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Mechanically Pumped Loop as Heatsink Solution for Advanced Onboard Data Processors

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1) NLR, 2) DEMCON Kryoz 3) ISISpace

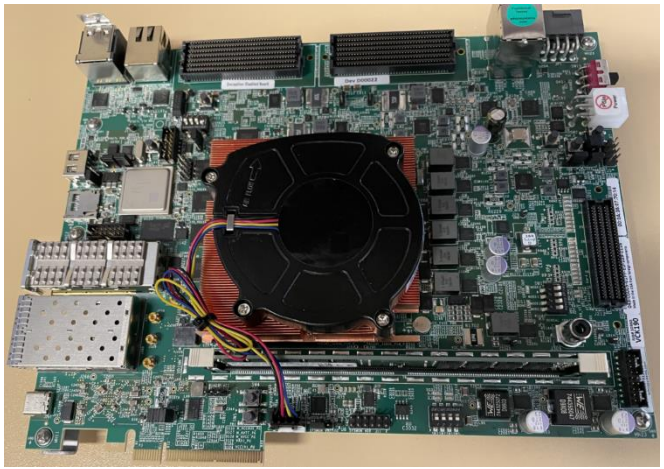
The challenge for upcoming advanced data processing…

"When the XCVC1902-1MSEVSVA2197 is fully implemented, ***its 0.8 V core voltage will draw around 140 A with a total device dissipation of 130 W****.*
• 57% of the overall power is consumed by the AI engines
• 13% by logic
• 10% by the high-speed transceivers
• 10% by clocking and PLLs
• 5% by processors and the remainder by memory and interfaces"

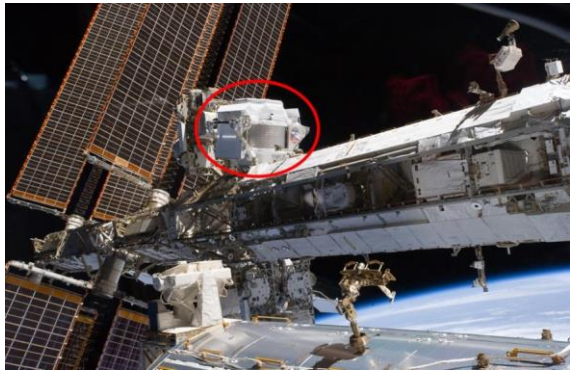
[1] Dr. Rajan Bedi, "In-Orbit Artificial Intelligence and Machine Learning for Space Applications : Versal Space Reference Design : First Design-In Experiences (Spacechips)," SpacE FPGA Users Workshop, 5th Edition, March 2023

"A quick look at the Versal Evaluation Board ***clearly shows that this board is far away from a Space board****, so when a new FPGA is introduced, a lot of steps are needed to assess how to use it for Space application. Topics such as package, assembly, power supply, boot,* ***thermal dissipation****, complexity of board place and route, knowledge of radiation effects, etc… shall be considered."*

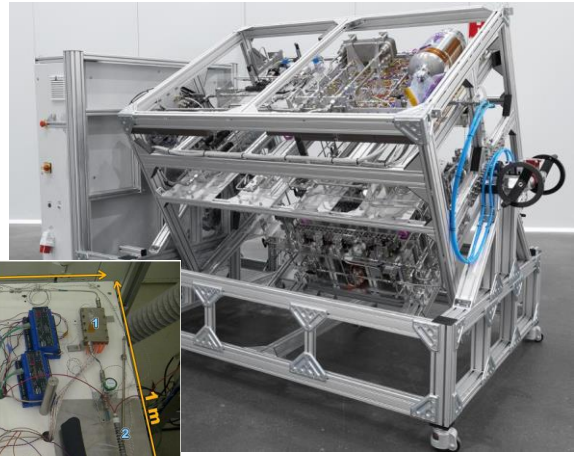
[2] Jean-Luc Poupat, "FPGA developments in Airbus products," SpacE FPGA Users Workshop, 5th Edition, March 2023.

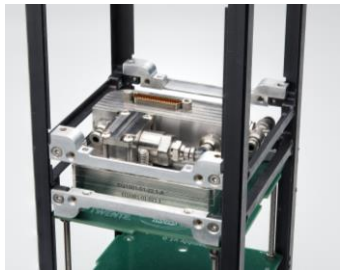


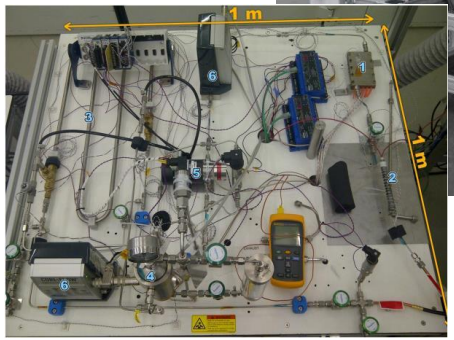
Mechanically Pumped Loops at NLR



- Tracker Thermal Control System (TTCS) for the Alpha Magnetic Spectrometer (AMS02) experiment residing on an ISS truss since 2011
- IMPACTA (H2020): Innovative Mechanically Pumped loop for Active Antennae in space, capable of transporting up to 10 kW heat
- NLR key expertise in thermal management technology:
  - Design, modeling, simulation and prototype development of single and two phase pumped loop thermal systems
  - Accumulator technology
  - Miniature Pump technology
  - Control loops and electronics







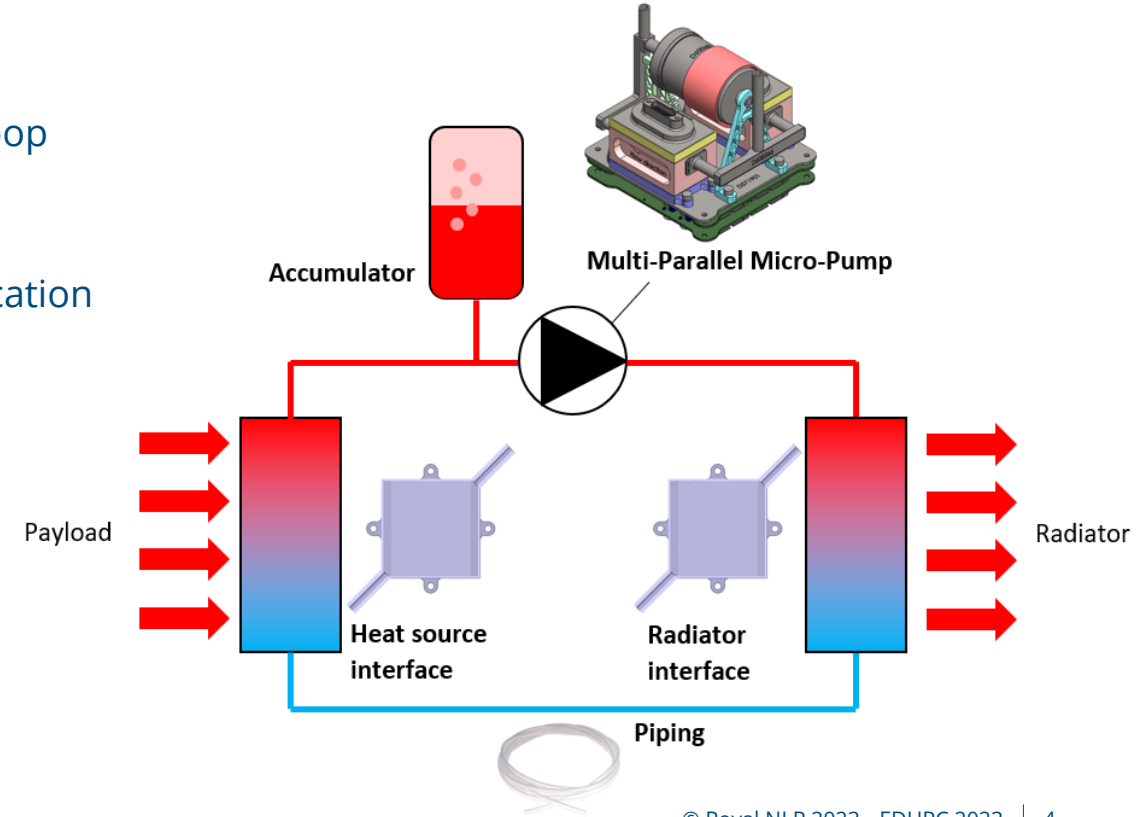
Mini-MPL | Concept

Key specifications:

- Fluidic (single phase) pumped loop
- 2 W to transfer 40 W heat
- 1 kg, 0.8 dm^3
- Larger CubeSats as target application

Key elements:

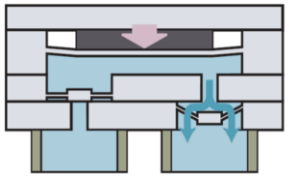
- Heat exchangers
- Fluid and Tubing
- Accumulator
- Pump
- Drive Electronics

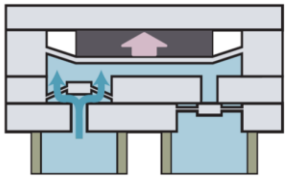


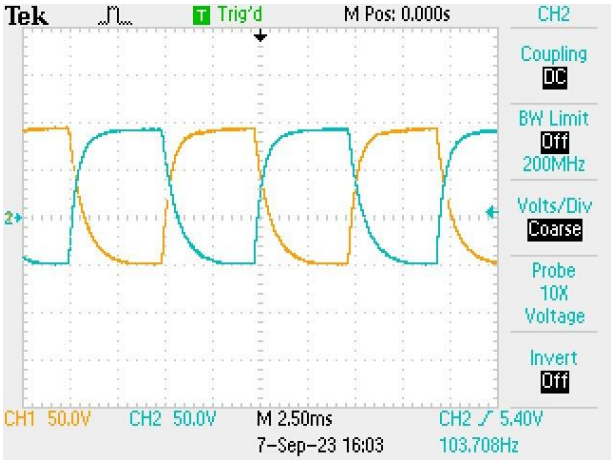
Mini-MPL | Piezo pump and Drive electronics

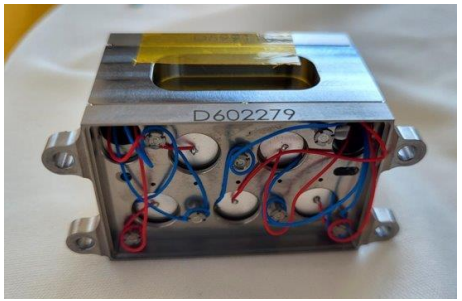
- 10 Piezo elements per pump block
- Pump block performance: up to 1.6 g/s
- Piezo elements are capacitive loads
  - 120 – 200 V
  - 100 – 300 Hz

- Dedicated drive electronics:
  - Simple interfaces: Power, optional bi-level commanding, digital and analogue telemetry
  - Scalable quality class from COTS to rad-hard → all components have EPPL listed equivalents
  - Software and firmware less (controlled by platform avionics)
  - Modular, robust and fault tolerant

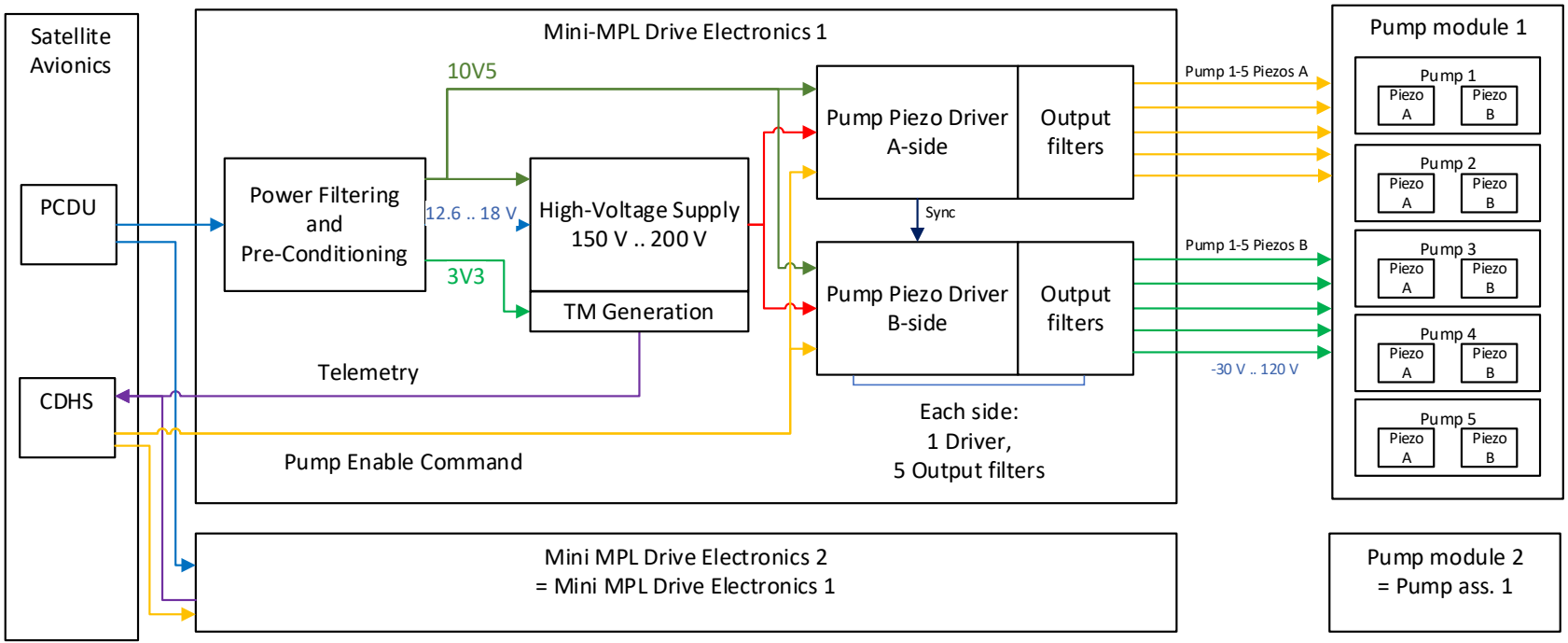






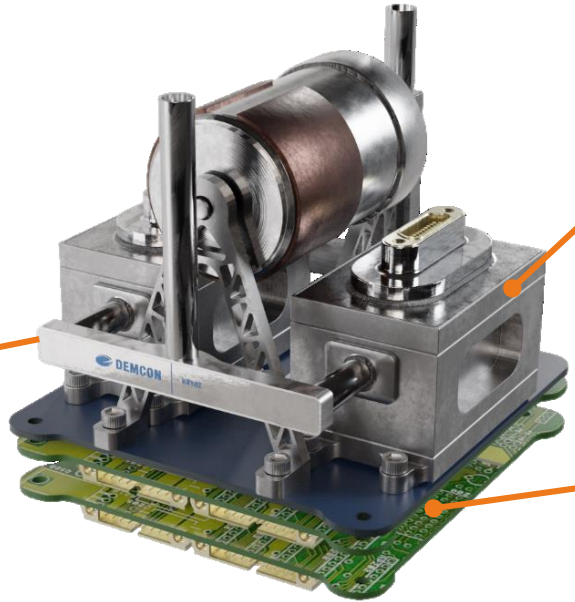


Mini-MPL | Drive Electronics

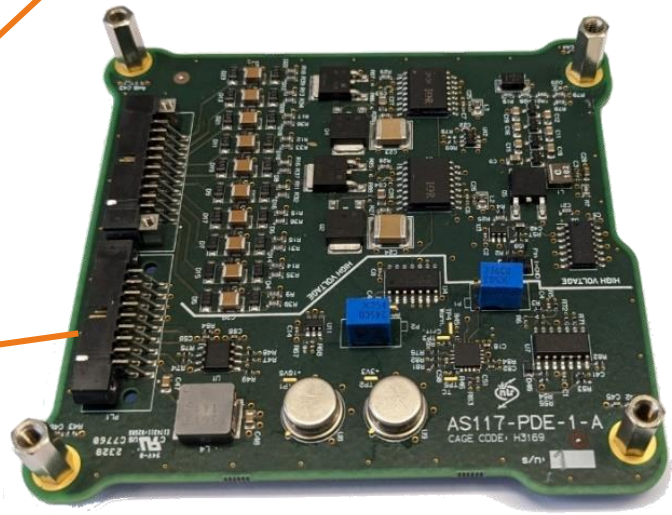


Mini-MPL | Application impression

Piezo Pump Block

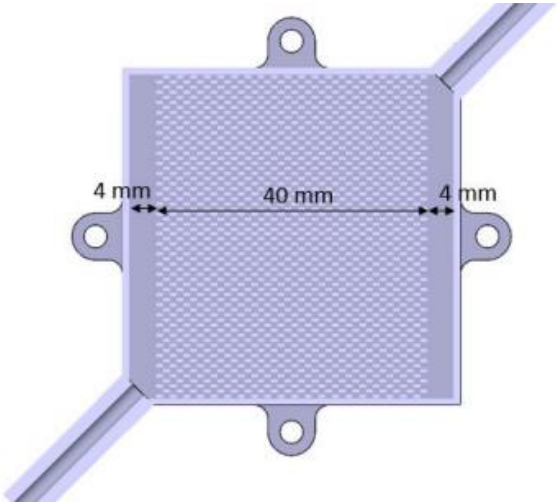


Pump assembly
10x10x8 cm^3



Drive electronics

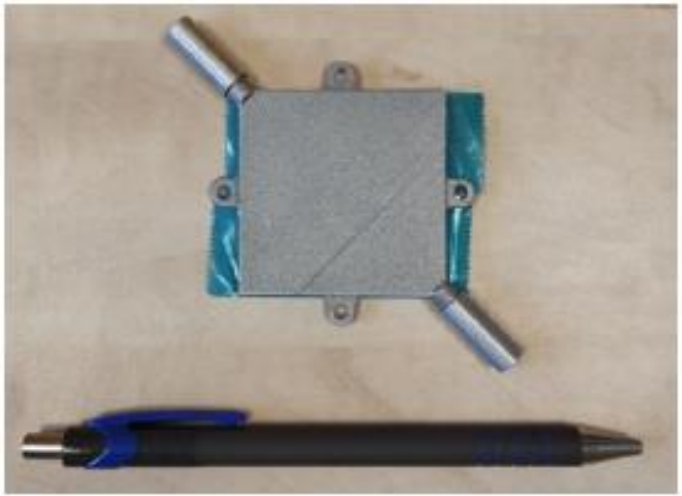
Heat Exchangers



- Two standard designs; 20x20 mm^2 and 50x50 mm^2
- Stripfin design for optimum performance
- 3D printed, AlSi10Mg selective laser melting process

- Tested heat transfer of 895 W/m^2K with 2 g/s mass flow

- Many possibilities to fit application needs, e.g. for high density avionics units
  - integrated fluid loop in avionics structure?



Mini-MPL | Scalability

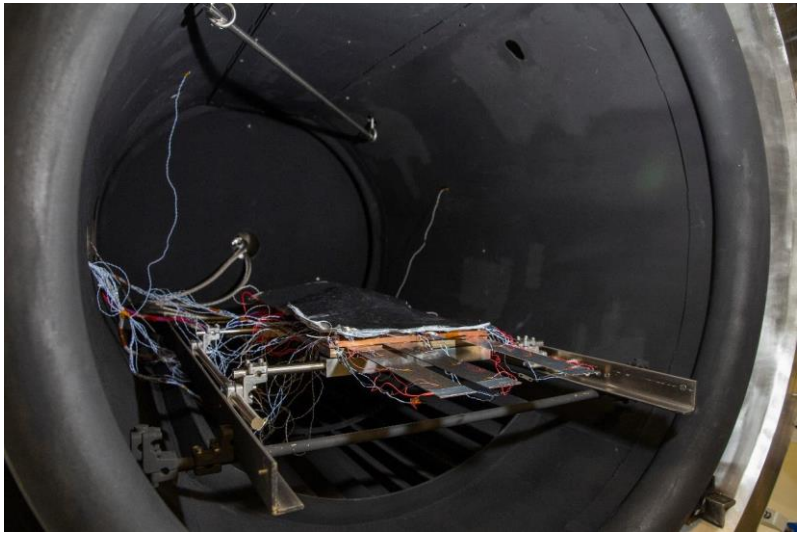
Current development: 40 W transport capability

- ✓ Scalable heat transport capability
- ✓ Flexible interfaces for power, command and telemetry (bilevel, I^2C, CAN, …)
- ✓ Flexible operation temperatures allowing multiple applications (electronics, propulsion, …)
- ✓ Scalable target mission classes, environments and in-orbit lifetimes

Specification	Current Mini-MPL Design	Expected Range by Scalability
Heat Power Transport Capability	40 W	10 to 200 W
Input Power	< 2 W	< 0.5 – 10 W (< 0.05 $W/W_{transport}$)
Supply Voltage	Unregulated 12.0 to 18.0 V	Unregulated 12 to 50 V
System Operating Temperature range	-40 to 80 °C	-40 to 80 °C
Operating Fluid Temperature ranges at heat exchangers (source and sink)	-40 to 70 °C	-100 to 90 °C
Mass (excluding radiator)	1 kg	0.5 – 2 kg
Fluid Type	Thermasolv IM2	Multiple fluids (depending on the application)
Volume (excluding heat exchager and radiator)	10x10x8 cm^3	10x10x5 cm^3 to 10x10x20 cm^3
In-orbit Operational Lifetime	3 years	3 – 5 years
Radiation Tolerance	LEO environment	LEO, MEO and GEO environment
Satellite Qaulity Classes	CubeSat and MicroSat	CubeSat, MicroSat, MiniSat

Mini-MPL | Product status

- Integration of test setup is ongoing
- Test campaign in Q4 2023
  - Mechanical testing
  - Fluidic, pressure and leak rate testing
  - Performance testing of full representative setup in TVAC
  - Endurance testing
- TRL-6 by early 2024
- Pre-selected for the EC Cassini IOD/IOV missions!



This project is carried out in close cooperation between Demcon kryoz, NLR and ISISpace, and is funded and performed under ESA contract No. 4000135822/21/NL/KML/va.

Thank you!

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Fully engaged

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