THALES

Stirling and Pulse Tube type compressors for space applications

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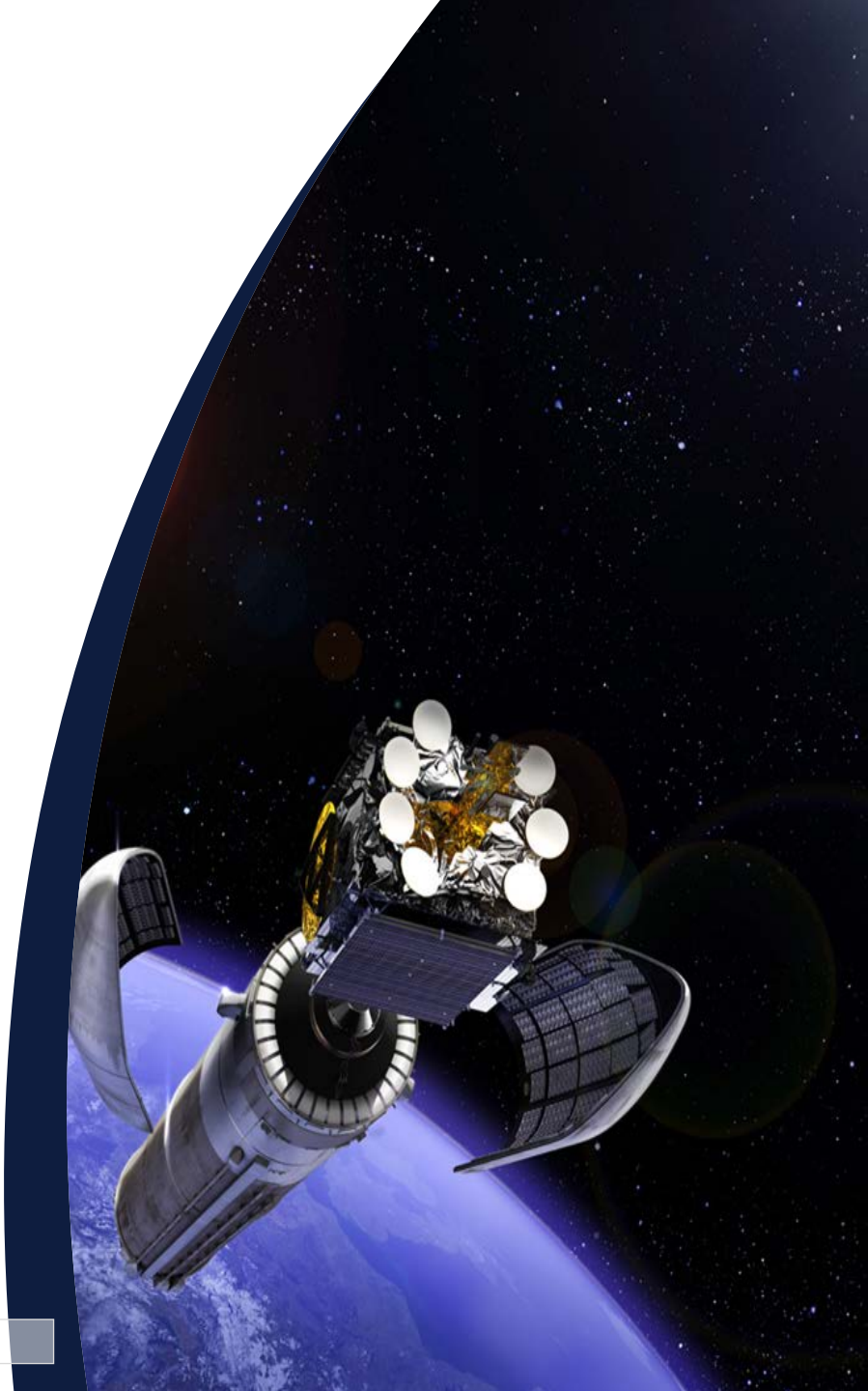
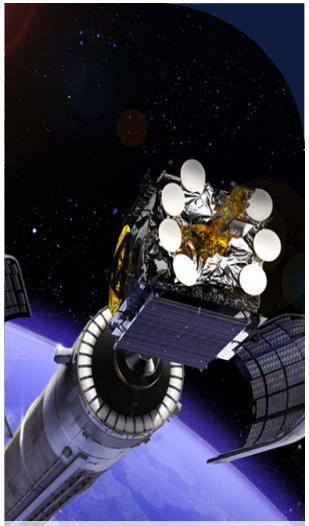


Contents

Markets served by the Thales group

DUAL MARKETS
Military & Civil

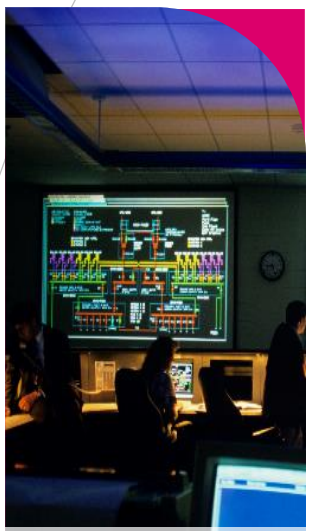
AEROSPACE



SPACE

GROUND TRANSPORTATION

DEFENCE



SECURITY

TRUSTED PARTNER FOR A SAFER WORLD

Thales Cryogenics organization

Thales Cryogénie SAS

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BP 70022
31701 Blagnac Cedex
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- Rotary coolers
- Joule Thomson coolers
- High Pressure Vessels

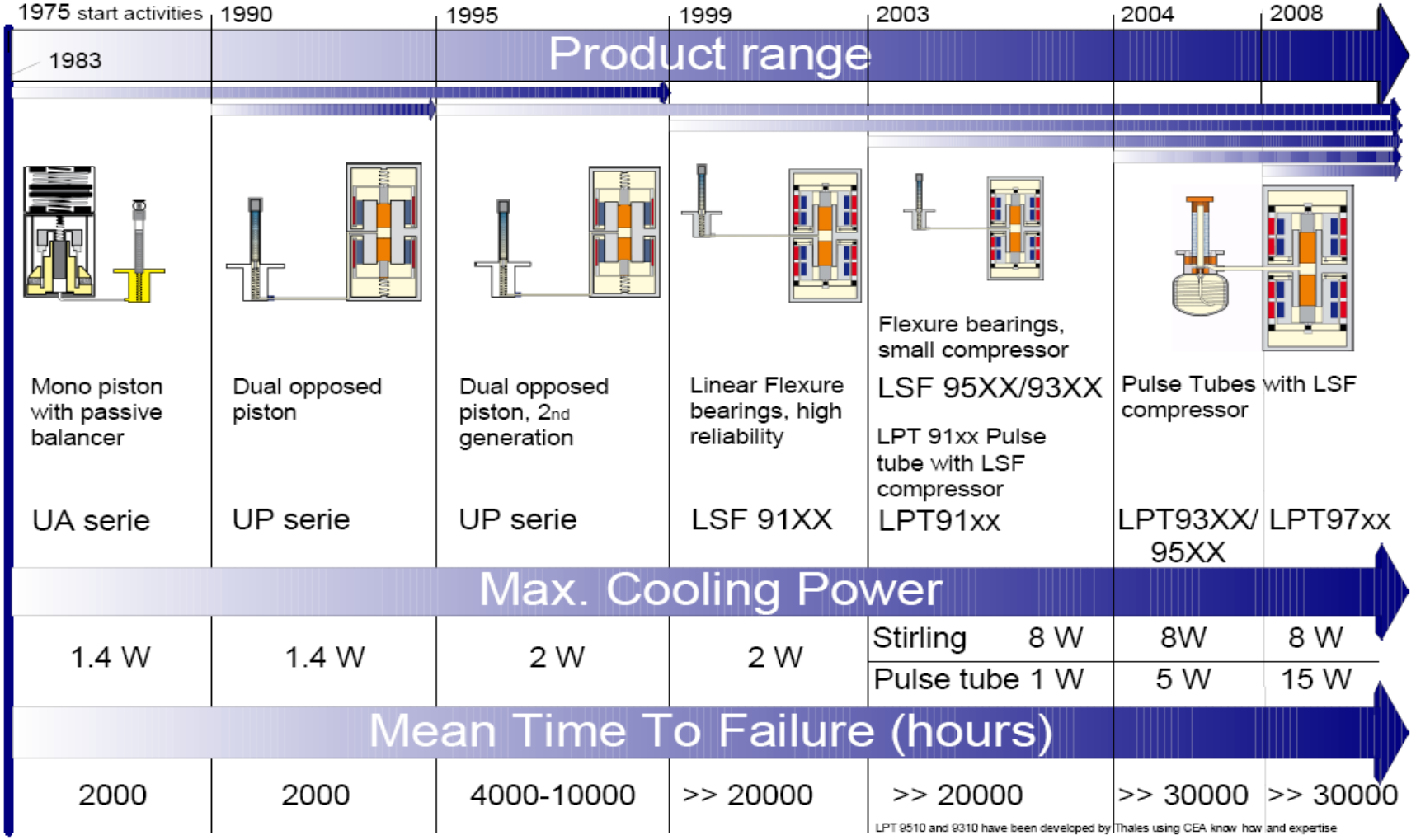
Thales Cryogenics BV

Hooge Zijde 14
PO Box 6034
5600 HA Eindhoven
The Netherlands
Tel : (31 40) 250 36 03
Fax : (31 40) 250 37 77

- Linear coolers
- Pulse tube coolers
- System integration
- Space cooler / compressors

One global vision for your cryocooling solutions

Thales Cryocooler development history



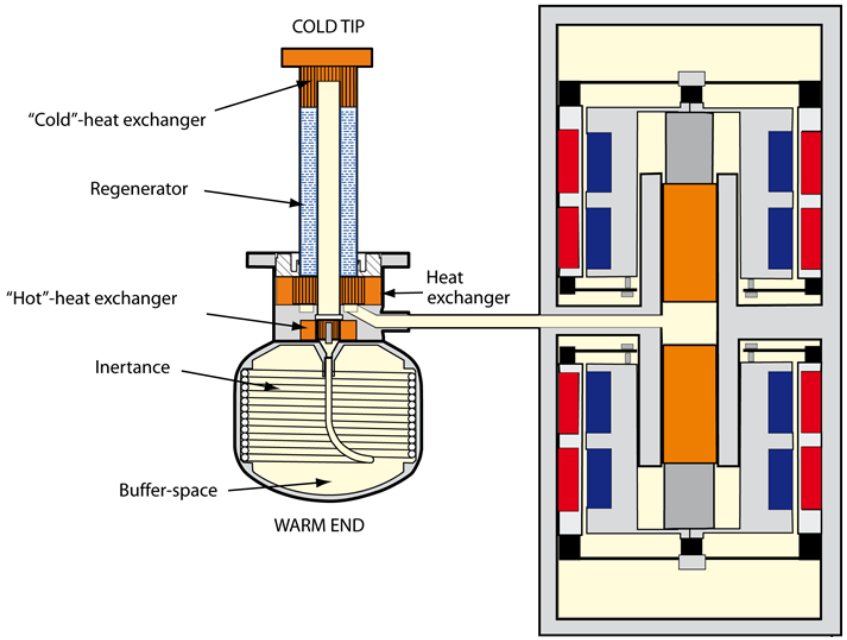
Field data: > 45.000 hrs

Field data: > 90.000 hrs

High frequency coolers

Compressor

- Transfer of electrical power in a pressure wave.
- Typical operating frequency between 25 and 150 Hz.
- “Resonance type”: the drive frequency has to be aligned with the eigen Frequency of the piston mass and spring stiffness



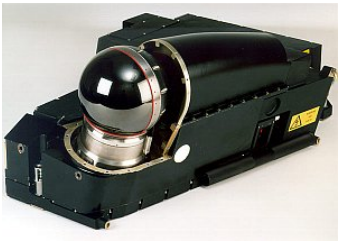
Cold finger

- Pulse tube or Stirling technology depending on the application needs.
- Both technologies use the pressure wave and gas movement of the compressor to produce a heat flux from “cold end” to “warm end”
- Thermodynamic operating frequency depends on detailed design of the cold finger.

Requirements on final area of use

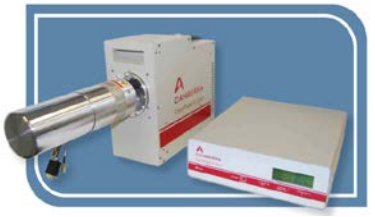
Military markets

- Enable for sensing IR systems



Civil markets

- Deliver a solution for cooling of devices
- Replace cryostats with liquid evaporation
- Cooling of HTc devices
- Proven reliability / simple maintenance

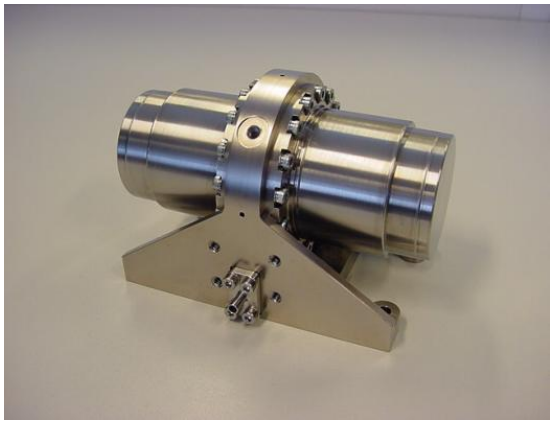


Space markets

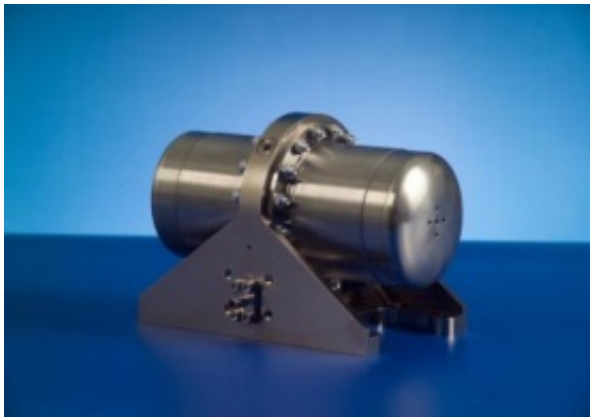
- Enabling of sensing
- Reliability / Availability is key
- Stringent requirements on weight and efficiency

Design criteria for space compressors

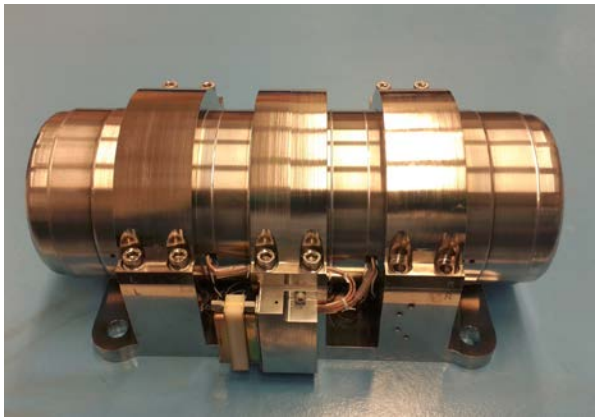
- Reliability / availability
- Efficiency of the electromotor
- Vibrations exported to the structure / system



MPTC compressor



LPTC compressor



15K compressor

Reliability / Availability

Avoid wear

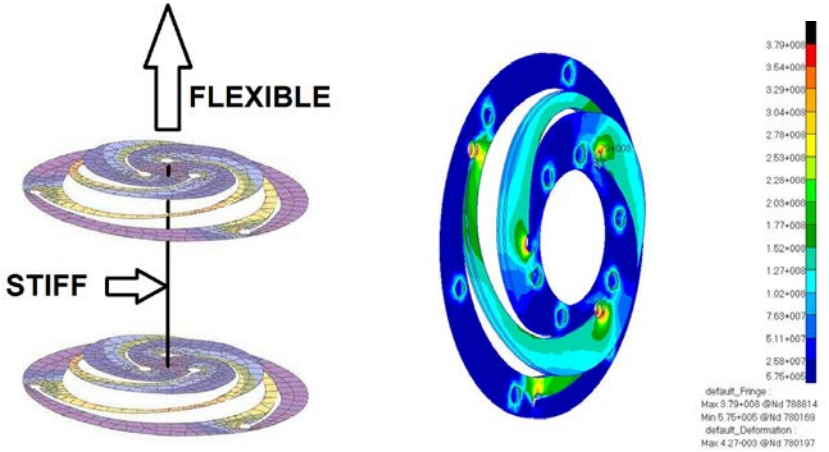
- Minimize contact between Piston / Cylinder

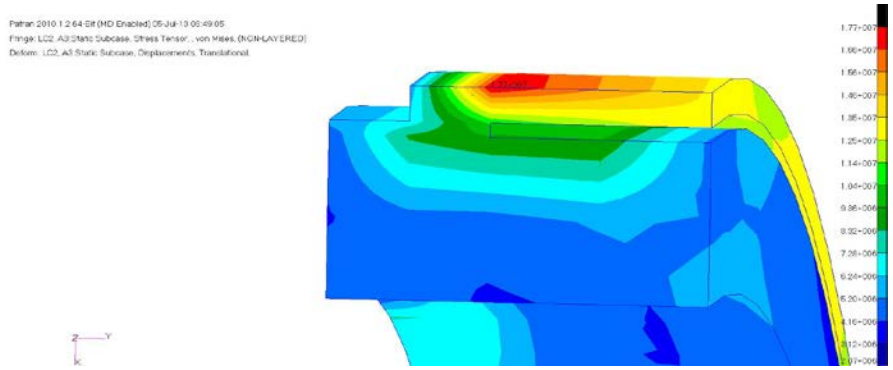
Avoid outgassing components

- Coils outside of Helium

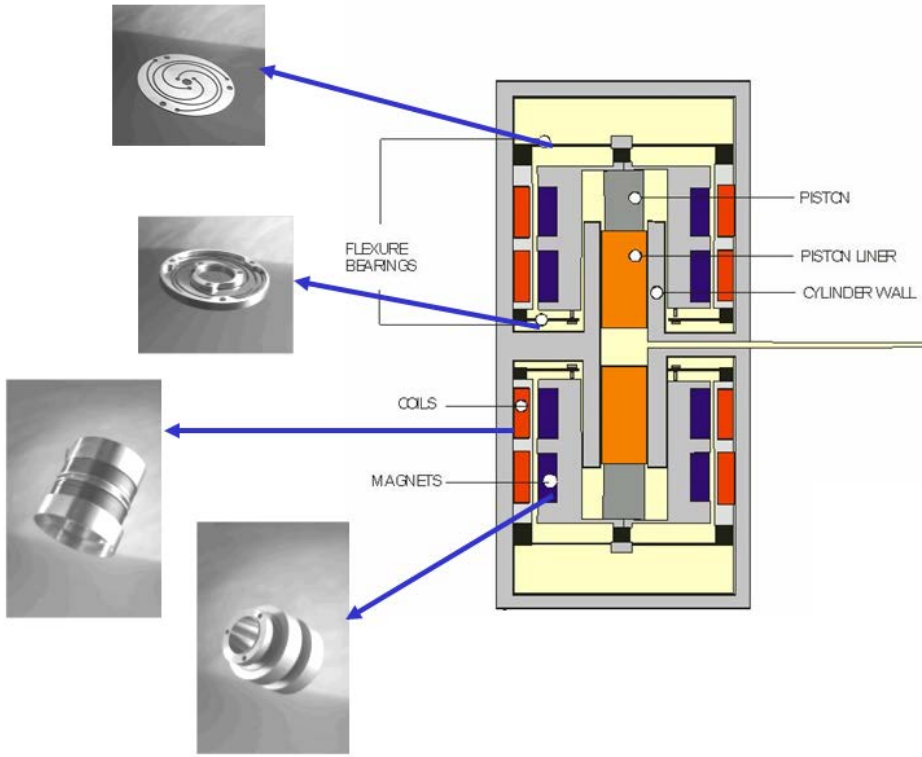
High focus on structural integrity

- Conform ESA design guidelines and accepted simulation tools.



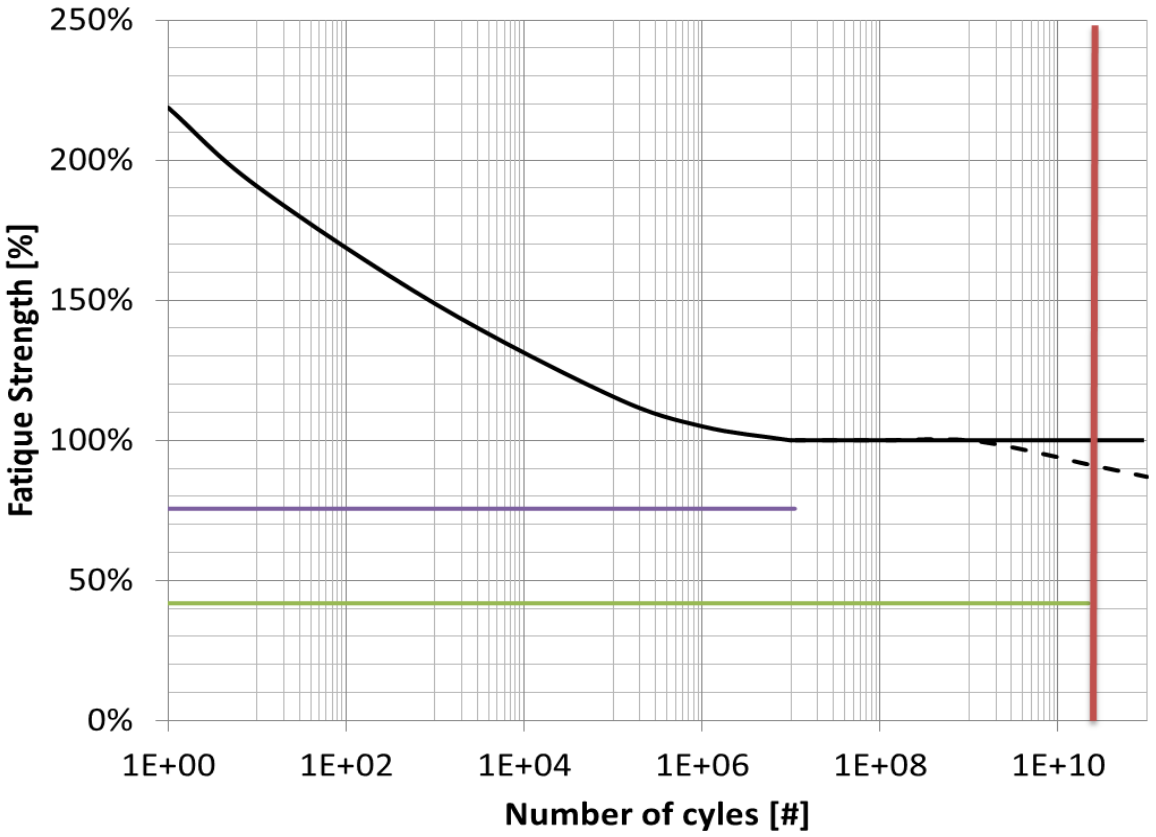


Von Mises stresses in the Weld 6/W9 - LC2



LPTC flexure design features & test results

Example of design criteria and validation plan of a flexure design for space coolers



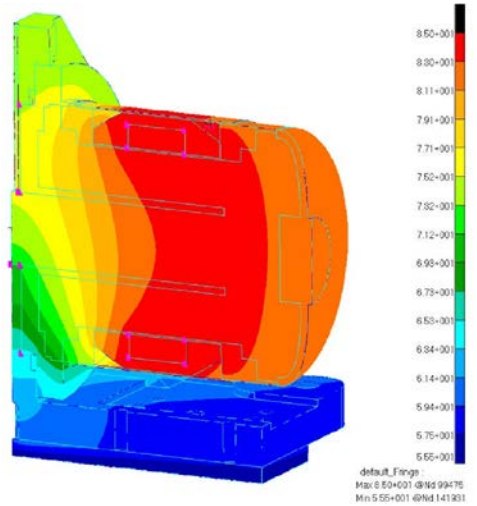
Literature Material S/N curve
Giga-cycle regime
Flexure stress at maximum input power
In assembly screening test level
MTG Compressor operational lifetime

Presented @ 5th European Space Cryogenics Workshop - 2013

Efficiency

Optimal motor design (more complex design)

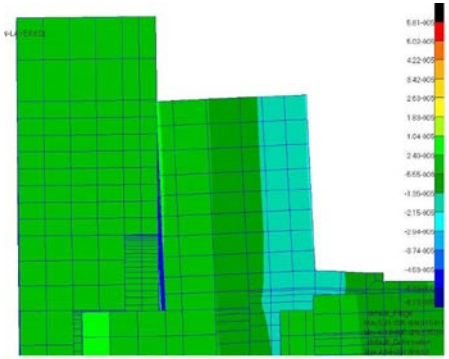
- **Civil - Cost driven:**
  Single axial magnet per motor part
- **Space - Efficiency / weight driven:**
  More complex motor systems with even 4 pole radial magnetized magnets per motor part.



Temp distribution over compressor

Optimal heat sinking (use of different materials)

- **Inconel for high strength**
- **Titanium for strength and low density but low thermal conduction**
- **Aluminum for adequate heat sinking and low density but low strength**
- **Different connections techniques required for helium tight connections between different materials**

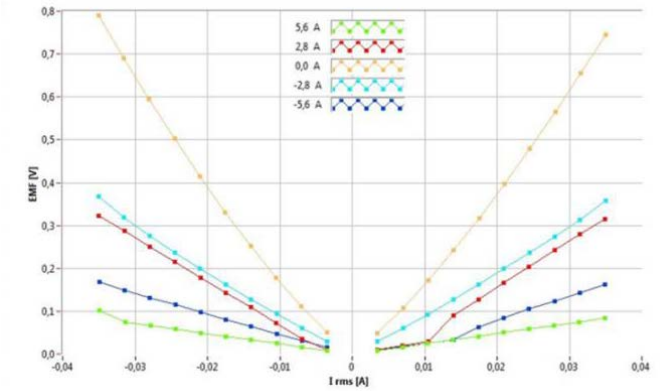


Deformation at sealing surface

Vibrations of cooler / compressor

Cooler induced vibrations are critical for Space applications thus :

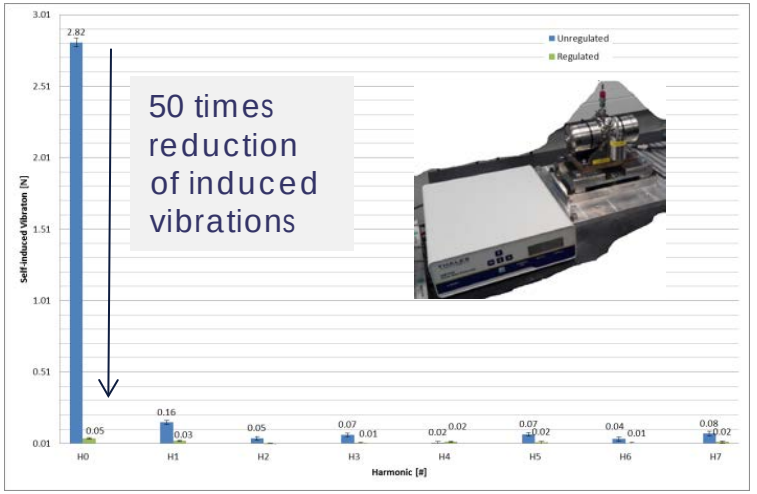
- Choice for PT cold fingers
- Choice for compressor with AVR drive electronics (axial movement)
- Requirements of flexible / active support for damping of remaining vibrations



Piston friction verification

By design manufacturers are required to:

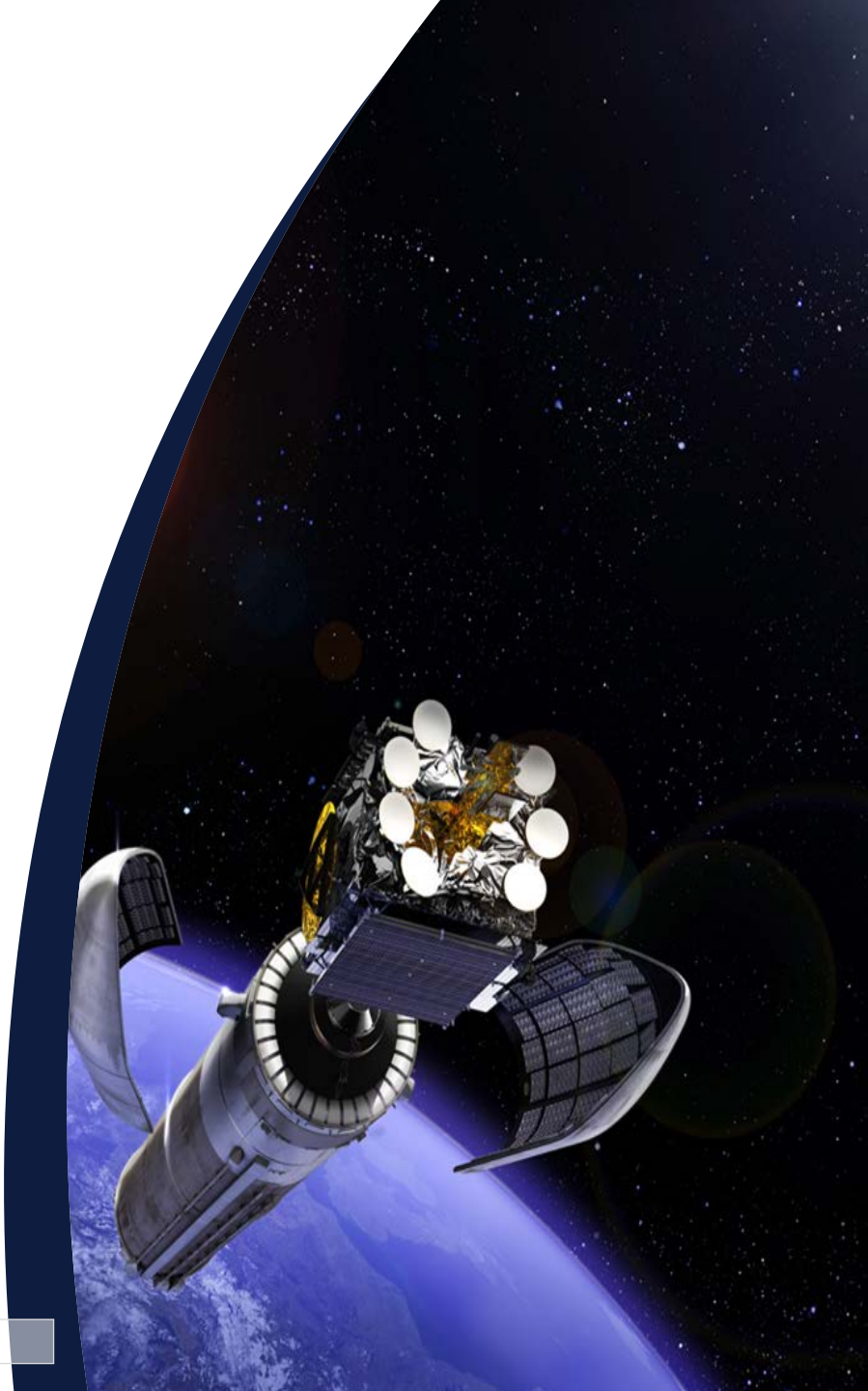
- Minimize off-axis vibrations by design & MAIT
- Correct motor balancing / matching to limit on-axis vibration
- Ensure proper alignment verification of flexures / pistons



Impact of AVR on vibrations

THALES

Examples of Thales Space compressors / coolers



www.thalesgroup.com

Various ESA TRP funded developments

MPTC
Compressor for Miniature Pulse-tube Cooler
80K cooler

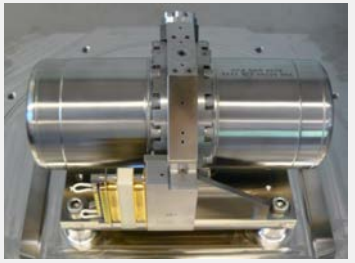
ESA Contract 14896/00/NL/PA , started in 2002.
Partners: Air Liquide, CEA

Product status
Compressor now used for new cooler
(Cooperation with external party)

LPTC
Compressor for Large heat lift pulse-tube cooler
40-80K application

ESA Contract 18433/04/NL/AR , started in 2004
Partners: Air Liquide, CEA

Product status
Used for various flight programs



15K
Cryocooler Drive Electronics for Space
ESA Contract 4200023025/10/NL/AF
Partners: Air Liquide, CEA

Product status
Engineering model currently under test

Image: Air Liquide

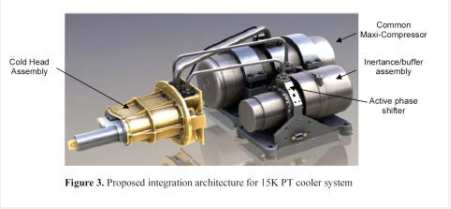


Figure 3. Proposed integration architecture for 15K PT cooler system

30-50K
Two-stages cooler and cryostat
ESA Contract 4000109933/14/NL/RA

Partners: Absolut System, CEA
Thales as prime contractor

Product status
PDR held at ESTEC

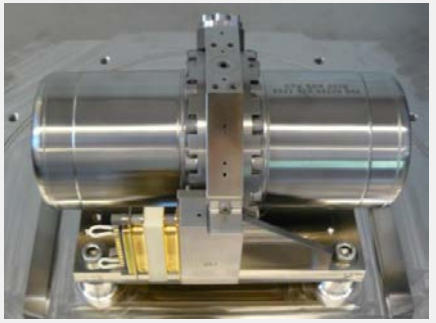
MTG – Under qualification / production

Project
Meteosat Third Generation

Also referred to as
MTG

Application
Weather forecasting
Weather monitoring

Thales Cryogenics product
LPTC compressor
Developed under ESA-TRP



Context
Air Liquide manufactures cryocooler
Thales Cryogenics supplies compressor

Project status
CDR ongoing

Technical information:

Max input power	180 W
Mass	4.9 kg
Cryocooler application	50 K

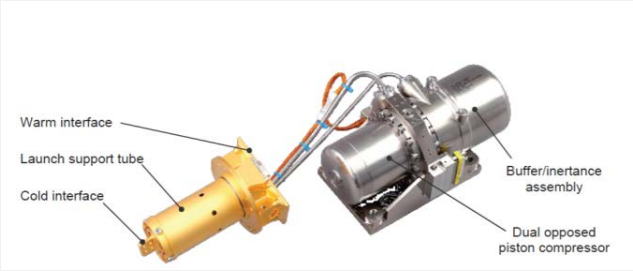


Image: Air Liquide

LSF9199/30 – Modified COTS cooler Flexure-supported

Projects
Supplied through Sofradir
Various non-US, non-EU customers

References:
"Development of cost-effective cryocoolers for space", ICC18, Syracuse, 2014

Thales Cryogenics product
LSF9199/30

Based on COTS designs
Flexure-bearing displacer

Upgraded materials
Upgraded build standard

Option:
Balancer
Option:
Vibration control

Context
Thales supplies cooler to Sofradir
Sofradir integrates various IDCA detector types
Various customers & applications

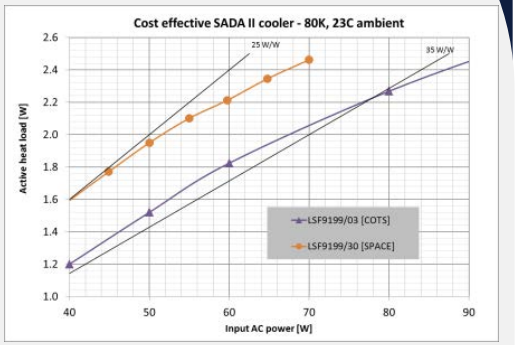
Project status
FMs delivered for first order
Several follow-up orders

Technical information:

Max input power	90 W
Application area	50 - 200 K
Flexure-supported displacer	
Flexure-bearing compressor	

IDCA-concept

Cold Finger:
SADA II-compatible



LPT9510 testing at JPL (use of COTS cooler)

Projects
Various potential projects for JPL

References:
"Flight Qualification Testing of the Thales LPT9510 Pulse Tube Cooler", ICC18, Syracuse, 2014

Thales Cryogenics product

LPT9510
Off-the-shelf Pulse-tube cooler

Context
Off-the-shelf cooler tested at JPL

Project status
LPT9510 now considered TRL6
Proposed for several space and airborne missions

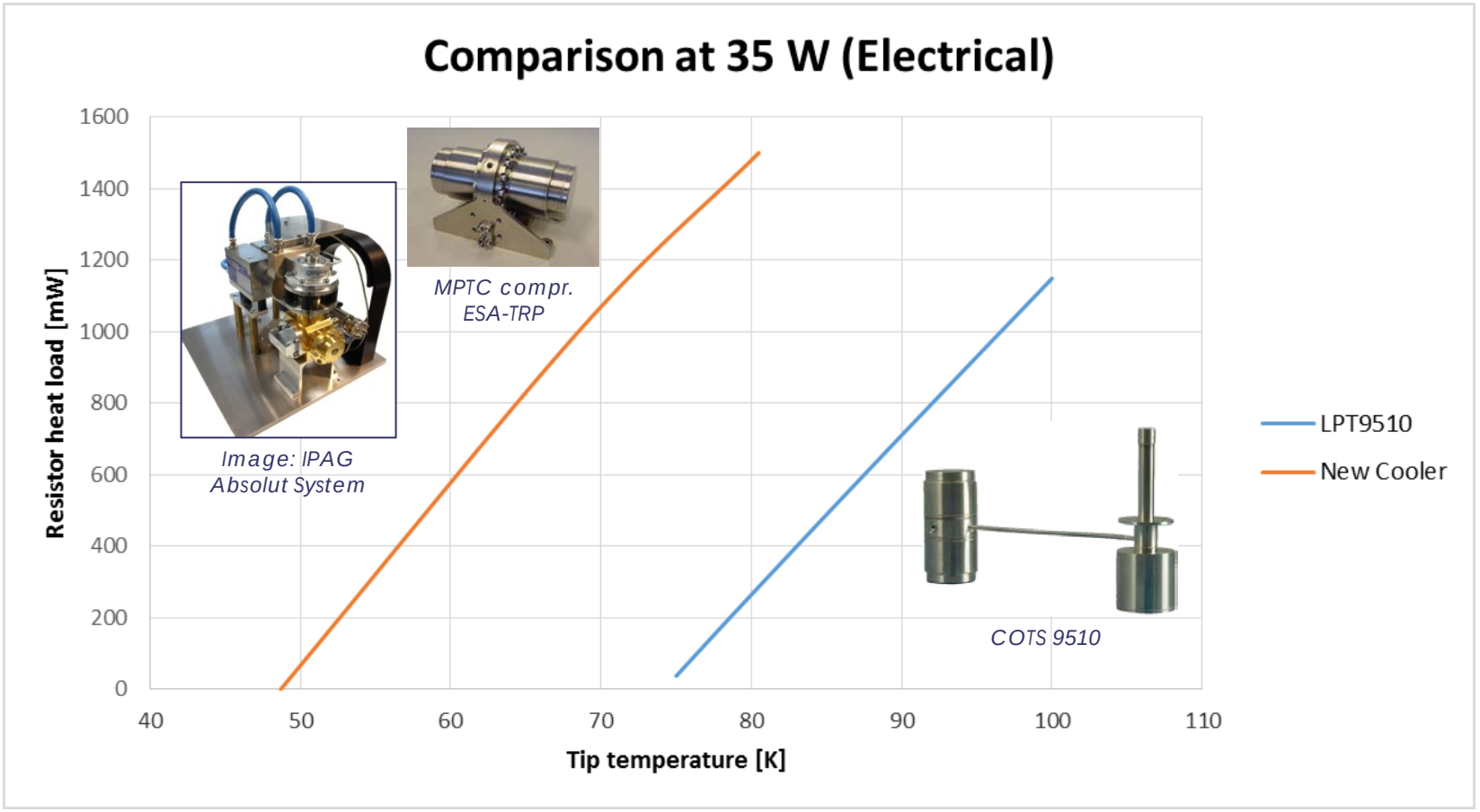
Jet Propulsion Laboratory
California Institute of Technology

Technical information:

Max input power	85 W
Mass	2.1 kg
Cryocooler application	80 K
Heat lift	1.4 W

Tested to GEVS proto flight qualification levels at JPL

Impact of cost cooler / Space cooler



Conclusions

Large commonality by design / function of compressor / cooler

- Requirements for full space or “COTS” is changing

Space has specific focus on requirements:

- Focus on availability
- Focus on efficiency
- Focus on mass / size
- Focus on justification / verification [design / manufacturing].

Space most challenging requirements:

- Vibration levels / system impact
- Robustness for environmental conditions

Large spin-off to other industries is existing for cryocoolers