

MINIATURIZATION OF ROTARY STIRLING CRYOCOOLERS

Christophe Vasse^a, Cédric Seguineau^a, Jean-Yves Martin^a,
Tonny Benschop^b

^aThales LAS France, Secteur Cryogénie, 4 Rue Marcel Doret
BP70022, F-31701 Blagnac FRANCE;

^bThales Cryogenics B.V., Hooge Zijde 14,
5626 DC Eindhoven, Netherlands



TABLE OF CONTENT

- 1 INTRODUCTION
- 2 SWaP REQUIREMENT
- 3 THE RMs1 PRODUCT
- 4 RMs1 PERFORMANCES
- 5 CONCLUSION

Introduction – SWaP cryocoolers



IR Thermal Imagers Cooled or Uncooled ?

The Cooled IR imagers still provides :

- Lower NETD
- MWIR sensing
- Smaller optics



Uncooled technologies progresses

New cooler must have added values :

- Smaller and Lighter
- With a lower power consumption
- With a shorter time to operation
- Cheaper

Better performances without cooled imagers drawback

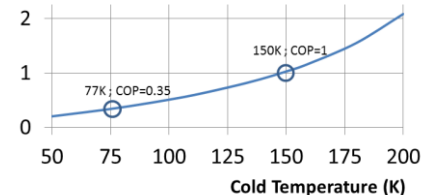


IR components with High Operating Temperature

HOT detector with RMs1 cooler enables that trend

- Higher Carnot efficiency at cooler level
- Lower power consumption
- Shorter cool down time
- Smaller and lighter cryocoolers

Carnot Efficiency at 296K Warm Side



SWaP ? The Cooler Requirements

SWaP

SWaP cooler: 3 main key characteristics to improve

SIZE **WEIGHT** **and** **POWER**



Inside a cube
with 50mm
length side



below 200gr



below 2W

Typical HOT dewar characteristics

Operating temperature	150 K
Total heat load	150 mW
Thermal mass	120 J



While keep other **key priorities**

- Quick **Cool Down Time** → Below 2min
- Low **Noise level** → Silent at 20m
- High **MTTF** → Higher than 15,000hr
... and **cheaper** coolers



Other generic specifications

- **High focal plan temperature range**
(110K to 170K)
- **Same legacy filling port than RM2**
- **6mm generic coldfinger**
- **12V** input voltage

The RMs1 Product

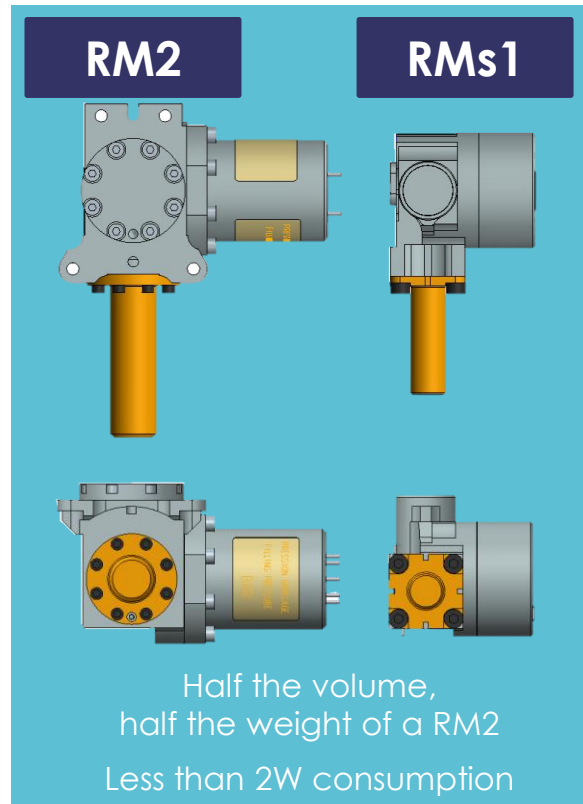


Trade-off between compactness, power and costs

- SPIE DS. 2015: first functional mockup in order to evaluate technologies leading to highest compactness
 - Compact Coldfinger
 - Welded casing
 - Internal miniaturization
- 2018: RMs1 actual product :
trade-off between cost and miniaturization



OPEN



The RMs1 Performances

Large Cryopower and quick cool down time



Cool Down Time : 2min from room temp.

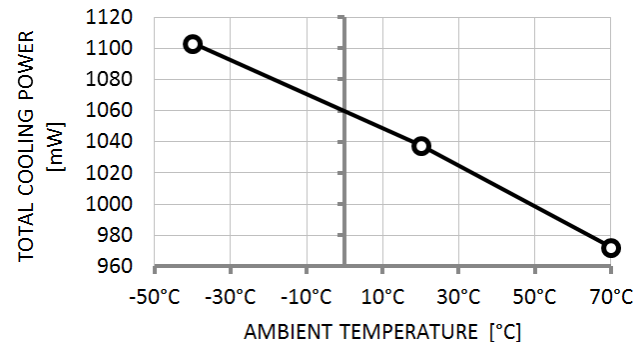
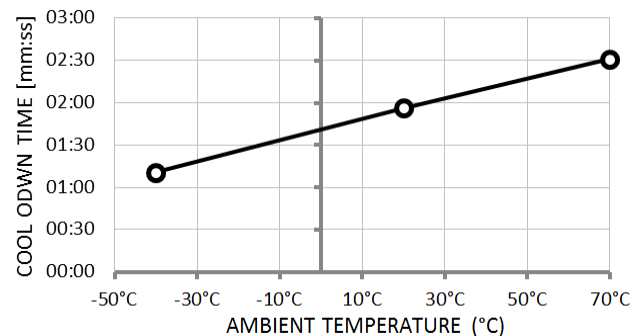
- Improved CDT compared to previous Coolers
- CDT is linked to the cryogenic power available
- Stand-by mode available to reach a time to operation within 1 min



Cryogenics Power available: 1W @150K

- The RMs1 is able to cool large array HOT matrix
- For typical VGA applications, the RMs1 is far from its max power → improved reliability expected
- The input electrical power is then below $P_{ac} \approx 10W$

Dedicated version for high heat loads will be proposed



The RMs1 Performances



Low power in a steady state regulation

- Impact of ambient temperature

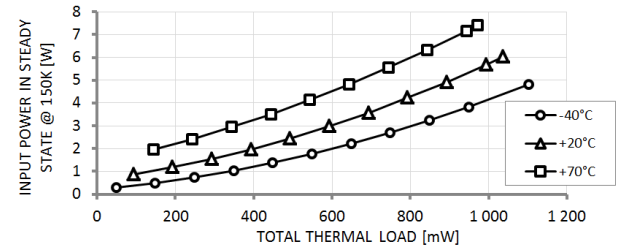
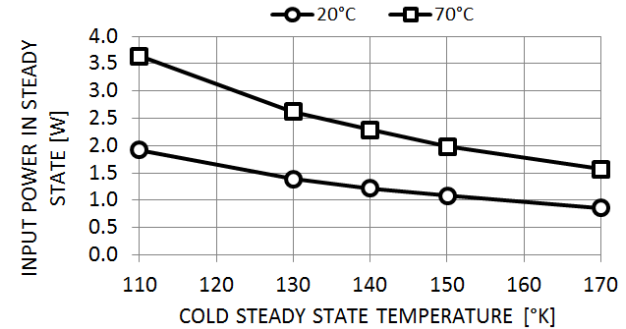
@71°C; 150K
@20°C; 110K } $P_{ac} = 2W$

- The RMs1 can regulate at 110K with still high margin

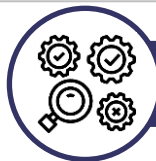
@71°C; 110K : $P_{ac} = 3.6W$
(1/3 of max input power)

- Thermal Regulation...

has been achieved with Thermal Load up to 950mW @71°C; 150K is below 0.7W with typical thermal load @-40°C;150K



The RMs1 Performances



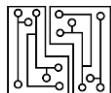
Qualification on-going (1/3)

> Mechanical stress

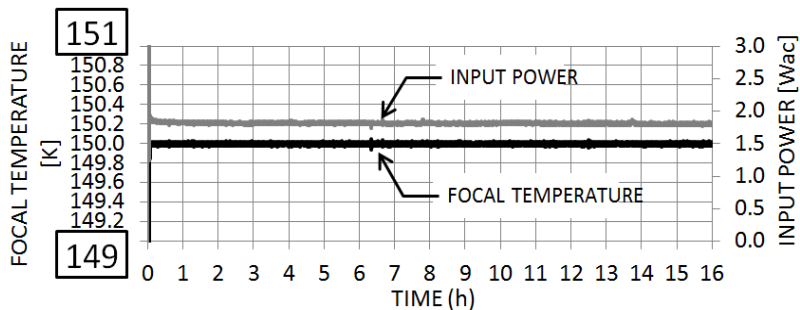
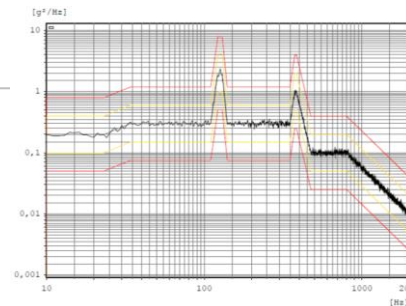


- Sine and shocks applied (HHTI, vehicule, airborne)
 - 16 grms random vibration profile
- } no impact on performances

> Cooler Driver electronics:



- Very accurate stability
- No drift of cold temperature over time
- Dedicated functionalities



The RMs1 Performances



Qualification on-going (2/3)

> Induced vibration:

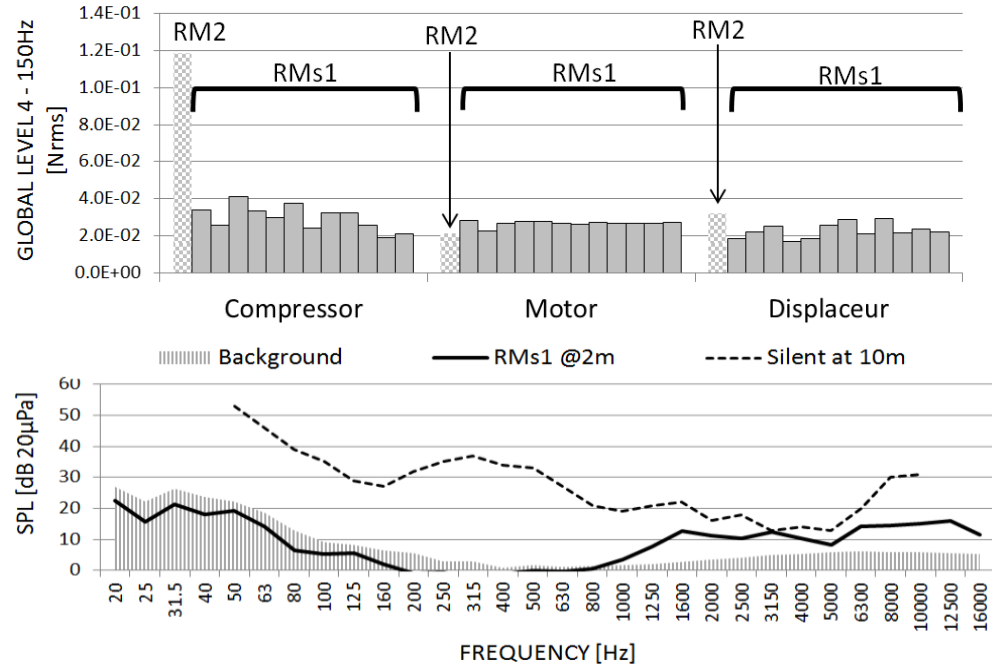
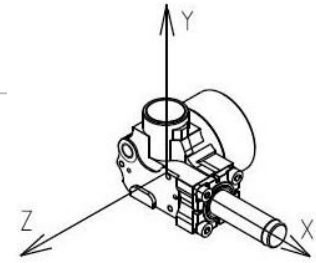


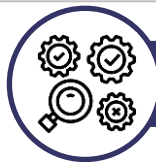
- better than balanced RM2
- Good reproducibility from one unit to another

> Noise level :



- The prototype tested is silent at 10m (MIL-STD-1474)
- Sound Power : 43 dbA (ISO3744)





Qualification on-going (3/3)

► Lifetime test (Accelerated test A20):



- Target 15,000hr in STP profile
- Design rules applied close to RM2
 - Current RM2 reliability > 40,000hr
 - Lower mechanical loads on RMs1
- 2 RMs1 have passed 4,000hr in A20
- 2 RMs1 have passed 2,000hr in A20
- 4 other units have just started A20

→ Current proven reliability: 12,000hr

→ The 15,000hr may be acquired before the end of the year.

We expect a MTF at the same level than RM2

N°	Lifetime test duration (h)	Status
1	5800	Still running
2	4300	Still running
3	3150	Still running
4	2250	Still running
5	1511	Still running
6	1465	Still running
7	450	Still running
8	450	Still running

The RMs1 Performances



Performances given for the following application :

- Tf = 150 K
- Dewar : 150 mW / 120 J

Typical performances and target specification

PARAMETER		TYPICAL VALUE	TARGET SPECIFICATION	
SIZE 	Optical axis	72,2mm	72,2mm	
	Motor axis	42mm S	42mm	
	Compressor axis	42mm	42mm	
WEIGHT 	Cooler	142gr W	< 150gr	
	Driver	10gr	< 15gr	
POWER @20°C 	Power in Reg.	AC	1.2 W a	< 1.5 W
		DC	1.65 W P	< 2 W
	Max. Power	11 W	<10 W	
	Cool Down Time	120 s	< 150 s	
	Cryogenic Margin	< 90K	till 110K	
MTF 		>15,000hr expected	> RM2 (15,000hr)	
NOISE 		Silent at 10 m	Silent at 20m	
VIBRATION 		< 40mN _{rms} (all axes)	Better than balanced RM2	

- Low consumption
- Quick CDT and High cryopower
- Reliable
- Noiseless
- Low vibrations

OPEN

This document may not be reproduced, modified, adapted, published, translated, in any way, or in part or disclosed to a third party without the prior written consent of Thales - © Thales 2015. All rights reserved.

CONCLUSION

RM_s1

- is **half the size** and weight of the RM₂,
- consumes **2W** to regulates at 150K at 71°C,
- can reach 150K in **2min**,
- can deliver a **cryopower of 1W** @150K ,
- can **operate at 110K** and below,
- induces **very low level of force** at the interface (below $40\text{mN}_{\text{rms [4-150]Hz}}$),
- may be qualified also for **vehicle and airborne** applications,
- is expected to have a MTTF **higher than 15,000hr** at 150K(12,000hr already proven)



The current RM_s1 is at the end of its qualification process

- All the harshest tests have been passed
- The prototypes have been built with production means: good reproducibility achieved
- The qualification shall be pronounced in July

OPEN

Thank you for your attention

Do you have any questions ?



OPEN