Thales Cryogenics
Recent developments

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

AEROSPACE  SPACE  GROUND TRANSPORTATION  DEFENCE  SECURITY

TRUSTED PARTNER FOR A SAFER WORLD

DUAL MARKETS
Military & Civil

Contribution to 2nd IWCS-HTS applications Karlsruhe Sept 2017
Our presence

Two sites  Common technology  Complementary products  Joint marketing & product strategy

Contribution to 2nd IWCS-HTS applications Karlsruhe Sept 2017
**Our profile**

**Thales Cryogenics (2016)**

- **Customer segmentation**
  - Defence: 75%
  - Civil: 25%

- **Head count**
  - 210 FTE

- **R&D population**
  - 20%

- **Production population**
  - 40%

- **Revenues**
  - 30 Million Euros

- **R&D efforts**
  - 20% of Revenues

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**Contribution to 2nd IWCS-HTS applications Karlsruhe Sept 2017**

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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

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Overview of Cryogeneics Product Line Perimeter

Defense Markets (Stirling coolers)
- Compact, robust & Efficient 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

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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
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

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

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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
**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)

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

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

Systems delivered by Air Liquide with TCbv compressor

Contribution to 2nd IWCS-HTS applications Karlsruhe Sept 2017
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 cooler could be integrated to reach lower temperatures.
## Expected Market Trends

<table>
<thead>
<tr>
<th>Entity</th>
<th>Product definition</th>
<th>Description</th>
<th>Value Proposition and differentiators</th>
<th>MTTF requirements</th>
<th>Market expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCBV</td>
<td>Contact seal coolers</td>
<td>Classical coolers</td>
<td>Compact solutions, MTTF 30,000 hrs</td>
<td>30,000 hrs</td>
<td></td>
</tr>
<tr>
<td>TCBV</td>
<td>SWaP rotary / linear</td>
<td>Micro-coolers for HOT detectors</td>
<td>SWaP coolers with good Qe / weight ratio</td>
<td>&gt; 15,000 hrs</td>
<td></td>
</tr>
<tr>
<td>TCBV</td>
<td>Long life &lt; 5W</td>
<td>Flexure Stirling, high reliability</td>
<td>Compact cooling solution with power &gt; 1 W @ 77K</td>
<td>45,000 hrs 90% @ 2 years</td>
<td></td>
</tr>
<tr>
<td>TCBV</td>
<td>Long life &gt; 5W</td>
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<td></td>
</tr>
<tr>
<td>TCBV</td>
<td>Pusle tube</td>
<td>Flexure Linear Pulse Tube</td>
<td>Compact low vibration cooling solution</td>
<td>90,000 hrs 90% @ 4 years</td>
<td></td>
</tr>
<tr>
<td>TCBV</td>
<td>SPACE</td>
<td>COTS products</td>
<td>&quot;low&quot; price setting, quick delivery time</td>
<td>95% @ 3 years</td>
<td></td>
</tr>
<tr>
<td>TCBV</td>
<td>SPACE</td>
<td>Dedicated products (ECSS standard)</td>
<td>High efficiency and availability (high NRC)</td>
<td>99% @ 5 years</td>
<td></td>
</tr>
</tbody>
</table>
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.
CONTRIBUTION TO 2nd IWCS-HTS APPLICATIONS KARLSRUHE SEPT 2017

THALES

SYNERGY

RELIABLE

ROBUST

AFFORDABLE