



PHOS Experiment: Implementation and Test of a Large Diameter Pulsating Heat Pipe on Board REXUS-18

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Pulsating Heat Pipes (PHPs)

Experimental apparatus and procedures

Experimental results

Conclusions and future developments

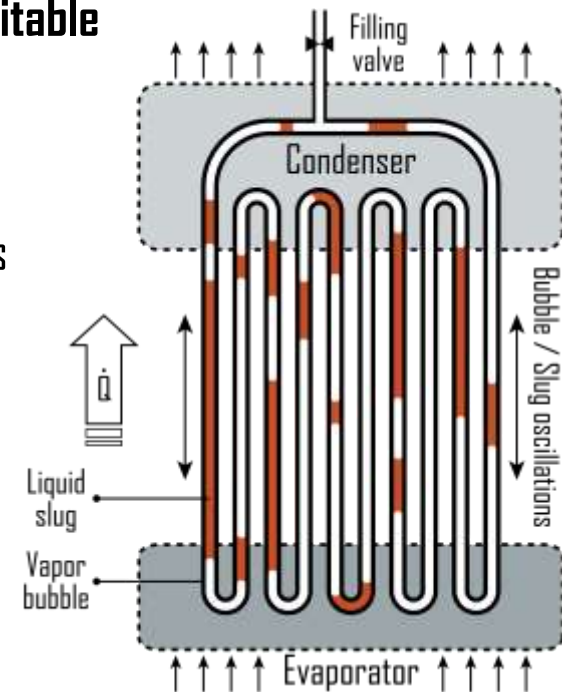
General characteristics

A two-phase passive heat transport device suitable for future space applications

Self-sustained thermally driven working fluid oscillations

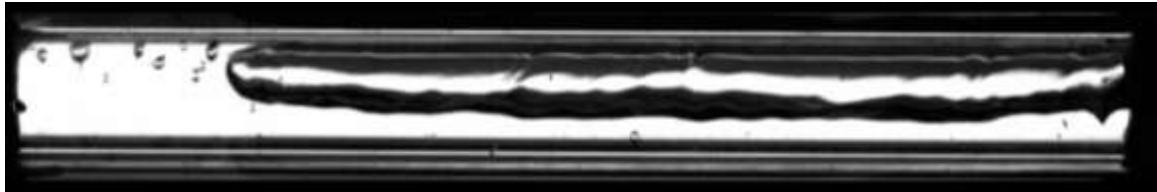
Forced convection sensible heat transport

On Earth gravity conditions, the typical flow pattern can form only if the tube has capillary dimensions

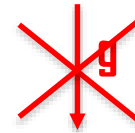


A large diameter PHP...

NORMAL GRAVITY



MICRO GRAVITY



ESA Parabolic Flight 61

inner tube diameter 3mm; working fluid FC-72; input heat power 50W (*)

(*) Mangini D., Mameli M., Georgoulas A., Araneo L., Filippeschi S. & Marengo M. (2015). A pulsating heat pipe for space applications: ground and microgravity experiments. *Int. J. of Thermal Sciences* 95 (1) 53-63.

... on board REXUS 18 sounding rocket

A long reduced gravity period



Parabolic flight
reduced gravity period ~ 20s



REXUS sounding rocket
reduced gravity period ~ 120s

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Test-cell

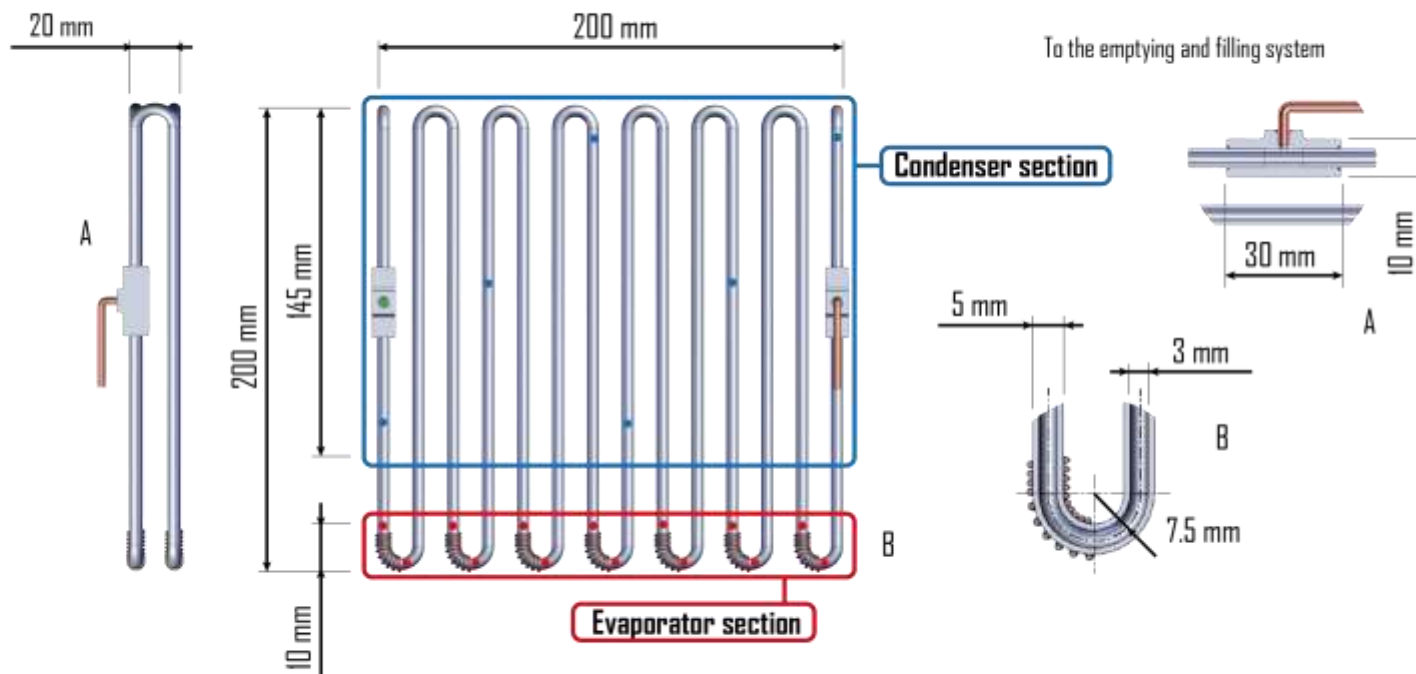


Aluminum tube
PHP-1: Internal Diameter = 1.7mm/3.2mm
PHP-2: Internal Diameter= 3mm/5mm
Double layer
14 U-turns at the evaporator
Fluid: FC-72, (FR = 0.5)



Test-cell

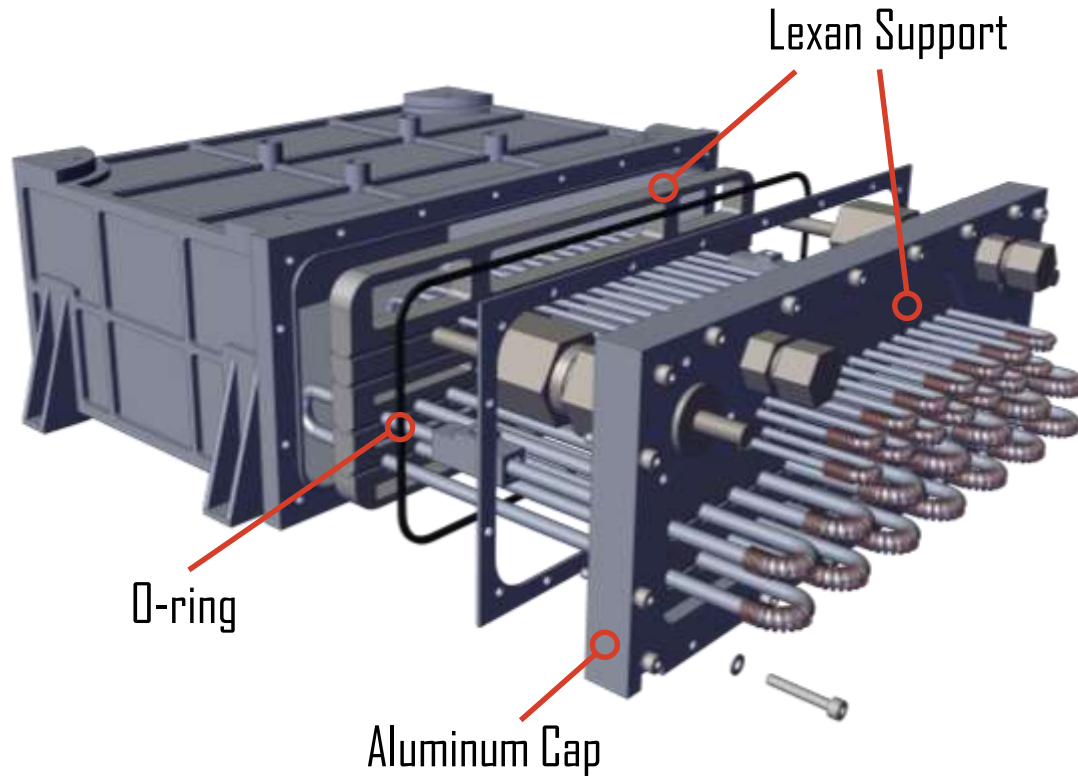
Large diameter PHP test-cell



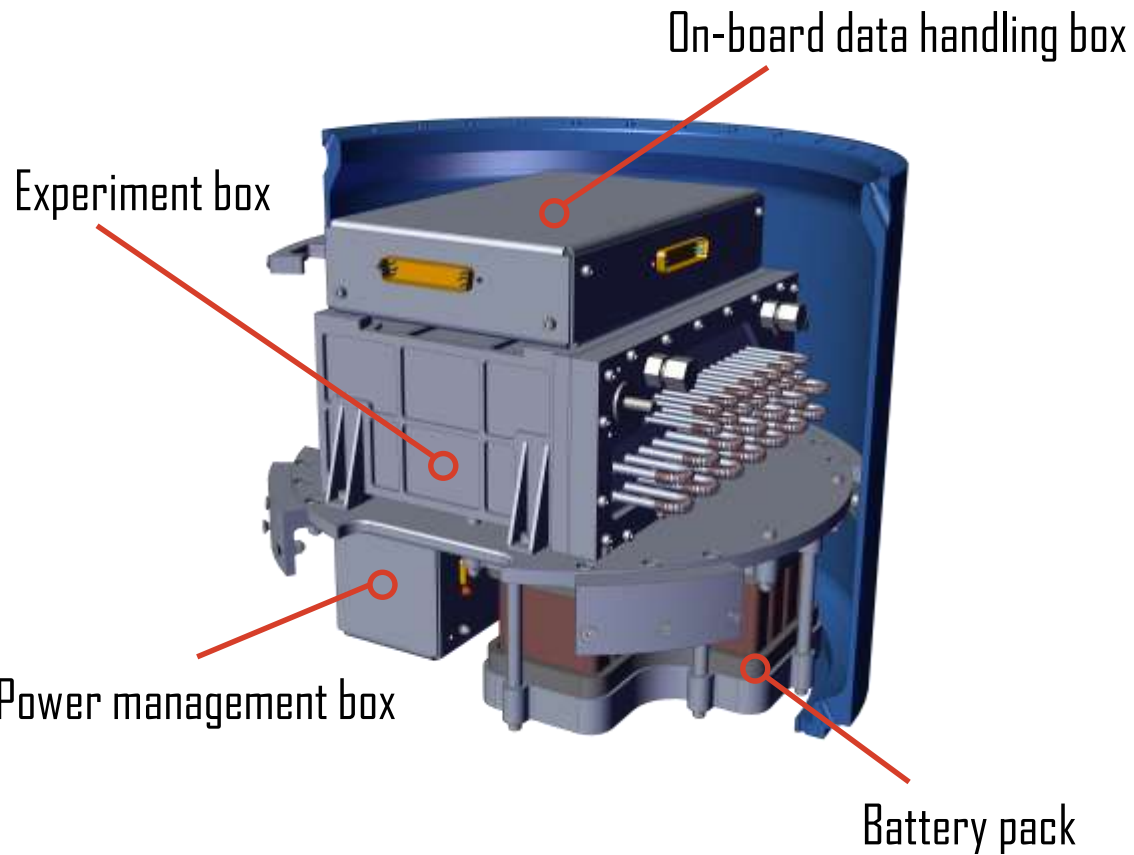
- Evaporator thermocouples
- Condenser thermocouples
- Pressure transducer

Experimental set-up

Experiment box

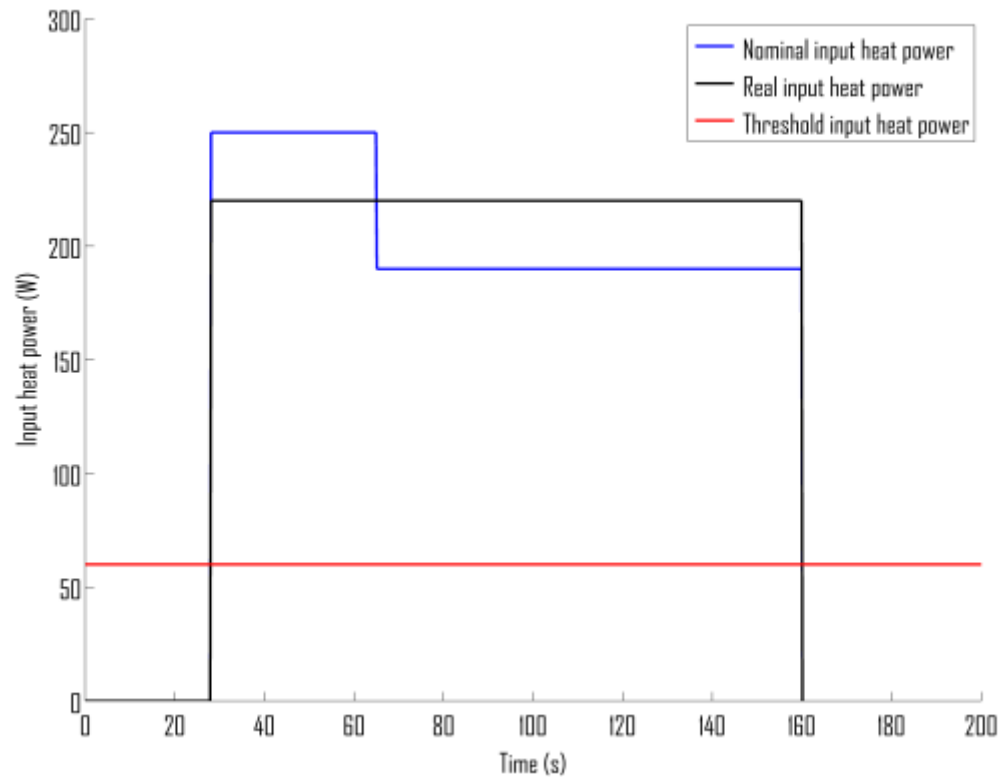


Experimental set-up



Experimental procedures

Large diameter PHP input heat power profile



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Pulsating Heat Pipes (PHPs)

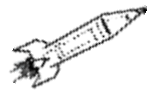
Experimental apparatus and procedures

Experimental results

Conclusions and future developments

Tests summary table

Analysis of the thermal response of two PHPs with different inner tube diameters



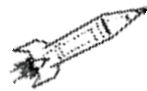
Large diameter PHP tested @ 220 W input heat power



Ground tests: vertical and horizontal positions



Flight tests



Small diameter PHP tested @ 60 W – 40 W input heat power



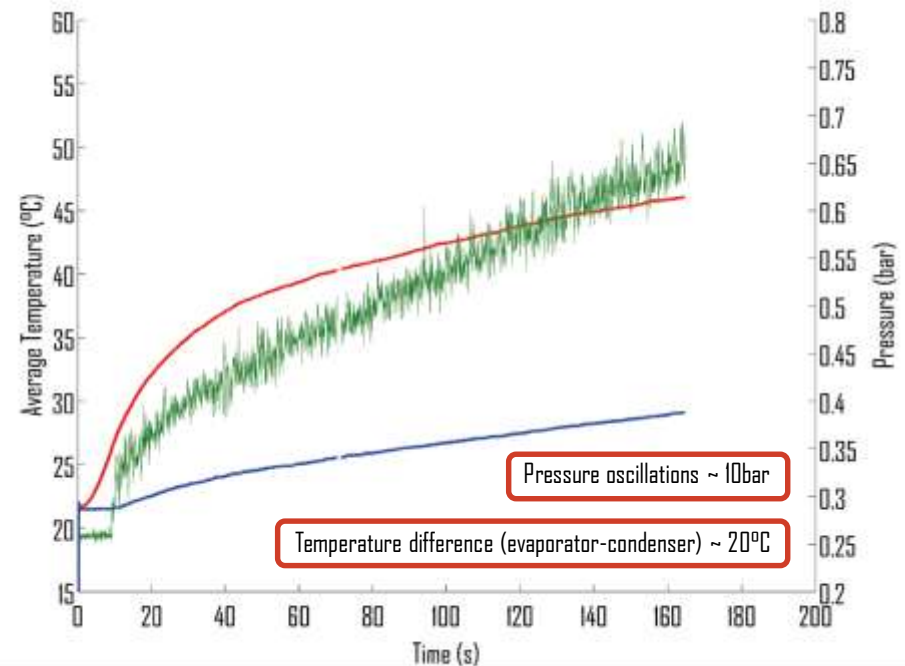
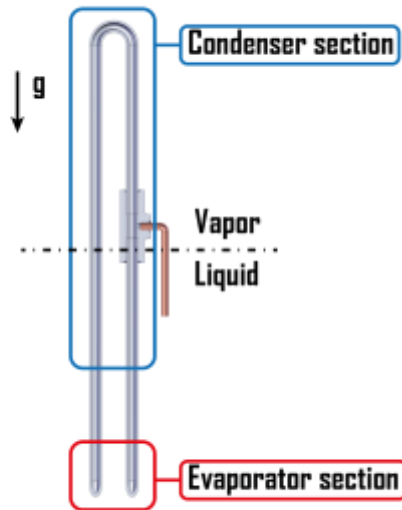
Ground tests: vertical and horizontal positions



Flight tests

Ground tests (1/2)

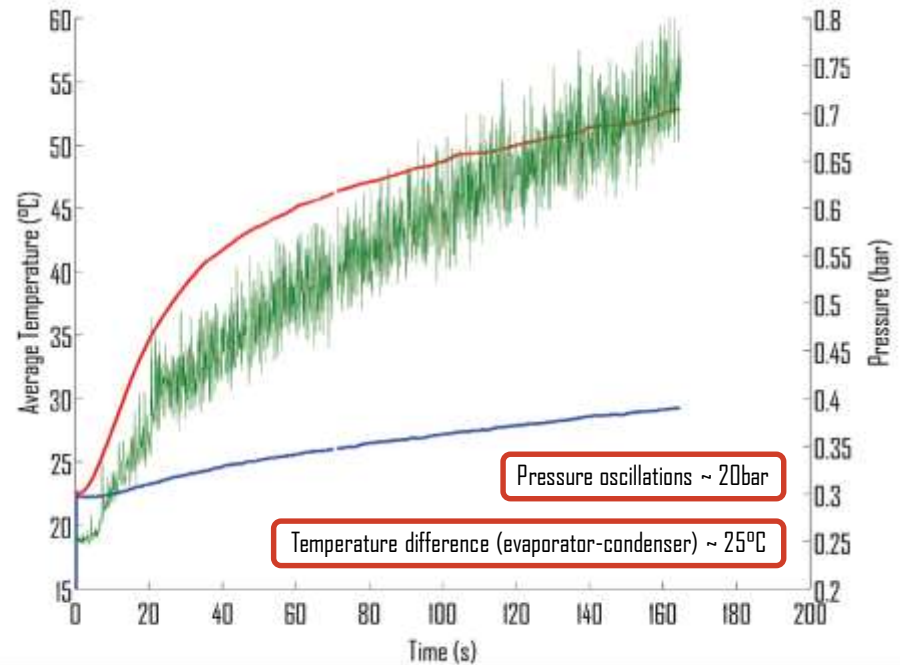
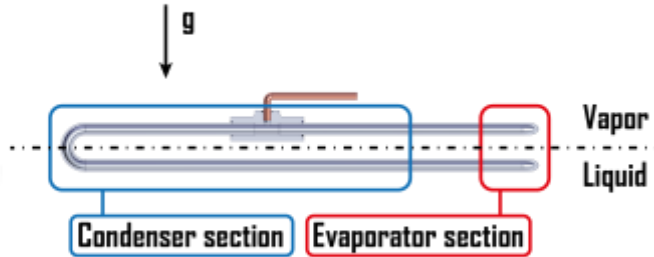
Large diameter PHP in vertical or Bottom Heated Mode (BHM) position



● Evaporator temperature ● Condenser temperature ● Pressure

Ground tests (2/2)

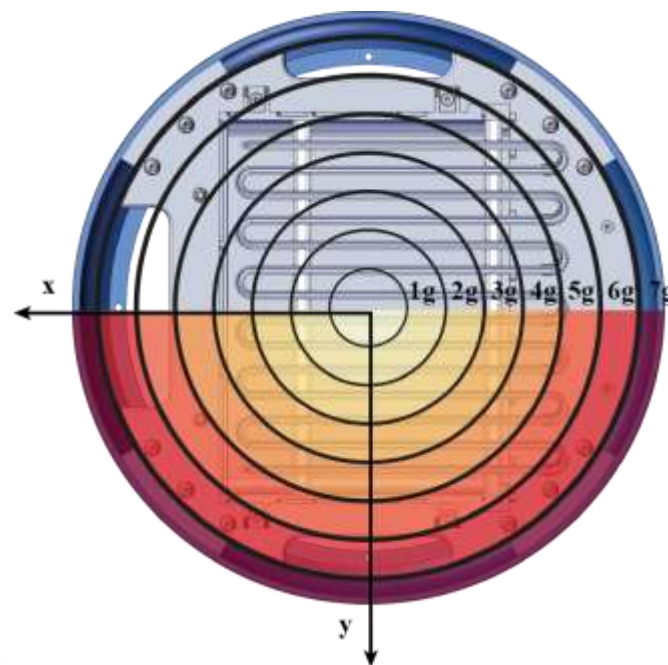
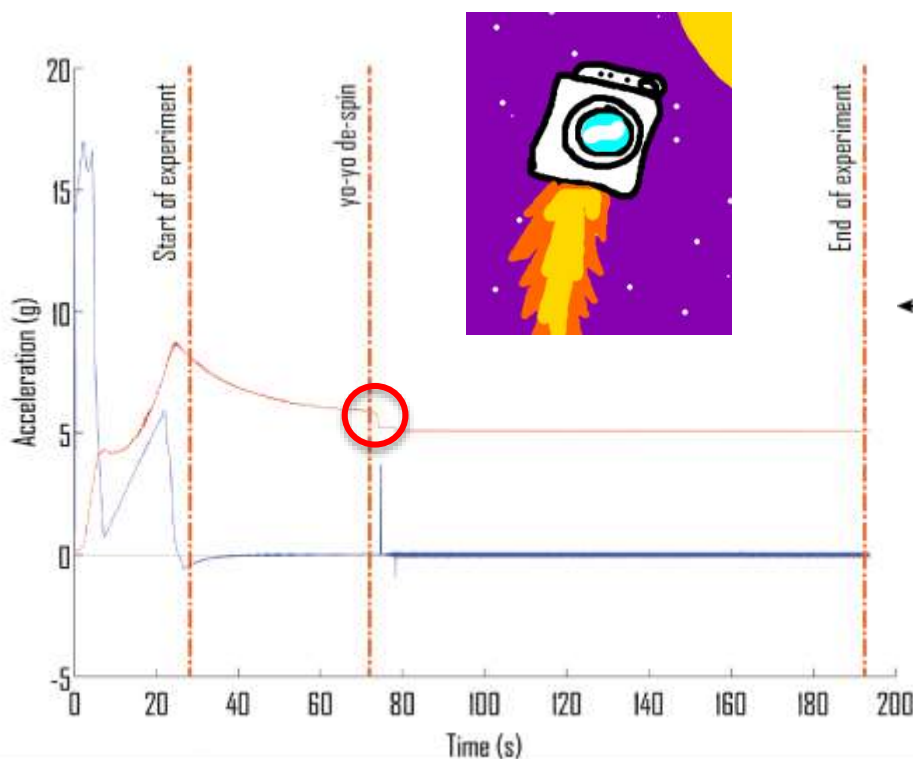
Large diameter PHP in horizontal position



● Evaporator temperature ● Condenser temperature ● Pressure

Flight tests (1/2)

Acceleration levels



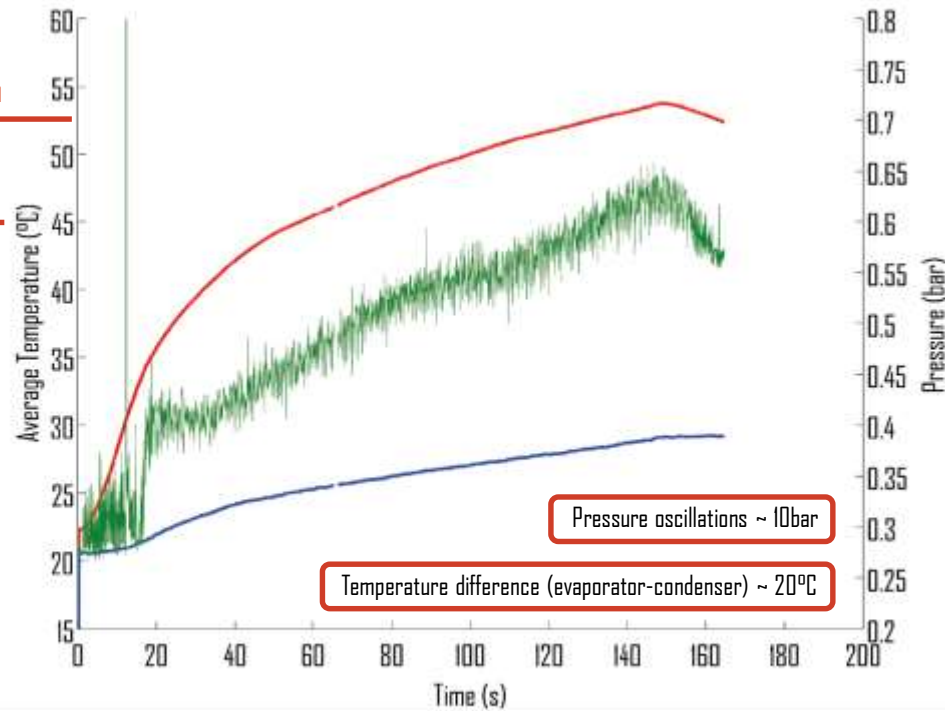
● z-axis acceleration ● x plus y-axis acceleration

Flight tests (2/2)

Large diameter PHP

T_e in horizontal position

T_e in vertical position



● Evaporator temperature ● Condenser temperature ● Pressure

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Conclusions



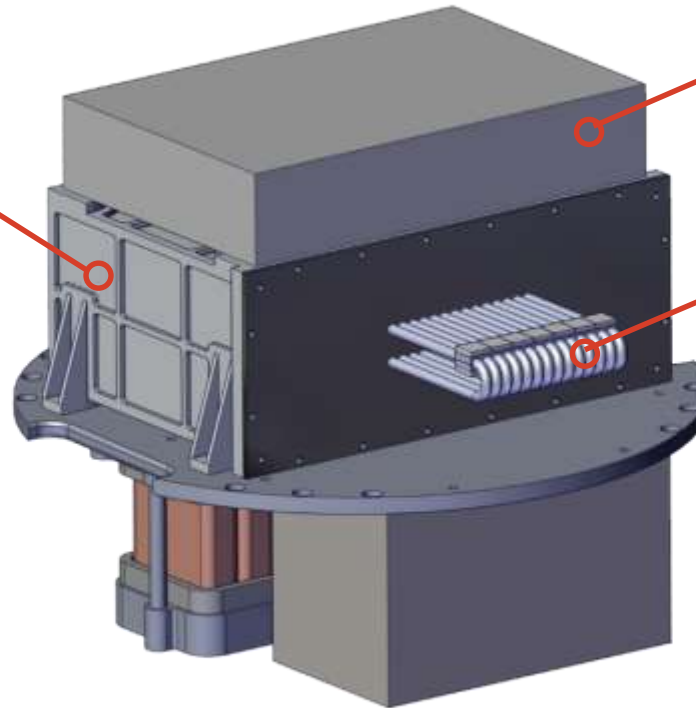
Main outcomes:

- The large diameter PHP didn't experience the expected reduced gravity conditions: as a result it was not possible to observe a net **transition** in the temperatures and pressure temporal evolution associated with the transition of the flow pattern from **stratified** to "**slug and plug**" flow;
- The overall thermal performance on **flight** and on ground with the device in **horizontal** position are comparable as on both cases the acceleration field acts to **separate** the liquid and vapour phase, thus resulting in an operational **detrimental effect**.
- The overall thermal performance on ground with the device in **vertical** position is the best as the acceleration field acts along the flow path direction, thus promoting the **working fluid motion**.

Future Developments

Rexus 21/22 Sounding Rocket Campaign: UPHOS Project

Paraffin dope with
Metallic Foam



New Electronic Boards

Different PHP Layout





Thanks for your attention



www.phosproject.com



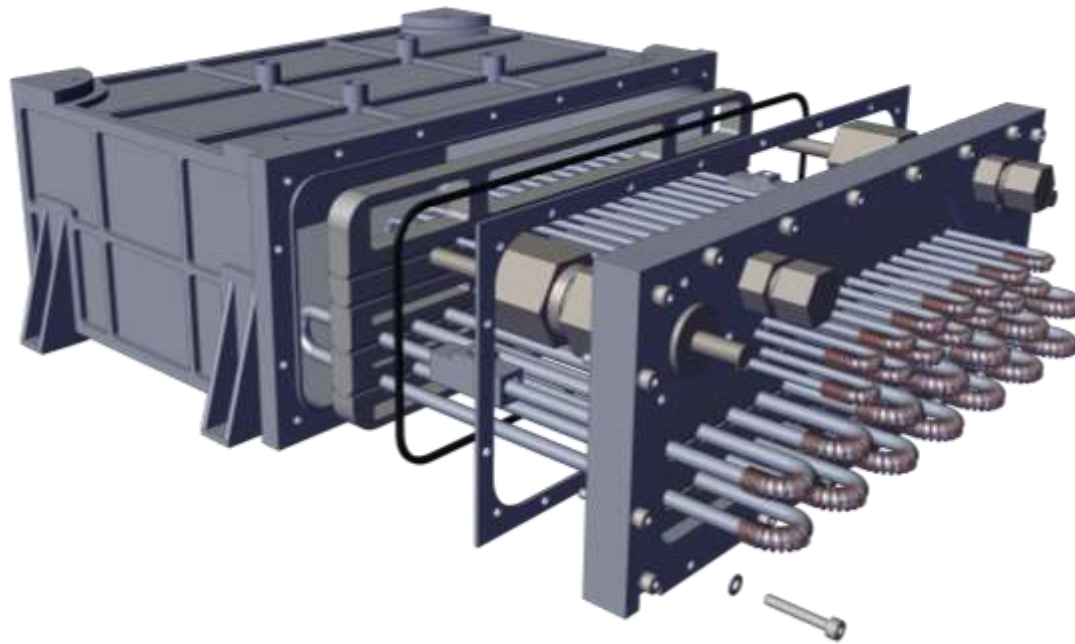
PHOS PROJECT

Pulsating Heat Pipe Only For Space



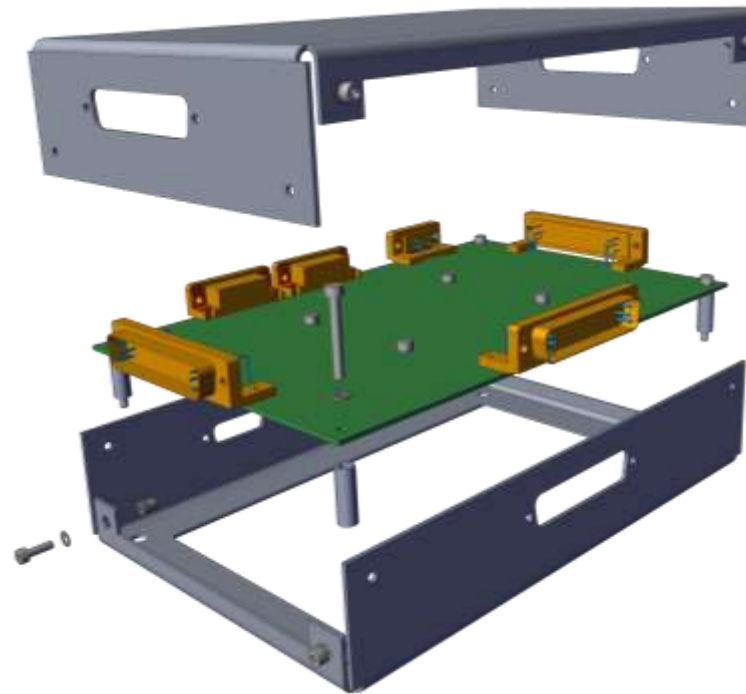
Experimental set-up

Experiment box



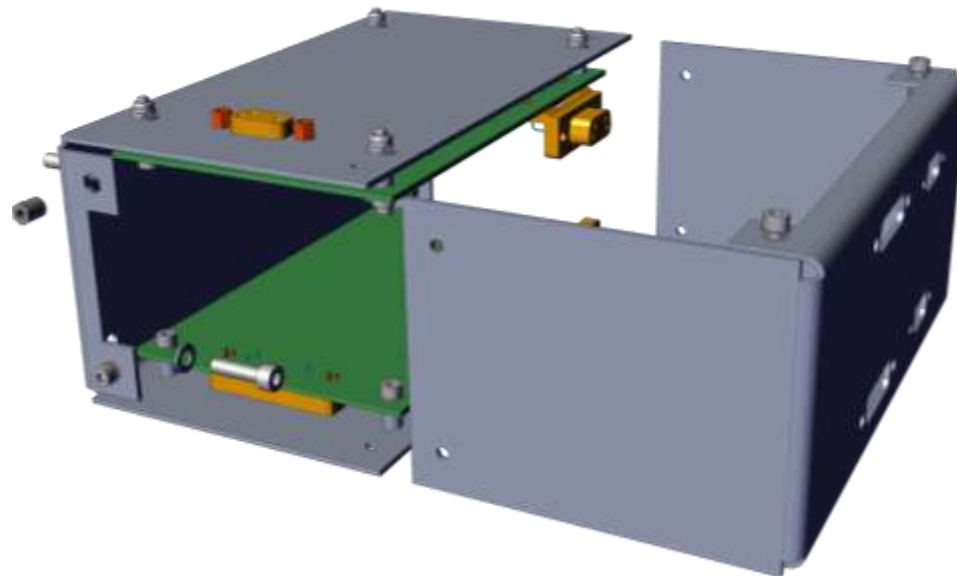
Experimental set-up

On-board data handling box



Experimental set-up

Power management box



Experimental set-up

Battery pack

