THALES

Thales Cryogenics
Recent developments

TONNY BENSCHOP

Our environments

WHEREVER SAFETY AND SECURITY ARE CRITICAL, THALES DELIVERS.
TOGETHER, WE INNOVATE WITH OUR CUSTOMERS
TO BUILD SMARTER SOLUTIONS. EVERYWHERE.

TRUSTED PARTNER FOR A SAFER WORLD

DUAL MARKETS
Military & Civil

THALES

Our presence

THALES

Our profile

Thales Cryogenics (2016)

Head count

210 FTE

R&D population

20%

Production population

40%

Defence **75%** | Civil **25%**

Customer segmentation

Revenues

30 Million Euros

R&D efforts

20% of Revenues

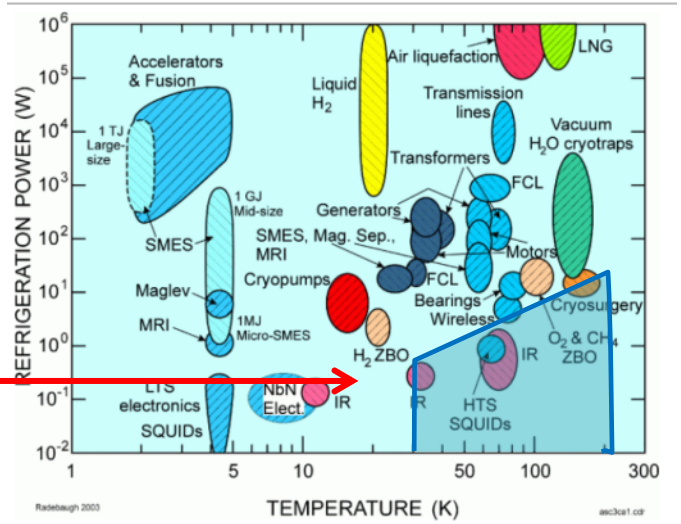
Markets for cryogenic coolers | Segmentation of TCbv products

Cryocoolers of TCbv

- Technologies: Stirling and Pulse tube coolers
- Max input power 500 W
- Cold tip temperature 30K .. 150K

Cooler Drive Electronics (CDE)

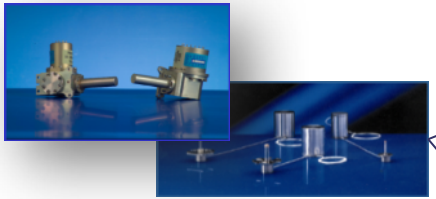
- Till 200W own CDE available
- Including VCR algorithms

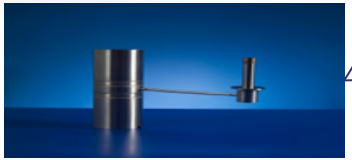


MTTF:

- Rotary coolers : 25.000 hrs (63 % failure)
- Stirling : 40.000 hrs (63% failure rate)
- Pulse Tube : >> 40.000 hrs (<< 63% failure rate) | high availability @ 5 years

Overview of Cryogenics Product Line Perimeter





Defense Markets (Stirling coolers)

- Compact IR-camera's
- Airborne applications
- IR Surveillance

Commercial Markets (Stirling & Pulse tube)

- Zero boil-off systems
- Cooling of Germanium detectors
- Cooling of HTc electronics

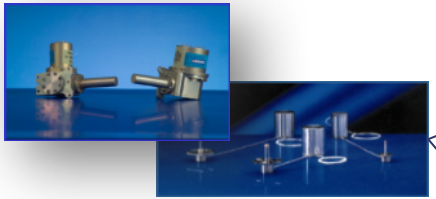
Space Markets (Pulse tube coolers)

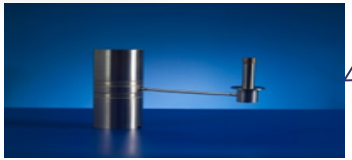
- Earth observation missions
- TRP - Research projects
- Cost effective solutions for space

Accessories:

- Drive electronics
- Heatsinking / Cold fingers
- System designs
- Dedicated test equipment @ Ground support equipment

Overview of Cryogencis Product Line Perimeter





Defense Markets (Stirling coolers)

Compact, robust &
Efficiënt solutions

Commercial Markets (Stirling & Pulse tube)

Extreme reliability &
Cost effective solutions

Space Markets (Pulse tube coolers)

Extreme reliability
High efficiency
"No" vibrations

Accessories:

- Drive electronics
- Heatsinking / Cold fingers
- System designs
- Dedicated test equipment @ Ground support equipment

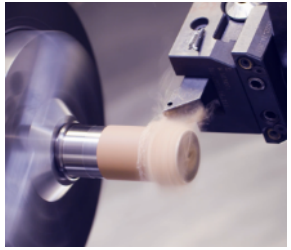
Technical & Industrial Synthesis

Production of Cryogenic Coolers based on Building Blocks

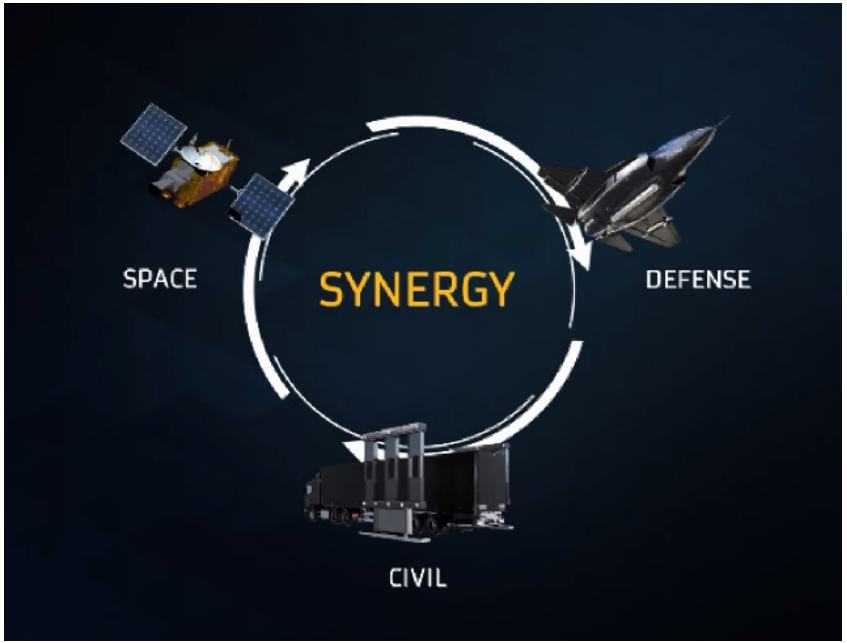
- Rotary coolers
- Linear Coolers Compressors // Cold fingers
- Drive electronics

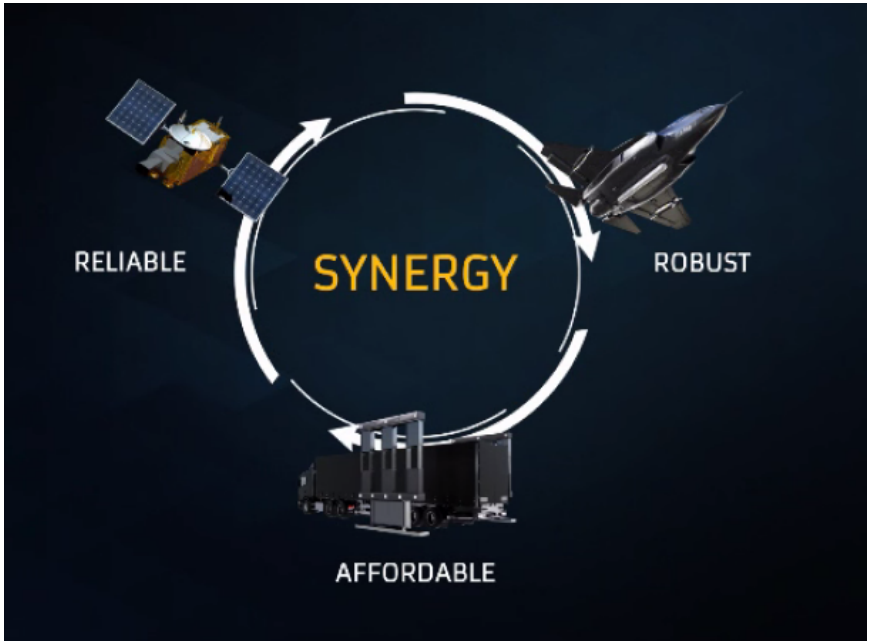
Development // Industrial Plan

- **Lean production area:**
  - Lin Coolers: 2000 units / year
  - Rotary Coolers: 6000 units / year
  - Space: > 1 space unit per month
- **Production Investment to maintain and support product quality and OTD**
  - Measuring // Welding // Test equipment



Combining different market technologies



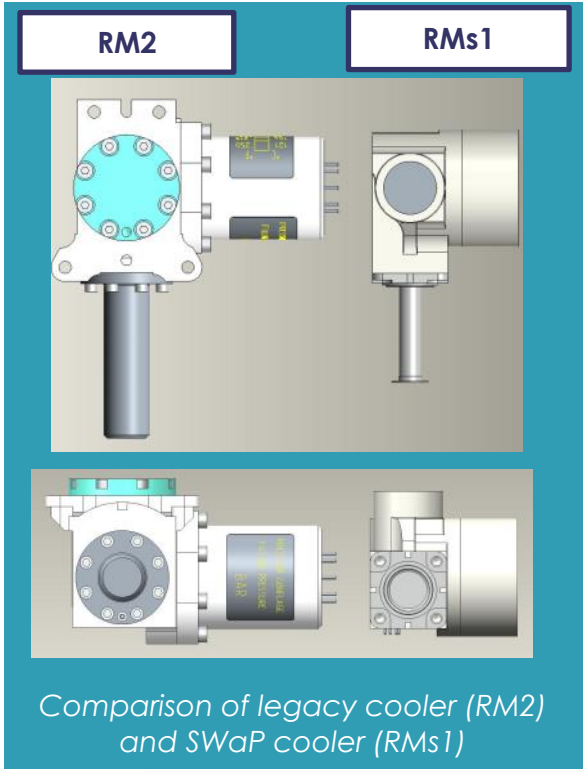


New developments

- Compact coolers
- High reliability coolers
- Space cooler
- Cryo testbench

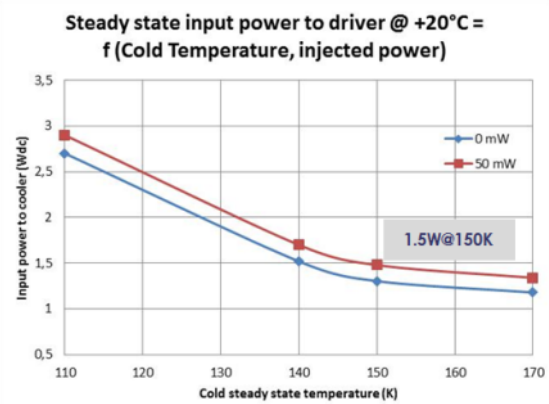
Thales Rotary SWaP cryocooler : RMs1

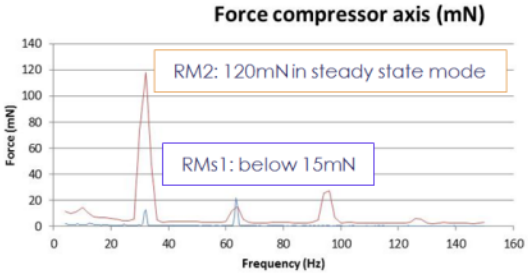
SWaP cooler: Size, Weight and Power



Comparison of legacy cooler (RM2) and SWaP cooler (RMs1)

- The SWaP Rotary cooler RMs1 is designed and optimized for HOT-IR applications. (>110K)
- Weight 150 gr , Noise < 40 dBa, IV < 40 MNrms



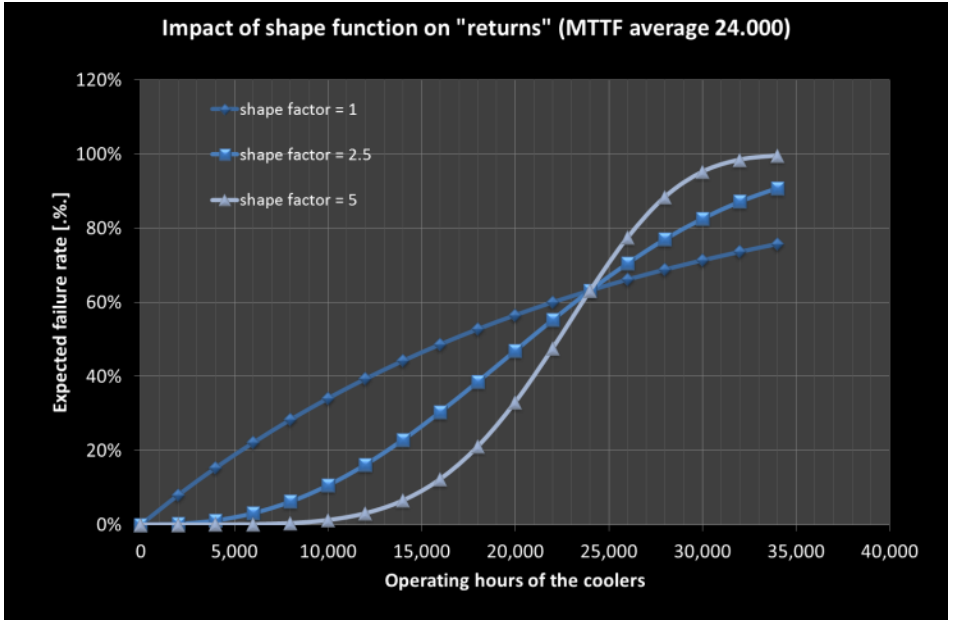


High reliability coolers

Definition of reliability

- Weibull failure characteristics:
  63 % of failures to reach product specification after … hrs.

- Performance Availability
  .. % probability that product will perform in line with specification for .. hrs.

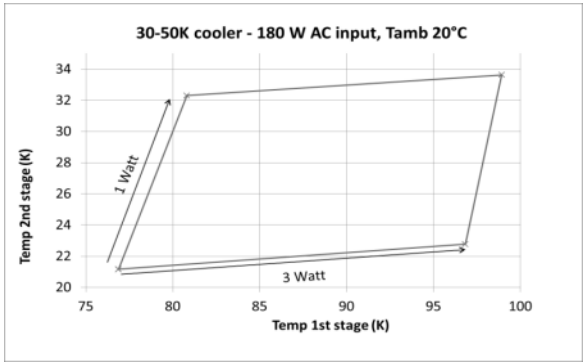


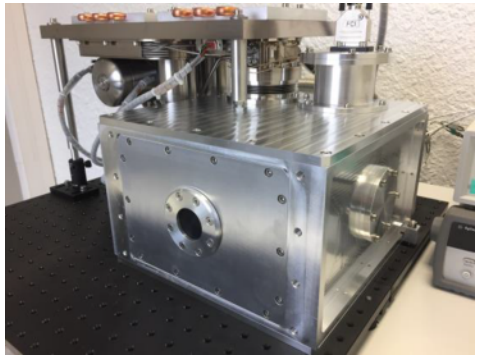
- **Weibull :** typically used when maintenance is possible >> Civil & Military applications
- **Availability :** typically used for Space applications

Different papers on the reliability assessment and reliability of Thales cryocoolers are available from our website.

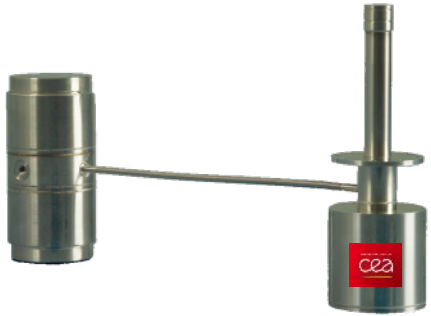
Space coolers / Tactical coolers

Requirements	Tactical	Space
Reliability	MTTF (63% failure probability) after xxxxx hours	High (99%) survival probability after xxxxx hours
Robustness	Random exposure to vibrations	Launch once
Induced vibrations	No particular sensitivity (line of sight stability / noise)	Critical (observation equipment)
Cooldown time	Critical	Not critical
Efficiency	Only critical for battery-driven applications	Critical

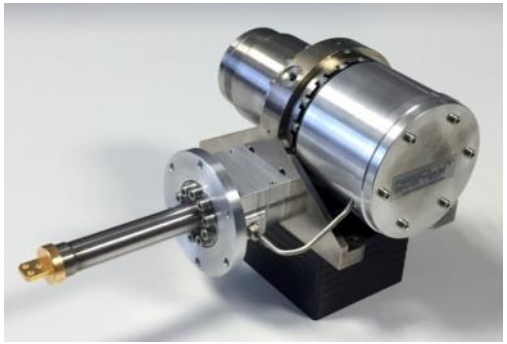




Pulse-tubes : COTS vs “COTS+” vs Space-pedigree



LPT9510
COTS cooler
Pulse tube 1 W @ 77K
<2.3 kg



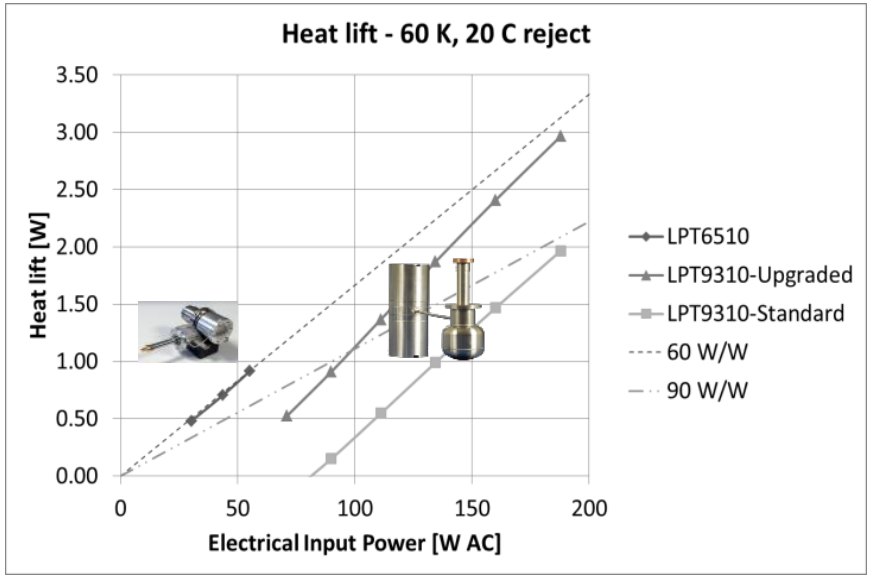
LPT6510
Space cooler
Pulse tube 1 W @ 77K
<2.8 kg

Under development, based on MPTC (ESA-funded) and Absolut System SSC80

LPT9310
COTS cooler
Pulse tube 5 W @ 77K
<7.0 kg

High-performance “COTS+” version available, delivered for JPL-ECOSTRESS project

Pulse-tubes – COTS vs "COTS+" vs SPACE-grade design

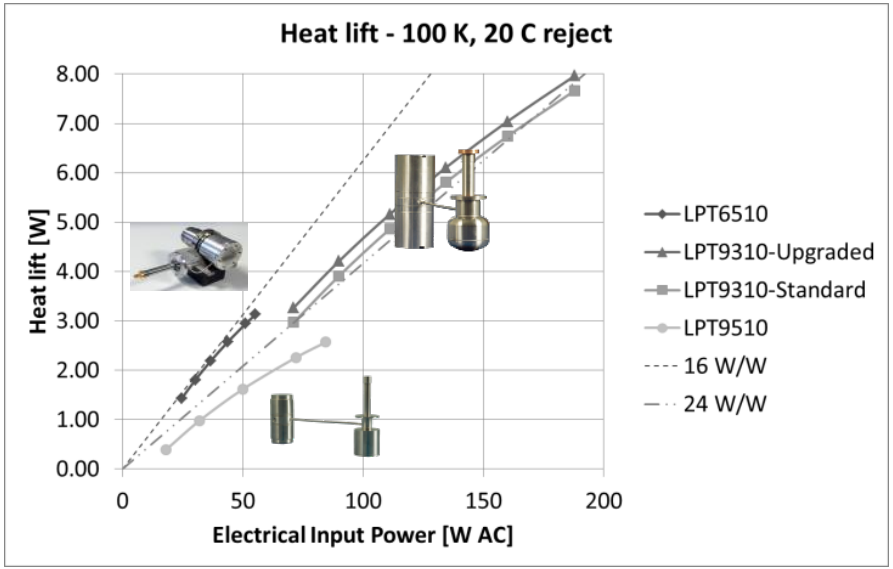


Conclusion?

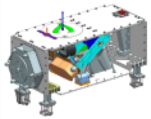
- Large-size "COTS+" LPT9310-HP cooler allows use at lower temperatures
- However, designed-for-space LPT6510 still has efficiency advantage

Conclusion?

- At higher tip temperatures, LPT6510 still has efficiency advantage over scale advantage of LPT9310



Space Coolers Market Vision – (technologies Involved in our market segment)

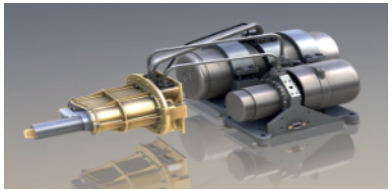




Systems delivered under TCbv responsibility without Air Liquide participation
35 units SFD
25 units USA
20 units ESA related

Technology	Advantages	Draw backs	Comments
Passive cooling	> No moving parts, no vibration > No energy needed > Low Costs	> Limited temperature (>80K) > Operational constraints	> Typically used for 120K sensors > Big market share for MWIR > Main competitor for MRTC
Stirling	> High efficiency	> Cold finger vibrations > Reliability	> Todays focus of UK consortium
Pulse Tube	> Acceptable efficiency > No moving parts cold finger	> Orientation constraints on the ground	> Our positioning
Joule Thomson	> Heritage for specific applications at low temperatures	> High pressure ratio required > Complex systems (pre cooling requirements)	> Science payloads only
Sorption	> Vibration free	> Limited cooling power > Complex systems	> Science payloads only
Turbo Brayton	> Low vibration level > High power density	> Difficult to scale down	> No product available
Thermo electric	> No moving parts	> Limited temperature (> 150K) > Low efficiency especially at low Te	> Fundamental material studies ongoing







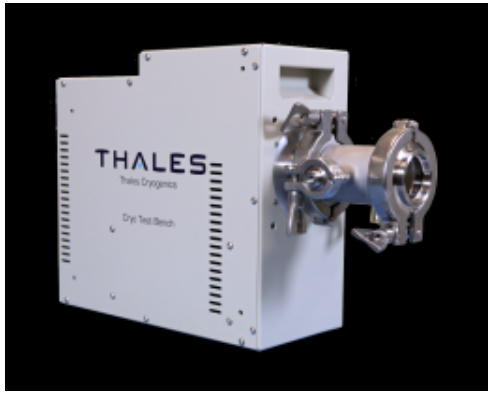
Systems delivered by Air Liquide with TCbv compressor

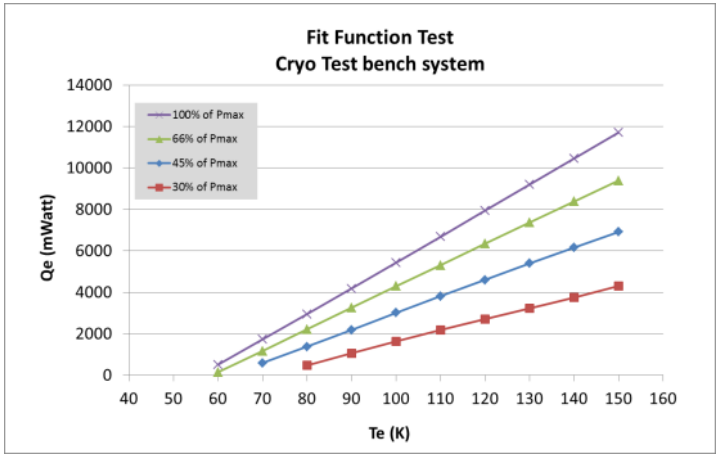
Cryotestbench

Based on available building blocks test bench made for sensor c.q. material characterization testing.

- Pulse tube cooler
- Induced Vibration reduction to limit induced vibration of object to be tested.
- KF50 flange for connection vacuum chamber.
- Copper mounting platform that can be tailored.

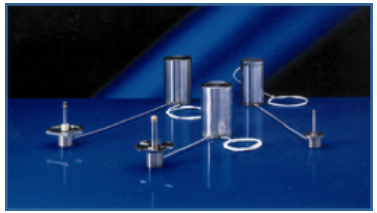
In the future a Stirling cooler or higher efficient Pulse Tube cooer could be integrated to reach lower temperatures.

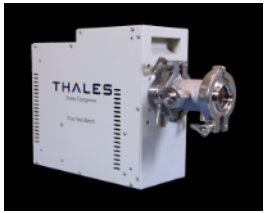


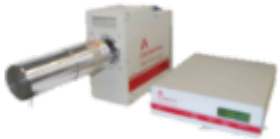


Expected Market Trends

Entity	Product definition	Description	Value Proposition and differentiators	MTTF requirements	Market expectations
TCBV	Contact seal coolers	Classical coolers	Compact solitions, MTTF 30,000 hrs	30,000 hrs	↘
TCBV	SWaP rotary / linear	Micro-coolers for HOT detectors	SWaP coolers with good Qe / weight ratio	> 15,000 hrs	↗ →
TCBV	Long life < 5W	Flexure Stirling, high reliability	Compact cooling solution with power > 1 W @ 77K	45,000 hrs 90% @ 2 years	↗
TCBV	Long life > 5W	Flexure Stirling, high power	Compact cooling solution with power > 5 W @ 77K	45,000 hrs 90% @ 2 years	↗
TCBV	Pusle tube	Flexure Linear Pulse Tube	Compact low vibration cooling solution	90,000 hrs 90% @ 4 years	→
TCBV	SPACE	COTS products	"low" price setting, quick delivery time	95% @ 3 years	↗
TCBV	SPACE	Dedicated products (ECSS standard)	High efficiency and availability (high NRC)	99% @ 5 years	→







Conclusions

- Cryocooler manufacturers have updated their portfolio in the last years to suit the markets needs, they have used modularity concept designs to be cost effective.
- Nearly all of the commercialized compact products - in the 50K to 150K range - are still using the Stirling or Pulse tube technologies.
- Very compact efficient cryocooler with the required MTTF's are readily available to cool HTc compact devices or to be able to deliver no-refill systems.
- The space market is changing / commercializing very rapidly. A strong reduction in costs (RC and NRC) and delivery time is required. The use of COTS and COTS+ products is more and more accepted in this - on heritage driven - market.
- Close cooperation between: end user, system integrator, sensor manufacturer and cooler manufacturer is strongly advised.
- The market is expanding but a launching customer fulfilling a large commercial need is still missing.