



**ThalesAlenia**  
A Thales / Finmeccanica Company *Space*

# Getting ready for RF MEMS GEO flight demonstration

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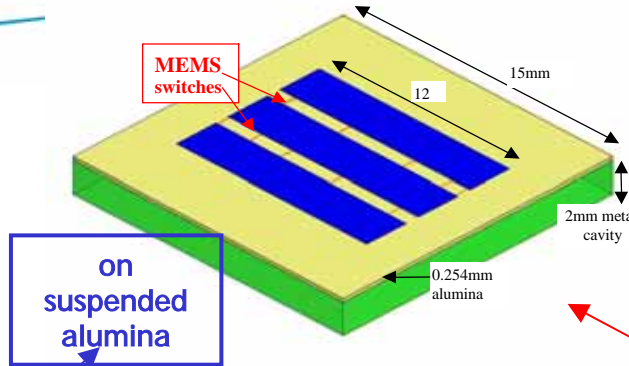
(1) CEA LETI MINATECH

(2) CNES

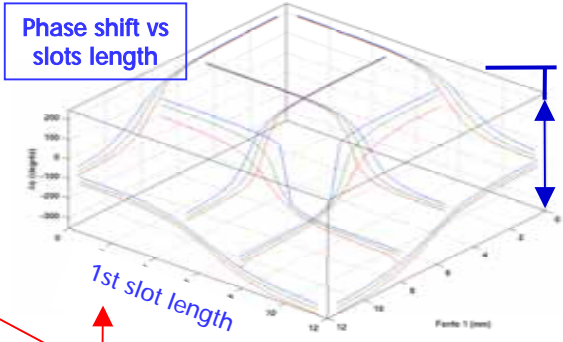
**THALES**

- Introduction
- Mission/experience presentation
- Description of the equipment constituents
  - Mechanical overview
  - TMTC
  - FPGA and dedicated ASIC
  - MEMS based hybrids
- EM manufacturing and test
- Conclusion and perspectives

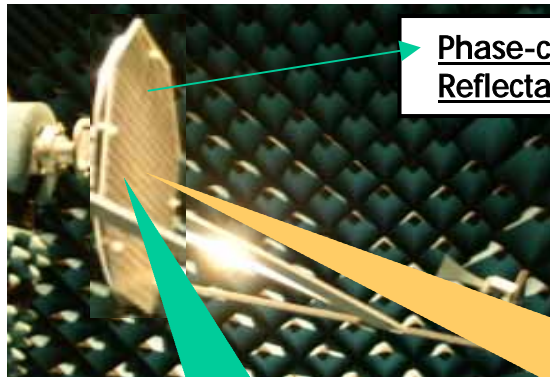
## MEMS-controlled ReflectArray



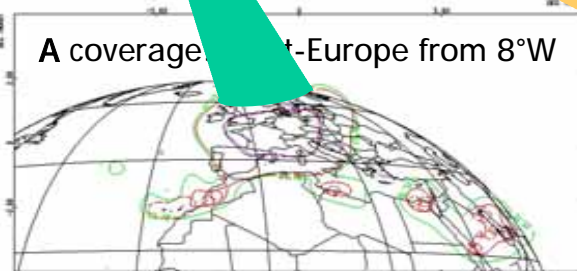
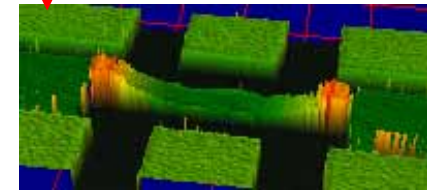
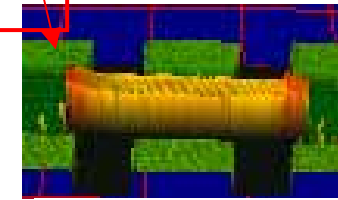
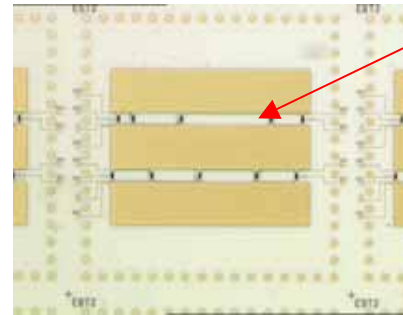
Phase shift vs slots length



on suspended alumina



on thinned silicon

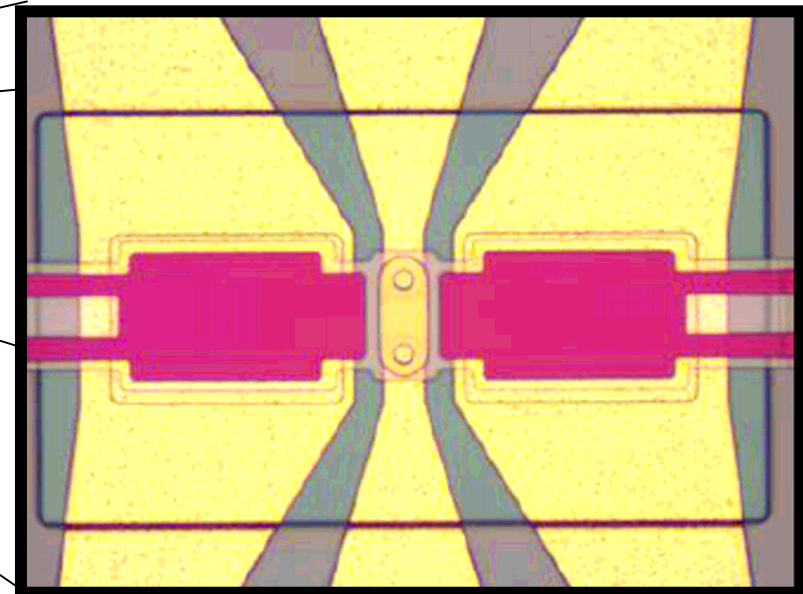
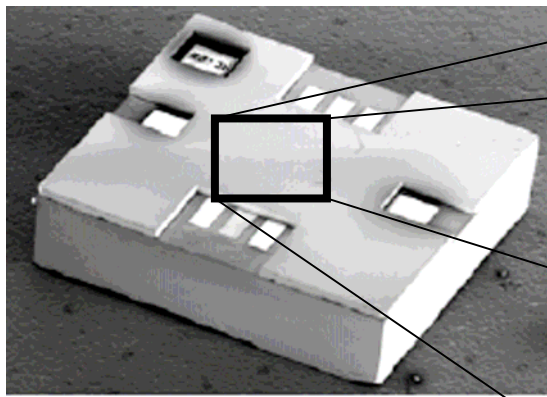


TAS-F + LETI, LAAS

Typical power-handling: 2 to 4 W per reflecting cell **1 to 2 W max through 1 switch** in worst case states of the 10 controllable ones

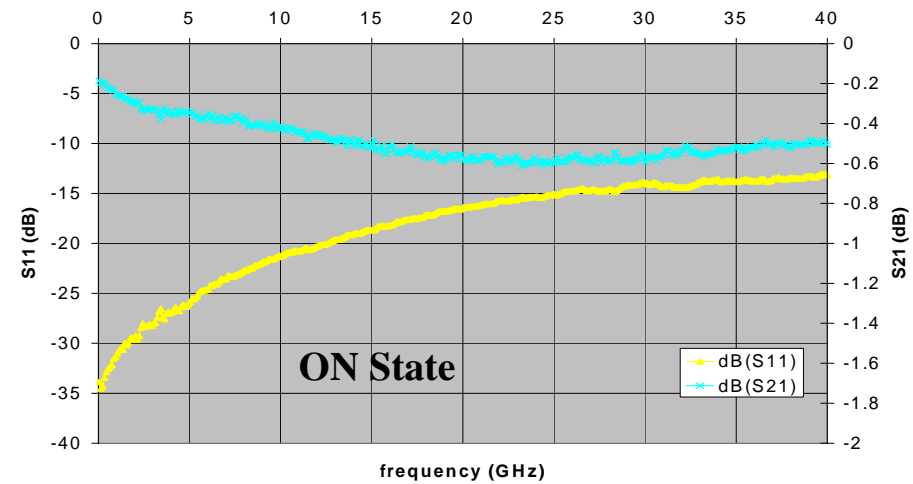
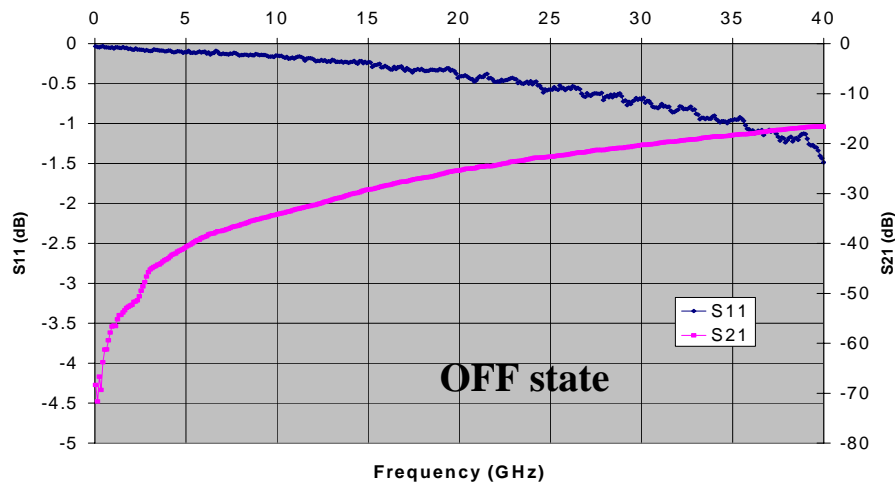
- Visibility of the new technology vs future customers
  - Internal
  - External
- Go from mid to high TRL
  - Refine design/test methodology applicable to flight models
  - Documentation
  - Industrialisation approach
- Enhance know-how of the new technology
  - Use into industrial environment
  - Technology integrated into flight proven technologies
  - Risk assessment
- Qualification of the available technology prior to flight demonstration

- CNES contract
- Thales Alenia Space : Prime contractor, design, manufacturing and test of the demonstrator
- RF MEMS technology
  - Ohmic switch technology from CEA LETI



- Technology qualification
  - Technical support from CNES at component level
  - TAS in-house capability

## Ohmic contact, serie switch from CEA-LETI (after flip-chip mounting)



### ■ Comparaison with a standard diode (Diode beam lead HPND 4005)

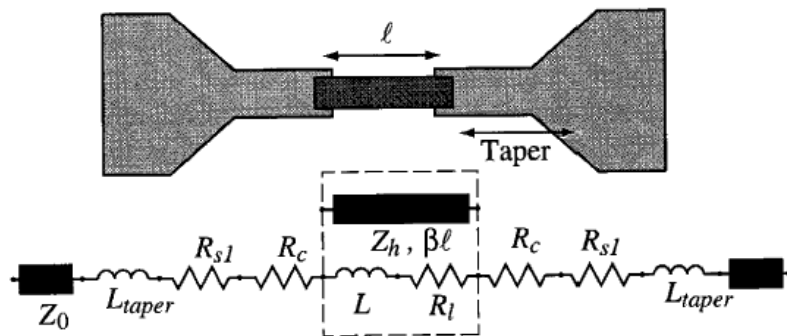
	Pertes de transmission : Etat ON à 30 GHz	Isolation : Etat OFF à 30 GHz	RON	COFF	1/(RON,COFF)
MEMS	0,29 dB	19,9 dB	1,7 ohms	9,8 fF	60 THz
Diode	0,76 dB	8,9 db	5 ohms	22 fF	9 THz

## Base for demonstrator definition

- Observed failure mode for ohmic contact switches
  - Contact :
    - Contact degradation
    - *Stiction metal-metal*
  - Membrane :
    - Residual stress, stress gradient, thermal stress
    - *Creep*
  - Electrostatic activation
    - Dielectric charging

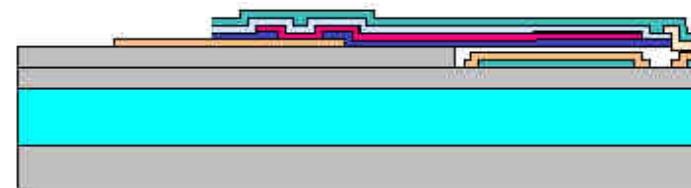
## Basement for experiment definition

- Based on DC parameters
  - Fundamental sollicitation modes
    - Application (redundancy, fast switching)
  - Advanced RF switch intrinsic characteristics :  $R_c$  (On) et  $V_p$



$$R_s = 2R_c + 2R_{sl} + R_l$$

$$pertes = \frac{4R_s Z_0}{|Z_s + 2Z_0|^2}$$



↕ g = gap

$$V_p = \sqrt{\frac{8k}{27\varepsilon_0 W w}} g_0^{3/2}$$

Membrane spring constant

$$k = 4Ew \left( \frac{t}{l} \right)^3$$

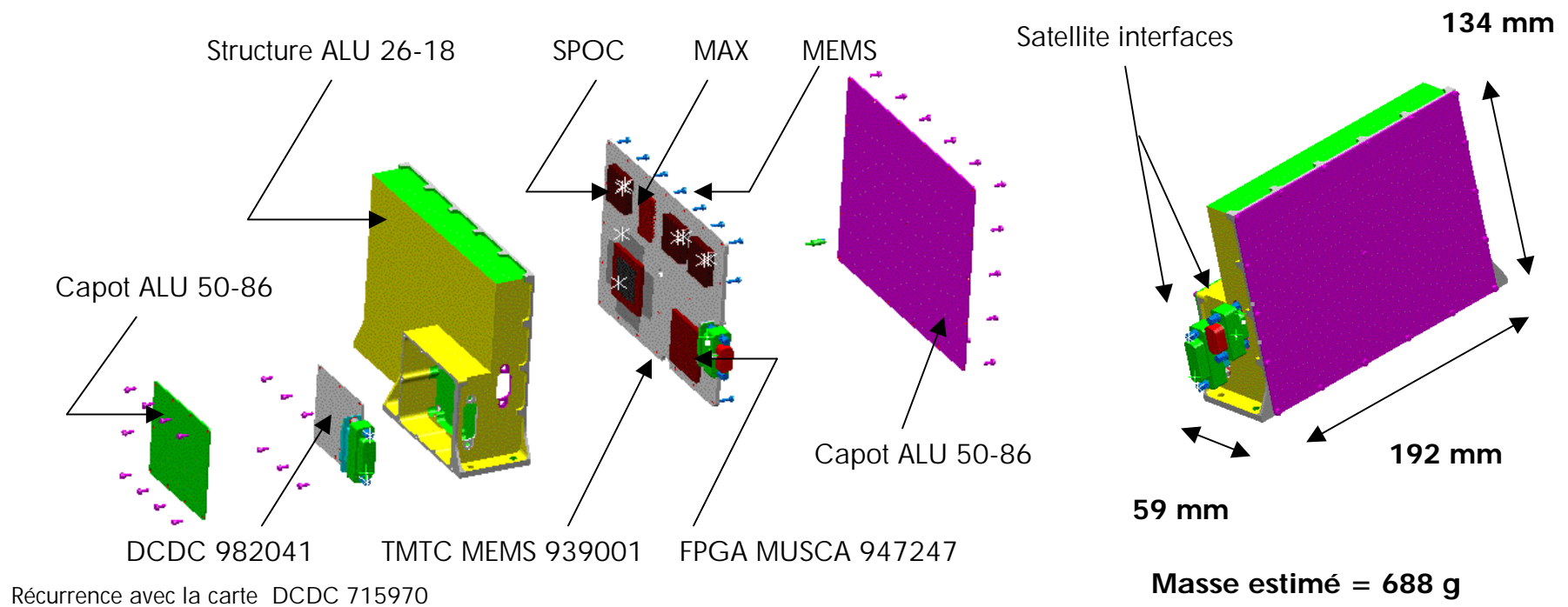


<i>Measured characteristics</i>	<i>Static performances</i>	<i>RF performances</i>	<i>Impact on reliability assessment</i>
Number of cycles with various profile	N/A	N/A	- Reliability rough figure - Effect according to cycling profile
Series resistance of the switch ( $R_s$ )	Contact resistance ( $R_c$ ) derived from analytic equation <sup>(2)</sup>	$S_{12}$ is derived from equation : insertion loss <sup>(1)</sup>	- Contact aging (pollution, tribology, radiations,...) - stiction, microsoldering,...
Pull-in voltage ( $V_p$ )	At known material characteristics, can be calculated ( $k$ ) <sup>(4)</sup> and derived gap ( $g_0$ ) <sup>(3)</sup>	$S_{12}$ is derived from EM 3D model : isolation	- Membrane deformation

- Mode INIT: all the MEMS are switched On/Off 5 times, launched by TC
- Mode(1) : MEMS aging due to On/Off cycling, launched by TC
  - 1 Cycle On/Off per second : 4 MEMS
  - 1 Cycle On/Off per day : 4 MEMS
  - 1 Cycle On/Off per year : 4 MEMS
- Mode(2) : MEMS aging with sollicitation close to redundancy application
  - TC launched switch : 4 MEMS .
- Mode(4): Pull-in/Pull-out measurements
  - TC launched sequence : 4 MEMS
- Temperature monitoring

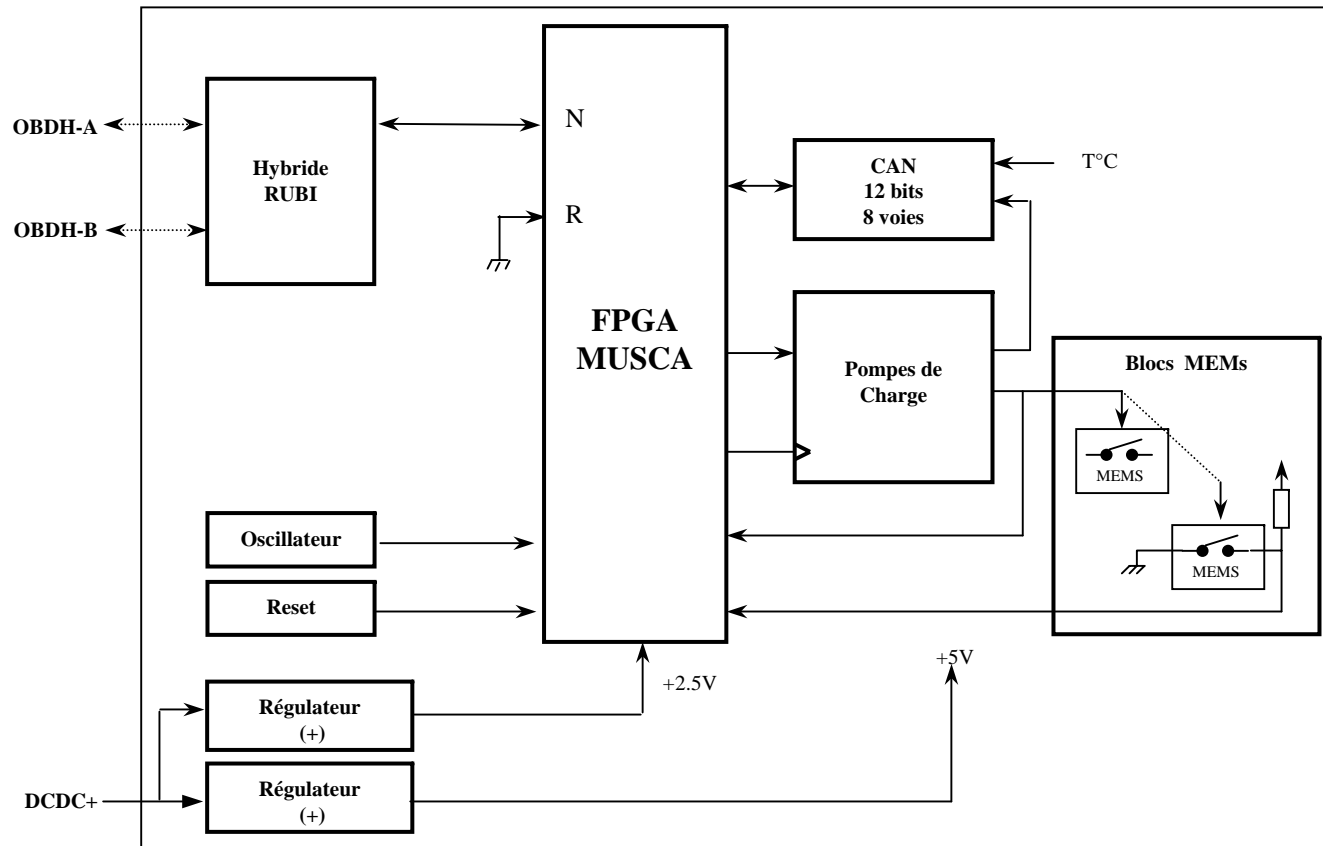
## Demonstrator is composed of 2 PCBs : 1 DCDC et 1 TMTc/MEMS

- Mono-structure in Al with 2 caps.
- Interfaces to satellite platform by Sub-D connectors (15pts DCDC et 9pts TMTc)



## Main functions realized by TMTC building block:

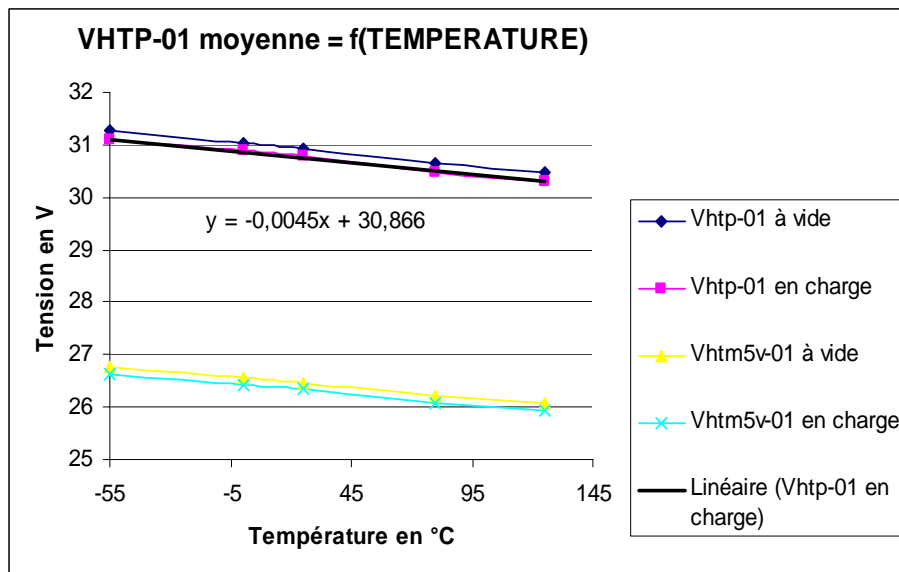
- Interface with SB4000 bus OBDH 485
  - Regulated biasing generation based on DCDC provided voltage
  - Generation of clocks and test signals
  - Acquisition, management and processing of MEMS commands
  - Acquisition, management and processing of MEMS measurements
  - Generation of TM.
- 
- This card is able to drive and monitor up to 5 charge pumps and up to 20 MEMS.



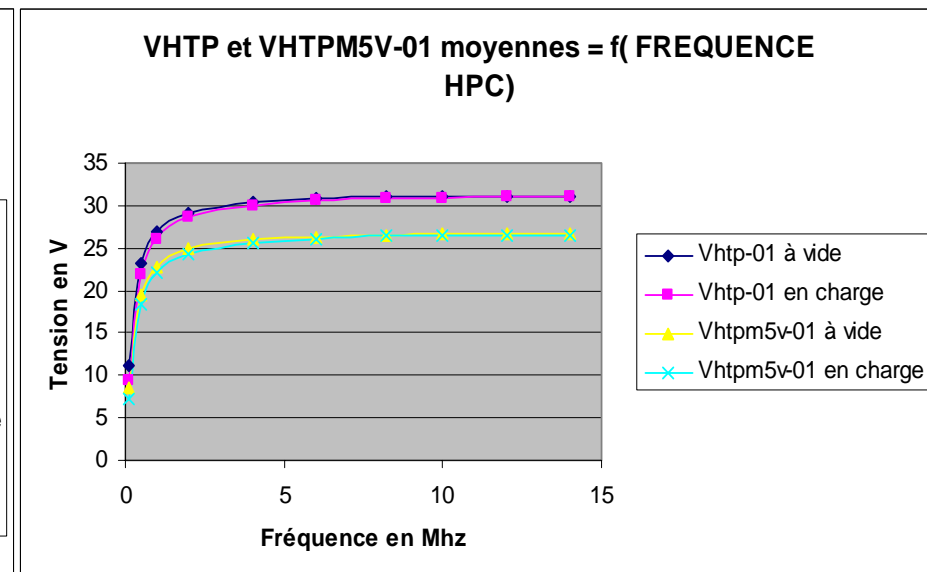
- Receive, decode, validation of serial bus ML16 coming from hybrid RUBI
- Management and treatment of data coming from RUBI through serial bus CS16
- Management of init procedure
- Management of MEMS through the charge pumps
- Management of the charge pumps (clocks, output voltage monitoring)
- Management of serial bus com/acq of 12 bits ADC
- Acquisition and treatment of data for TM
- Send TM on serial bus AS16 via RUBI.
- FPGA address set at 00000.

## ■ Robustness of the design, compliant with space constraints

### Temperature stability

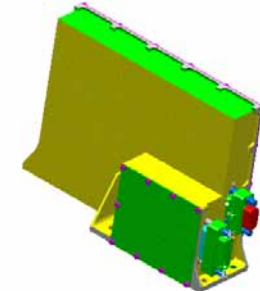
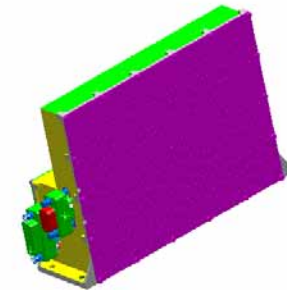


### Stabilité en fréquence HPC



## ■ Packaged in hermetic ceramic package, qualified by lot

SUB ASSEMBLY :					Total			Total
					Basic mass			Max mass
<b>MEMS CNES</b>					<b>625</b>	<b>10%</b>	<b>63</b>	<b>688</b>
<b>938968</b>								
Eléments	Date	Reference	Qty	Unit	Total	To lér,	Uncert.	Max mass
				basic mass	basic mass			
				(g)	(g)	(%)	(g)	(g)
Structure mécanique		938970	1	300	<b>300</b>	10%	30	<b>330</b>
Capot TMTC MEMS		938981	1	40	<b>40</b>	10%	4	<b>44</b>
Capot DCDC		938985	1	10	<b>10</b>	10%	1	<b>11</b>
Carte DCDC		982041	1	45	<b>45</b>	10%	5	<b>50</b>
Carte TMTC MEMS		939001	1	200	<b>200</b>	10%	20	<b>220</b>
Vis serie		**	1	20	<b>20</b>	10%	2	<b>22</b>
Peinture		**	1	10	<b>10</b>	10%	1	<b>11</b>





**NOTA :**

- THE INFORMATIONS CONTAINED ON THIS SHEET ARE VERIFIED DURING "FINAL INSPECTION"  
LES INFORMATIONS DONNEES DANS CETTE PLANCHE SONT CONTROLÉES EN INSPECTION FINALE
- JOK-JOK-JOK  $\oplus$  SPHERICAL  $\oplus$  X|XYZ
- CONTACT AREA: [P]  
MATERIAL: ALUMINIUM ALLOY 2618A T851  
FINISH: CR XI1  
SURFACE DE CONTACT [P]  
MATIERE: ALLIAGE ALUMINIUM 2618A T851  
FINITION: CR XI1
- REMARKS OF THESE PARTS MUST BE READY AVAILABLE ON THE TABLEAU CI-CONTRE FONCTION: DETAIL/ANNÉE-REPLACE
- FINISH: BLACK PAINTING  
FINITION: PEINTURE NOIRE
- EXTERNAL COATING FREE AREA  
- J01 TO J02 CONNECTORS  
- GROUNDING HOLES, GROUNDING STUD TROX  
- MOUNTING HOLES, VENTING HOLES  
- PLAN [P]  
RESERVE DE REVERTEMENT DE SURFACE  
- CONNECTEURS J01 A J02  
- PRISE DE MASSE, BORNE DE MASSE TROX  
- TROUS DE FIXATION, TROUS D'ÉVENT  
- PLAN [P]
- DIMENSIONS ARE MILLIMETERS  
DIMENSIONS EN MILLIMÈTRES
- VENTING HOLE (APPROXIMATE LOCATION)  
TROU D'ÉVENT (POSITION APPROXIMATIVE)
- IDENTIFICATION MARKING AREA  
ZONE DE MARQUAGE D'IDENTIFICATION  
MARKING IN ACCORDANCE WITH DOCUMENT TYPE 080  
MARQUAGE SELON DOCUMENT TYPE 080
- REMARKS OF THESE PARTS MUST BE READY AVAILABLE ON THE TABLEAU CI-CONTRE FONCTION: DETAIL/ANNÉE-REPLACE
- REMARKS OF THESE PARTS MUST BE READY AVAILABLE ON THE TABLEAU CI-CONTRE FONCTION: DETAIL/ANNÉE-REPLACE

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REV	DESCRIPTION	DATE	BY	CHK	APP	COMMENTS
1	ISSUE FOR MANUFACTURE	02/10/05				
2	REVISION					

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**Mechanical environment** : SB4000 specification S000329 ed04

Zone A (1A+2A) : larger covering for P/L equipment

Sinus :

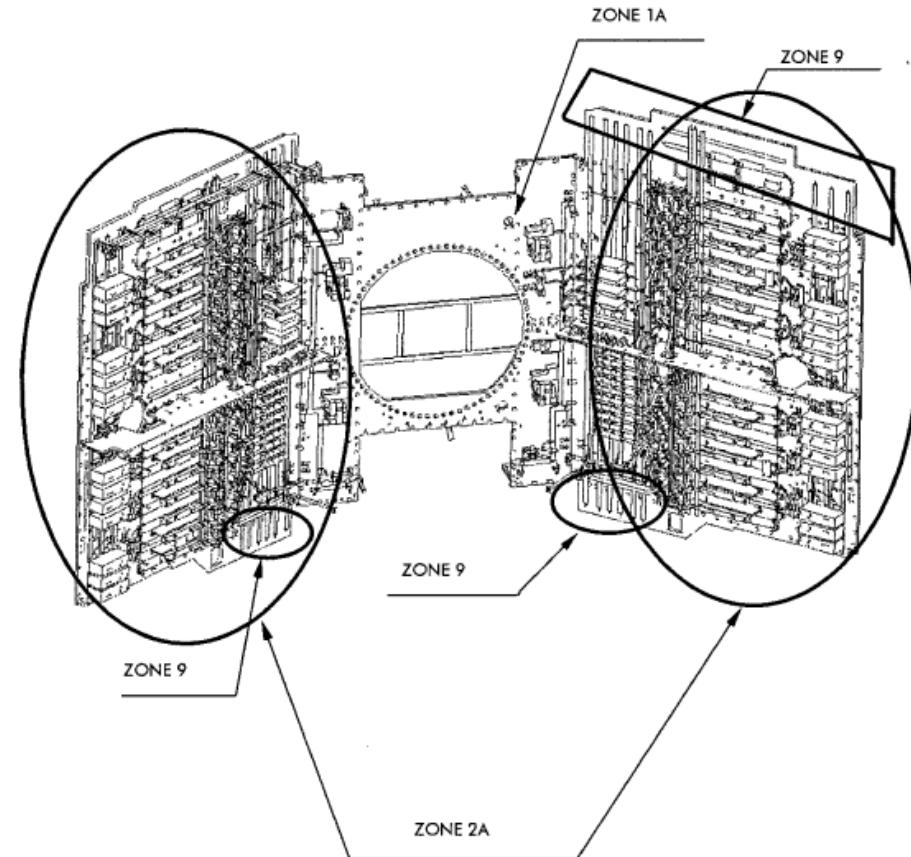
Perpendicular to mounting plane (Z)		parallel to mounting plane (X, Y)	
Range ( Hz )	Level	Range ( Hz )	Level
5 - 21	±10 mm	5 - 17	±10 mm
21 - 100	± 18 g	17 - 100	± 12 g

Vibrations

Perpendicular to the mounting plane (Z)		Parallel to the mounting plane (X, Y)	
Range (Hz)	PSD Level	Range (Hz)	PSD Level
20 - 50	+ 6 dB/oct	20 -100	+ 6 dB/oct
50 - 350	0.8 g <sup>2</sup> /Hz	100 - 500	0.1 g <sup>2</sup> /Hz
350 - 447	- 12 dB/oct	500 - 2000	0.05 g <sup>2</sup> /Hz
447- 1000	0.3 g <sup>2</sup> /Hz		
1000 - 1565	- 12 dB/oct		
1565 - 2000	0.05 g <sup>2</sup> /Hz		
Global : <b>23.76 g RMS</b>		Global : <b>10.9 g RMS</b>	

Shocks : Zone S4

Frequency (Hz)	Qualification Shock Response (g) / Q = 10
500	200
3000	2000
10000	2000



•**Thermal environment:** SB4000 specification S000329 ed04

Environment RX TTC

	Operating mode	
	T min. (°C)	T max. (°C)
Qualification	-30	+70
Acceptance	-25	+65

Equipment with black paint : emissivity of 0.85

Start up cold : -35°C Qualif et -30°C Acceptance

Dissipated power for TMTC = 1.24W typical

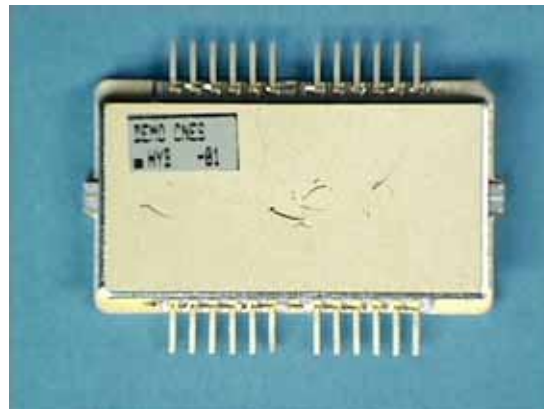
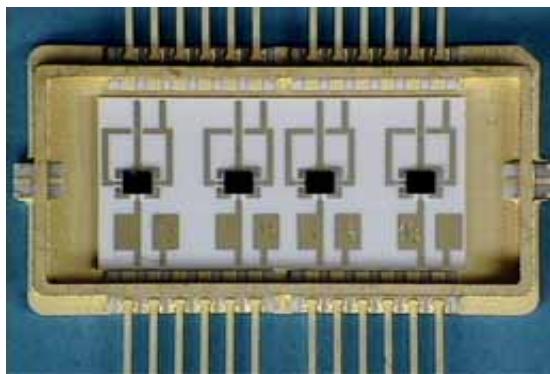
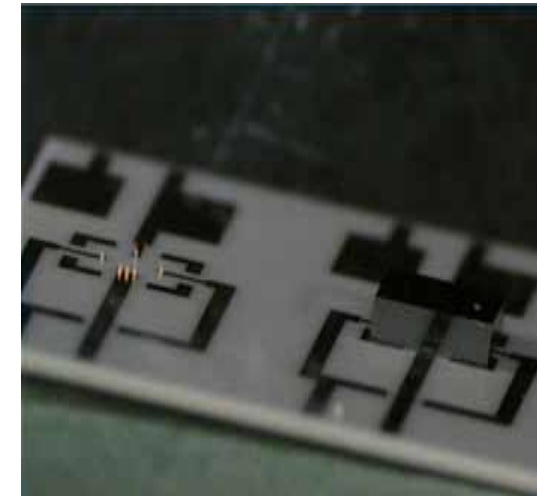
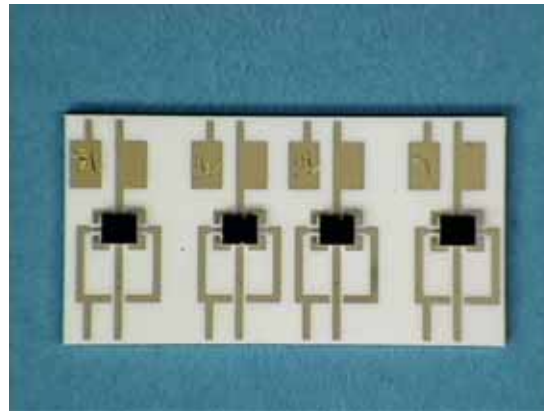
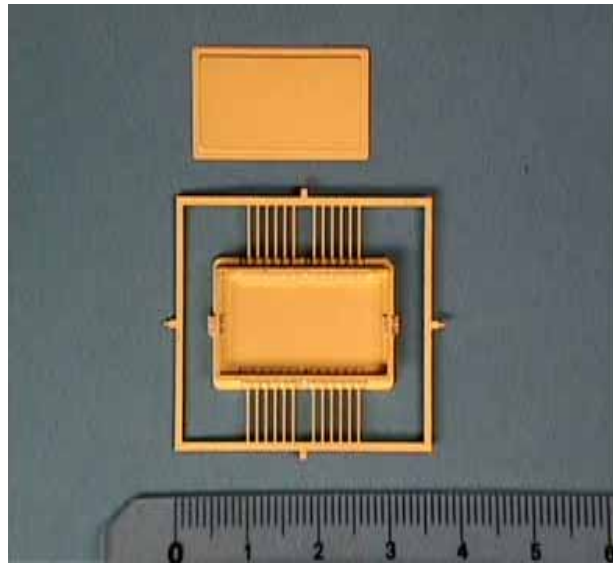
Dissipated power for DCDC = 0.56 W typical

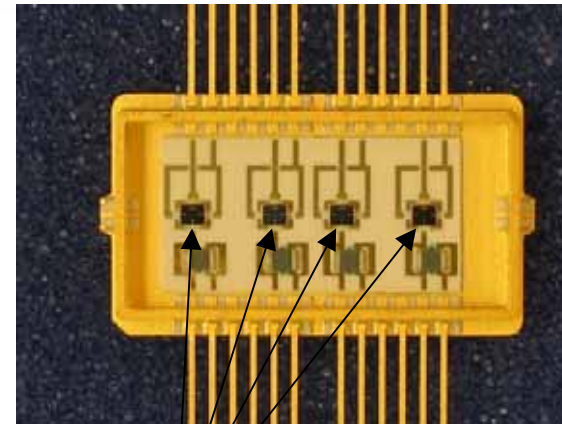
•**EMC environment** : SB4000 spécification S000330 Ed 03

Equipment OFF during launching

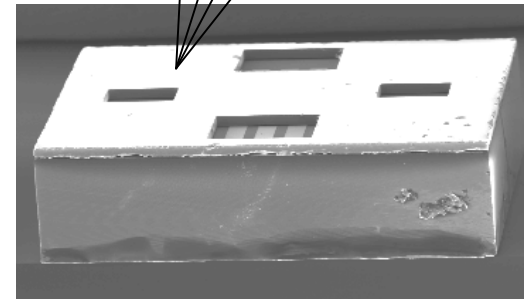
•**Radiating environment** : SB4000 specification CN11 et CN12

Al cube 0.8 mm in thickness.





Micro-package  
w/ 4 MEMS



**Manufactured MEMS Demonstrator  
(EM)**



Example of TC used for demonstrator operation:

16 bits Serial command (CS16)															P	Actions							
@FPGA					CMI				COM ID														
b0	b1	b2	b3	b4	b5	b6	b7	b8	b9	b10	b11	b12	b13	b14	b15								
@ FPGA					1 0 0 0				n° Mode		0 0		0 0		on/off		P	<b>TC-START/STOP Modes(x)</b>					
									0						0			0		0	1	TC-STOP Mode(1) (x2)	
									1						0			1		1		TC-START Mode(1)	
					1		0		0		1		1		TC-START-A Mode(2)								
					1		0		0		1		1		TC-START-B Mode(2)								
					1		0		0		1		1		TC-START Mode(4)								
					0 0 1 1 0 1										<b>TC-START Gen</b>								
					0 0 1 1 0 1										TC-START-GEN								
									n°bus		Val. bus								<b>TC-CPC(x)</b>				
					1 0 1 0				0 0		0		0		0			TC-CPC1(1)					
													1		1			TC-CPC1(2)					
													1		0			TC-CPC1(3)					
													1		1			TC-CPC1(4)					
									1		0		1		0			TC-CPC2(1)					
									1		0		1		0			TC-CPC2(2)					
1		0		1					0		TC-CPC2(3)												
1		0		1					0		TC-CPC2(4)												
1 1 1 0				0 0		1		0		0		TC-CPC3(1)											
								1		1		TC-CPC3(2)											
				1		0		1		0		TC-CPC3(3)											
				1		0		1		1		TC-CPC3(4)											
1 1 1 1				0 1		0		0		0		TC-CPC4(1)											
								1		1		TC-CPC4(2)											
				1		0		1		0		TC-CPC4(3)											
				1		0		1		1		TC-CPC4(4)											
										<b>TC-INIT</b>													
										<b>TC-RESET (x2)</b>													





- New equipment developed aiming at prove in-orbit operation
  - Autonomous, interface to the platform is flight proven
  - Compatible with GEO telecom platform
    - SB4000 from Thales or E\*3000 from Astrium
- Functionality of EM validated, passed the standard procedure applied to commercial satellite equipment (EMC, thermal vacuum, vibration/chocs)
- FM produced, waiting the end of the RF MEMS qualification
  
- Know-how increased on how to implement RF MEMS into FM space equipments