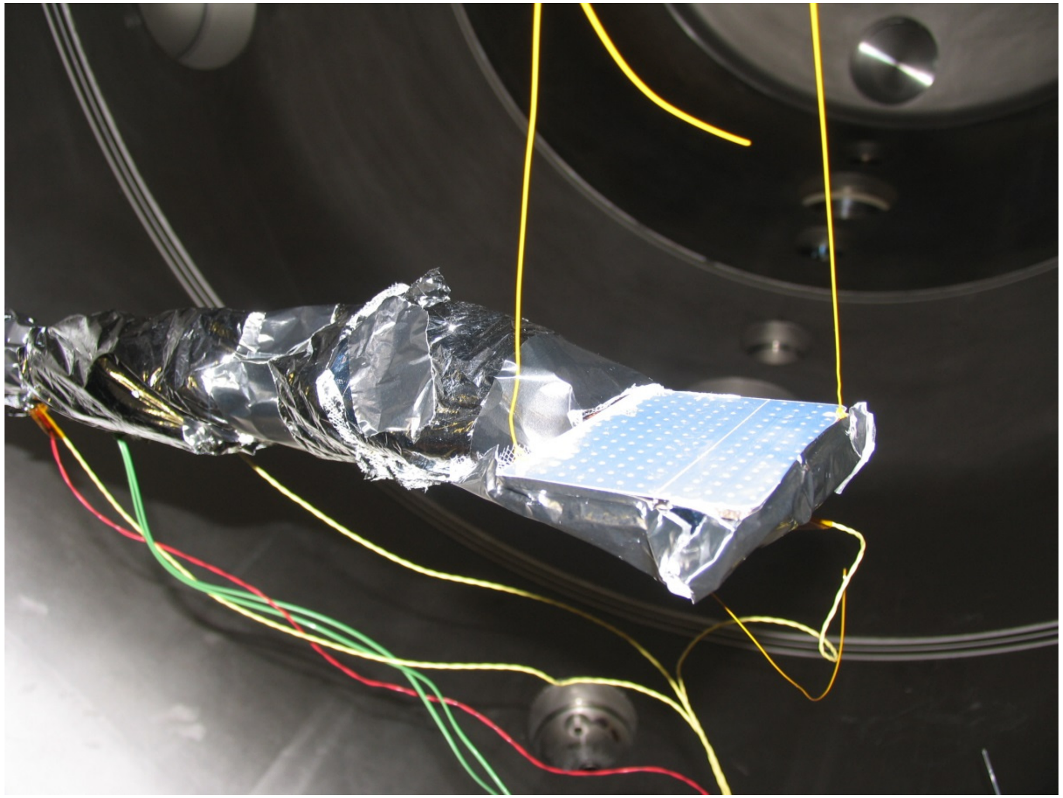


- *Increased wettability, that means the LHP is ready to start because the porous structure is wet;*
- *Smaller pore size of the graphene layer (Nano-meter range) compared to sintered metal structures, that have pores diameters in the 1-10 micron range;*
- *Increased local thermal conductivity, which helps transferring heat from the source, located outside the sealed shell, to the capillary pump inner bore, where fresh cooling fluid, in liquid phase, arrives from the condenser ready to evaporate.*

Space Simulator with LHP installed



Detail of the Condenser



Operational procedure for steady state tests

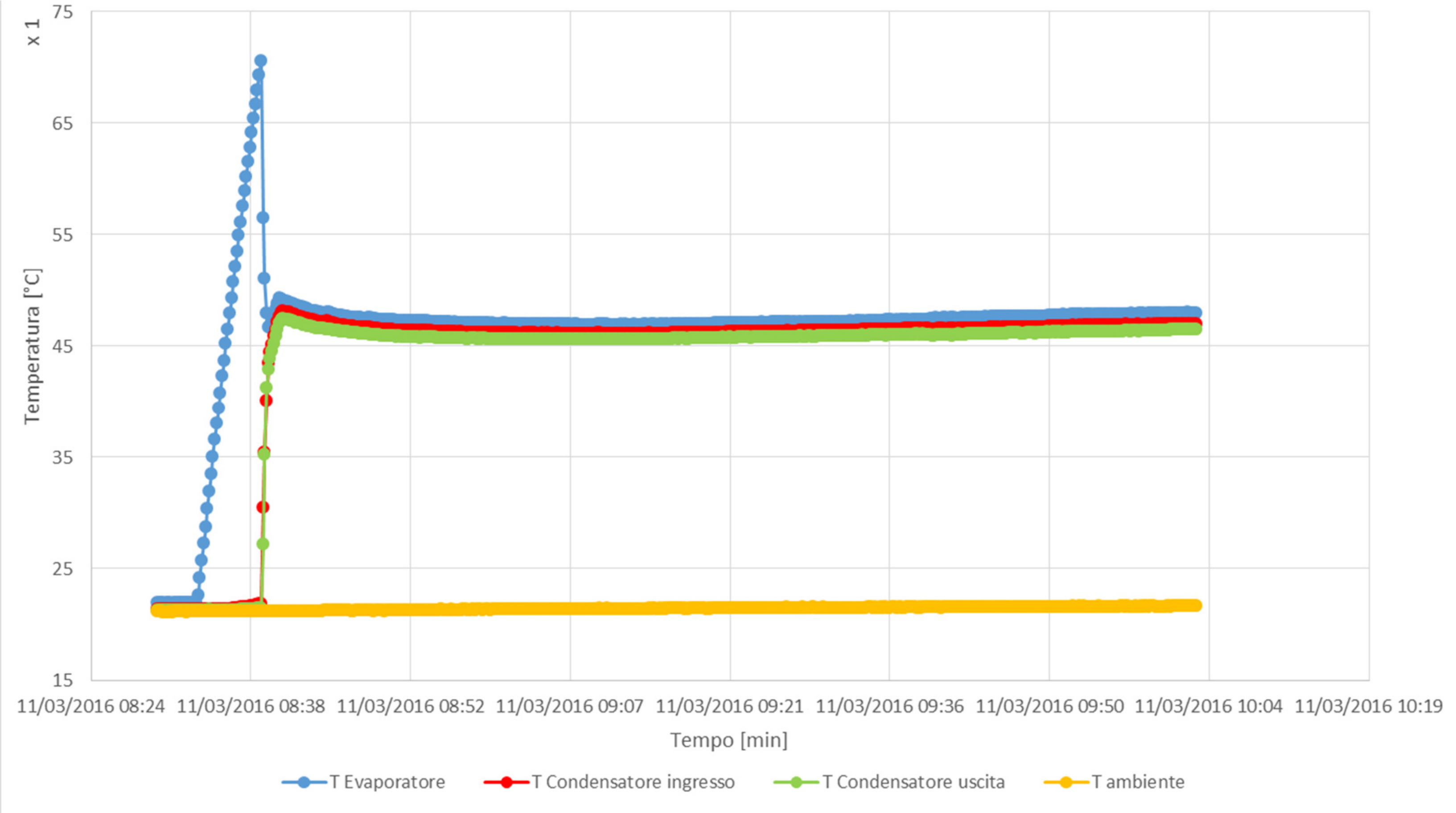
- Evacuate chamber (10-6 mbar)
  - It takes ~3 hours

- 10 W startup power

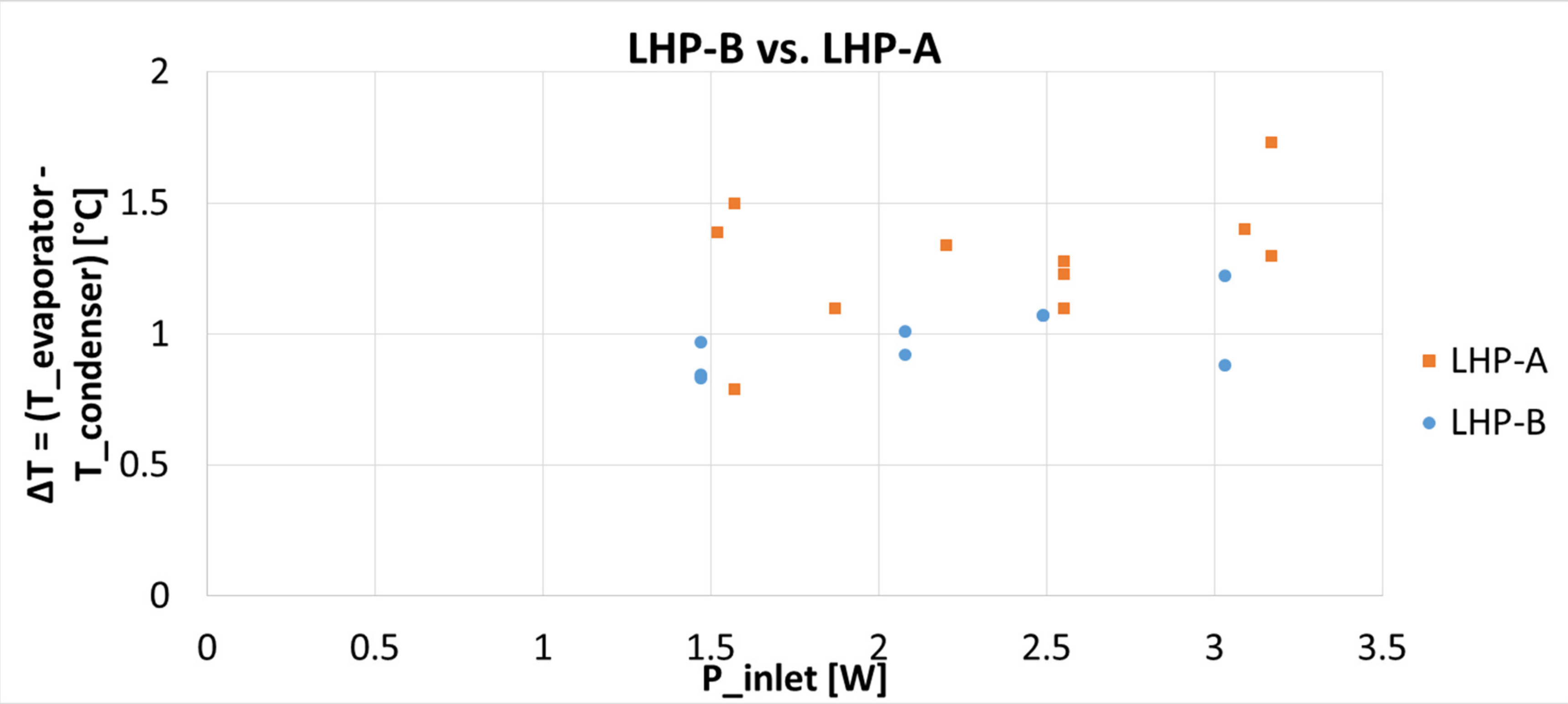
- Power steps of 1.5; 2.0; 2.5; 3.0 [W]

- **Stabilization criterion =** $\frac{dT}{dt} < \frac{1°C}{1\ h}$

Example: 10 W, then 1.5 W

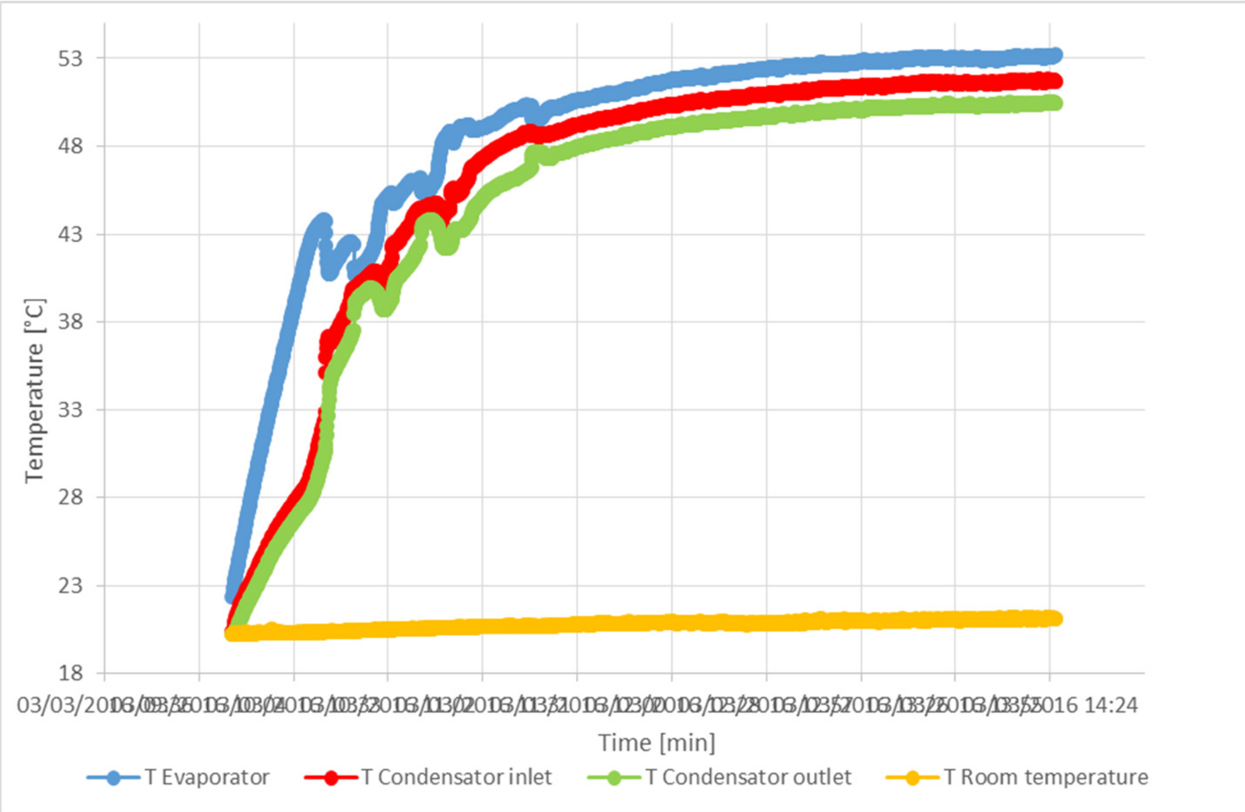


LHP A(=Ni) vs. LHP B (=Ni+GO) : ΔT comparison

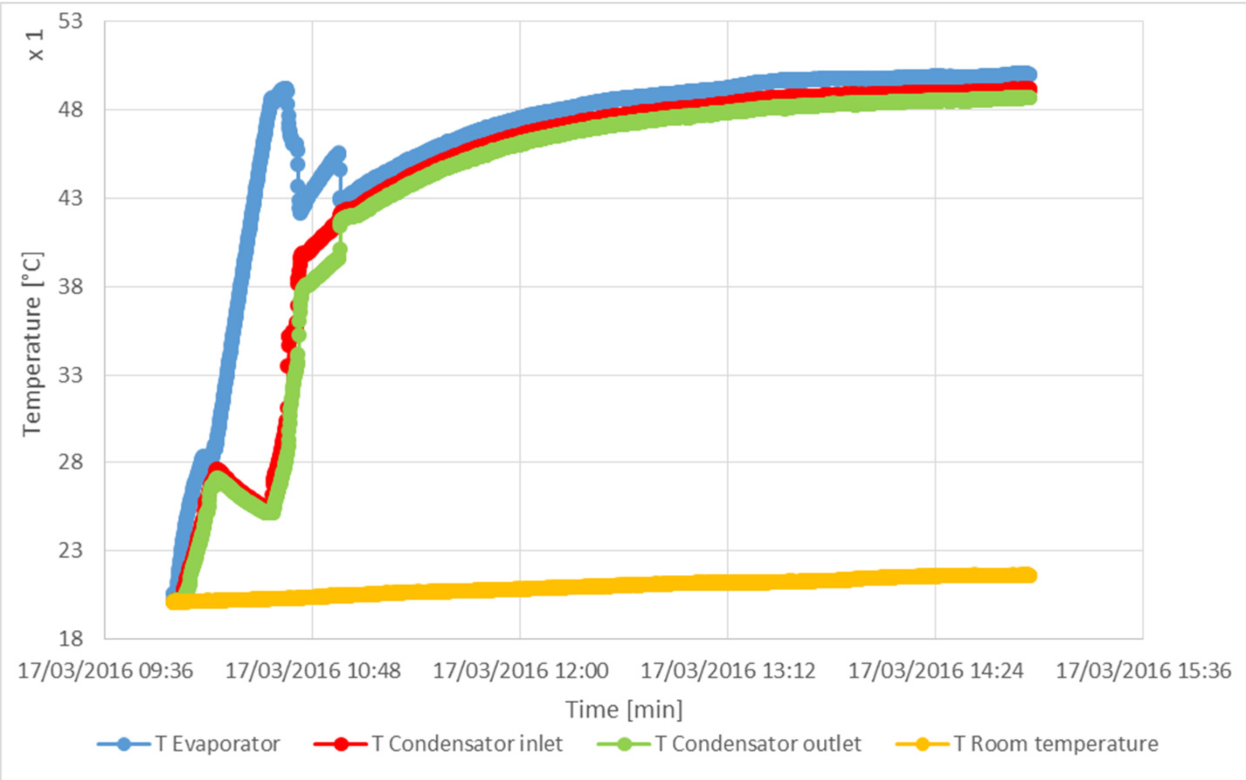


TRANSIENT TESTS - STARTUP

Ni LHP


Temperature [°C]
53
48
43
38
33
28
23
18
Time [min]
T Evaporator
T Condensator inlet
T Condensator outlet
T Room temperature

Ni+Graphene Oxide LHP



SHARPER
Start-up at low power

ROADMAP TOWARD IN ORBIT DEMONSTRATION

H1 2017 - More tests with various fluids and sintered wick material

- ammonia / methanol
- stainless steel / Nickel

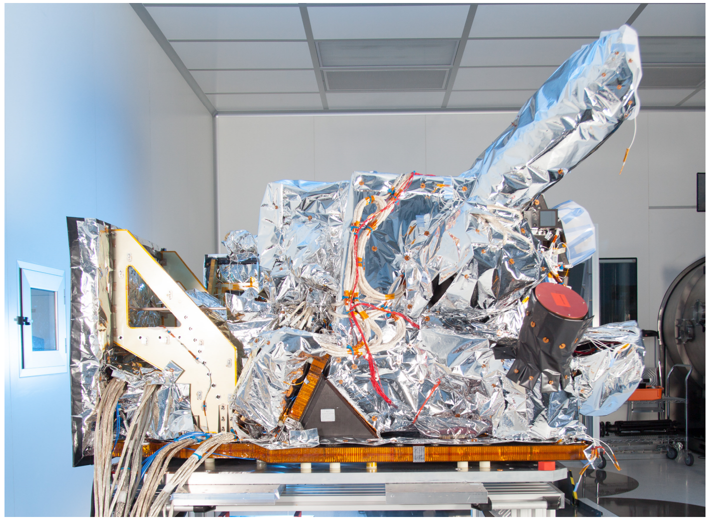
H2 2017 - Parabolic flight to demonstrate operation capability in zero-g

H1 2018 - Demonstrator #2 with optimized metallic matrix + Graphene deposition coating

Core 2 (2020)- Demonstrator # 3 with space quality standard, for a flight opportunity

CONCLUSIONS

- Graphene Oxide coating on Ni wick provides better conductance in steady state conditions (+50%)
- Graphene Oxide coating on Ni wick provides enhanced (shorter) start-up capabilities at low power
- More data are being collected to have higher statistics, especially on Graphene deposition depth and structure
- Possibility of a full-Graphene wick under investigation



SLSTR: the Copernicus Sentinel 3 radiometer by Leonardo (example of instrument could benefit of Graphene LHP)