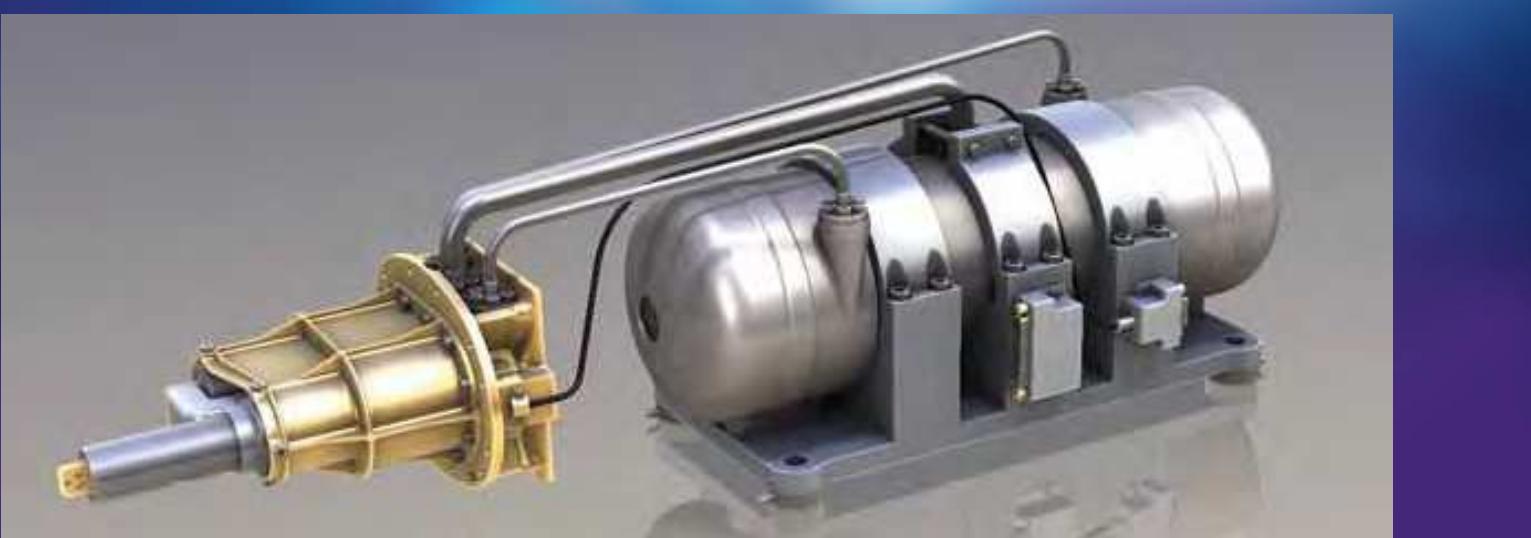




Performance Testing of a 15K Pulse Tube Cooler for Space Applications

CEC , 2015-06-29 | James Butterworth



Participants

- J. Butterworth
G. Aigouy
S. Martin
C. Chassaing
 - Air Liquide Advanced Technologies, France



- J-M. Duval
I. Charles
 - SBT, UMR-E CEA / UJF-Grenoble 1, Grenoble, France



- G. de Jonge
J. Mullié
 - Thales Cryogenics, Eindhoven, The Netherlands



- M. Linder
 - European Space Agency (ESA), The Netherlands



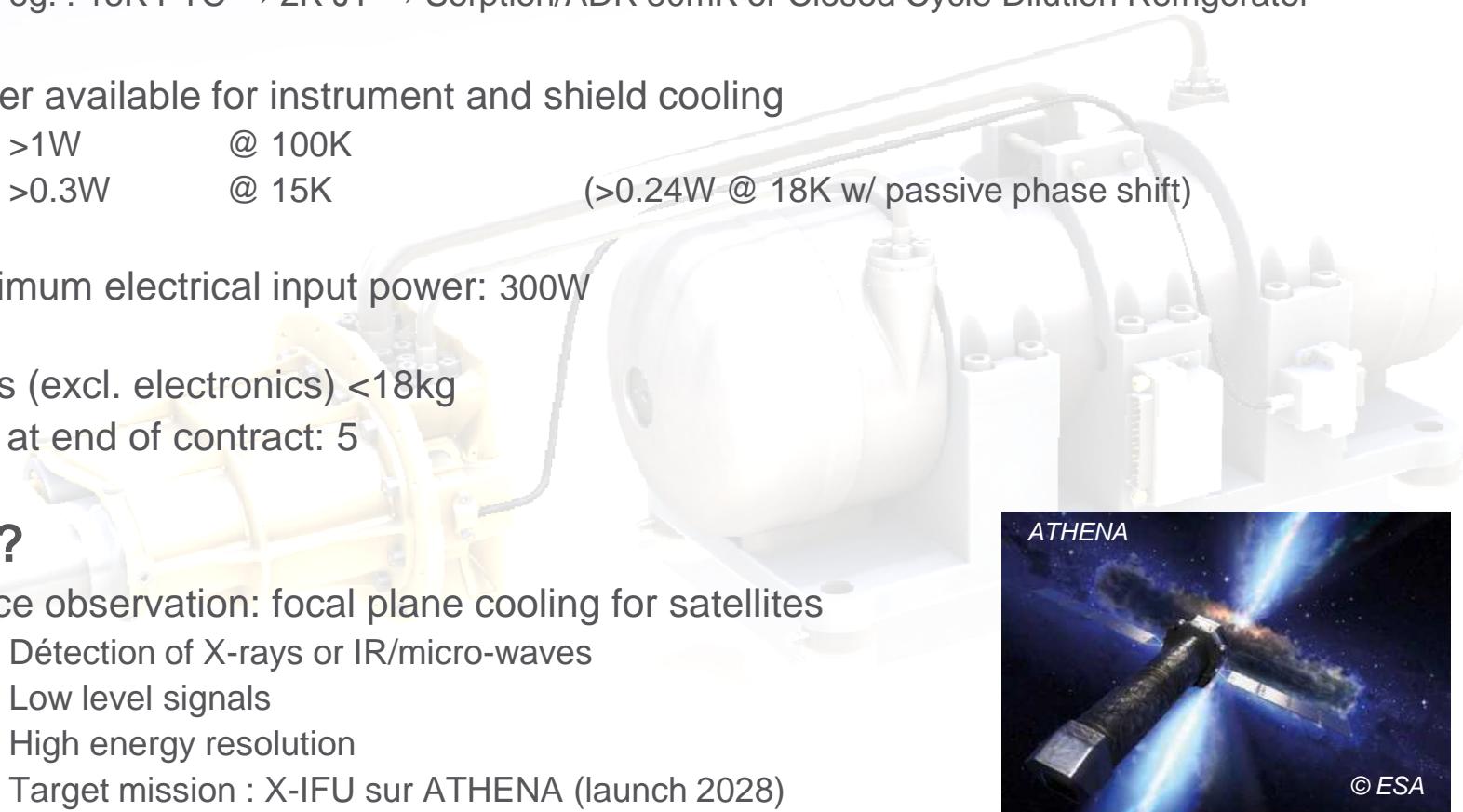
15K Pulse Tube Cooler

Aims ?

- Pre-cool a low temperature cryogenic chain
 - eg. : 15K PTC → 2K JT → Sorption/ADR 50mK or Closed Cycle Dilution Refrigerator
- Power available for instrument and shield cooling
 - >1W @ 100K
 - >0.3W @ 15K (>0.24W @ 18K w/ passive phase shift)
- Maximum electrical input power: 300W
- Mass (excl. electronics) <18kg
- TRL at end of contract: 5

Why ?

- Space observation: focal plane cooling for satellites
 - Détection of X-rays or IR/micro-waves
 - Low level signals
 - High energy resolution
 - Target mission : X-IFU sur ATHENA (launch 2028)

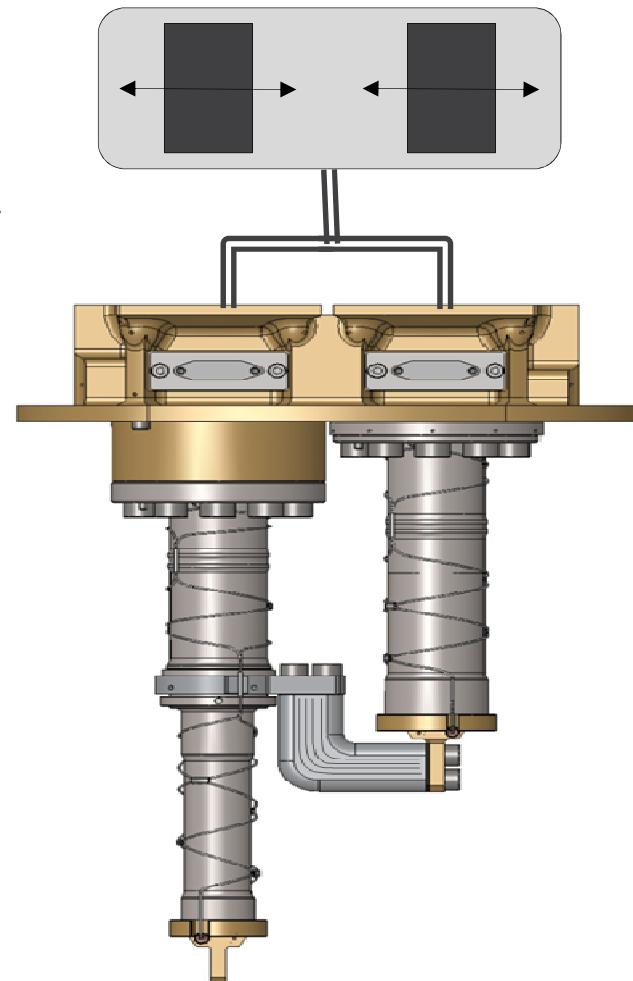


© ESA

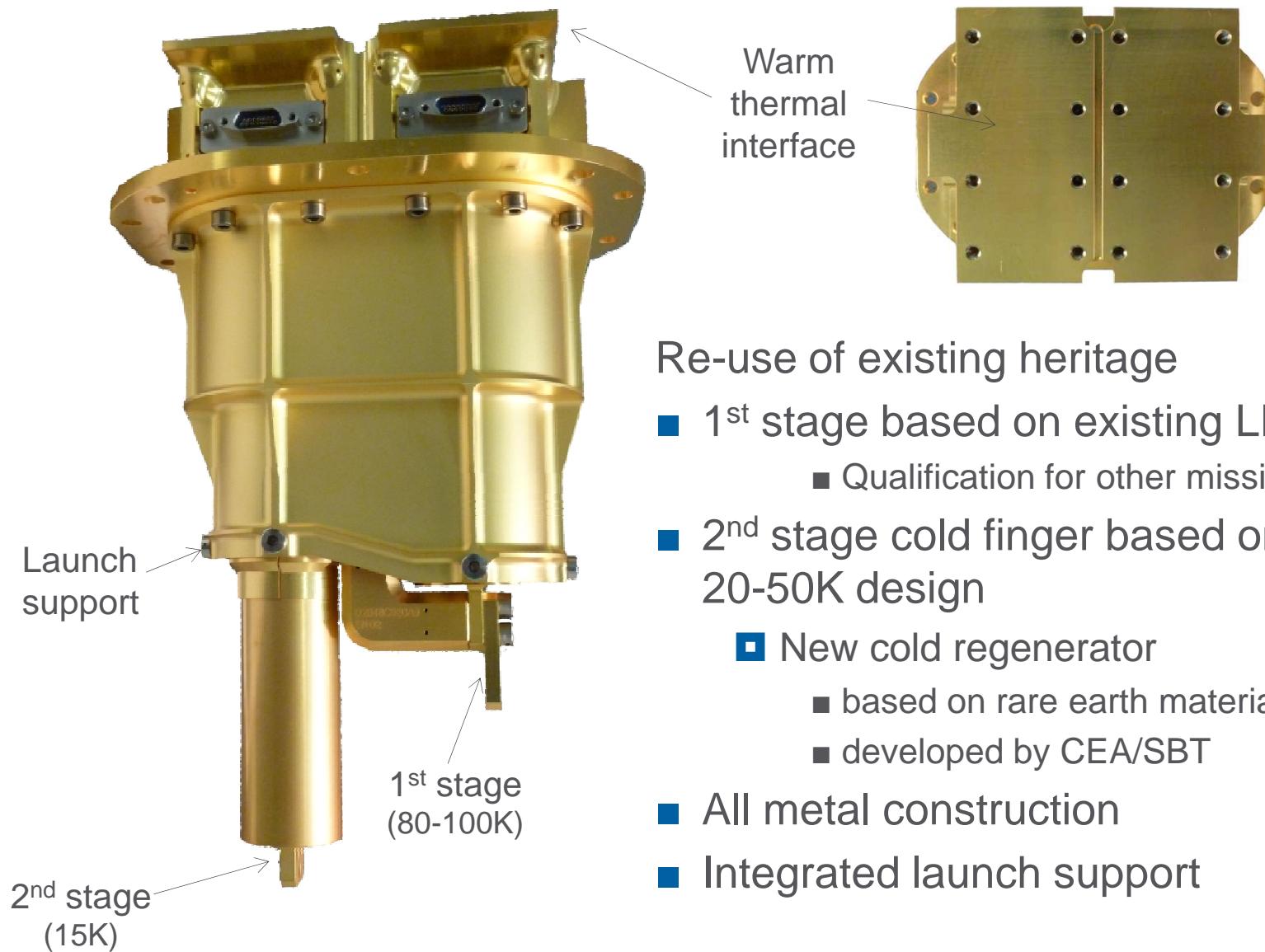
15K PTC : Design

Selected configuration :

- 2 cooling stages
 - Single cold head with 2 cold fingers driven by a common compressor
 - A 15K cold finger pre-cooled by
 - A cold finger based on the existing LPTC
 - Re-use of existing developments
 - Large Pulse Tube Cooler Design already being qualified for other missions (eg. MTG)
 - Previously developed 20-50K PTC
- New 300W compresseur
- Engineering model manufactured in 2014



15K PTC Cold Head



Re-use of existing heritage

- 1st stage based on existing LPTC
 - Qualification for other missions
- 2nd stage cold finger based on an improved 20-50K design
 - New cold regenerator
 - based on rare earth materials
 - developed by CEA/SBT
- All metal construction
- Integrated launch support



15K PTC Compressor



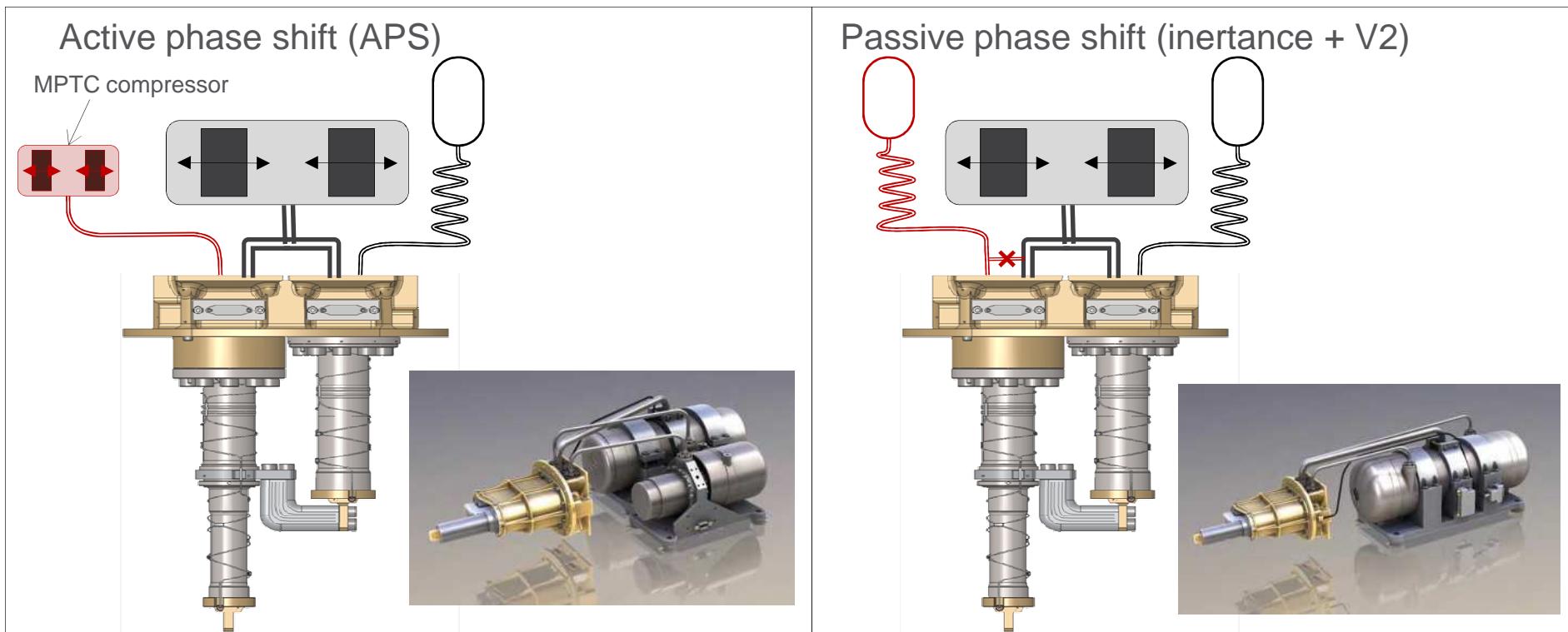
- Dual opposed pistons
- Flexure bearings
- Clearance seal
- All welded design
- 300W electrical power

Developed in collaboration with Thales Cryogenics BV

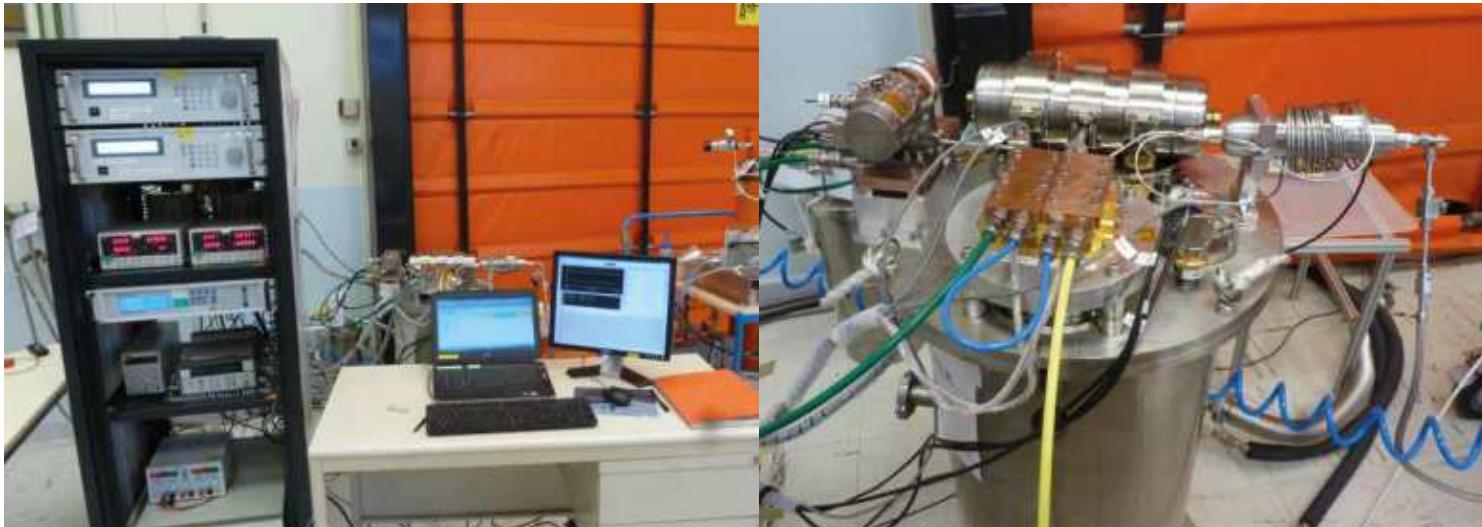
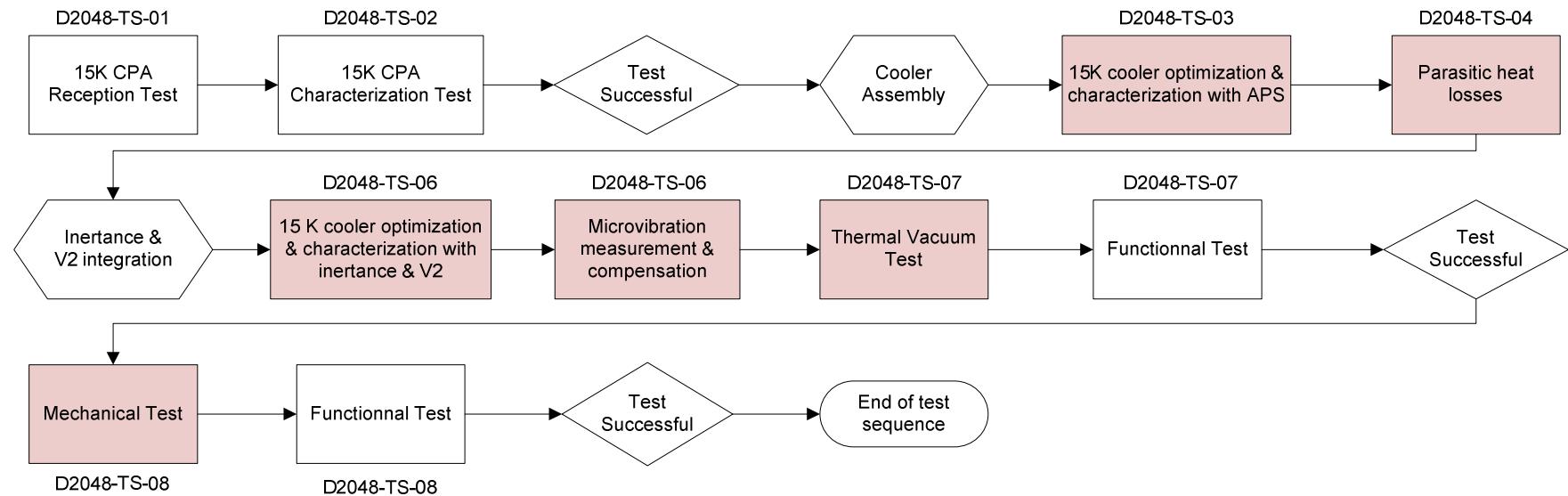
THALES

15K PTC : Phase shifter design

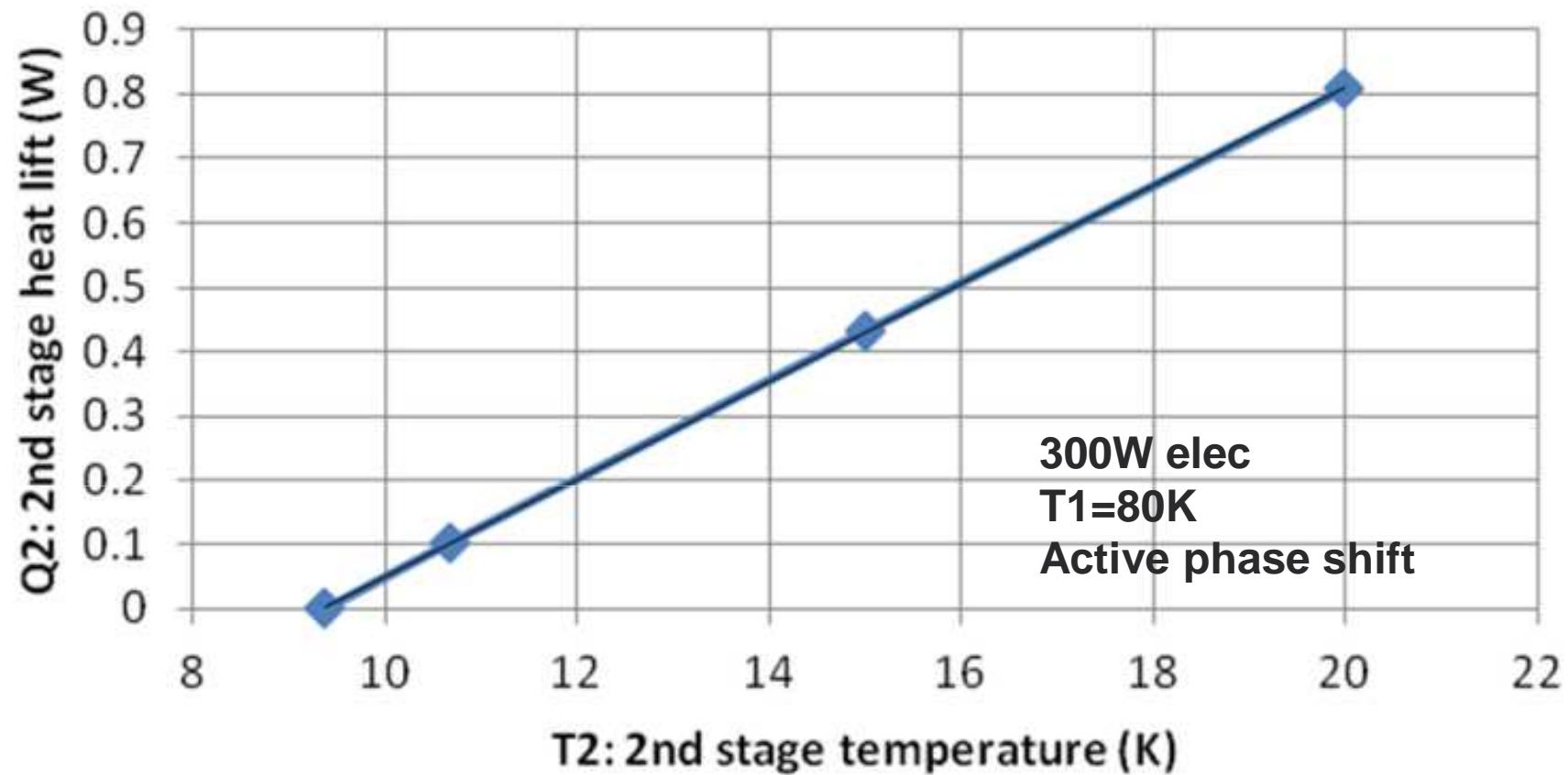
- 2 options are considered
 - Active phase shift (APS, based on the MPTC compressor)
 - More complex but in principal better performance at low temperature
 - Passive phase shift (inertance + double injection)
 - Simpler but with lower performance
 - *Initially considered for 18K operation (⁴He JT pre-cooling)*



15K PTC test campaign

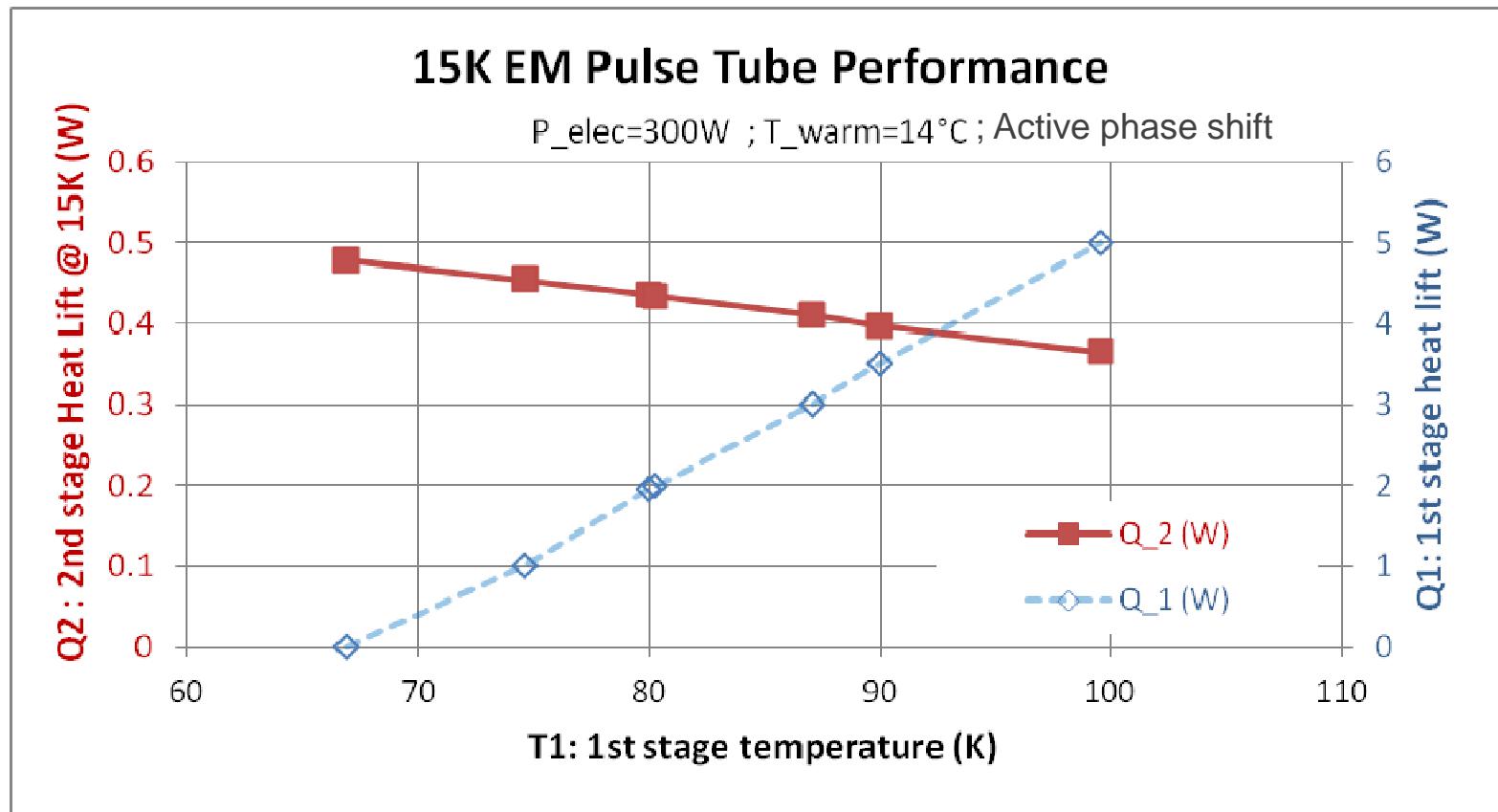


Test results: 2nd stage performance with APS



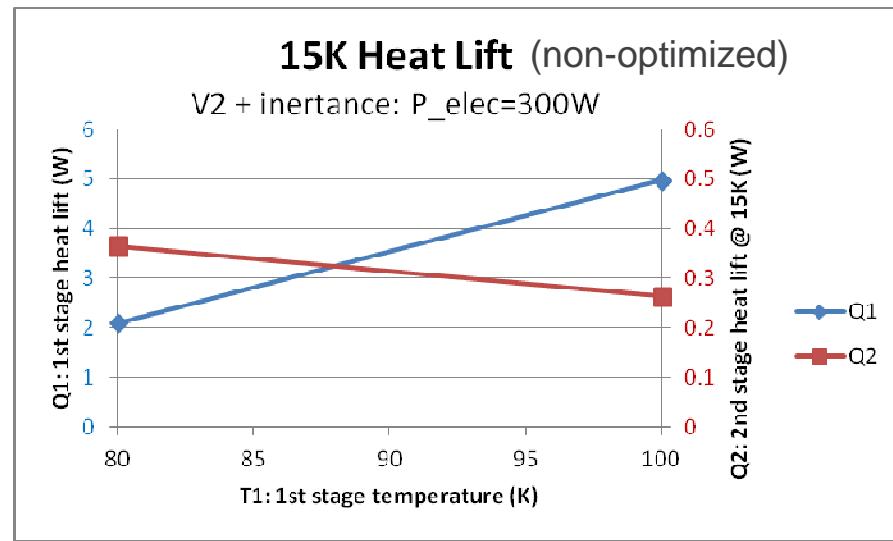
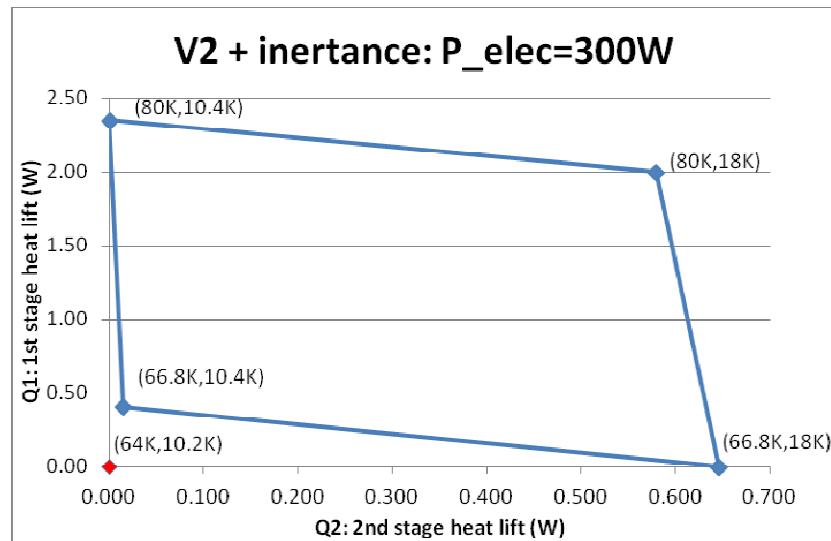
- Active Phase Shift Configuration
 - $T_{min} = 9.2K$
 - 435mW @ 15K
 - 650mW @ 18K

1st stage temperature dependence (APS)



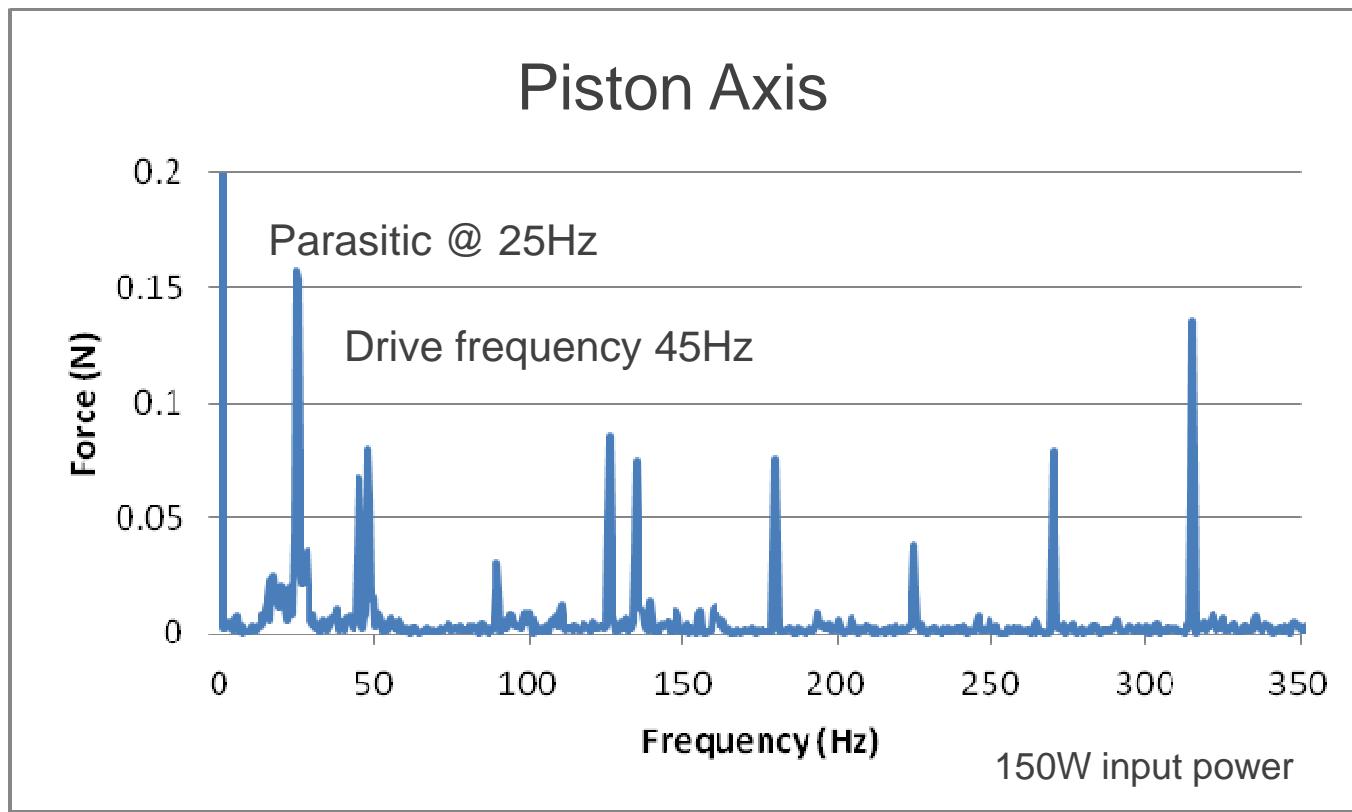
$Q_1 \text{ (W)}$	$T_1 \text{ (K)}$	$Q_2 \text{ (mW)}$	$T_2 \text{ (K)}$
0.0	67	479	15.0
3.5	90	397	15.0
5.0	100	365	15.0

15K PTC with passive phase shift (double inlet + inertance)



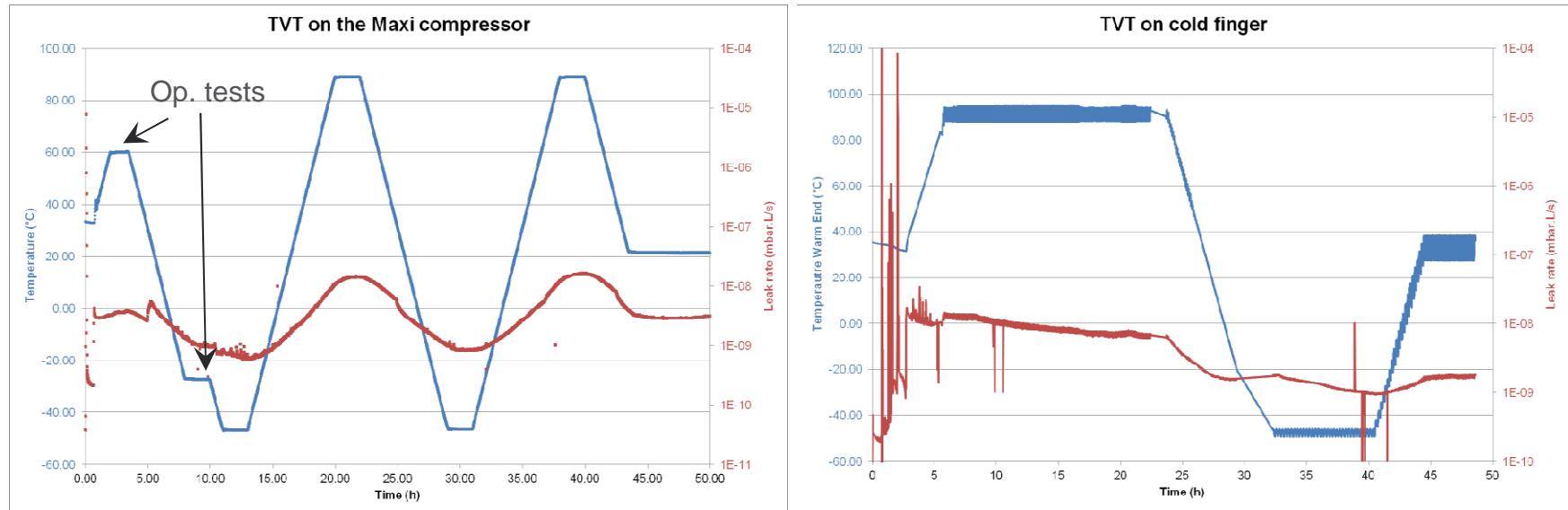
- Originally foreseen for 18K operation (simplified configuration)
 - 18K heat lift up to 650mW
- But also very good 15K performance
 - Heat lifts up to **416mW @ 15K** have been achieved (+2W @ 80K)
- This provides a very attractive configuration
 - Further work is in progress to validate this approach

Compressor exported vibrations



- Piston axis vibrations well compensated over 7 harmonics
 - Parasitic vibrations @ 25Hz not from compressor
- However, off-axis vibrations remain at a significant level
 - Will be addressed for next EM

Thermal vacuum tests



- Thermal Vacuum Tests performed on both compressor and cold head
 - T_{\min} (non operating) = -50°C
 - T_{\max} (non operating) = 90°C
 - T_{\min} (operating) = -30°C
 - T_{\max} (operating) = 60°C
- No performance loss
- No indication of leak

Mechanical Tests

■ Standard Mechanical Vibration requirements (Ariane launch)

Requirements to apply during the vibration tests are the following in sinus and in random [AD03/ER2]:

Table 2: Mechanical Environment (Qualification Level)

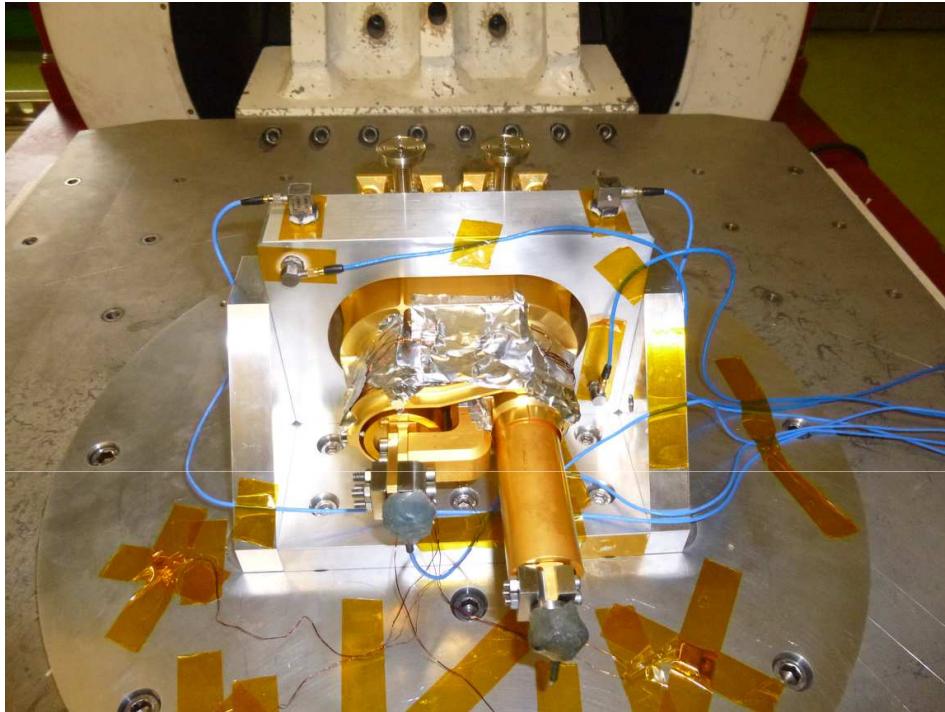
Frequency (Hz)	Level
5 – 100	25 g
Sweep Rate	2 octaves/minute, 1 sweep up

Random Vibration (any direction)

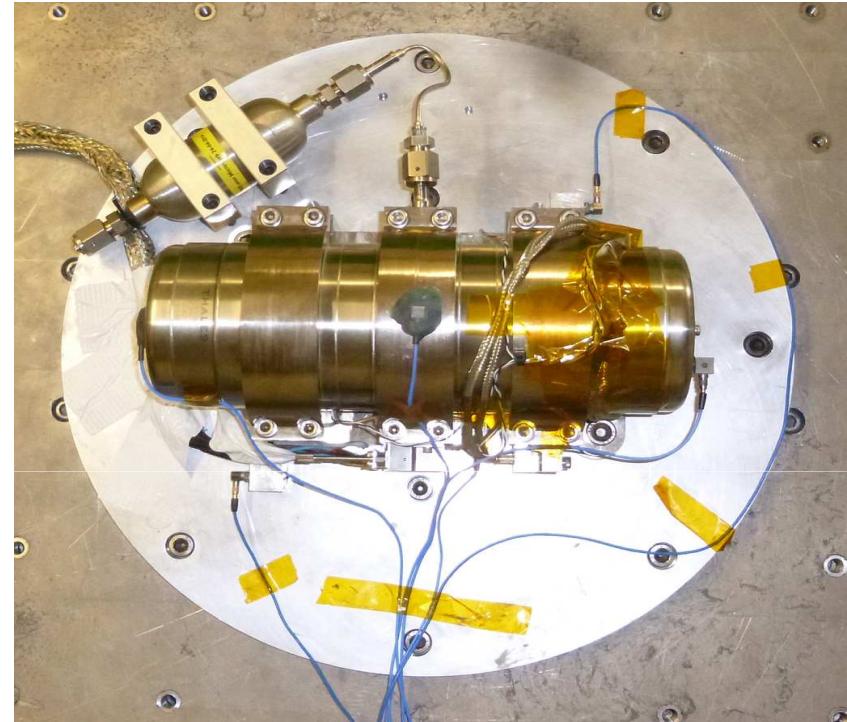
Frequency (Hz)	Level
20 – 100	+3 dB/oct.
100-300	0.3 g ² /Hz
300 – 2000	-5 dB/oct.
Composite	12.1 g rms

Duration 2.5 min/axis

Mechanical test set-up

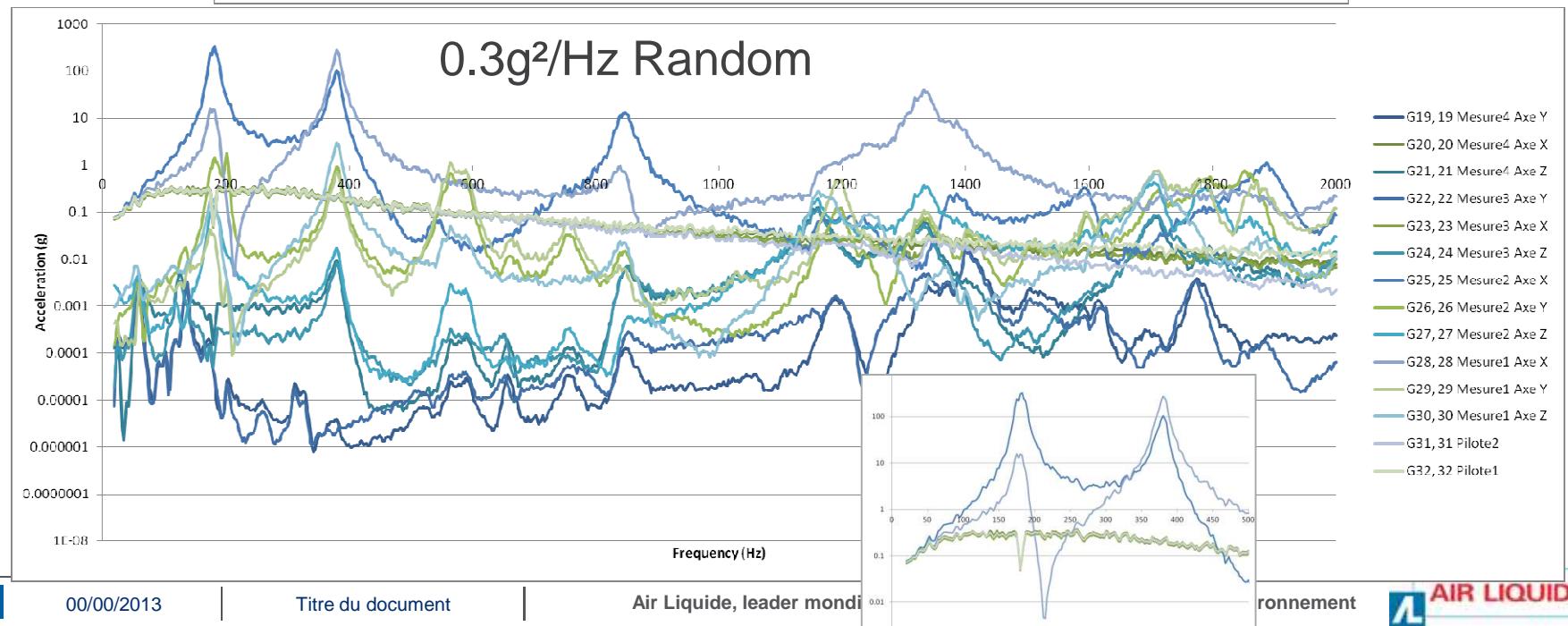
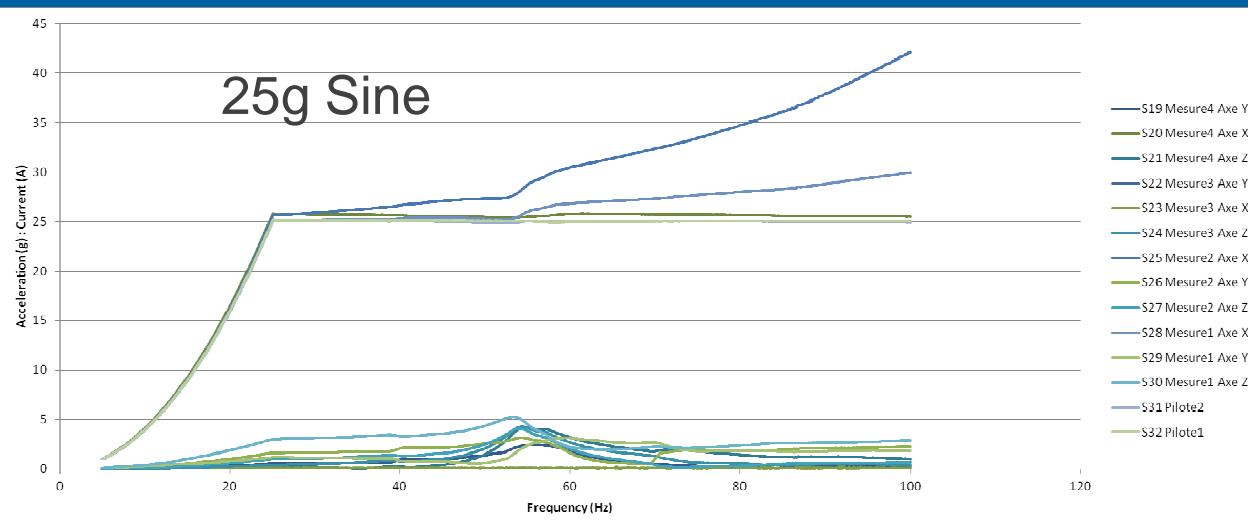


Cold Head



Compressor

CFA X-axis: Sine & Random



15K PTC : Conclusion

- The 15K PTC has now been manufactured and tested.
- Performance exceeds the specifications
 - ▣ 300W electrical compressor power
 - ▣ 435mW @ 15K + 2W @ 80K (active phase shift)
 - ▣ 416mW @ 15K (passive phase shift)
 - Further work is required to consolidate this result
 - ▣ Up to 5W @ 100K available for shield cooling
- Mechanical and TV tests have been performed
- Next steps
 - ▣ Validation of passive phase shift configuration
 - ▣ Maturation to TRL 5/6 by 2019 for ATHENA
 - New EM Cold Head + Compressor
 - Drive electronics
 - Lifetime tests



Thank you for your attention

