MINIATURISED CAPILLARY PUMPED FLUID LOOP : A REALITY FOR ELECTRONIC THERMAL DISSIPATION

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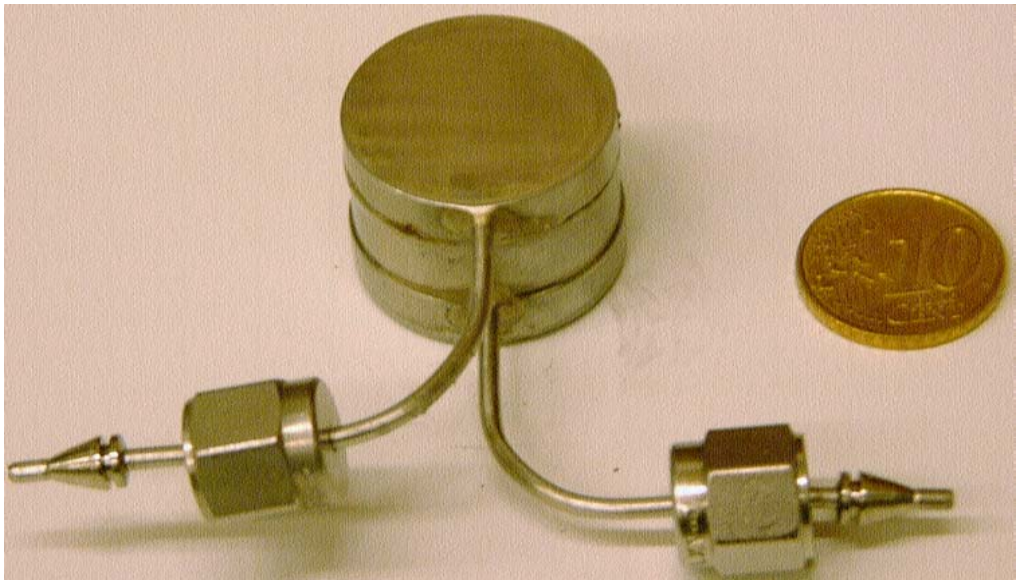


With the participation of ESA/ESTEC and CNES

SCOPE

3 kind of thermal problems : cause of limited performances

Terrestrial

Thermal regulation in confined area :
Limitation of CPU frequency

Q = 25 / 30 W (increase of Q : perfo)

T < 40°C (decrease of T : cost)

S < 30 x 30 , l = 130 mm

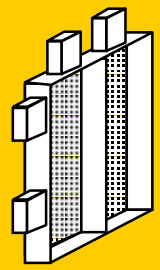
Spatial

Stellar sensor or CCD component :
Limitation of the performance

Q = 5 W (increase of Q: Nbr of CCD)

T = - 25°C (decrease of T : perfo)

S = 10 x 10 , l = 200 mm



Electronic board (ADE4 type):
Limitation of component reliability

Q = 15 W (Increase of Q: perfo)

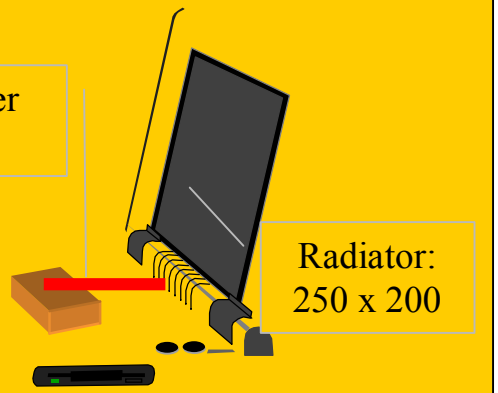
T = 80°C (decrease of T : reliable)

S < 30 x 30 , l = 500 mm

SCOPE

3 kind of thermal requirements: Which are future **K**ey **S**uccess **F**actors

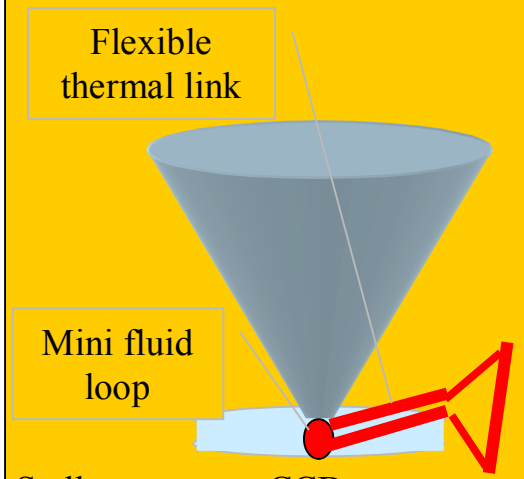
Terrestrial



Thermal regulation in confined area :
Existing solution: HP with C<0,8W/K

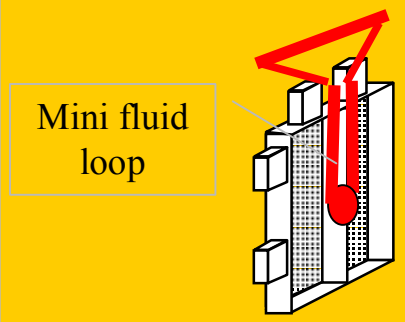
K.S.F of future Mini Thermal Device
C > 0,8 W/K
cost < 1 US$/W
low bulk, low mass

Spatial



Stellar sensor or CCD component
Existing solution: conduction

K.S.F. of future Mini Thermal Device
M < 100 g
Flexible thermal link

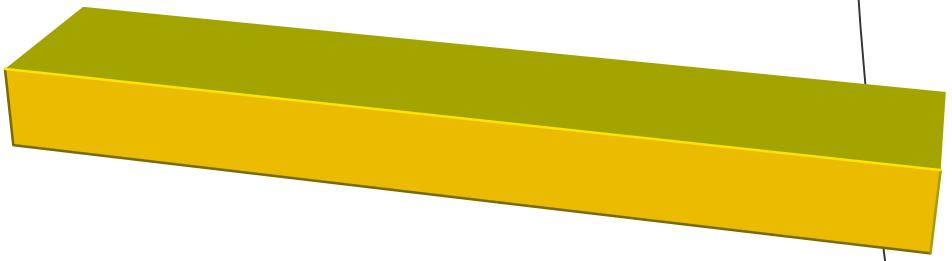


Electronic board
Existing solution: conduction, HP

K.S.F. of future Mini Thermal Device
C > 0,8 W/K
M < 100 g
cost < 20 US$/W

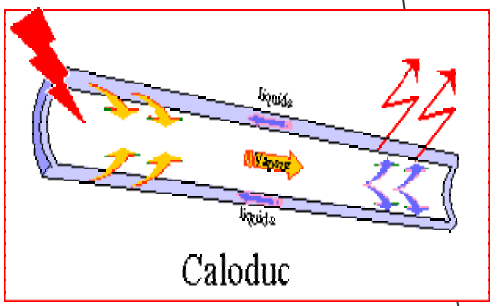
CANDIDATE SOLUTIONS

Copper or Metal Matrix



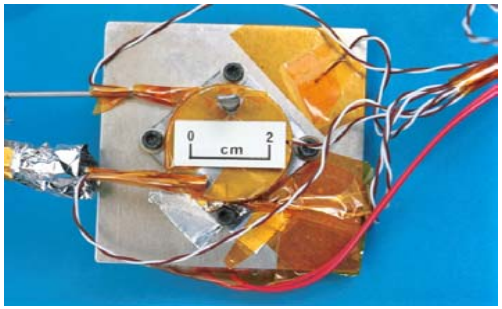
Mini HP (early 90)

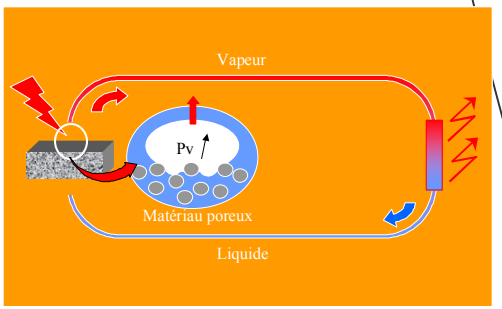
(ASTRIUM, …)



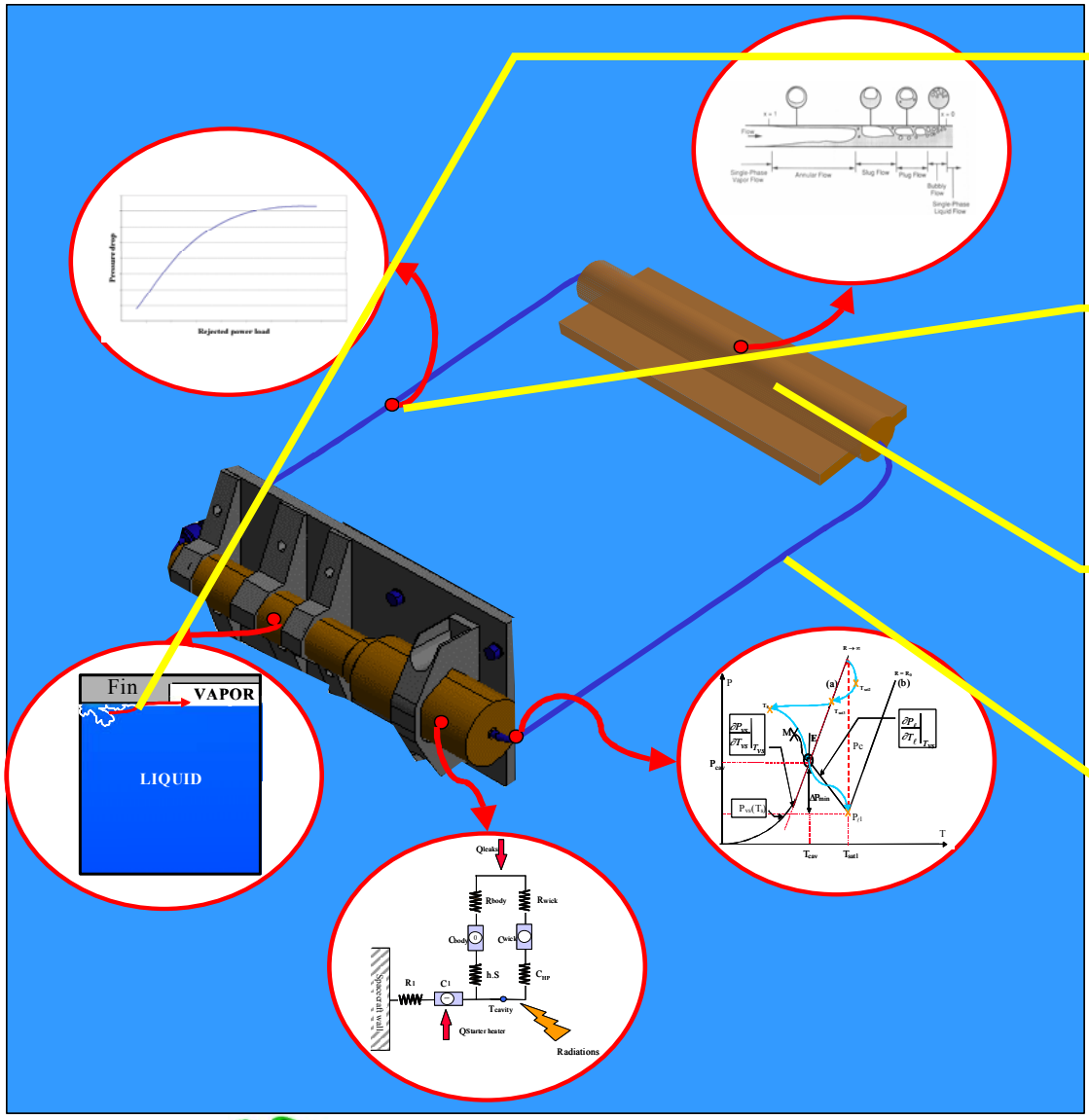
Mini fluid loop (96)

(ASTRIUM/ESTEC mini-loop)





HOW DOES LHP WORK ?



1- Evaporation at Wick/Fin interface

2- Vapor bubble growth along the tube

3- Condensation in the colder area

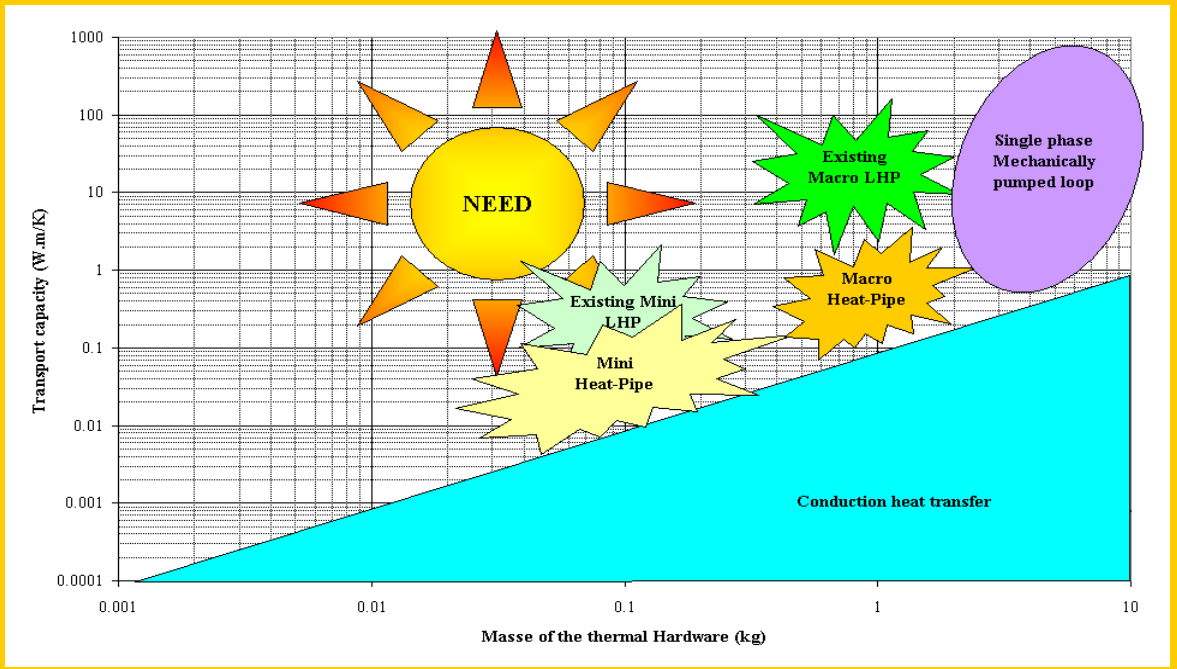
4- Liquid flow back to the evaporator due to the vapor production

THERMAL PERFORMANCES OF EXISTING SOLUTIONS

Designation	STATUS	Evaportor size	Weight "W" (kg)	Temperature NOP (°C)	Temperature OP (°C)	Maximal power load(W)	Transport length "L" (m)	Overall conductance "C" (W/K)	Performance ratio C.L/W
Copper conduction	Space qualified	/	8900 kg/m3	/	/	/	/	700 W/m/K	0.08 W.m/kg.K
Mini-Heat pipe	Space qualified	/	0.08	-50 / 110	50/110	20 W	0.15	1.1	2 W.m/kg.K
Mini BF 1° generation	Prototype	30 x 30 x 15 mm	0.1	-50 / 60	-20 / 50	15 W	1	0.2	2 W.m/kg.K
Specifications	Prototype	30 x 30 x 15 mm	< 100 g	-50 / 90	-50 / 90	30 W	0.5	> 0.8	> 4 W.m/kg/K

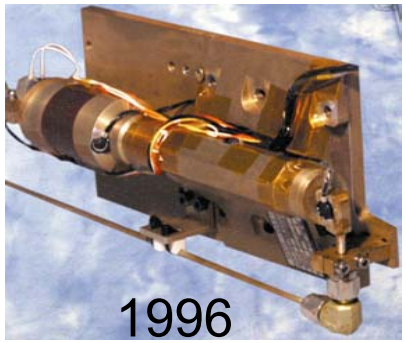
Most of the future thermal hardware needs is not yet covered.

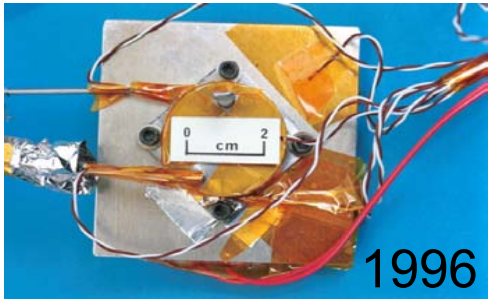
It will be the main challenge of the decade

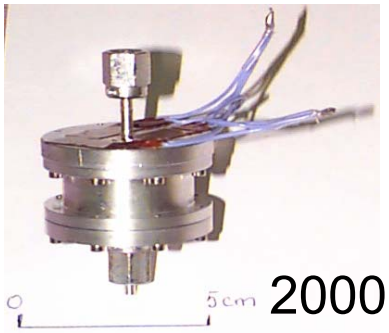


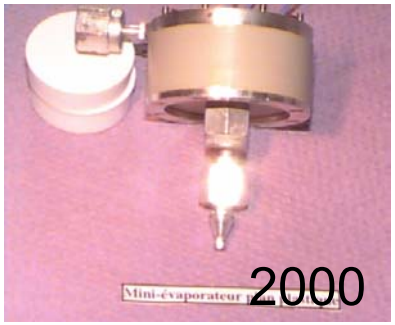
TRADE-OFF ON DIFFERENT BREADBOARD CONCEPTS

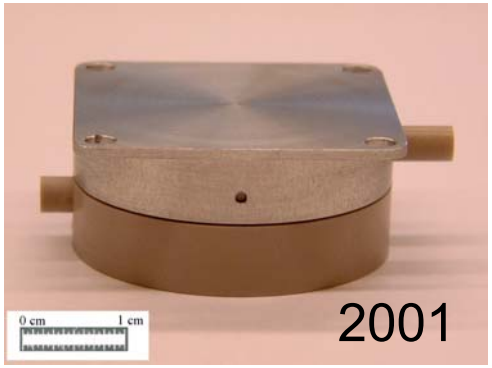
During 4 years more than 200 tests were performed on about 10 different mini-LHP design, in order to improve performance and reliability

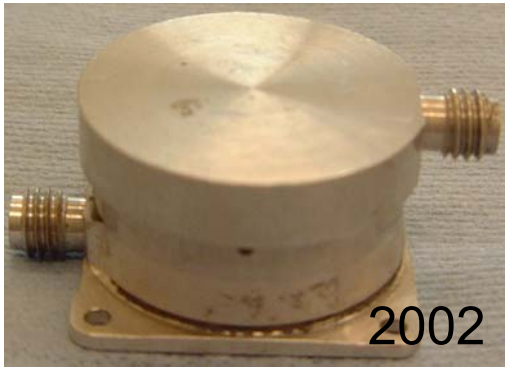


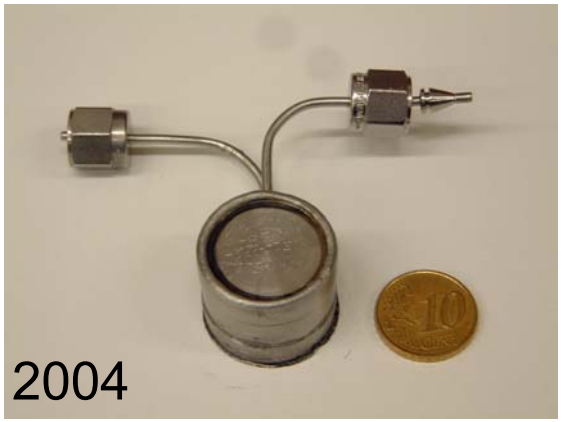






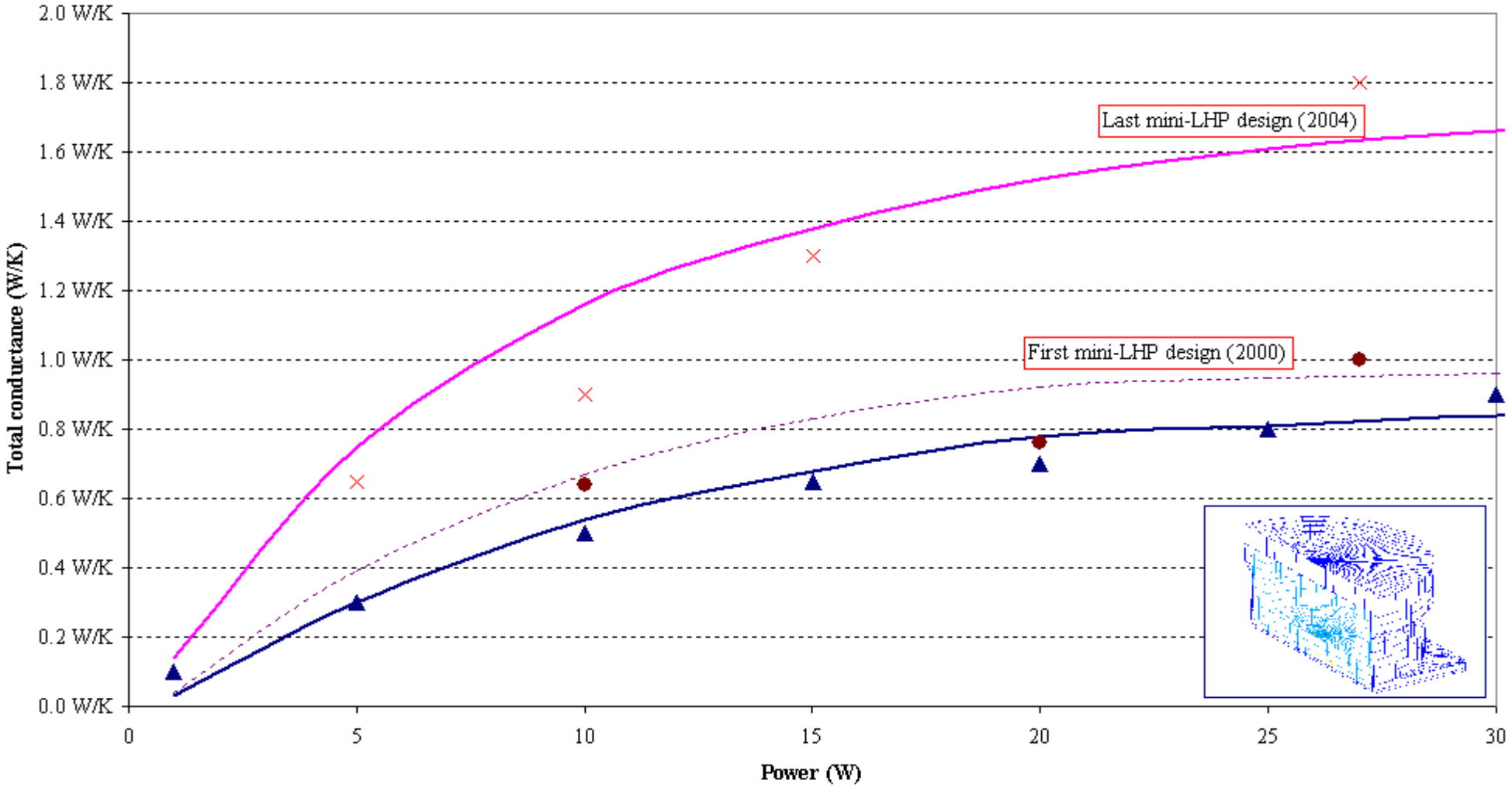






PERFORMANCE EVOLUTION

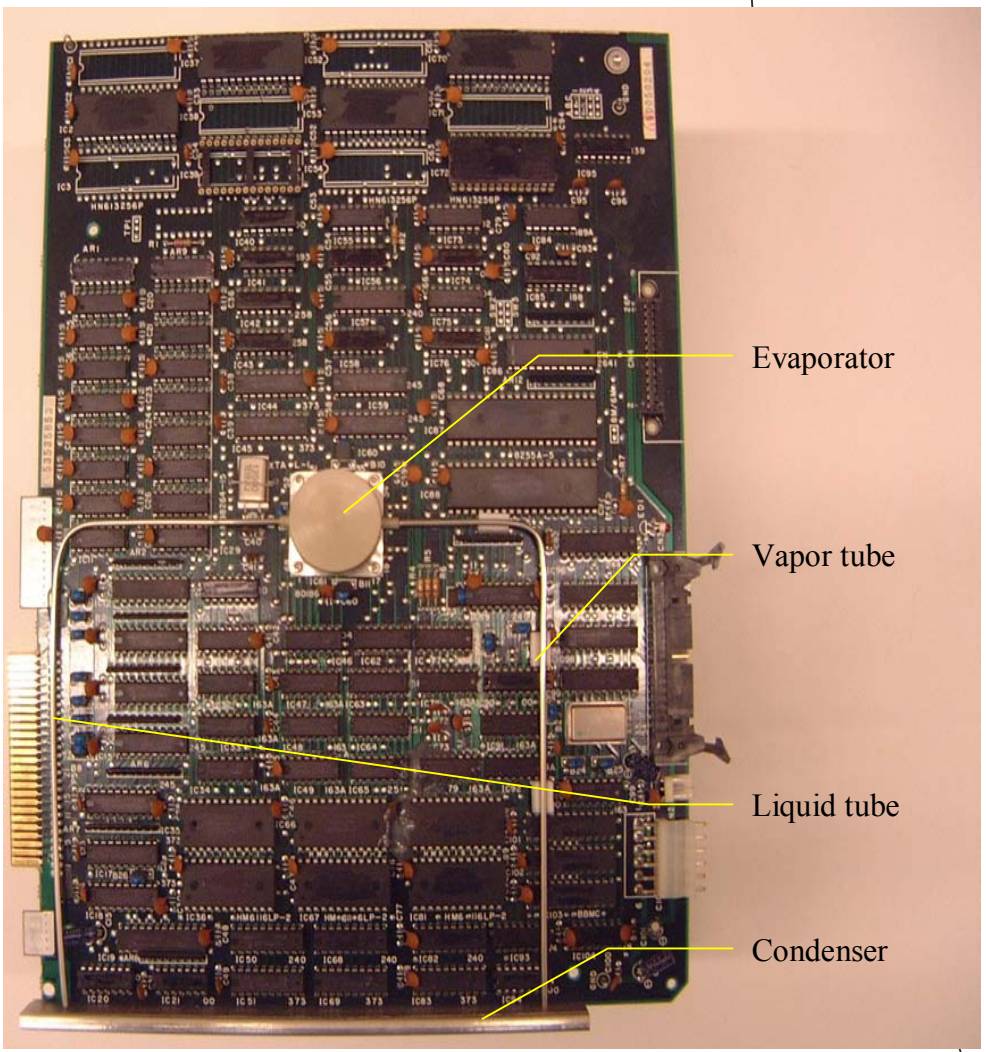
Since 2000, the thermal performance of the LHP as tripled



MINI-LHP STATUS

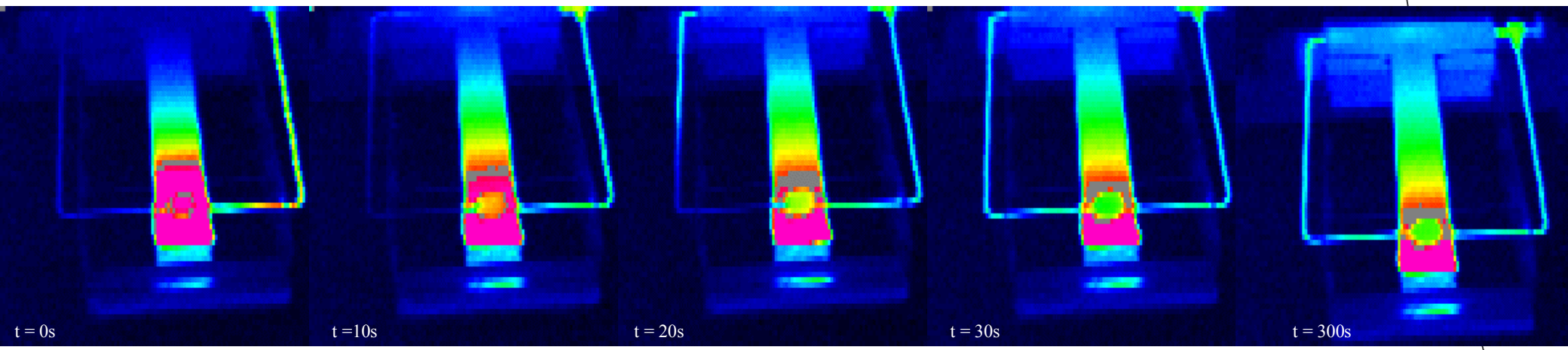
The final mini-LHP design is fully compliant with our requirements with :

- Evapo mass : 40 g
- Evapo size : 26 x 26 x 19 mm
- LHP mass : 80 g
- Tube size : ID 1.6, OD 2 mm
- Tube length up to 2 x 0.5 m
- Proof pressure : 150 bars
- Burst pressure : 478 bars
- QS : 250 g
- Sine : 20g on 20-100 Hz
- Random80 gRMS (0.1-2 kHz)
- He leak : $< 10^{-9}$ atm.cm^3/s
- Tube flexibility : < 1 kN/m
- OP Temperature : -20/+90°C



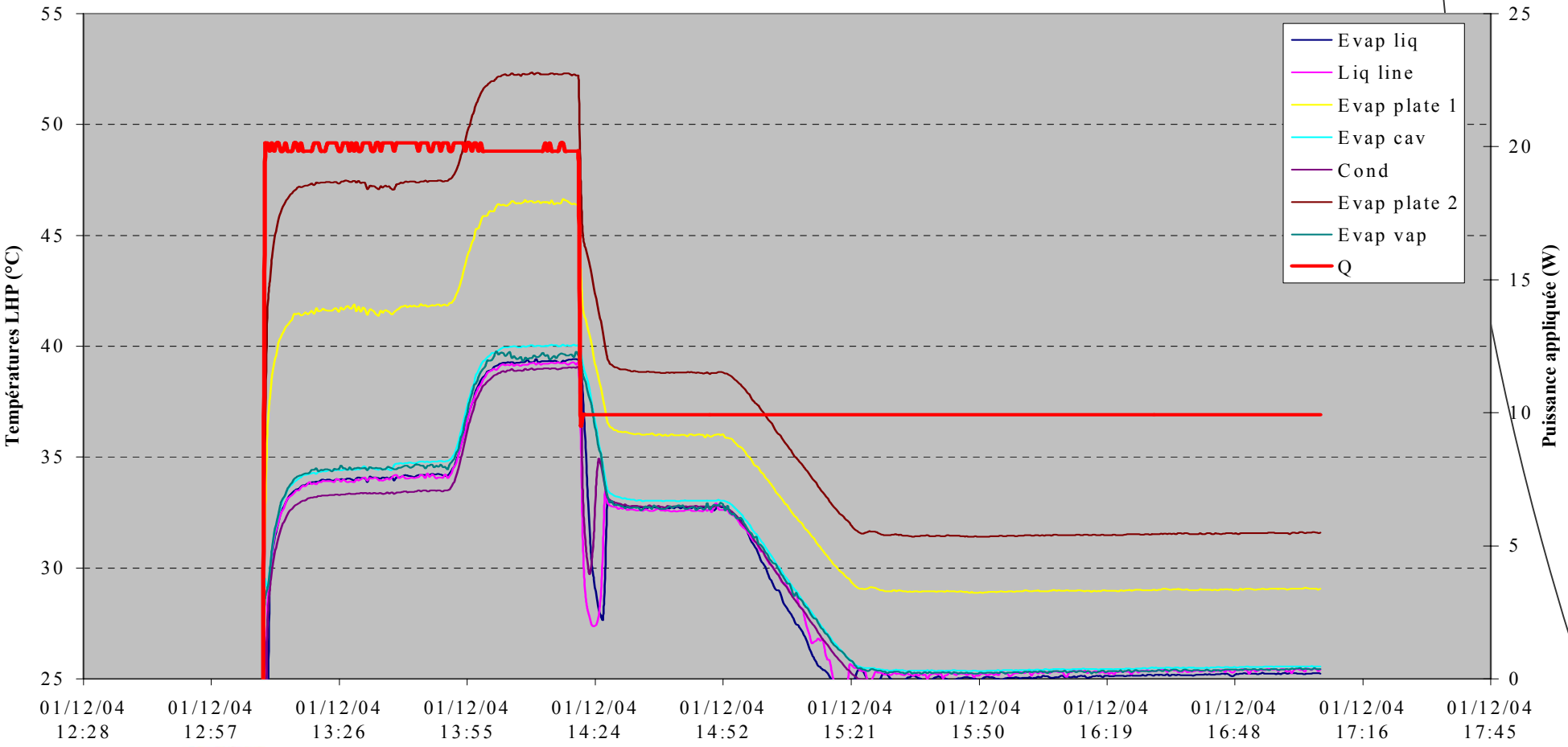
TEST OF A MINI-LHP ON A BOARD

The mini-LHP has been functionally tested in different configuration (vacuum, against gravity,…), an Infra-red imagery of a mini loop start-up shows the impact of the LHP working on the temperature of a board



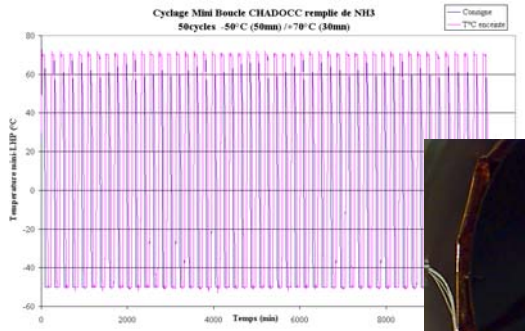
QUALIFICATION TESTS OF A MINI-LHP 1/3

An example of the mini LHP behaviour for different power load and condenser temperature

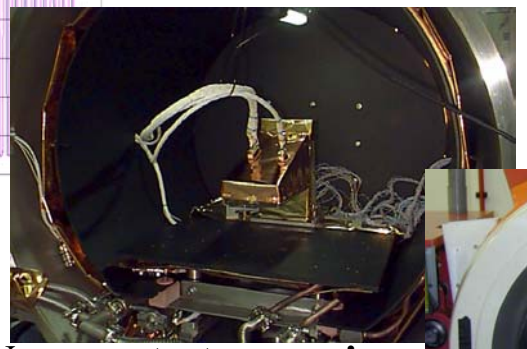


QUALIFICATION TESTS OF THE MINI-LHP 2/3

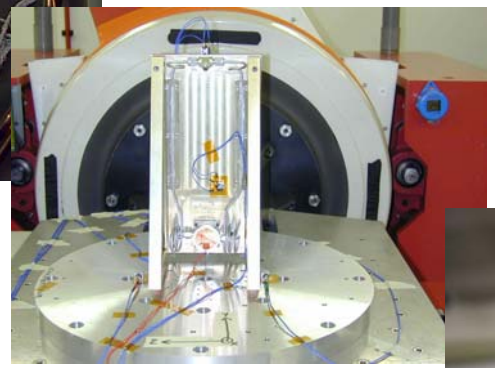
The following qualification tests have already been performed on the Mini-LHP :



50 thermal cycling –20/+90°C



Vacuum test campaign

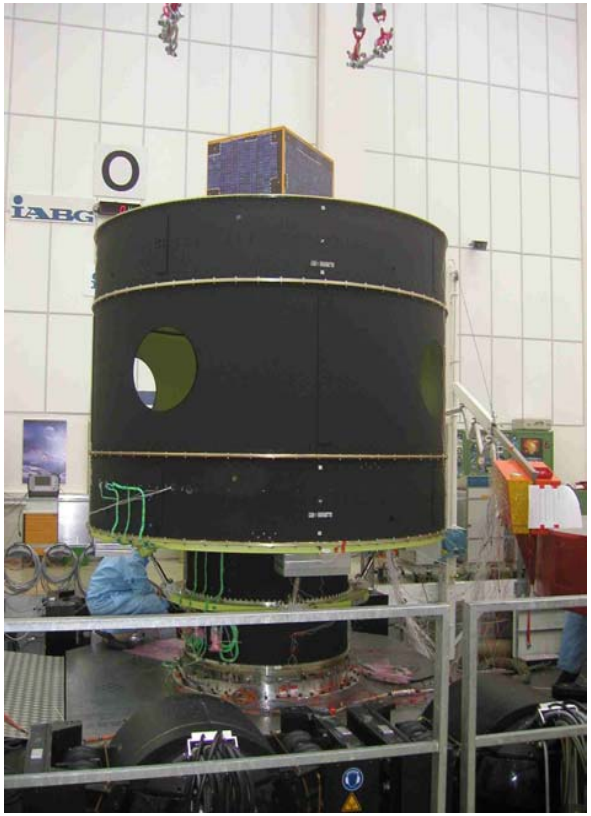


Vibration : 80gRMS

Burst test at 478 bars

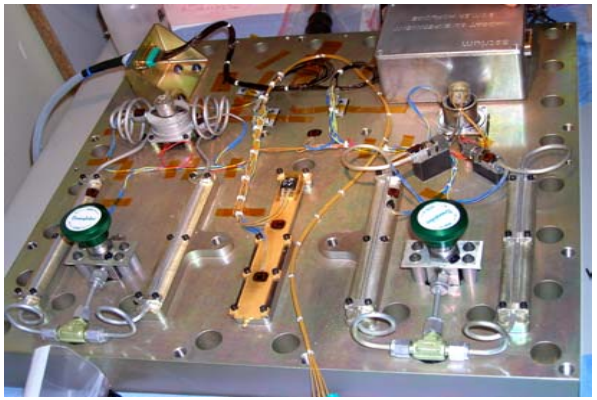
QUALIFICATION TESTS OF A MINI-LHP 3/3

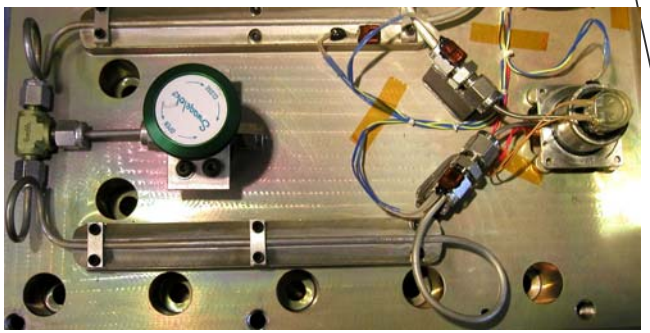
➢ Two mini-LHP have been delivered for flying mid 2004 onboard next A5 ECA launcher.



➢ Another LHP will be delivered end of this year for flying mid 2005 onboard Russian launcher

➢ A life test campaign of more than 2 years on 6 mini-LHP will start in mid 2004



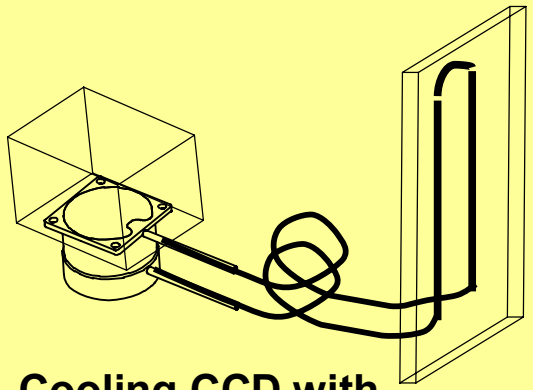


At mid 2005 the mini-LHP will be fully qualified and ready for commercial applications.

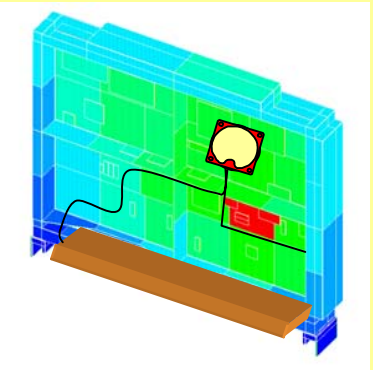
MINI-LHP APPLICATIONS

At this time the mini-LHP is already identified and planned in order to be implemented in :

- Start tracker component (2 to 5 W applications)
- New small & powerful electronic equipment (10 to 20 W)
- LASER cooling (50 W to 100 W)



Cooling CCD with flexible thermal link



Electronic board/equipment cooling

EADS-ASTRIUM MINI-LHP POSITIONNING

Designation	STATUS	Evaportor size	Weight "W" (kg)	Temperature NOP (°C)	Temperature OP (°C)	Maximal power load(W)	Transport length "L" (m)	Overall conductance "C" (W/K)	Performance ratio C.L/W
Copper conduction	Space qualified	/	8900 kg/m3	/	/	/	/	700 W/m/K	0.08 W.m/kg.K
Mini-Heat pipe	Space qualified	/	0.08	-50 / 110	50/110	20 W	0.15	1.1	2 W.m/kg.K
Mini BF 1° generation	Prototype	30 x 30 x 15 mm	0.1	-50 / 60	-20 / 50	15 W	1	0.2	2 W.m/kg.K
Mini LHP EADS-AST	**PFM**	**26 x 26 x 19 mm**	**0.08**	**-50 / 90**	**-20 / 90**	**100 W**	**1**	**1.8**	**22 W.m/kg.K**
Specifications	Prototype	30 x 30 x 15 mm	< 100 g	-50 / 90	-50 / 90	30 W	0.5	> 0.8	> 4 W.m/kg/K

This hardware is about 250 times better than classical conductive straps, and 10 times better than heat pipes.
For heat length of 1m