Thermal Modeling Issues Concerning the Mechanically Pumped Two-Phase CO_2 Cooling for the AMS-2 Tracker

A.A.Woering, A.Pauw, A.W.G. de Vries, A.A.M. Delil

National Aerospace Laboratory NLR, The Netherlands

B. Verlaat

National Institute for Nuclear and High-Energy Physics NIKHEF, The Netherlands

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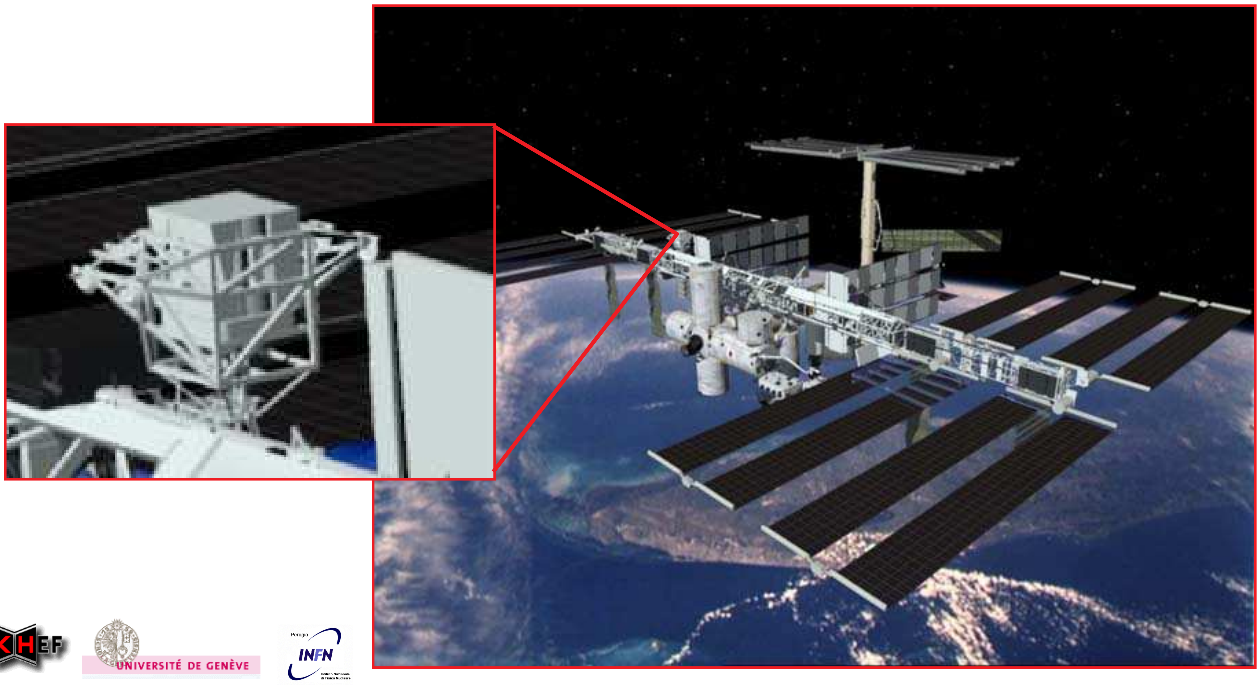
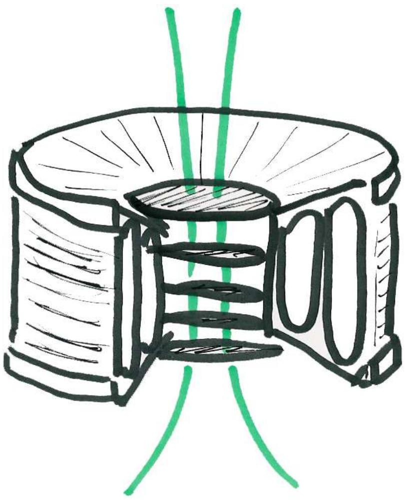
Alpha Magnetic Spectrometer



AMS Silicon Tracker



- **(x,y,z) particle trajectories determined by momentum and charge sign**
  - Curvature radius : momentum
  - Curvature direction : charge sign
- **Energy loss in each silicon plane yields charge magnitude**

AMS Silicon tracker thermal requirements

Silicon wafer thermal requirements:

- ***Operating temperature:***
  -10 ºC / +25 ºC
- ***Survival temperature:***
  -20 ºC / +40 ºC
- ***Temperature stability:***
  3 ºC per orbit
- ***Maximum accepted gradient between any silicon:***
  10.0 ºC
- ***Dissipated heat:***
  2.0 Watt EOL

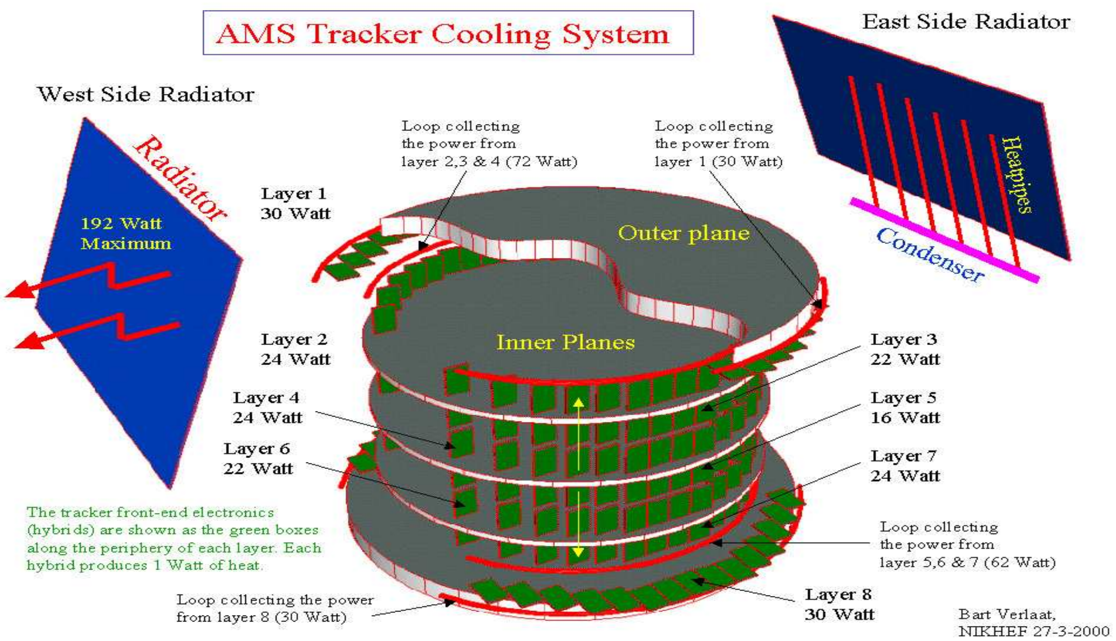
Hybrid circuit thermal requirements:

- ***Operating temperature:***
  -10 ºC / +40 ºC
- ***Survival temperature:***
  -20 ºC / +60 ºC
- ***Dissipated heat:***
  192 Watt total, 1 Watt per hybrid pair

General requirements

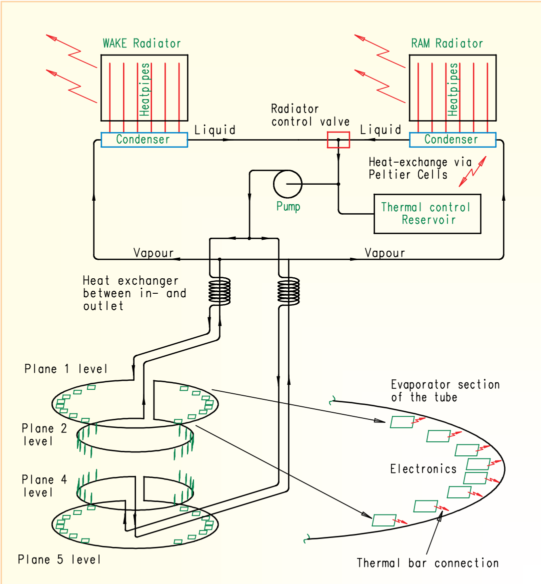
Limited mass (70 - 80 kgs)

Limited power (< 80 W)

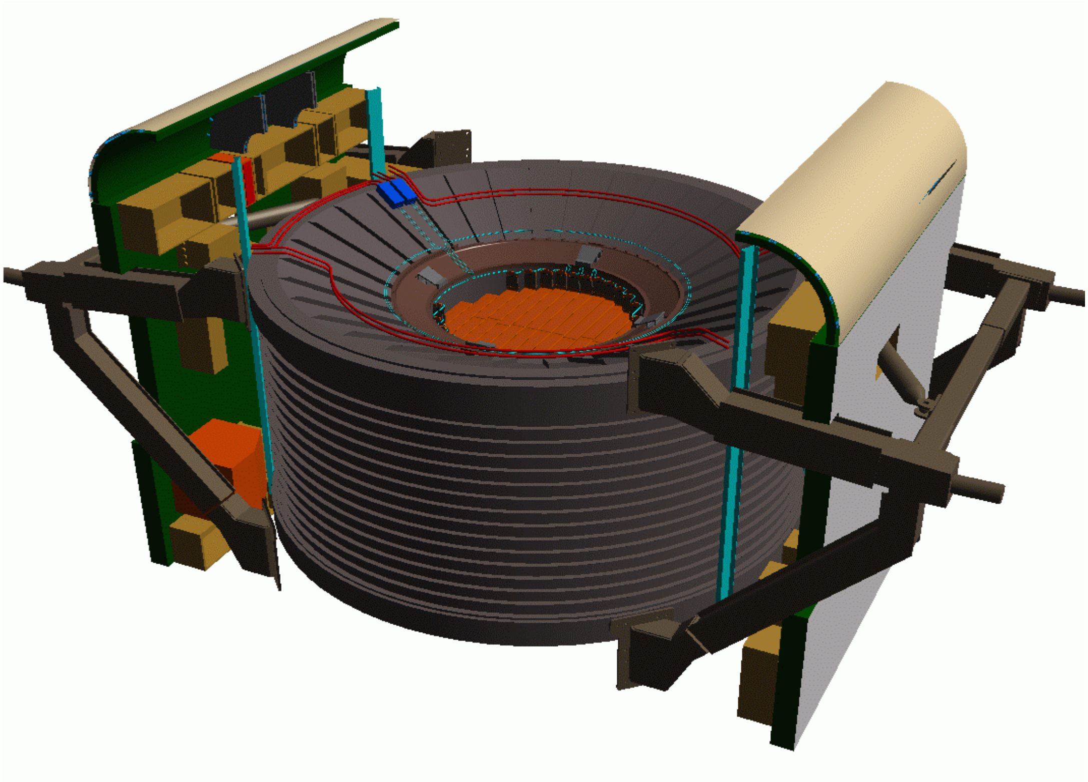


Heat dissipation in the AMS-Tracker

TTCS summary

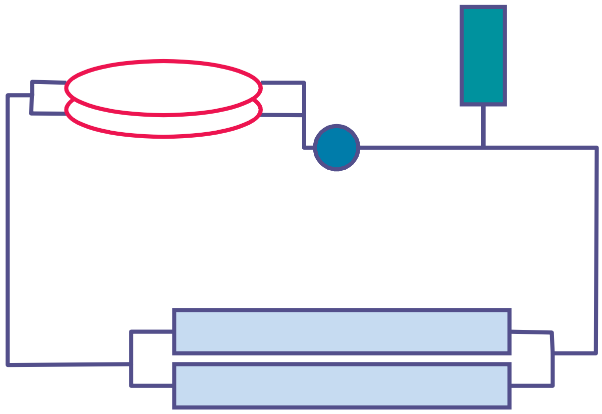


- **2 Identical completely separated loops (1 for redundancy)**
- **2 serial evaporators in parallel per loop**
- **2 parallel condensers controlled per loop controlled by a 3-way valve.**
- **Pressure controlled with a thermal control reservoir**
- **Thermal control using standard AMS control module**
- **Critical components in redundant configuration (pump, valves)**
- **Most fluid components in 2 dedicated TTCS boxes on the support structure at wake side**
- **RAM and WAKE heat pipe radiator**
- **All hardware is placed in debris-safe areas; a specific debris shield is added when needed**



Tracker (component) design

- **2 parallel evaporator branches**
- **2 parallel condenser branches, 2 radiators**
- **pump assembly**



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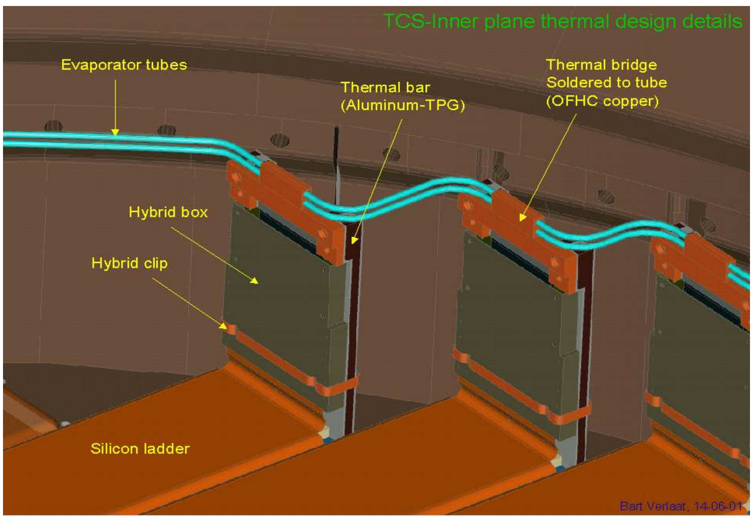
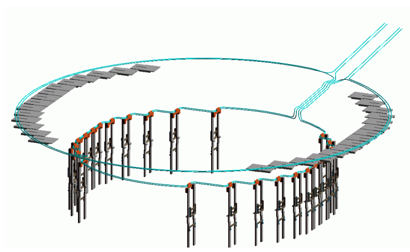
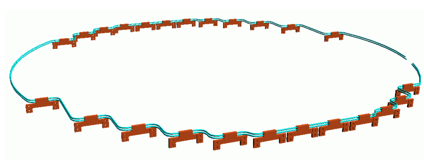
Evaporator



TTCS evaporator connection to inner thermal bars



Complete thermal system in side the tracker (Thermal bars+ evaporators)



Inner planes evaporator

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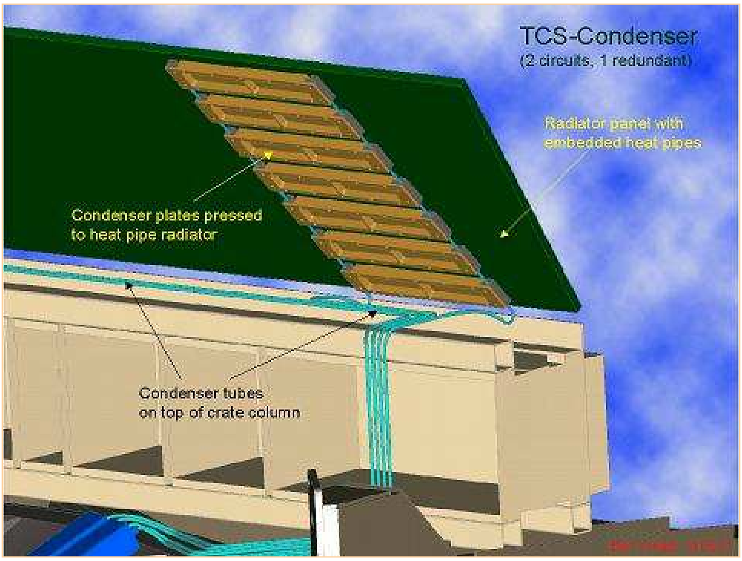
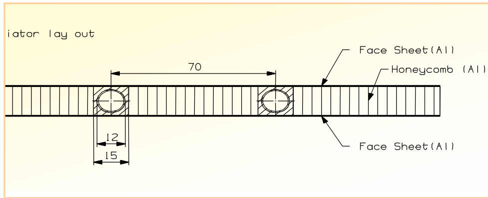
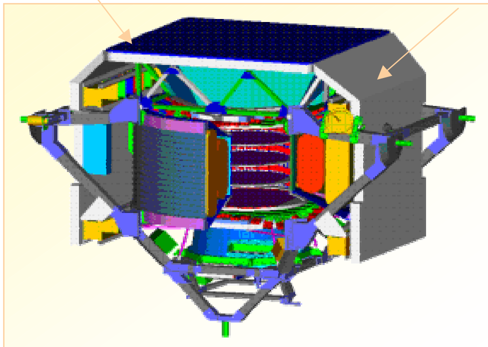
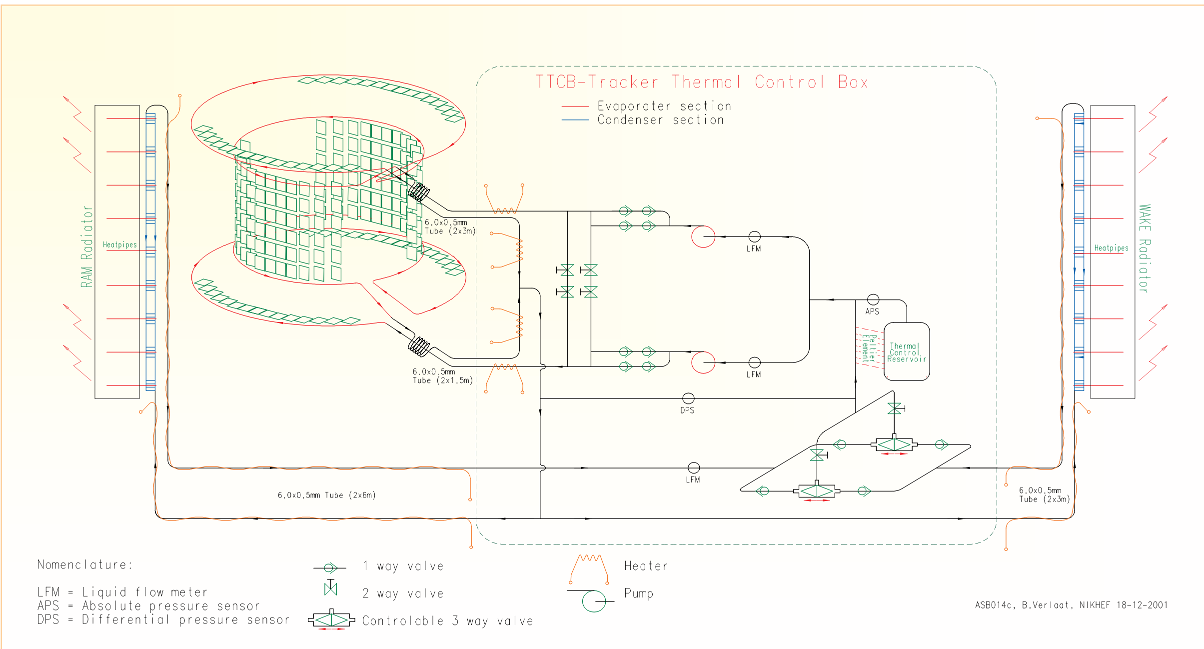
Radiators





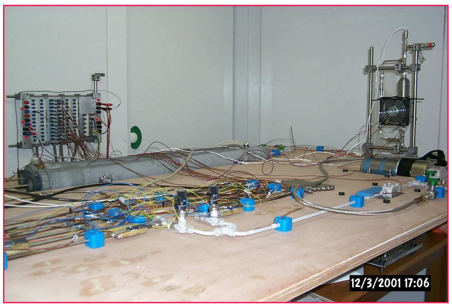


Plumbing schematic

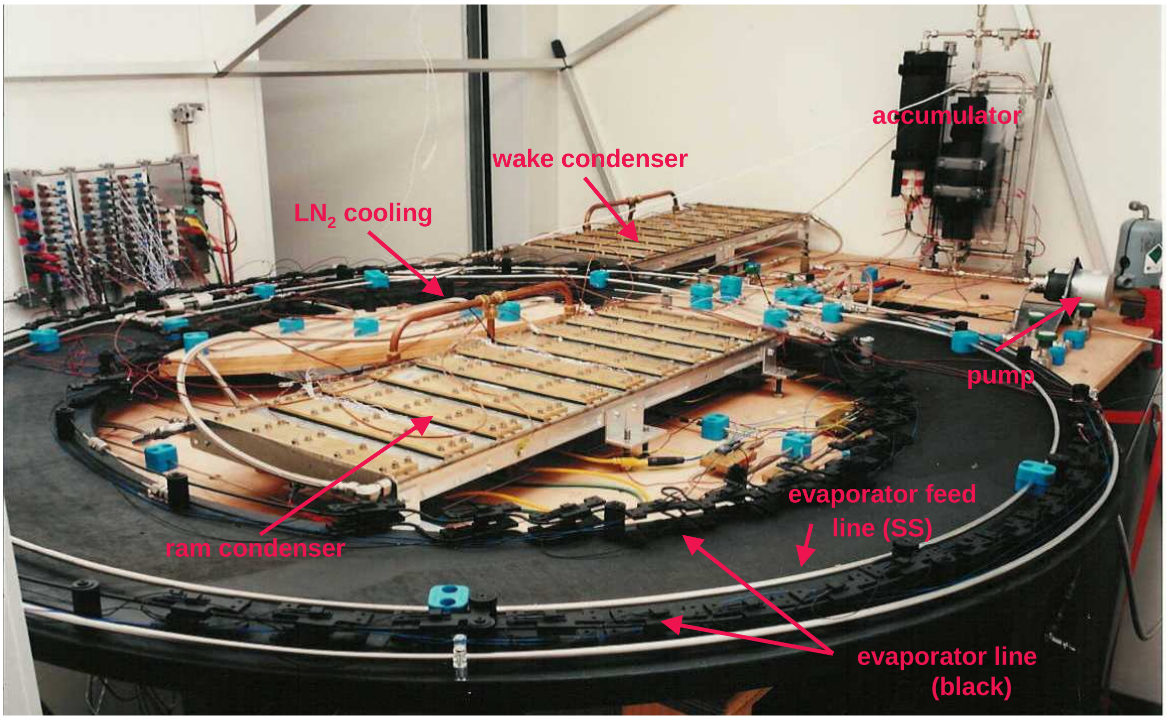


Experiments

- **Feasibility test set-up @ NIKHEF**
- **Control BBM @ NLR**
- **Real size BBM @ NLR operational since early this year**
  - First tests are promising
  - Full test campaign expected to start in fall 200



Breadboard



Numerical modeling

- **Modeling information flows**
- **Component modeling fixed with loop temperature**
- **Simulation cases for design optimization**
  - Radiator size, mass and shape
  - Heat pipe puncture
  - Preheating

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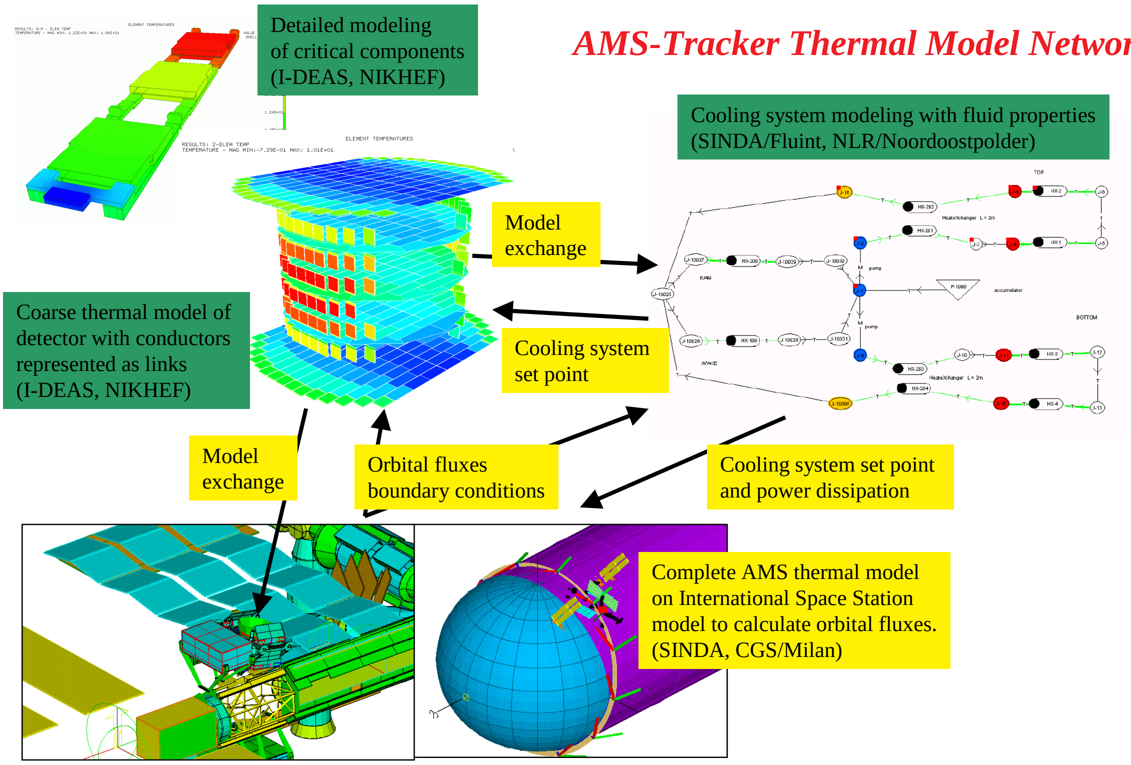
AMS-Tracker Thermal Model Network



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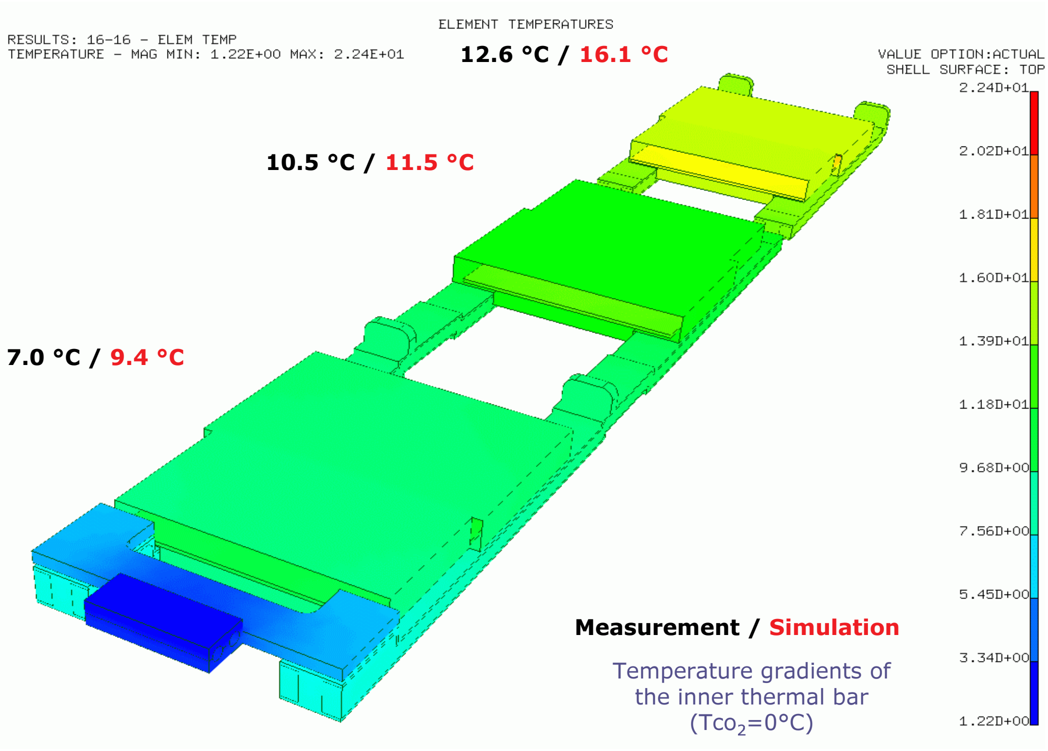

Temperature gradients of the inner thermal bar (T_{CO_2}=0°C)

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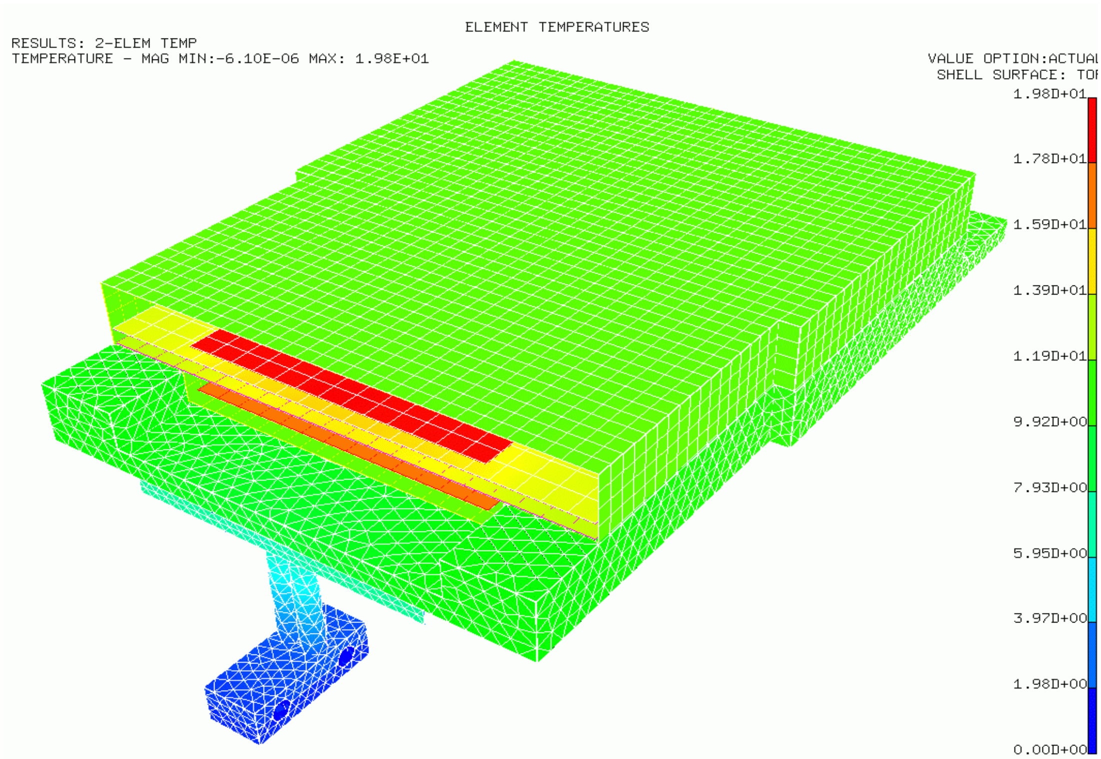

uter plane thermal bar thermal simulation

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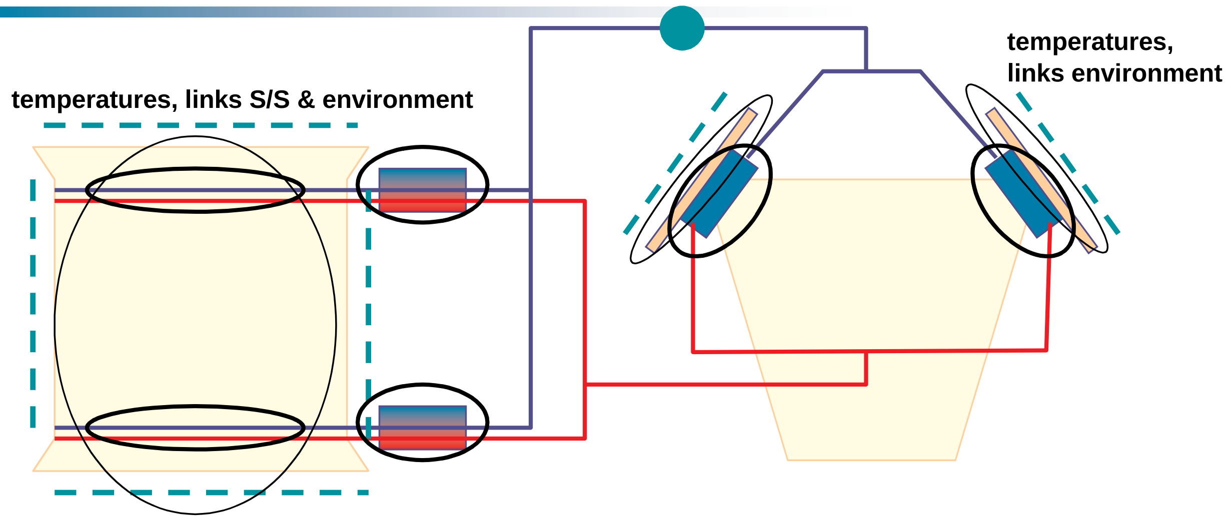
Loop model



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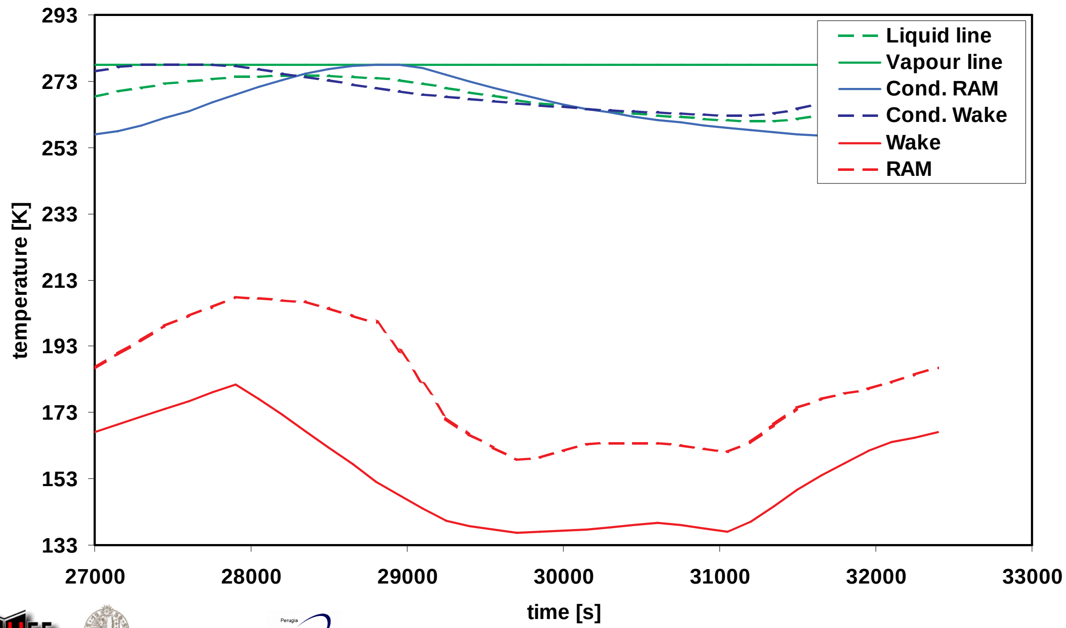
TTCS loop, typical result



β=0
MPA
flat radiator

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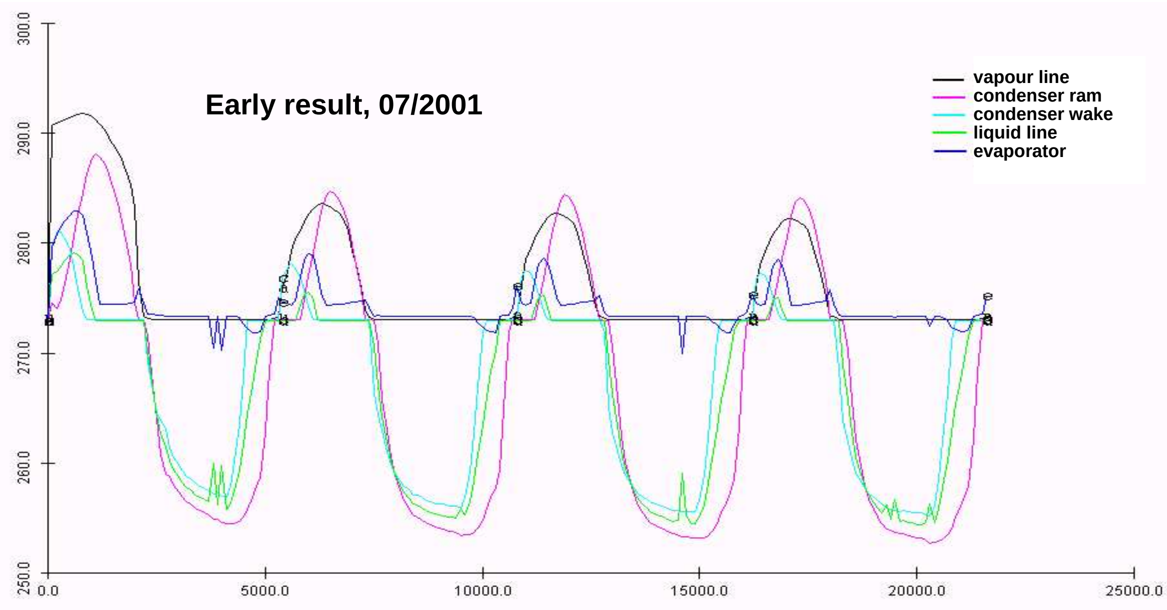
Radiator size, mass and shape



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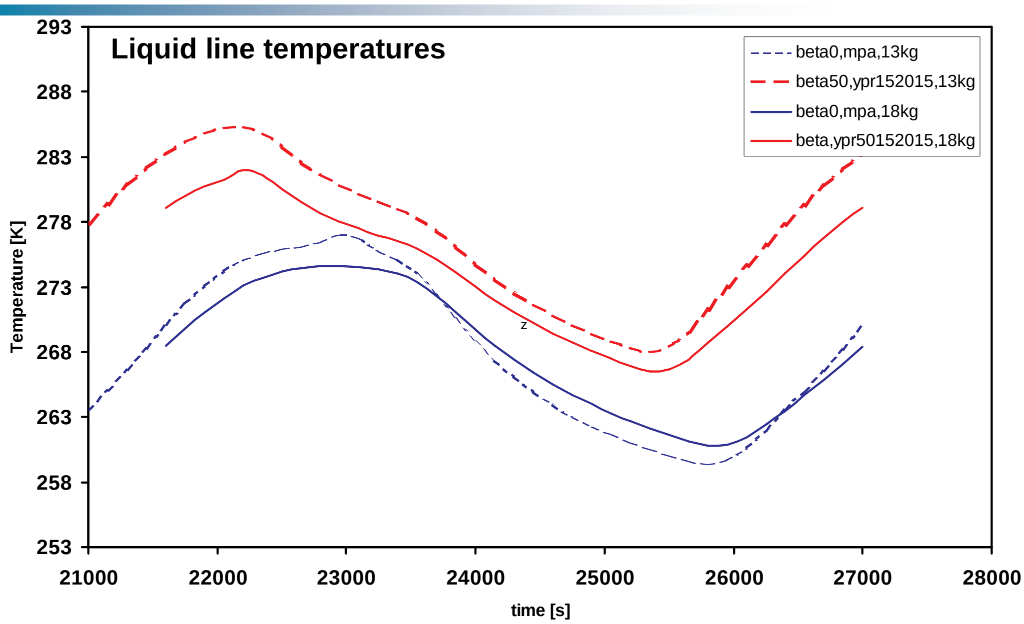
Radiator mass



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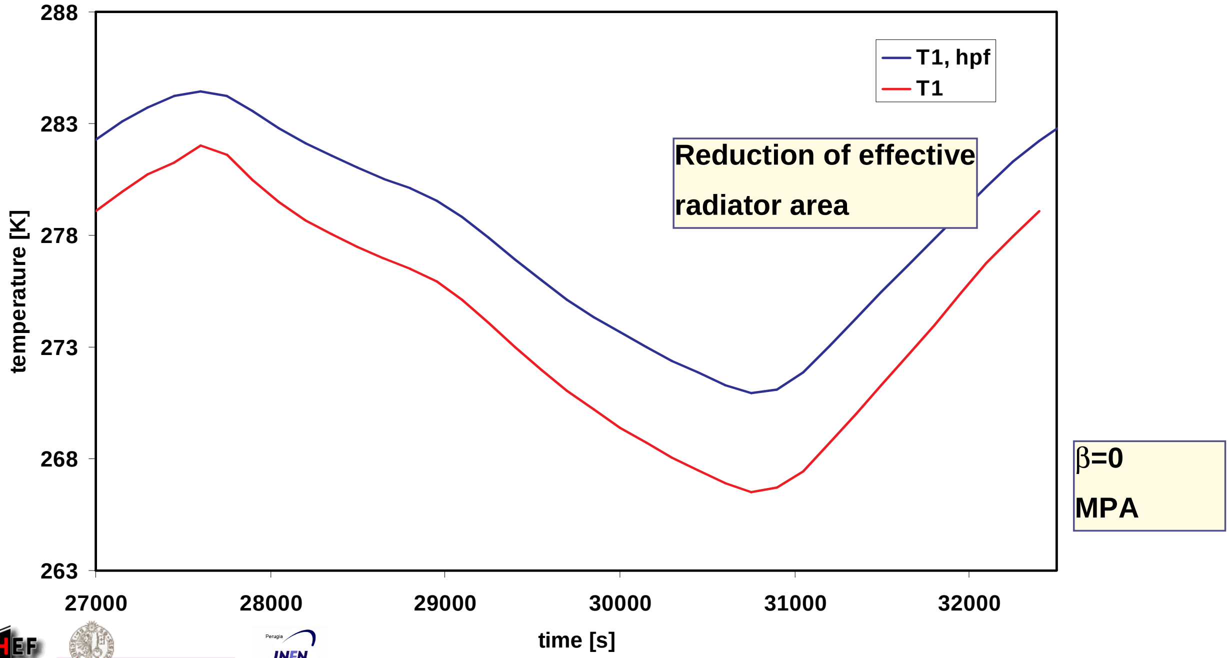
Radiator size: Heat pipe failure



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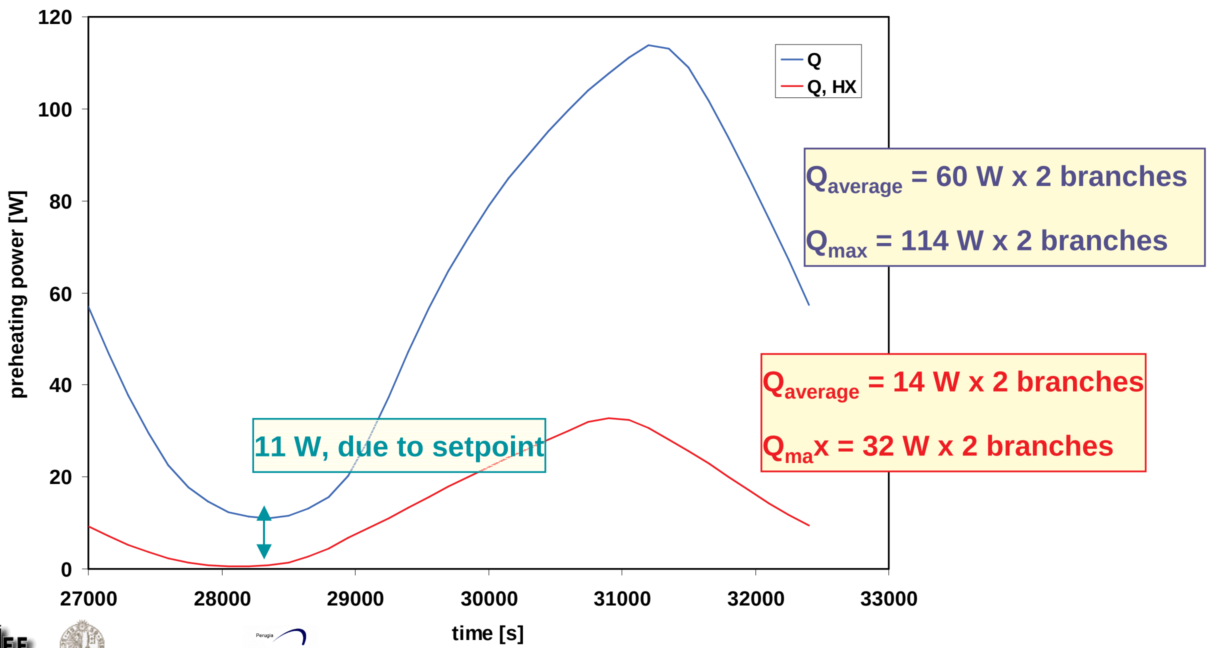
Preheating



Conclusions

- **Feasibility of TTCS supported by numerical model**
- **Several design choices based on and supported by thermal modeling**
- **Proven to be an important tool in engineering discussions with AMS experimenters**