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COTS coolers for space infrared detectors

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THALES CRYOGENICS

IR DETECTION FOR SPACE WORKSHOP, TOULOUSE, 2023

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Outline

Overall philosophy of COTS to Space cryocoolers

LPT9310, LPT9310-HP and LPT9510 pulse-tube coolers

- History, Life time and reliability statistics
- LPT9510 programs
- LPT9310 programs

LSF9199/30 Stirling cooler with flexure cold figner

LSF9997 Stirling cooler

Introduction

Continuing demand for Space Cooled IR, >60 K operating regime

- Thermal InfraRed detectors of 60 K and up
- SWIR applications ≥150 K
- Interest in IR imaging for New Space type applications

Active cooling holds significant advantages over passive solutions

Drive towards reduced:

- Cost
- Lead time

But of course…

- Still with long life time and low risk on life time
- High reliability & availability

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Overall approach

General principle:

- Field-proven and life time test-proven reliability of many COTS/tactical cooler designs exceeds the R required for space

Take a commercial-grade high-reliability cryocooler and justify flight

- Example: the Thales LPT9310 series as used for ECOSTRESS and EMIT (JPL)

Or use proven design elements from tactical cryocoolers in a high-performance designed-for-space cryocooler

- Example: The Thales LSF9199/30 cooler

Use a rationalized set of testing to justify use as FM

Typical additional tests done:

Additional batch-level inspections on critical parts

- Identify points where COTS-standard inspections are not sufficient

Additional burn-in

- Eliminate any workmanship or part-related infant mortality

Random Vibration Test

Thermal Vacuum Test

Additional compressor diagnostics (ring-down testing)

Extended drying/curing (100 C vacuum applied to cooler internals)

- Eliminate risk of contamination issues

Typical additional justification provided to customer:

- Limited structural analysis results (pressure load validation)
- Overview of Materials & Processes
- Past test data, including burst test data
- Field data from terrestrial cryocoolers

Thales LPT9510 & LPT9310 pulse-tube cryocoolers

Developed initially in the early 2000's, coaxial pulse-tube design licensed from CEA

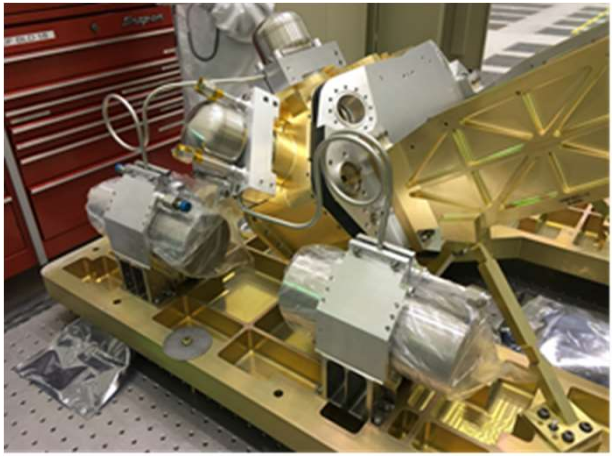
- >3000 LPT9310 built to date, >500 LPT9510 built to date
  - >1200 units with over 5y continuous operation
  - >400 units with over 10y continuous operation
- LPT9510: <3 kg, 1.4 W of lift at 80 K
- LPT9310: <7 kg, 5.1 W of lift at 80 K
- LPT9310-HP: <7 kg, 3 W of lift at 60 K

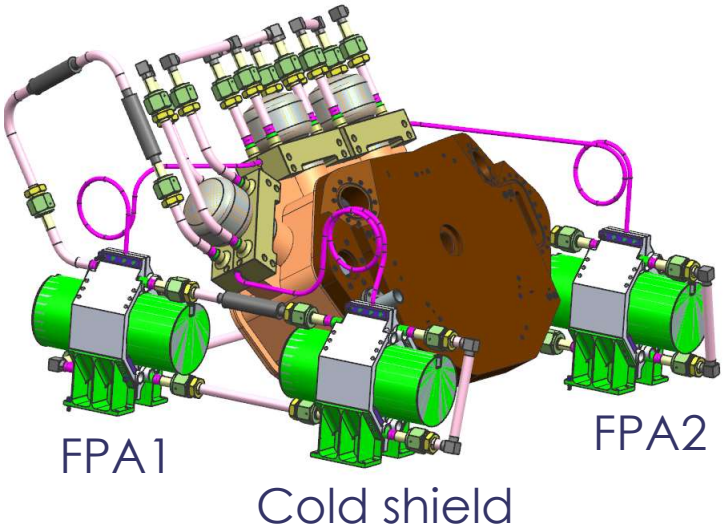
Thales LPT9510 & LPT9310: FM built and delivered

Cryocooler	Customer	Mission	Status
1x LPT9510 2x COTS CDE	Raytheon	TacSat-3 / Artemis	Launch May 2009, burn-up on re-entry after 3 years of nominal operation
3x LPT9310-HP 6x COTS CDE	NASA JPL	ECOSTRESS	Instrument turn-on July 2018, 3 units >40000 hours without any degradation.
1x LPT9310	NASA JPL	EMIT	Instrument turn-on July 2022, operation nominal to date
1x LPT9310	AIRS	Undisclosed	Launch date not disclosed to Thales
7x LPT9310	Undisclosed (USA)	Undisclosed	First unit launched 2023. Follow-up order received.
3x LPT9510	Undisclosed (USA)	Undisclosed	Delivered in 2020, launch date not disclosed to Thales
4x LPT9510	Undisclosed (USA)	Undisclosed	Delivered in 2022, launch date not disclosed to Thales

ECOSTRESS instrument design and project

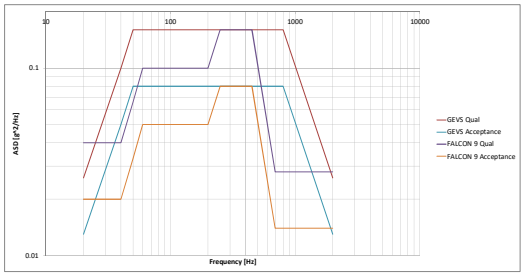
- NASA Jet Propulsion Laboratory
- Based on PHyTIR (Prototype Hyperspectral Thermal Imaging Radiometer)
- 2 coolers to keep FPA below 65 K, 1 cooler for cold shield
- Mission lifetime 1 year (“Class D”)

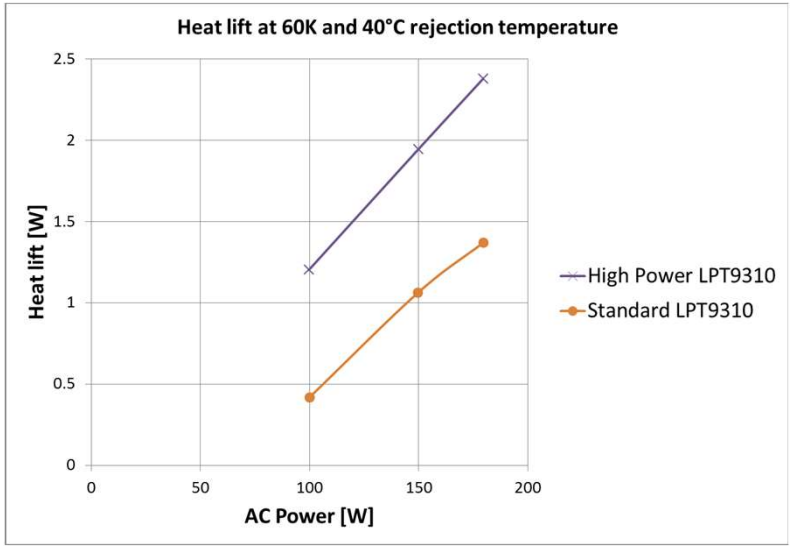


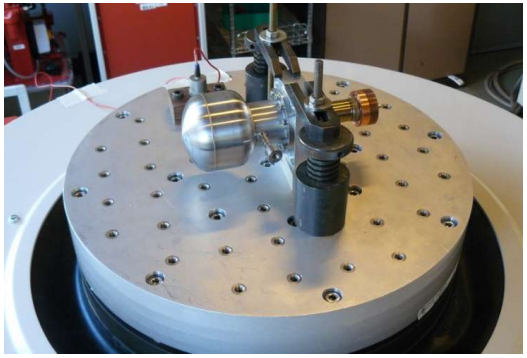


LPT9310-HP

- Additional performance needed:
  power budget lowered, reject temperature increased
- High-performance definition designed, built & Tested
  - Low-conductance tube
  - Optimized regenerator matrix
- Full test campaign, including:
  - Pressure cycling, Temperature cycling
  - Random vibration

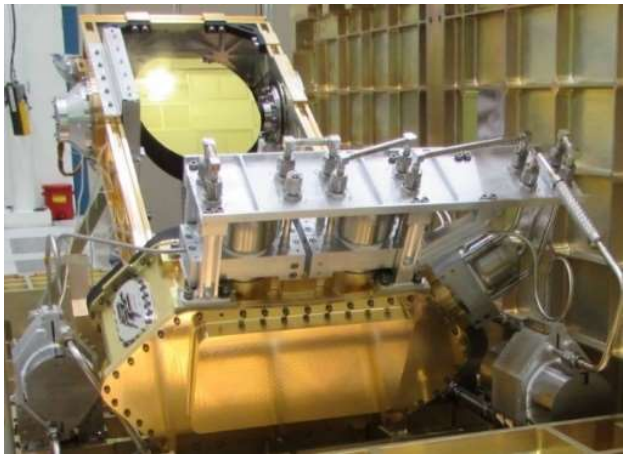






ECOSTRESS operation

- Instrument commissioned on-board ISS
  - Launch June 2018
  - Three Thales LPT9310 units
  - Confirmed >4 years of degradation-free operation
  - Off-the-shelf Thales XPCDE drive electronics



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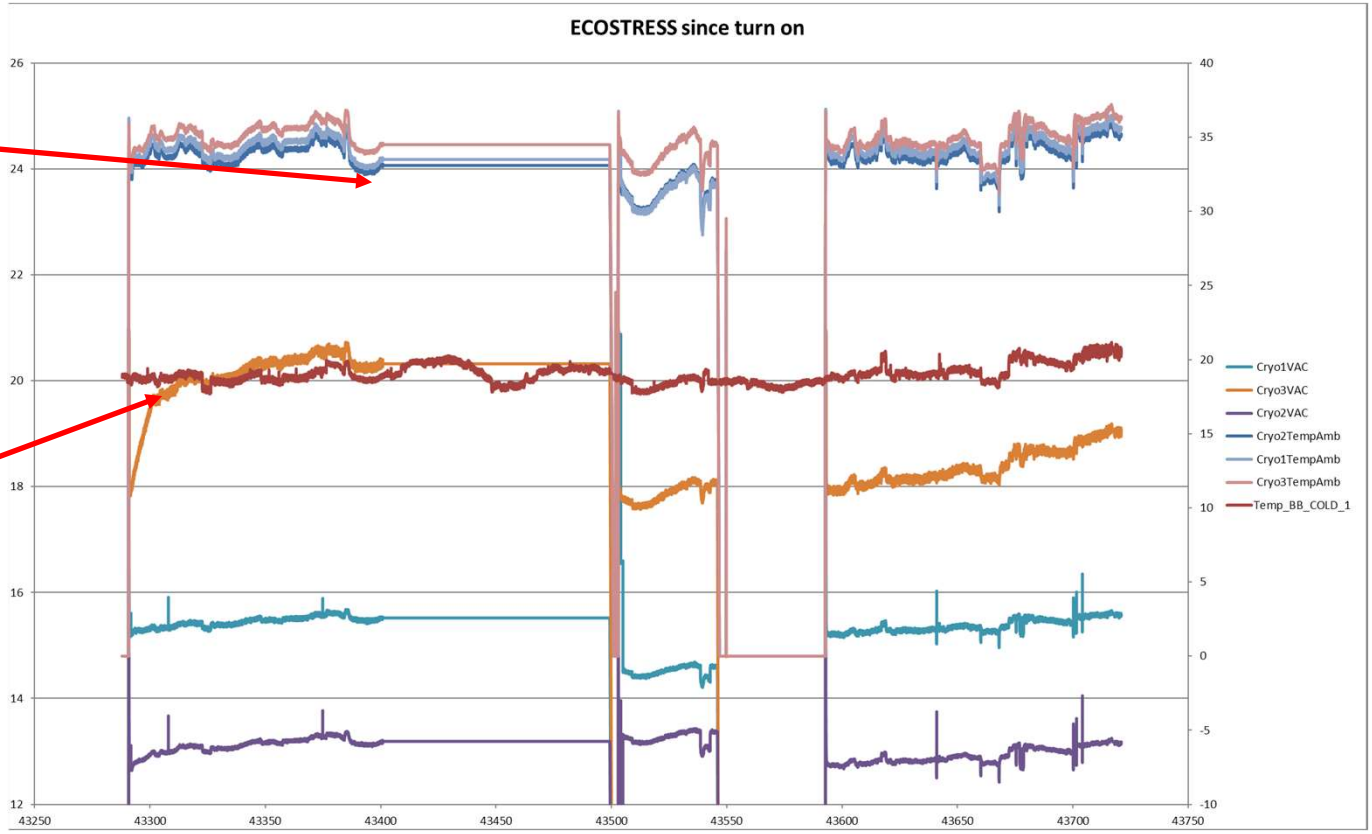
Telemetry since power-on

Comms issue (not caused by Thales hardware)

Slow deposition of contaminants on cold shield



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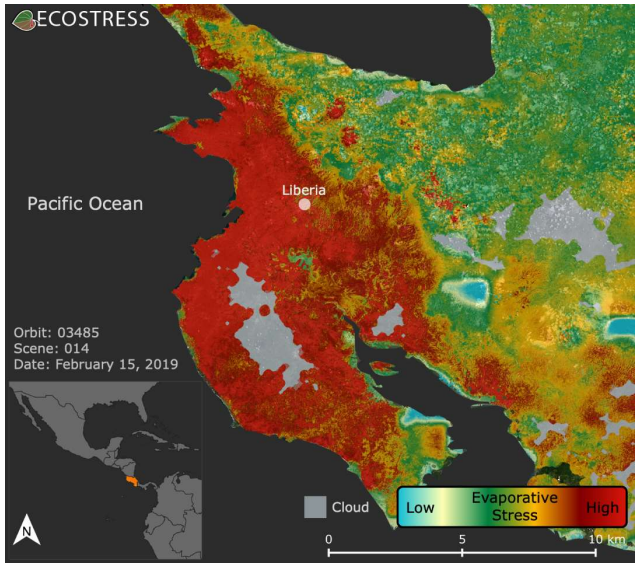

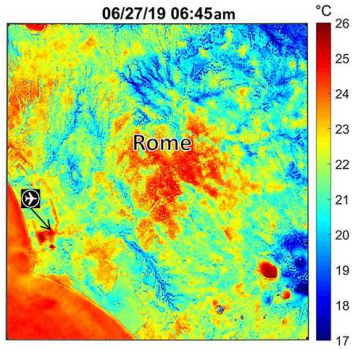

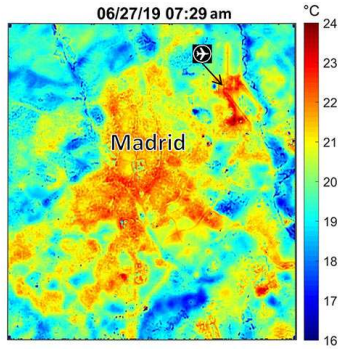

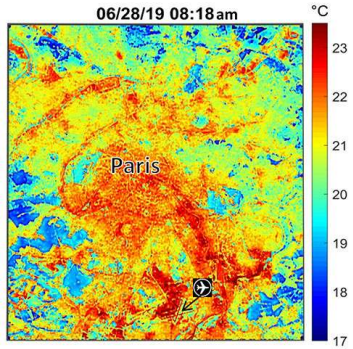

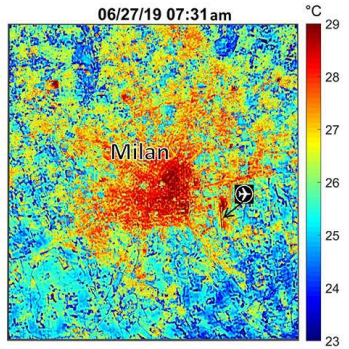

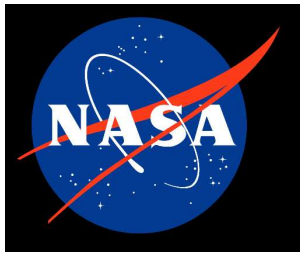

Jet Propulsion Laboratory
California Institute of Technology

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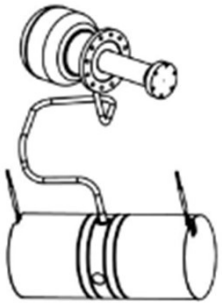
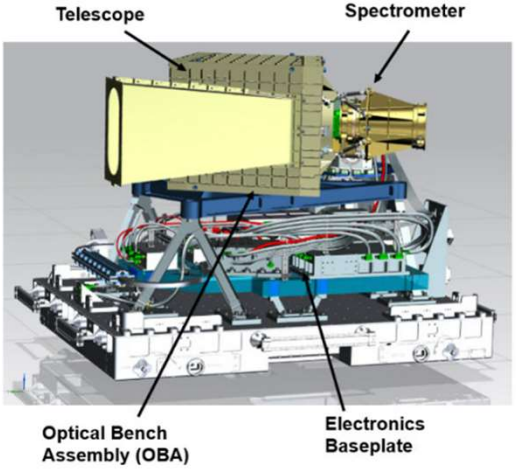
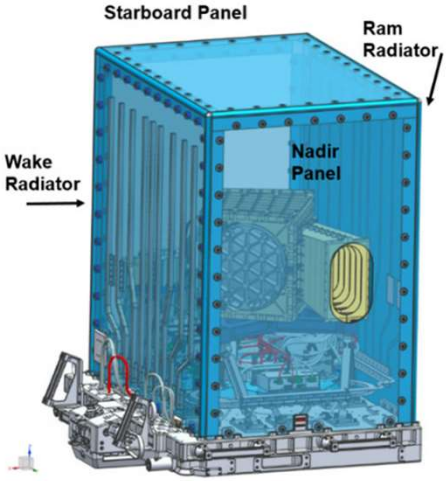
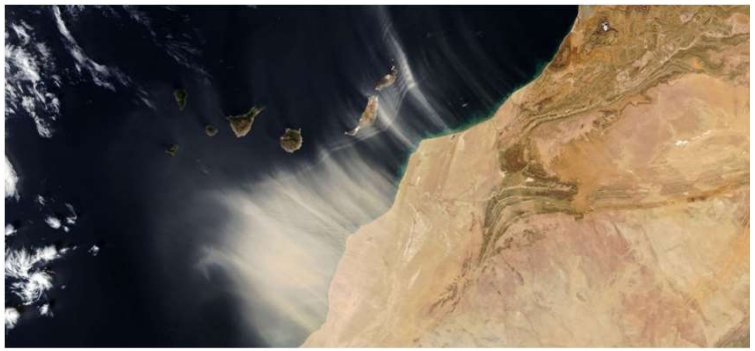
EMIT (NASA JPL)

- Earth Surface Mineral Dust Source Investigation
- 1x LPT9310 to provide cooling at 155 K
- IRIS HP-LCCE2 drive electronics used









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LSF9199/30

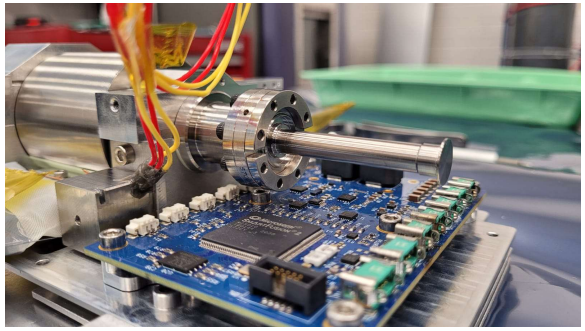
LSF9199/30 Flexure bearing Stirling

- Tactical cooler building blocks
- <2.5 kg
- SADA-compatible ½" displacer allows existing dewars to be used
- Flexure bearings in cold finger
- High efficiency and heat lift from 50 K to 150 K

1 unit in life time test >40000 hours

>60 units delivered (Lynred), multiple launches

LSF9997



LSF9997 in SPIRIT EM, courtesy of University of Melbourne

True COTS IDCA Stirling cooler design

- 1 kg mass
- Flexure-bearing compressor
- Thales standard ¼" IDCA cold finger interface
- Designed for >80 K

Standard version delivered to:

- University of Melbourne (SpIRIT)
- SSTL
- Undisclosed US customers

Design upgrade in progress to implement High Availability cold finger, qualification planned Q3-Q4 2023

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Conclusion

- Several Thales COTS coolers can be considered for low-cost IR missions without compromise on availability & reliability
- Pulse-tube coolers, Stirling coolers with flexure bearing cold finger, or COTS Stirling coolers available
- Standardized way of working was developed to deliver COTS coolers for flight, with high level of adoption in the USA

Thank you for your attention!