A HEAT PUMP FOR SPACE APPLICATIONS

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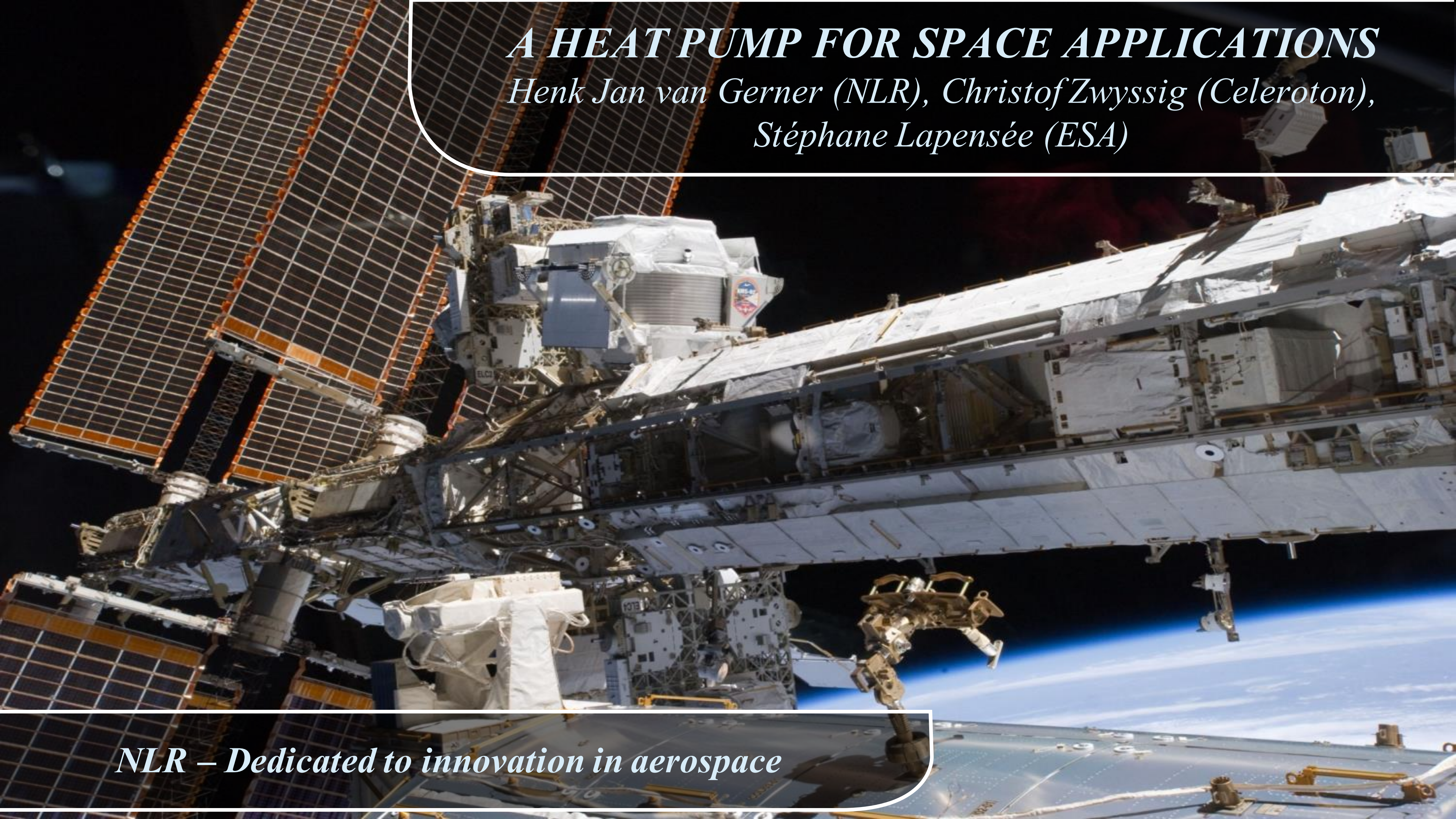
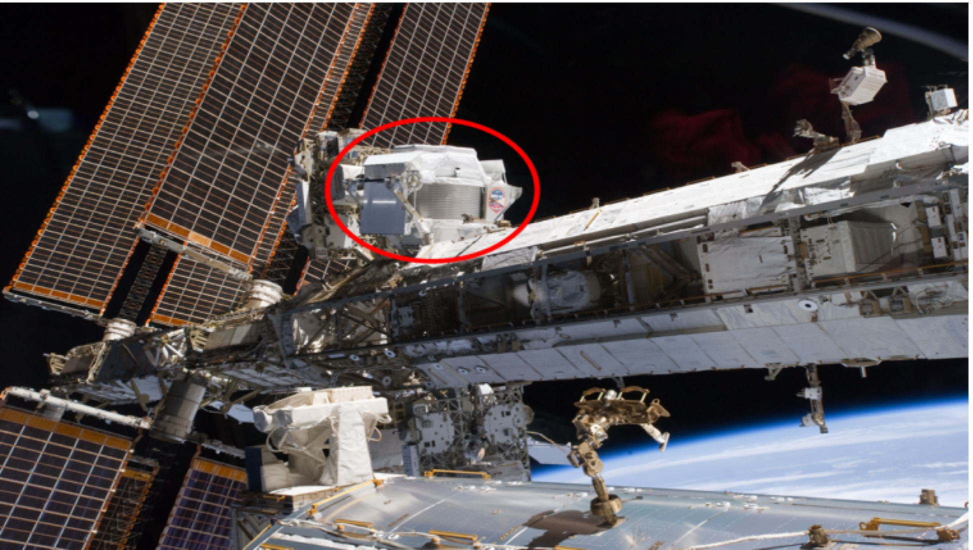


NLR – Dedicated to innovation in aerospace

About Netherlands Aerospace Centre (NLR)

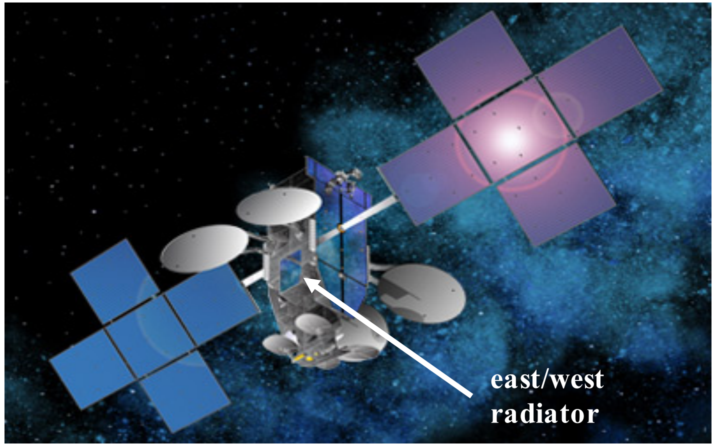
- NLR is the Netherlands' national knowledge centre for aerospace with 650 employees
- NLR has built the thermal control system for the AMS02 tracker which uses CO_2 as refrigerant
- AMS02 is a large detector (8500kg) for cosmic particles that was mounted on the International Space Station in May 2011



Why would we need a Heat Pump in space?

- The heat rejection capacity of radiators is a very limiting factor for commercial communication satellites
- Increasing the size of the radiators to increase the capacity results in too large spacecraft
- A heat pump that increases the radiator temperature from 45°C to 100°C increases the payload heat dissipation capacity with 73%
- Traditional compressors are too heavy (20 kg) and cause too much vibrations
- Therefore, a lightweight (<2 kg), low-vibration centrifugal compressor has been developed in an ESA project

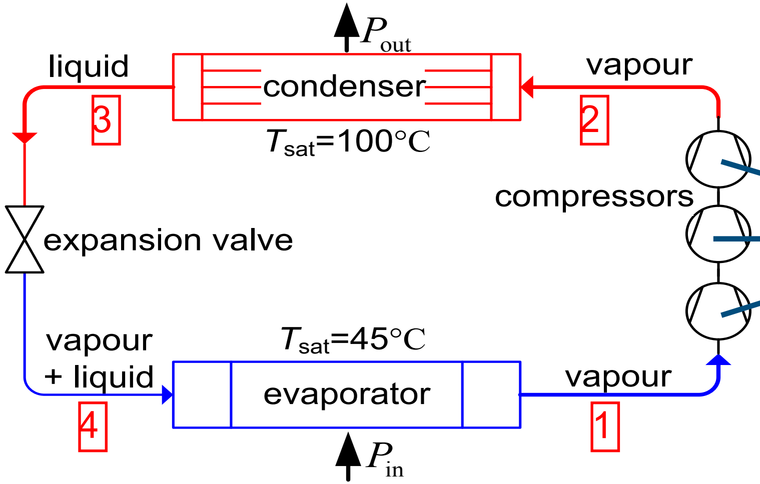
Ciel 2 satellite on a TAS Spacebus 4000C4 platform

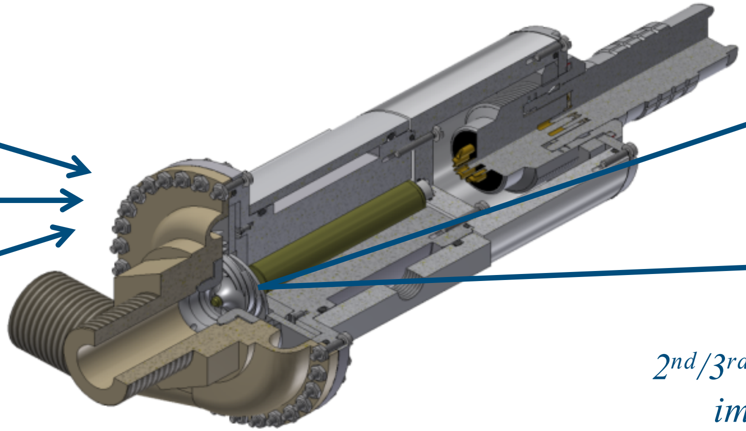


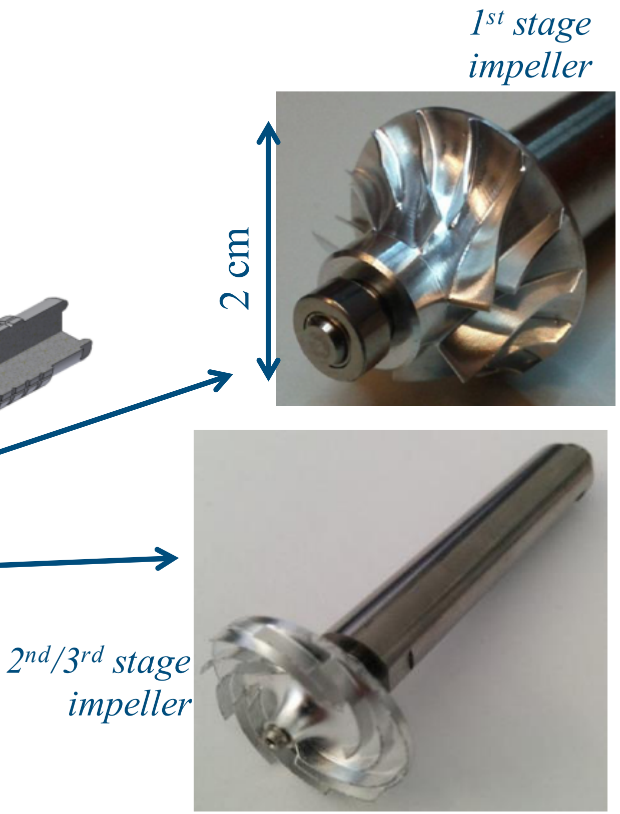
Viasat 1 satellite on a Loral LS1300S platform with small additional east/west radiator panels

How does the heat pump work?

- The heat pump is based on a vapour compression cycle
- Three centrifugal compressor stages are used in a serial configuration
- The developed centrifugal compressors run at very high speed (180,000 RPM) → high power density → low mass
- The compressors are designed and built by Celeroton in Switzerland



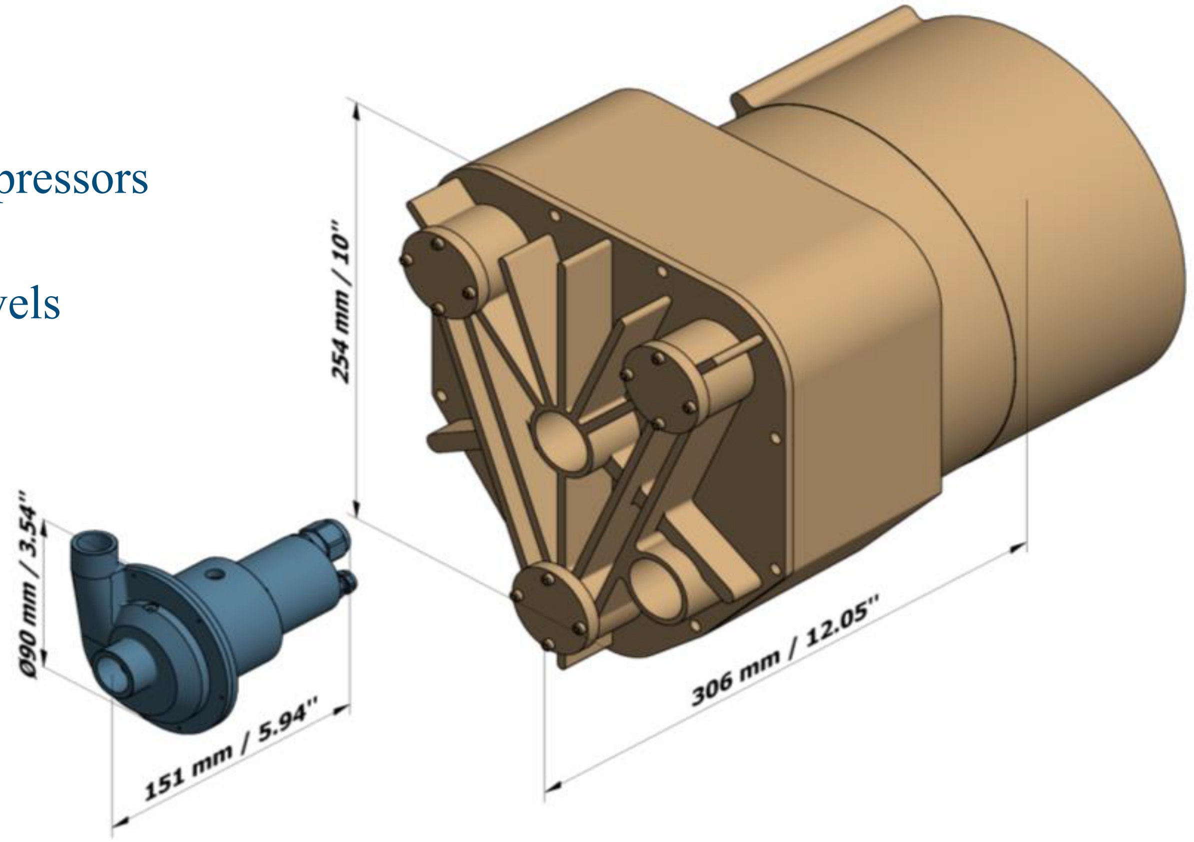




Compressor comparison

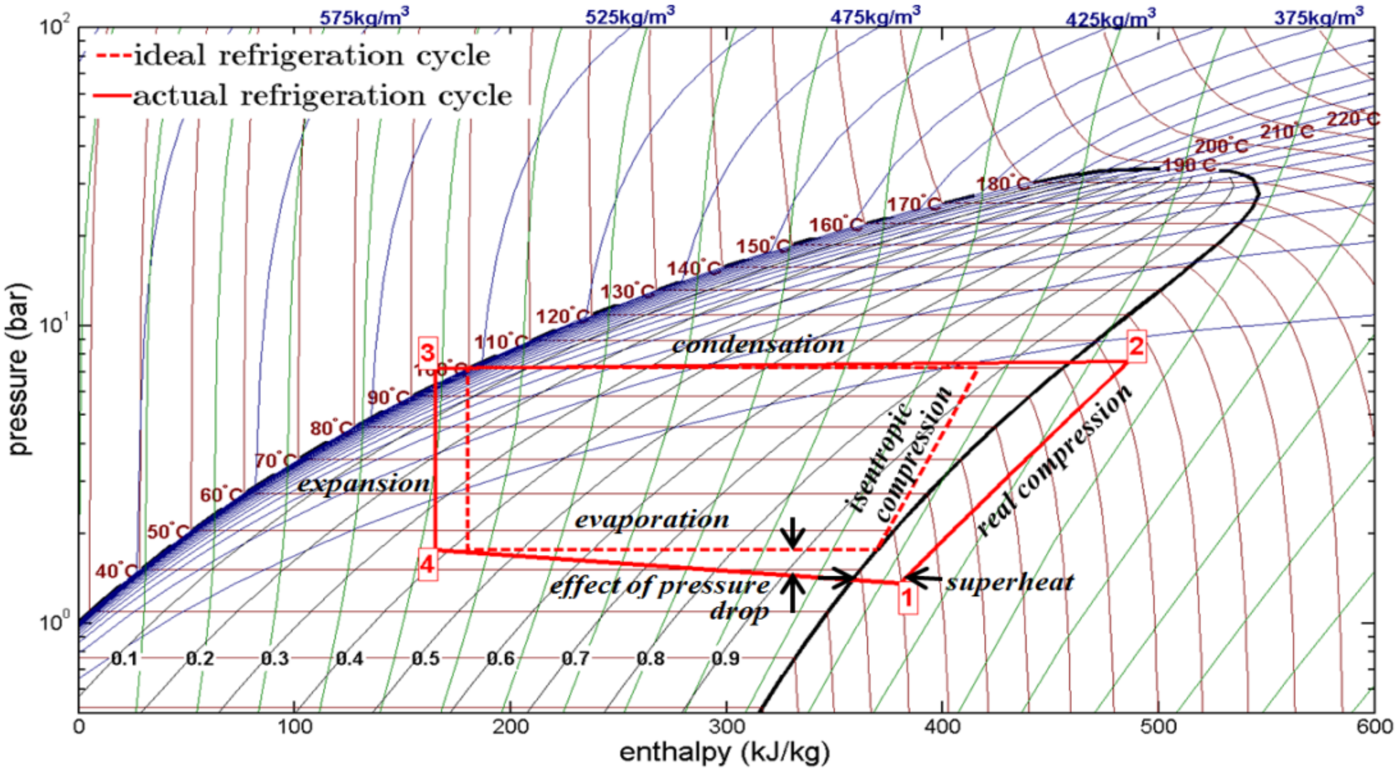
The compressors developed in this project have a:

- ~10 times lower mass than commercial compressors and comparable efficiency
- ~ 5 times lower mass than aerospace compressors and a much higher efficiency
- Orders of magnitudes lower vibrations levels
- Oil free



Fluid selection

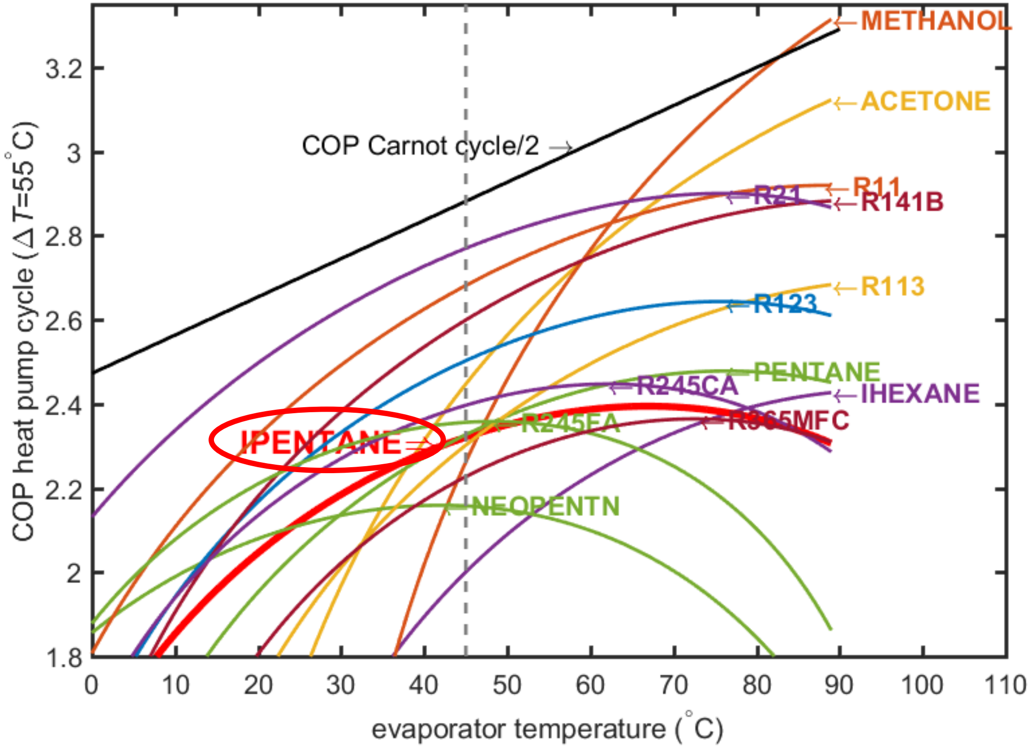
- The space heat pump must have a high COP=$\frac{P_{cool}}{W_{compressor}}$
- The COP of a heat pump cycle is calculated for all fluids in the REFPROP database



ATMOsphere EUROPE solutions for europ natural refrigerant

Fluid selection

- The space heat pump must have a high $\text{COP} = \frac{P_{\text{cool}}}{W_{\text{compressor}}}$
- The COP of a heat pump cycle is calculated for all fluids in the REFPROP database
- The analysis shows that thermally, the best fluids are R21, R11, R141b, and R123
- However, these fluids are banned (or being phased-out) by the Montreal protocol
- The next best fluids are R245fa, R245ca, acetone, pentane, and isopentane (R601a)
- A compressor CFD analysis showed that the best performance is obtained with isopentane
- Isopentane has excellent radiation hardness



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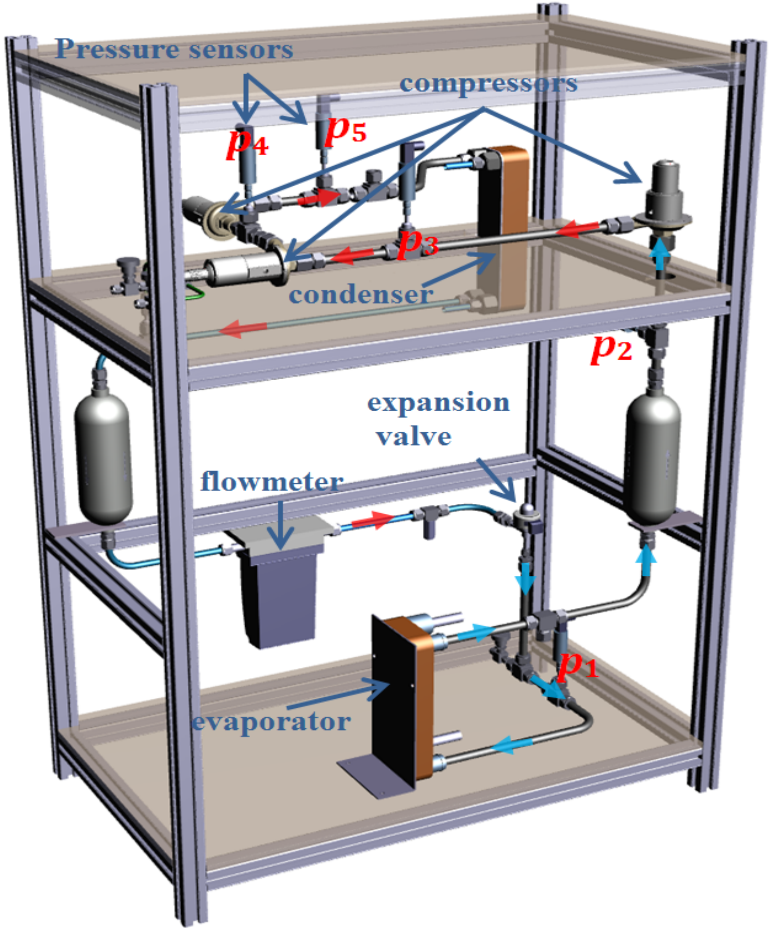
Heat pump demonstrator

- A heat pump demonstrator has been built with the following characteristics:

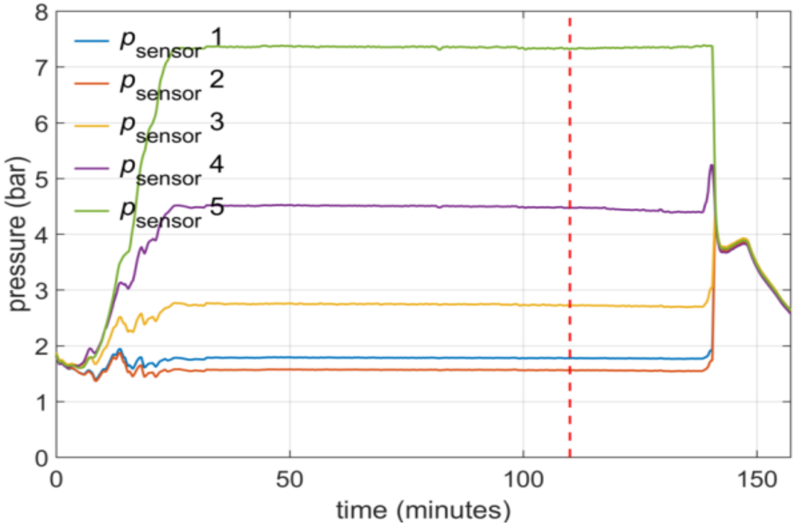
Saturation temperature in the evaporator	45°C
Saturation temperature in the condenser	100°C
Heat pump cooling capacity (evaporator heat load)	5 kW
Total compressors power	~2.1 kW divided over 3 compressors in a serial configuration
Condenser capacity	7.5 kW (5 kW for heat load and 2.5 kW for compressor power)
Target COP ($P_{cool}/W_{compressors}$)	2
Refrigerant	Isopentane (R601a)

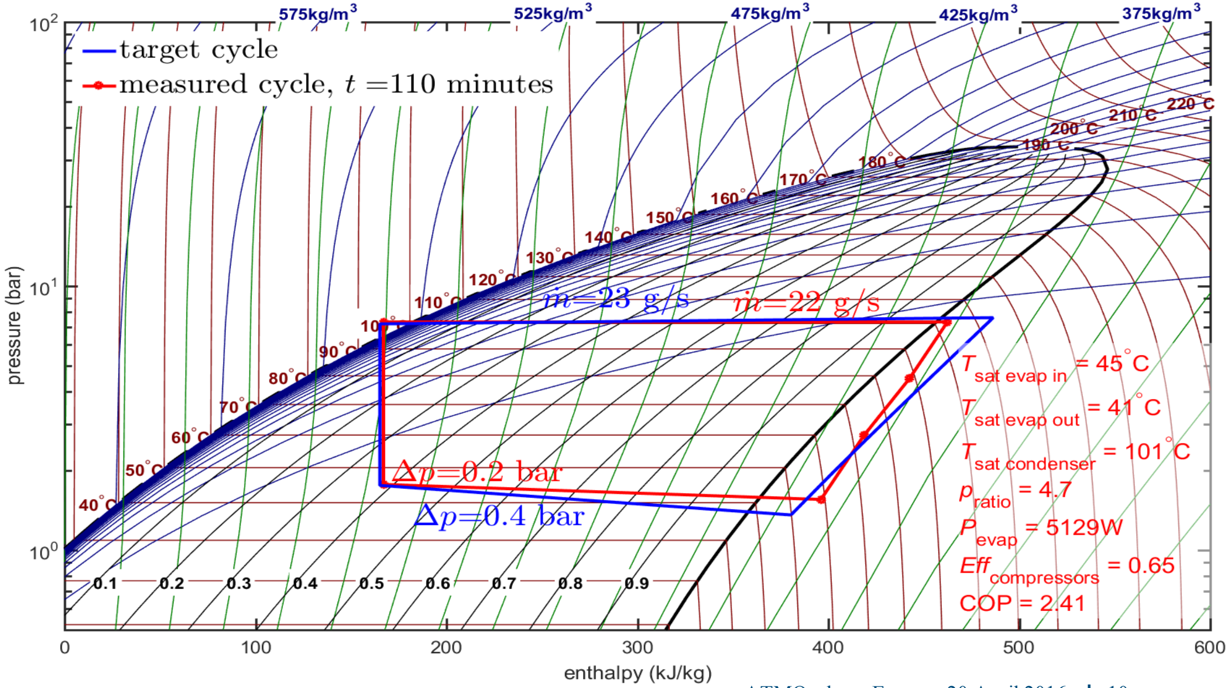
Heat pump demonstrator



Heat pump test results

- The heat pump breadboard has achieved a very high performance
  → The measured COP is 2.4, compared to the ESA requirement of 2
- The isentropic efficiency $\left(= \frac{W_{\text{compressor Isentropic}}}{W_{\text{compressor Actual}}}\right)$ of 65% for the compressors is very good
  → much higher than aerospace compressors and comparable to commercial compressors
- Results are very reproducible





Conclusion/Further work

- The heat pump demonstrator has achieved a high performance
  → The measured COP is 2.4, compared to the ESA requirement of 2
- The compressors developed in this project produce little vibrations and have a lower mass than existing (aerospace) compressors
- Isopentane is the best fluid for this application
- Possible other application areas for the space heat pump:
  - Cooling of sensors in aircraft (pods)
  - Air-conditioning in electric cars?
  - ???

- Current work is on increasing the lifetime of the compressor by using gas bearings

Questions?

Back-up slides

Future work

- Use a Liquid-Suction Heat Exchanger (LSHE) to increase the COP
  - Normally, the fluid enters the evaporator with a fraction of 0.4
  - This means that a large portion of the latent heat of the fluid is not used in the evaporator
  - With a LSHE, a larger portion of the latent heat is used
  - This increases the COP with ~18%
  - Furthermore, it provides the required superheat for the compressors