Synergies between designed-for-space and tactical cryocooler developments

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THALES CRYOGENICS BV

INTERNATIONAL CRYOCOOLER CONFERENCE 2018

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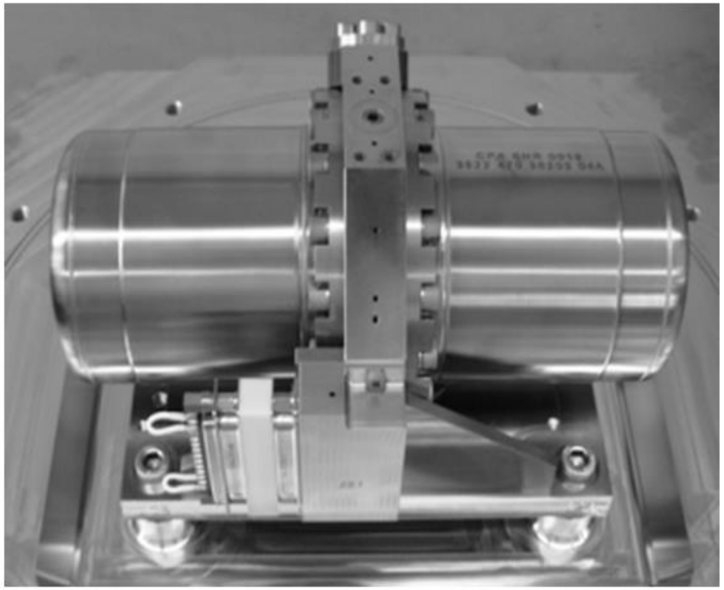
Requirements

Requirement	Tactical	Space
Reliability	MTTF (63% failure probability) after x hours	High (99%) survival probability after x hours
Induced vibrations	No particular sensitivity	Critical for many applications
Heat lift/ Cool down time	Critical	Not so critical (provided sufficient lift is available)
Efficiency	Only for battery-driven applications	Critical – There is usually a power consumption budget

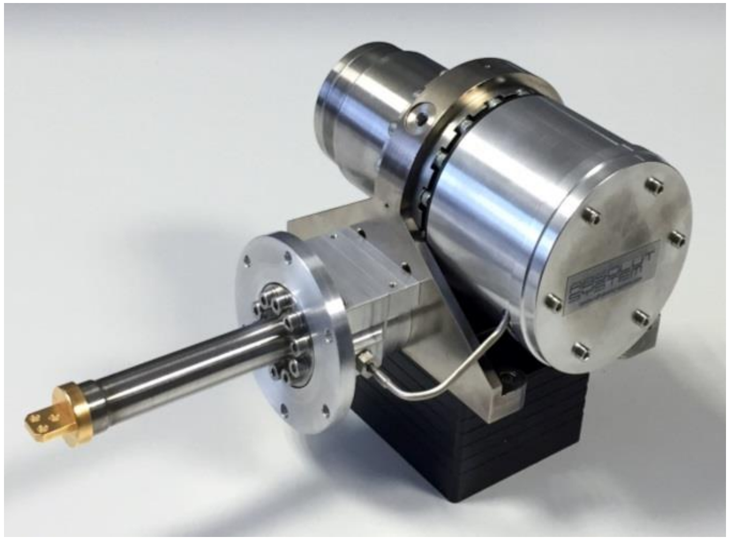
Design Impact – flexure bearing compressors

Failure mechanisms (Ross, 2000)	Modern Off-the-shelf Compressor?
Excessive Internal Cooler Contamination (due to outgassing)	Bake-out step, produced in clean room environment. Moving magnet design.
Hermetic Seal of Feedthrough Leak	Moving magnet design, no flying leads in Helium volume.
Comp. Flexure Spring Breakage from Fatigue	Inspection procedures well-understood: absence of latent failure mechanism can be verified.
Comp. Motor Wiring Isolation Breakdown	Risk eliminated in modern designs
Comp. Piston Alignment Failure (Binding)	AIT procedures available even for COTS compressors
Comp. Piston Blowby due to Seal Wear	Practically eliminated in modern COTS designs
Compressor Piston Position Sensor Failure	Not Applicable – no piston position sensor in COTS design

Space versus COTS



Stirling vs Pulse-tube: LSF9199/30 vs LPT6510



LSF9199/30 Flexure bearing Stirling

Based on:

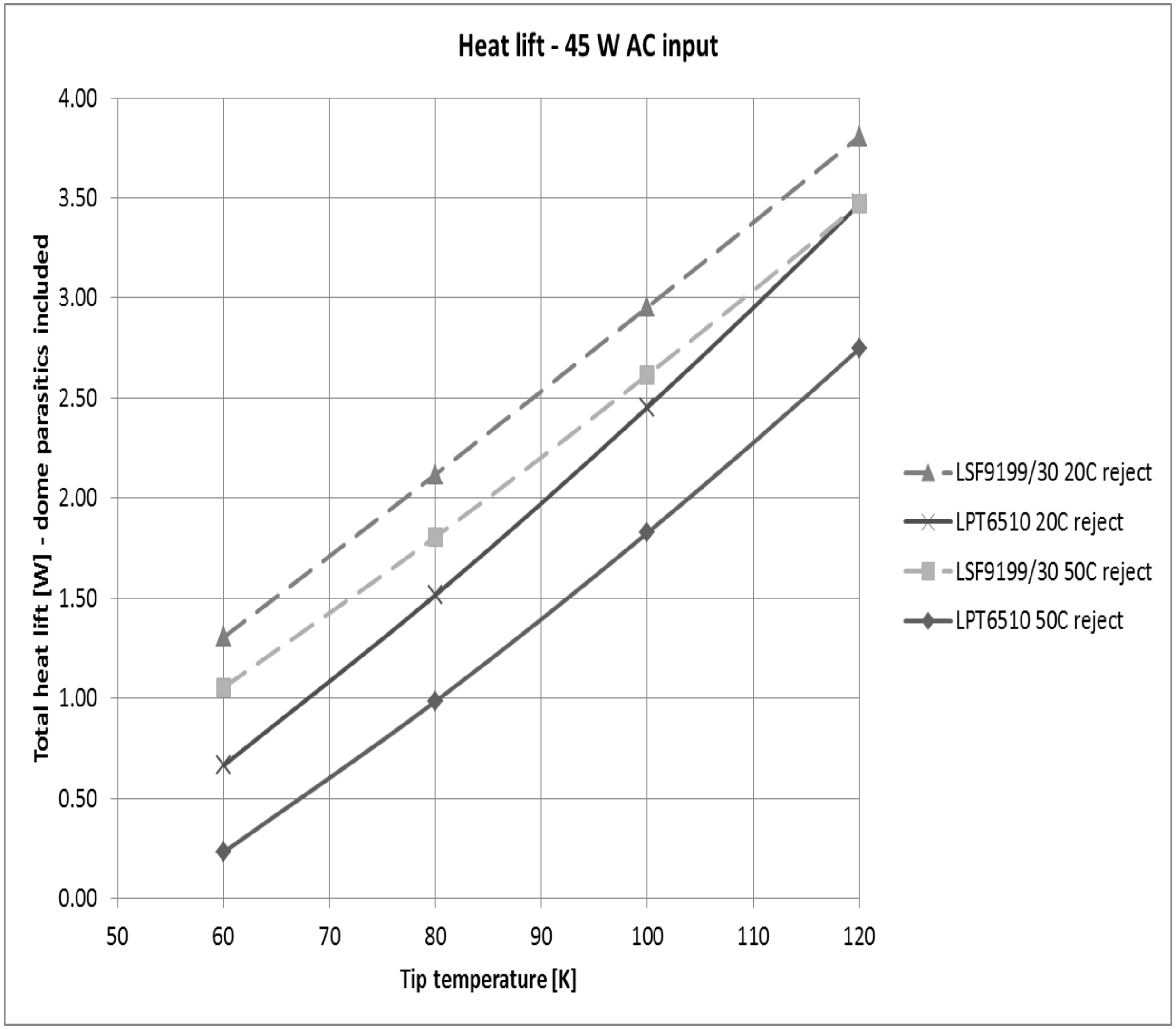
- Tactical cooler building blocks
- SADA-compatible ½" displacer allows existing dewars to be used
- Flexure bearings in cold finger

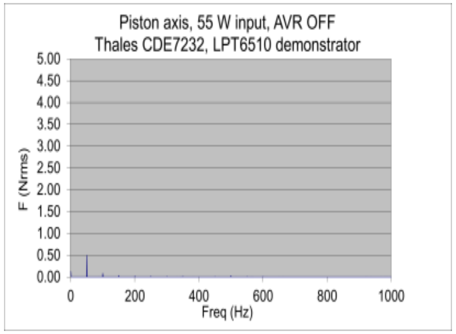
LPT6510 Pulse-tube

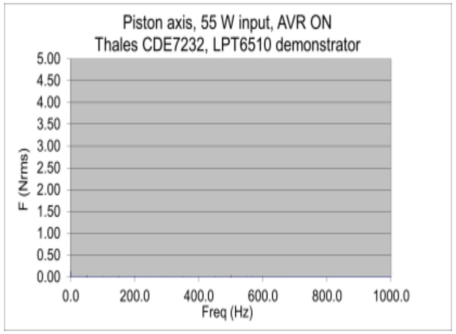
Based on :

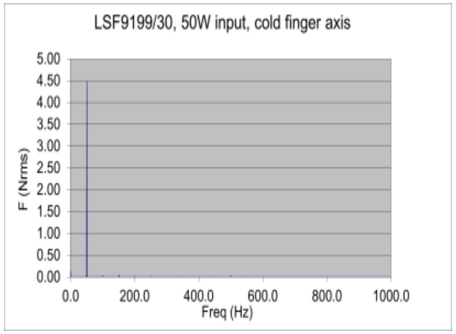
- MPTC compressor, developed under ESA contract
- SSC80 pulse-tube by Absolut System
- Integral design

Comparison of the LPT6510 and LSF9199









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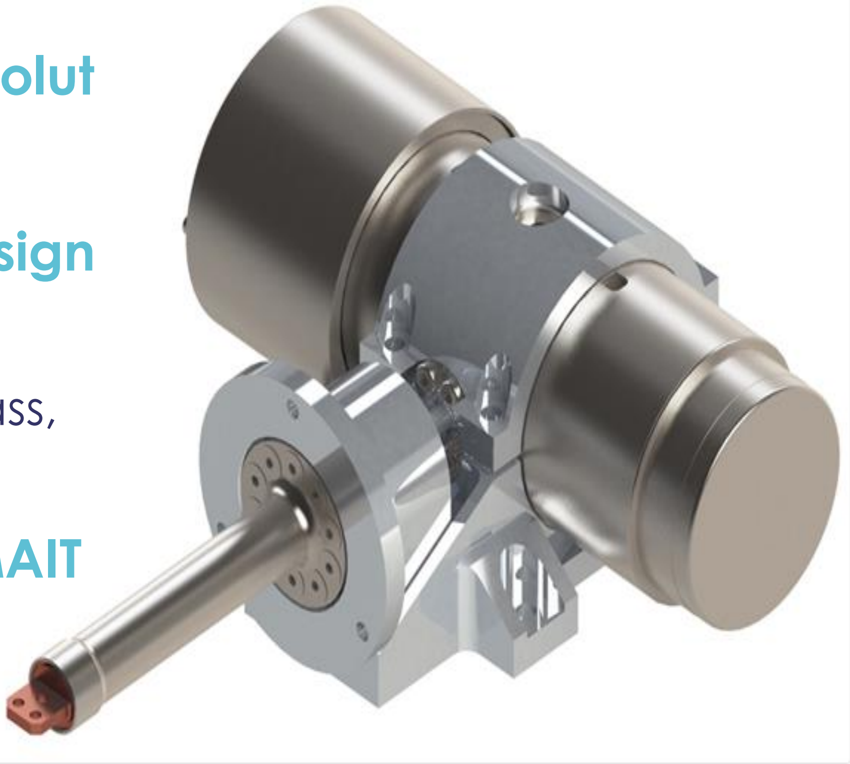
LPT6510 developments

- Current TRL = 4
- Partnership between TCBV and Absolut System to further develop cooler
- Compressor design using 'COTS design principles'
  - All-welded compressor minimizing mass, complexity, and seals
- Use maximum heritage of known MAIT processes used in LPTC and other space products
- Goal is to reach TRL=6 in Q2 2019



LPT9310 – LPTC matching study

LPT9310 pulse tube cooler (COTS) has previously been upgraded for use in ECOSTRESS instrument

- 'Space version' of LPT9310 COTS cooler

Study performed to investigate coupling of the LPT9310 cold head to 'full space' LPTC compressor.

Drive frequencies of LPTC and LPT9310 do not match

- Pulse tube has an optimum frequency where inertance phase shift is optimum
- Compressor has an optimum frequency at resonance

For maximum cooler-level efficiency, both frequencies should match

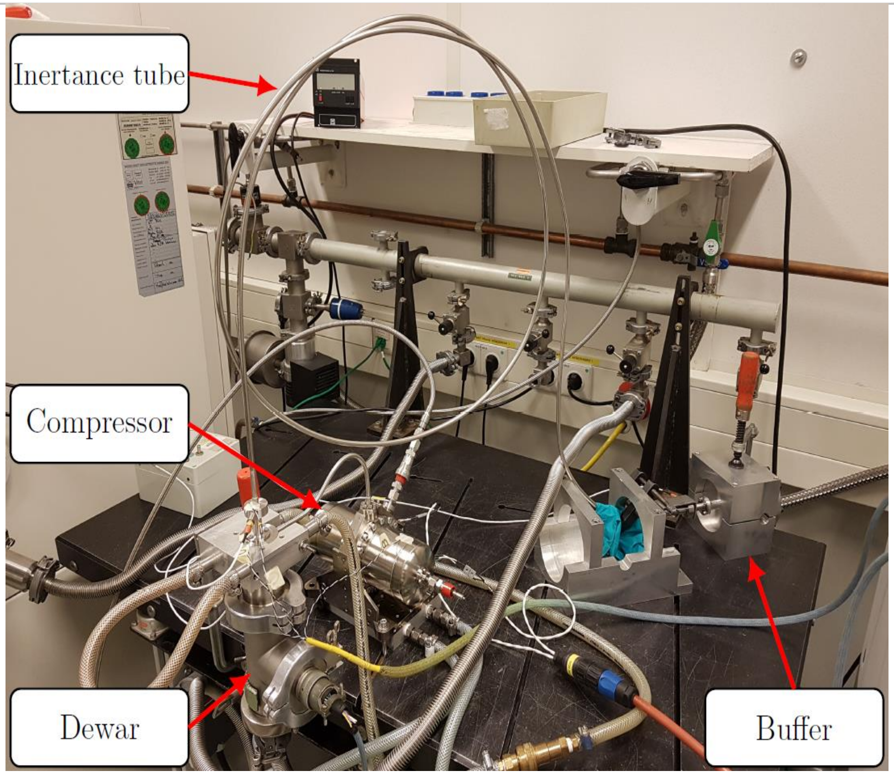
LPT9310 – LPTC matching study

Parameter study using SAGE

- Including compressor efficiency calculation
- Only variables are length and diameter of inertance tube

Experimental study to compare calculations to simulations

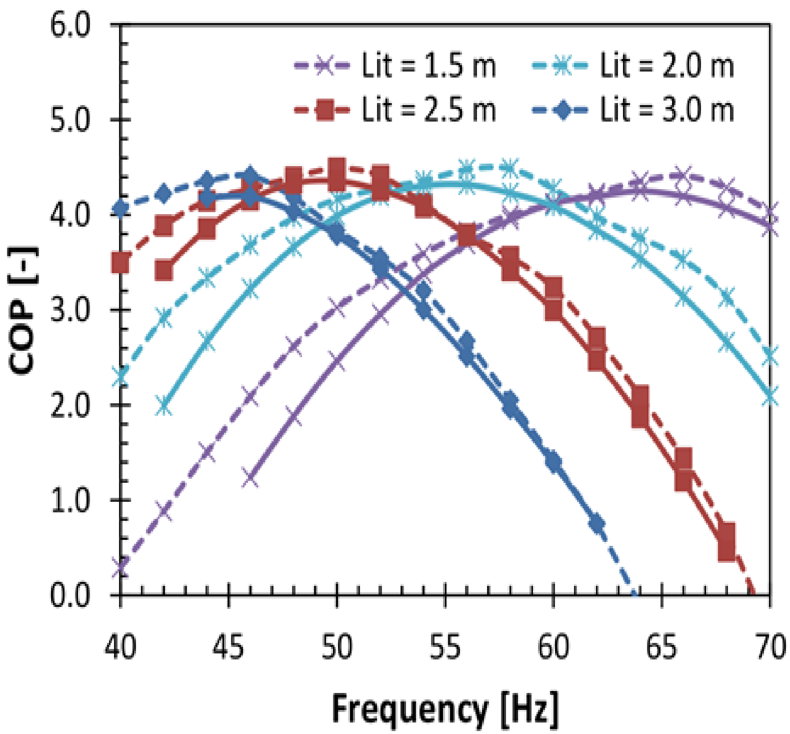
- Adapted LPT9310 cold head to fit different inertance tubes and additional instrumentation

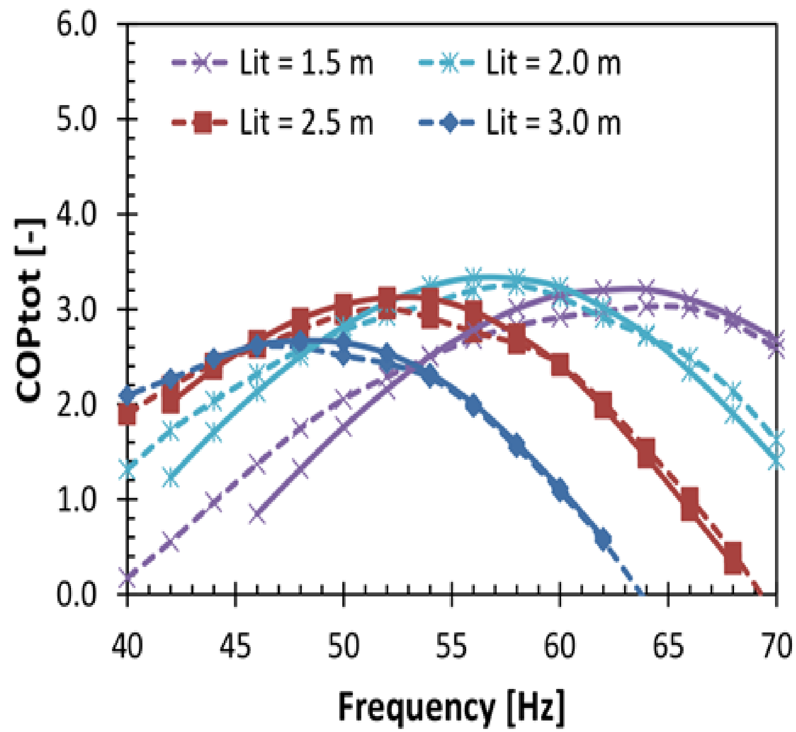


LPTC – LPT9310 matching study

Measurement and simulation results

- Cold head efficiency (left) and cooler efficiency (right)





LPTC – LPT9310 matching study

Overall results:

	Freq.	COP_{el}	COP_{CH}	COP_{tot}
LPT9310 standard	46 Hz	61 %	4.9 %	**3 %**
LPTC with standard LPT9310	48 Hz	54 %	4.6 %	**2.5 %**
LPTC with optimized LPT9310	58 Hz	79 %	4.4 %	**3.5 %**

Overall efficiency improvement ~20%

Stock LPT9310 pulse-tube is optimized for 80K operation

- Further improvements for higher cooling power or lower tip temperature is are available

Conclusions

- Differences between series-produced (tactical, COTS) and ‘designed for space’ coolers are not so large
- Requirements are comparable, use of COTS products in space possible with compromises on some requirements
- Building blocks of COTS coolers used in space – E.g. LSF9199 Stirling cooler or LPT9310 for ECOSTRESS instrument
- Design principles from COTS coolers used in space product- e.g. LPT6510 pulse-tube cooler
- Breadboard testing of COTS pulse-tube with LPTC compressor presented.