MEDA

Mars Environmental Dynamics Analyzer

for NASA/JPL's Mars 2020 mission

Characterization, Screening and Qualification of the MEDA Wind-Sensor ASIC

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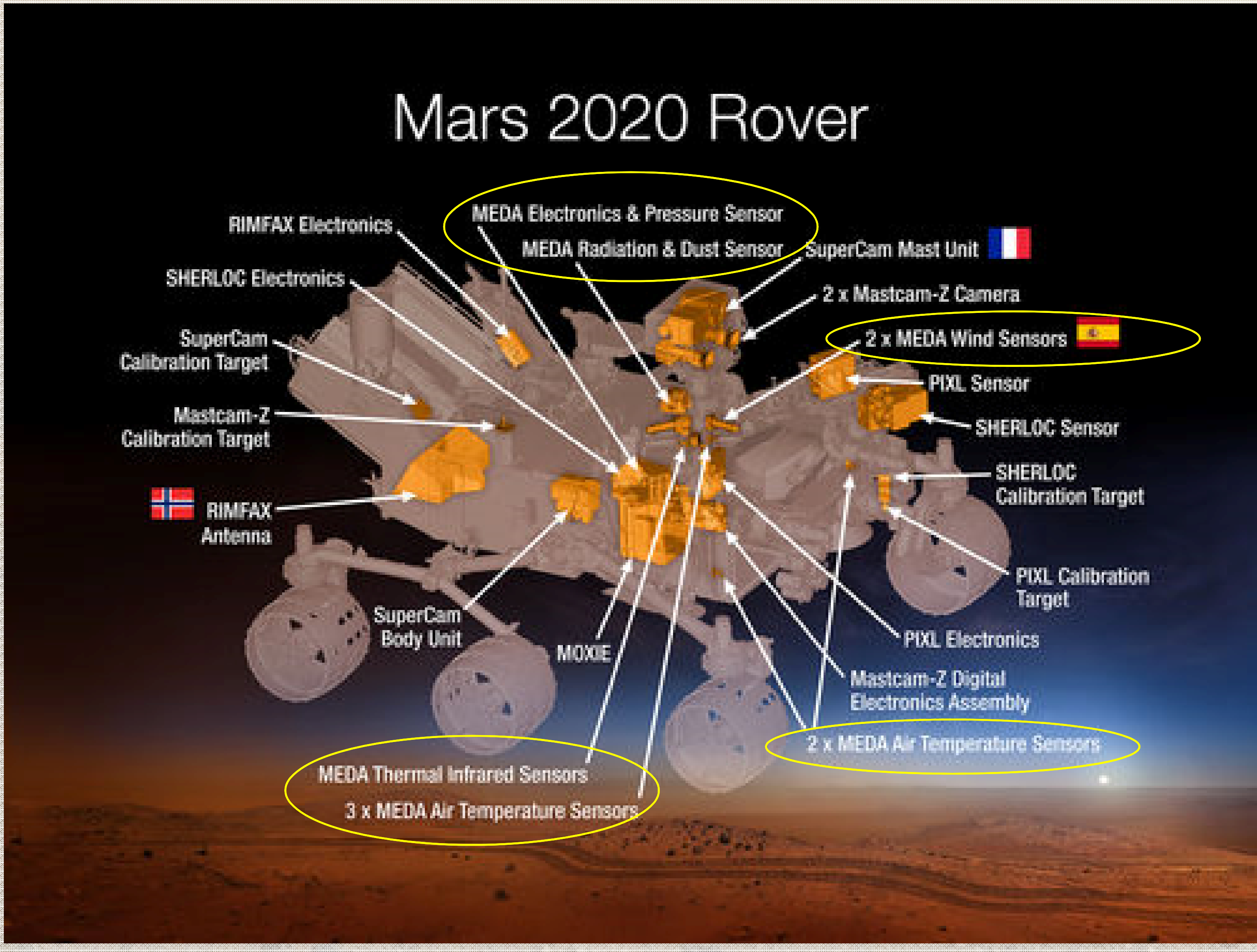
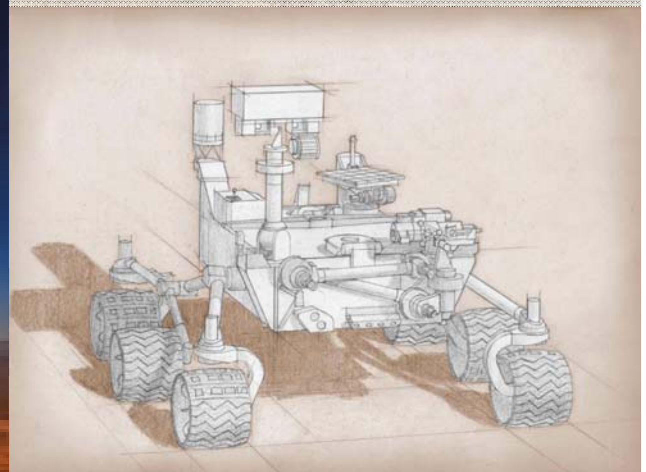
MEDA: Mars Environmental Dynamics Analyzer (NASA Mars 2020 Mission)

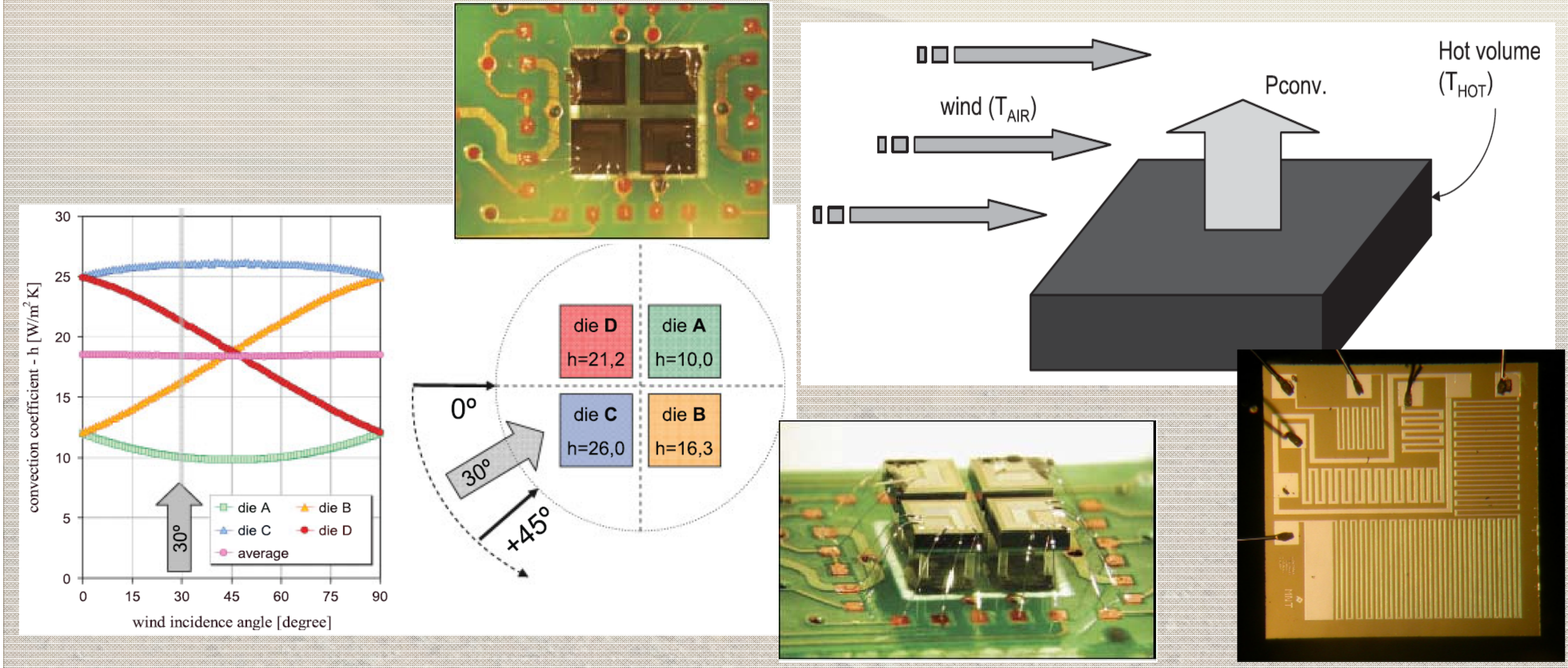




Images taken from & further details at: http://mars.nasa.gov/mars2020/

The MEDA Wind Sensor Concept

- ✓ Developed at Polytechnic University of Catalonia (*1)
- ✓ Evolved version of a similar sensor used in REMs (*2)



(*1) M. Domínguez, V. Jiménez, J. Ricart, L. Kowalski, J. Torres, S. Navarro, J. Romeral, and L. Castañer, "A hot film anemometer for the martian atmosphere," Planetary and Space Science, vol. 56, pp. 1169 – 1179, June 2008

(*2) http://cab.inta-csic.es/rems/es/

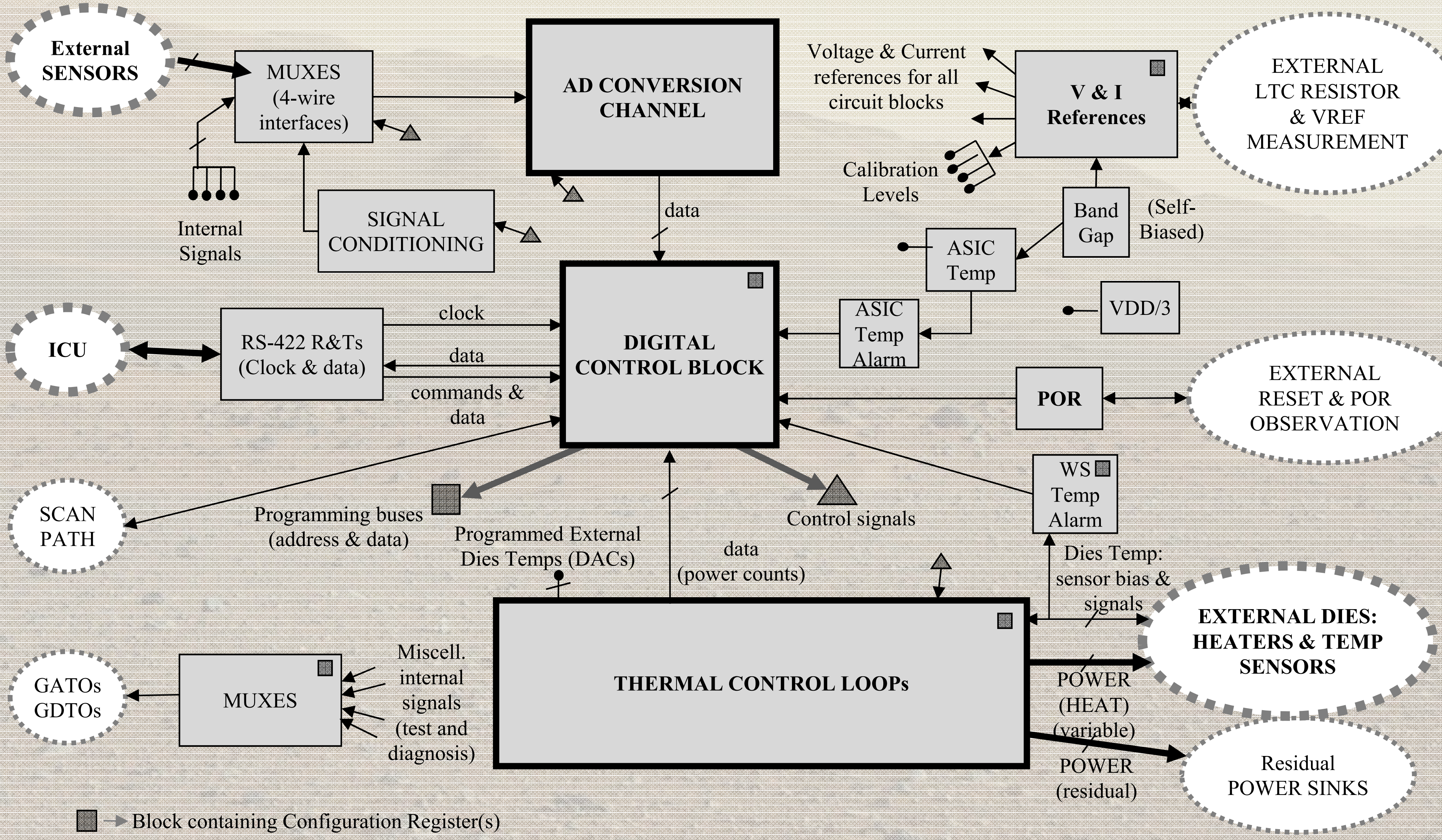
The MEDA WS ASIC

- AMS 0.35μm CMOS technology.
- 3.3V transistors only along the chip
- Builds on previous efforts by the authors:
  - Characterization of radiation and low-temperature effects on devices in this technology
  - Development and validation of a rad-hard library of digital cells
  - Previous development of several other mixed-signal space ASICs

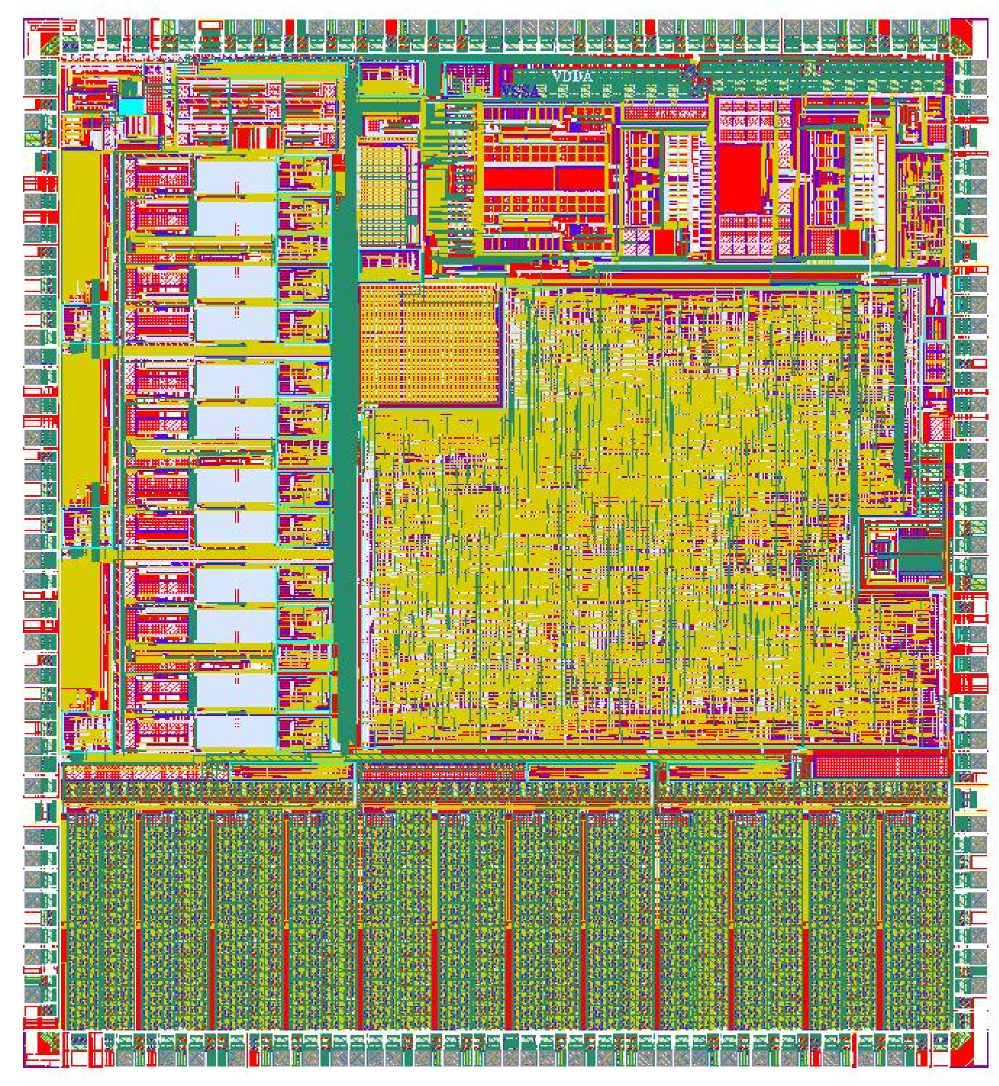
The MEDA WS ASIC

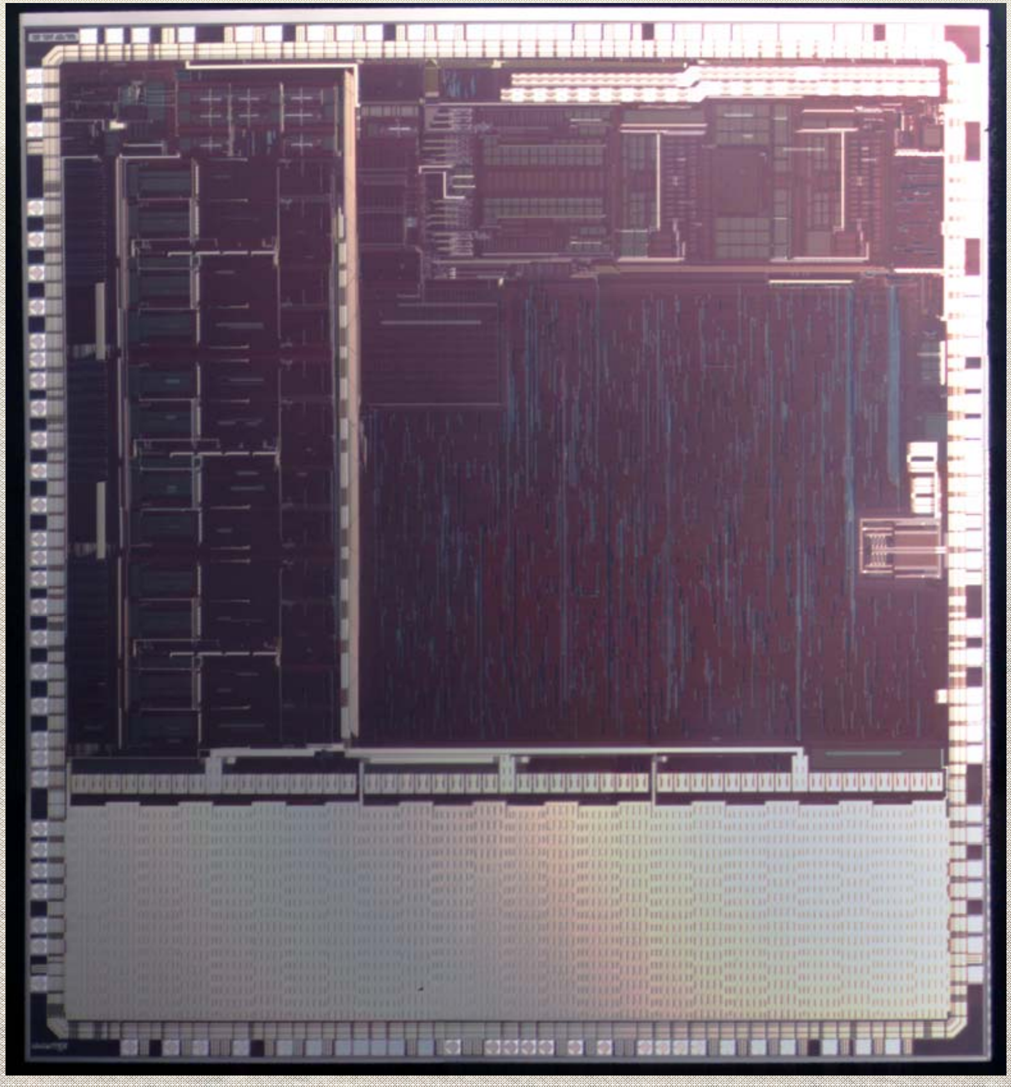
- Must measure various temperatures (ADC channel)
  - Temp measurements based on external Pt resistors
  - Must provide bias current
  - Must measure and digitalize voltages
- Must control the temperature of external “hot-dies”, keeping it constant at prescribed values
- Must provide and measure the heating power required to do so
- Must interact and communicate with the Instruments Control Unit (ICU)

The MEDA WS ASIC



The MEDA WS ASIC

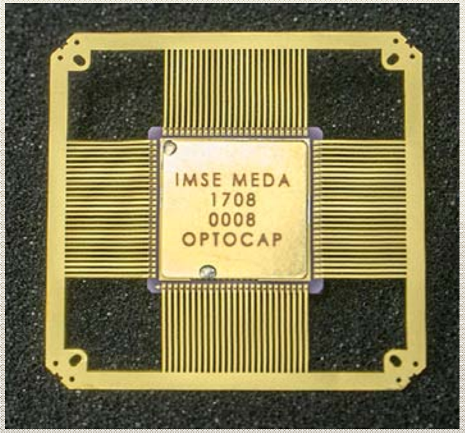




Die size: ~ 5 x 5 mm^2

External Interface (Pins)

- Communication (Rx & Tx) and clock (**6 pins**)
  - RS-422 differential signals
  - Rx (2), Tx (2), Clk 2.4MHz (2)
- External analog input channels (**18 pins**)
  - 9 differential external input channels
- Thermal control loops (**36 pins**)
  - 12 thermal control loops
  - Each: Current bias and Temp measurement (1), heating current (1), and current sink (1)
- Power and Ground (**29 pins**)
  - 6 power domains. Non-paired VDD/GND distribution
- Miscellaneous uses (**11 pins**)
  - Vref (1), Iref (1), Rst (1), Scan-path (4), Observability (2+2)



Total: 100 pins. Package: CQFP-100

Characterization

- Operative and within specs (dispersion, Temp. stability)
  - ✓ ADC
  - ✓ Biasing current sources
  - ✓ Heating current sources
  - ✓ Comparators, thermal control loops
  - ✓ Voltage & current references
  - ✓ POR
  - ✓ Temperature alarms
- Operative down to -128 ºC (& up to +50ºC)

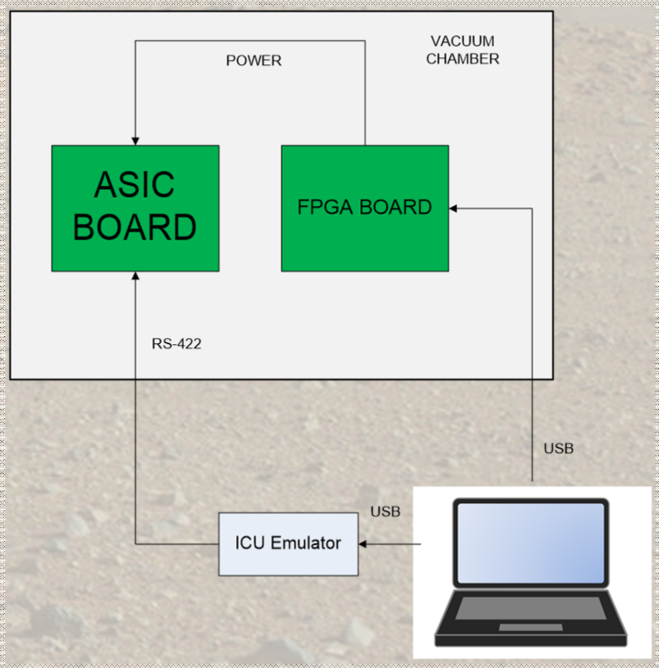
Radiation tests

- SEEs
  - Latchup
  - SEUs / SETs/ SEFIs (ASIC structure & test strategy)
- TID
  - Parametric measurements
- DD

Radiation tests: SEEs

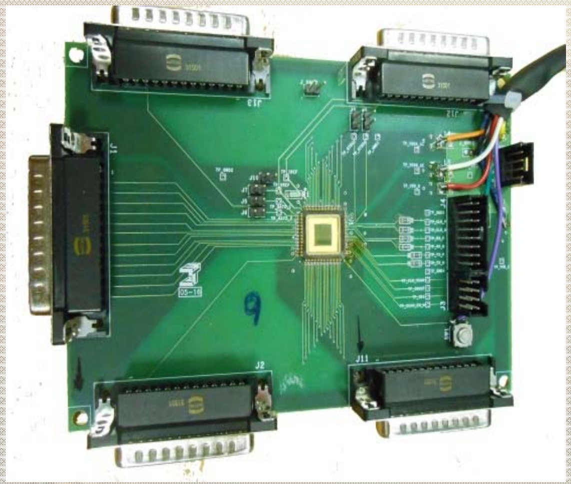
- Tests done at HIF-UCL
  - Beam flux: between a few and $1.5 \cdot 10^4$ particles/(s·cm²)
  - Homogeneity: ± 10 % over a 25 mm diameter
- Die self-heating control loop: die-T ≈ 65ºC

Ion	M/Q	Energy on device [MeV]	Range [µm]	LET on device [MeV/(mg/cm²)]
$^{13}C^{4+}$	3,25	131	269,3	1,3
$^{22}Ne^{7+}$	3,14	238	202	3,3
$^{27}Al^{8+}$	3,37	250	131,2	5,7
$^{40}Ar^{12+}$	3,33	379	120,5	10,0
$^{53}Cr^{16+}$	3,31	513	107,6	16,0
$^{58}Ni^{18+}$	3,22	582	100,5	20,4
$^{84}Kr^{25+}$	3,35	769	94,2	32,4
$^{103}Rh^{31+}$	3,32	972	88,7	45,8
$^{124}Xe^{35+}$	3,54	995	73,1	62,5

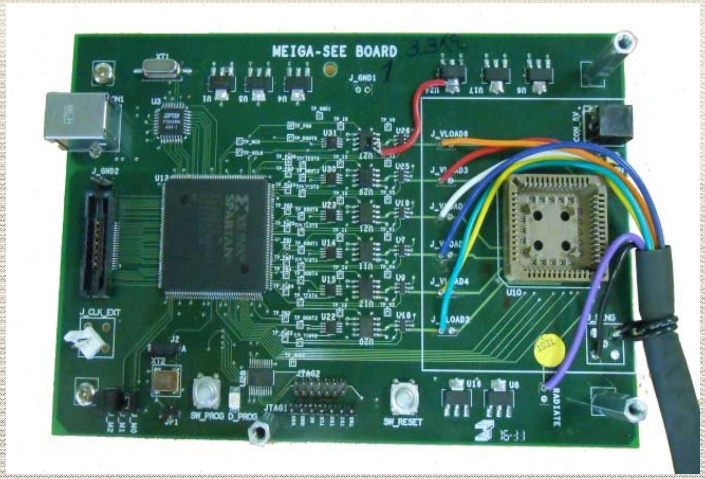


Radiation tests: SEEs

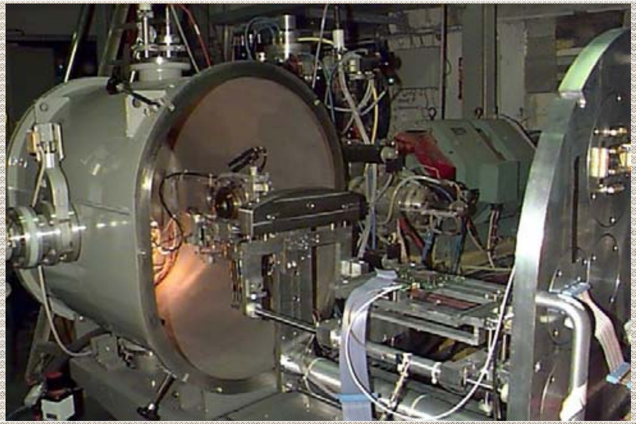
ASIC BOARD

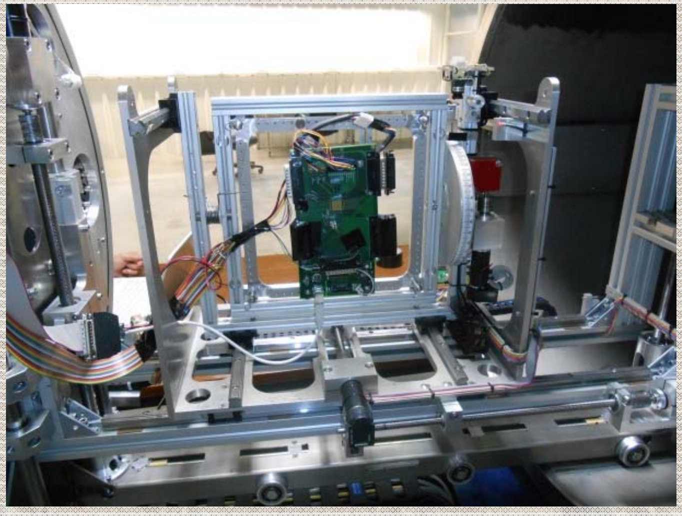


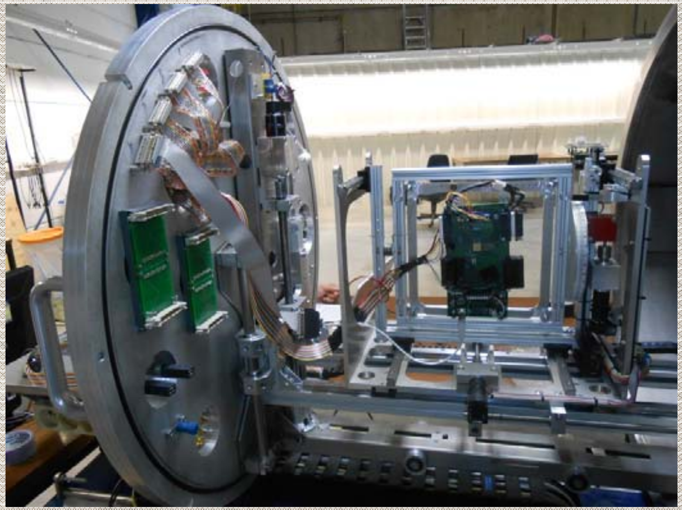
LATCHUP AWARE BOARD



ICU EMULATOR





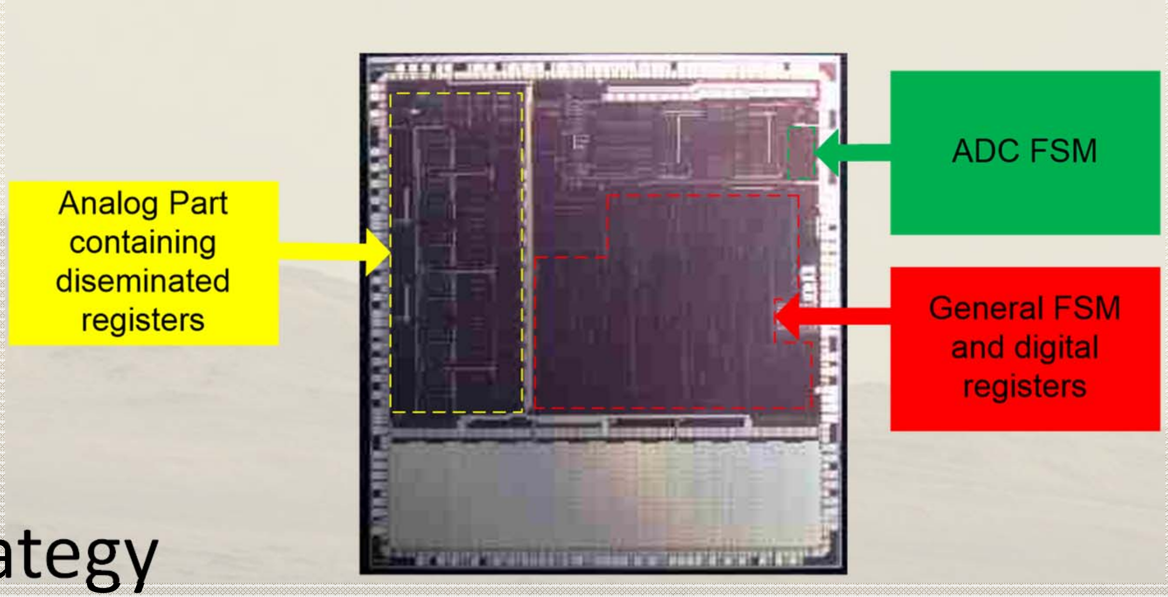


Radiation tests: SEEs – Latch-up

- **No Latch-up. Up to 81,6 MeV/(mg/cm²)**
- $^{124}Xe^{35+}$, θ = 40º.
- Total fluence: $6.6 \cdot 10^{6}$ ions/cm^2
- Temperature (die): 65 ºC
- Two samples tested

Radiation tests: SEEs – SEUs, SETs, SEFIs

- ASIC structure:

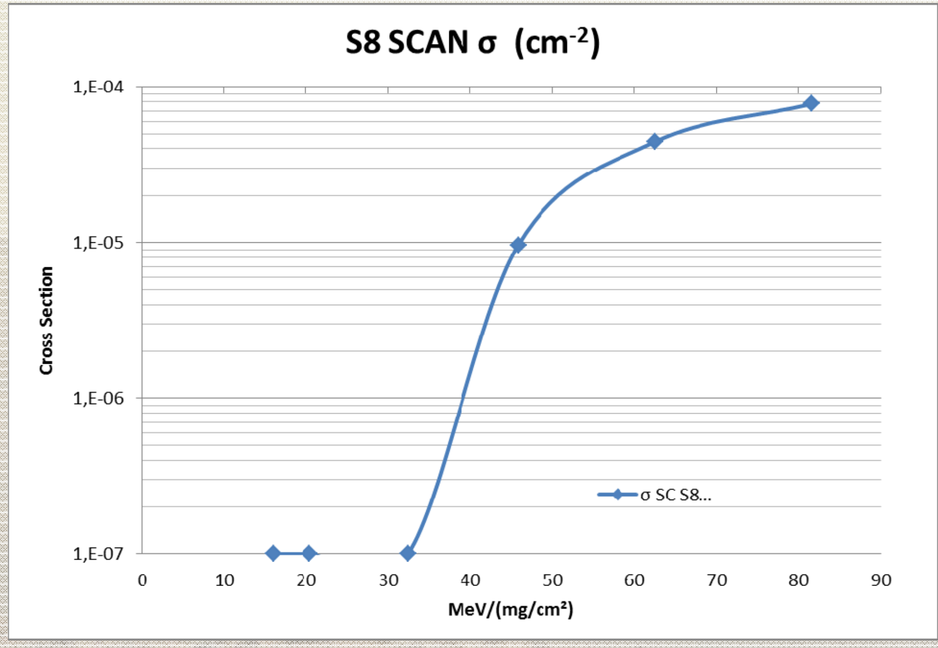


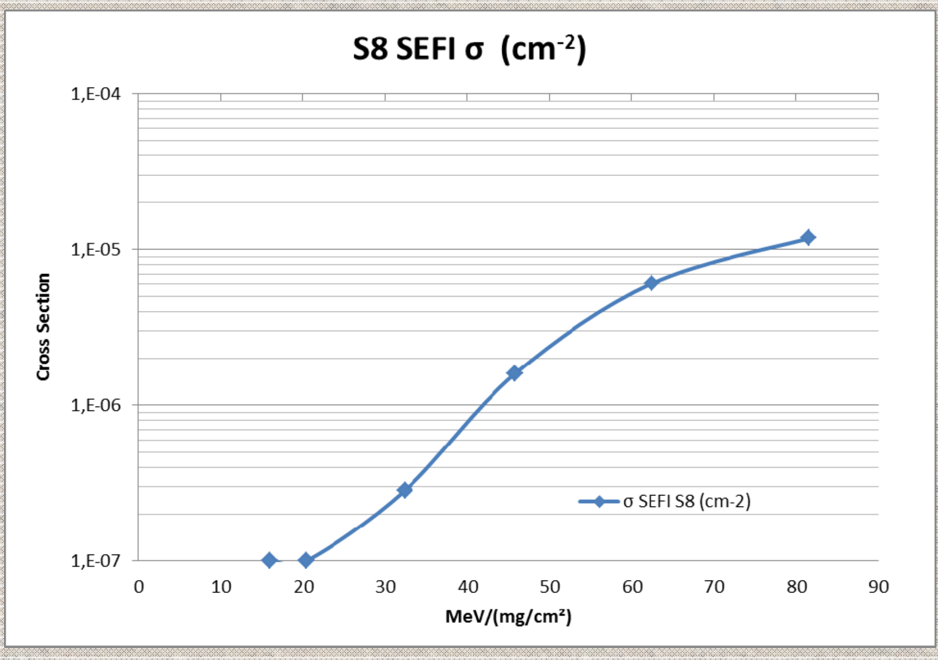
- SEUs: dual test strategy
  - Continuous read of programming registers through RS422 port.
  - Scan path for General FSM and digital registers
- SEFIs: checked and registered simultaneously (SEFI: Time-out after ICU command, or > 10 bit discrepancies in registers)

Radiation tests: SEEs – SEUs, SETs, SEFIs

Ion	Range (µm)	LET (α=0)	Angle (α)	LET Effective	Flux (ions/s · cm²)	Fluence in Registers (ions/ cm²)	Fluence Scan (ions/ cm²)	SEUs in registers	SEFIs in registers	SEUs in scan	σ (cm⁻²) SEUs Registers	σ (cm⁻²) SEFI Registers	σ (cm⁻²) SEUs Scan
$^{58}Ni^{18+}$	100,5	20,4	0	20,4	10000	3831666	2640000	0	0	0	0	0	0
$^{84}Kr^{25+}$	94,2	32,4	0	32,4	10000	3778888	2580000	8	1	0	2,117E-06	2,6463E-07	0
$^{84}Kr^{25+}$	94,2	32,4	45	45,8	5000	1960694	1275000	19	5	3	9,6904E-06	2,5501E-06	2,3529E-06
$^{103}Rh^{31+}$	88,7	45,8	0	45,8	5000	1910555	1215000	16	0	7	8,3745E-06	0	5,7613E-06
$^{103}Rh^{31+}$	88,7	45,8	43	62,6	5000	1942222	1215000	39	13	47	2,008E-05	6,6934E-06	3,8683E-05
$^{124}Xe^{35+}$	73,1	62,5	0	62,5	5000	1947500	1260000	35	12	107	1,7972E-05	6,1617E-06	8,4921E-05
$^{124}Xe^{35+}$	73,1	62,5	40	81,6	5000	1950138	1305000	113	23	101	5,7945E-05	1,1794E-05	7,7395E-05

Radiation tests: SEEs – SEUs, SETs, SEFIs





FOM*:

$\sigma_{LH} \approx 2 \cdot 10^{-5}$ cm^2

$R < 6 \cdot 10^{-9}$ Errors/bit-day

$R_D < 1.5 \cdot 10^{-6}$ Errors/day =

$= 0.5 \cdot 10^{-3}$ Errors/year

(*) E.L:Petersen et al. "The SEU Figure of Merit and Proton Upset Rate Calculations". IEEE Transaction on Nuclear Science. Vol 45 Nº6. Dec. 1998.

Radiation tests: TID

- Tests done at RADLAB Facility of Centro Nacional de Aceleradores (CNA), Sevilla, Spain
- Accumulated dose after 50H in one step:
  - 10.6 Krads @ 200 [rad(Si)/h]
- 6 samples irradiated.
- Initial and post-irradiation electrical characterization @ IMSE facilities
- Conclusion:
  - **No variations in electrical measurements**

Radiation tests: TID

Functional Blocks measured:

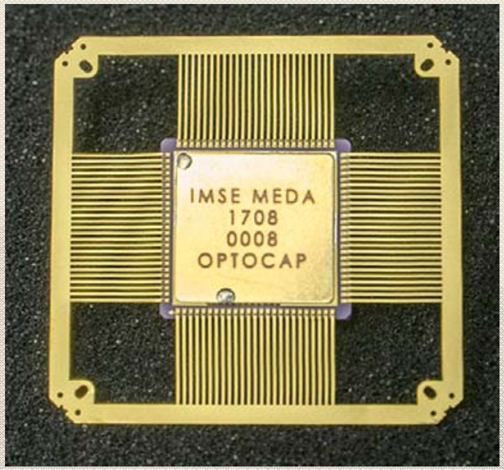
- POR
- Bandgap
- Current sources
- DACs
- Ixs
- ADCs
- Ibias
- Ihs
- Comparators
- RS 422 Communications
- Power

^{60}Co Gamma Source

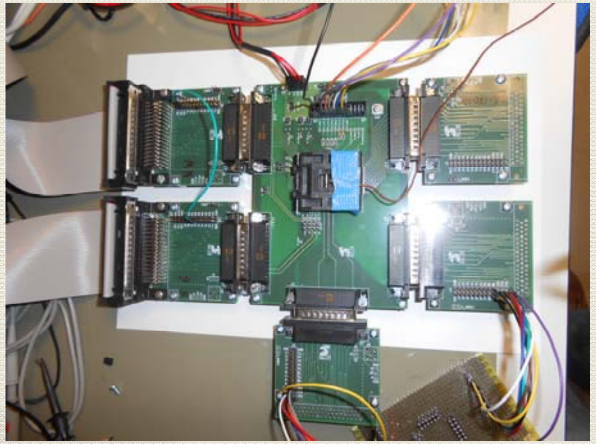
Irradiation Board

Radiation tests: DD

- Neutrons tests initially planned but finally waived by JPL.
  - CMOS microelectronic devices are largely immune to DD and thus, to neutrons. Leakage increases produced by DD are expected to be much lower than that produced by high TID gamma radiation.
  - Neutrons do not (directly) produce ionization in their path through silicon, and therefore, are unlikely to contribute to trapped charges or produce single events.
  - Secondary emissions can contribute to TID and can produce single events but their contribution is low as compared to those of gamma-radiation and heavy-ions.

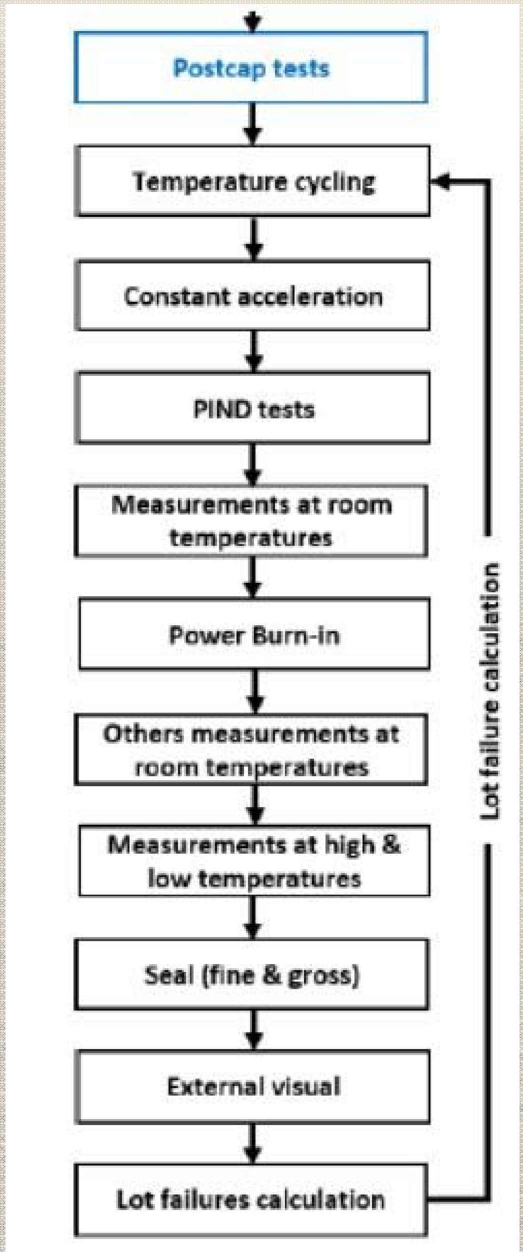


Packaging



- Ceramic Quad-Flat Package: CQFP-100
- Same packages used in REMs. Verified traceability. Same sockets and carriers
- Two lots: Corwill, Optocap
- Space specific procedure and protocol
- Temperature coefficient θ_{jc} measured

Screening: by **Alter Technology TÜV Nord**



Screening Test Plan

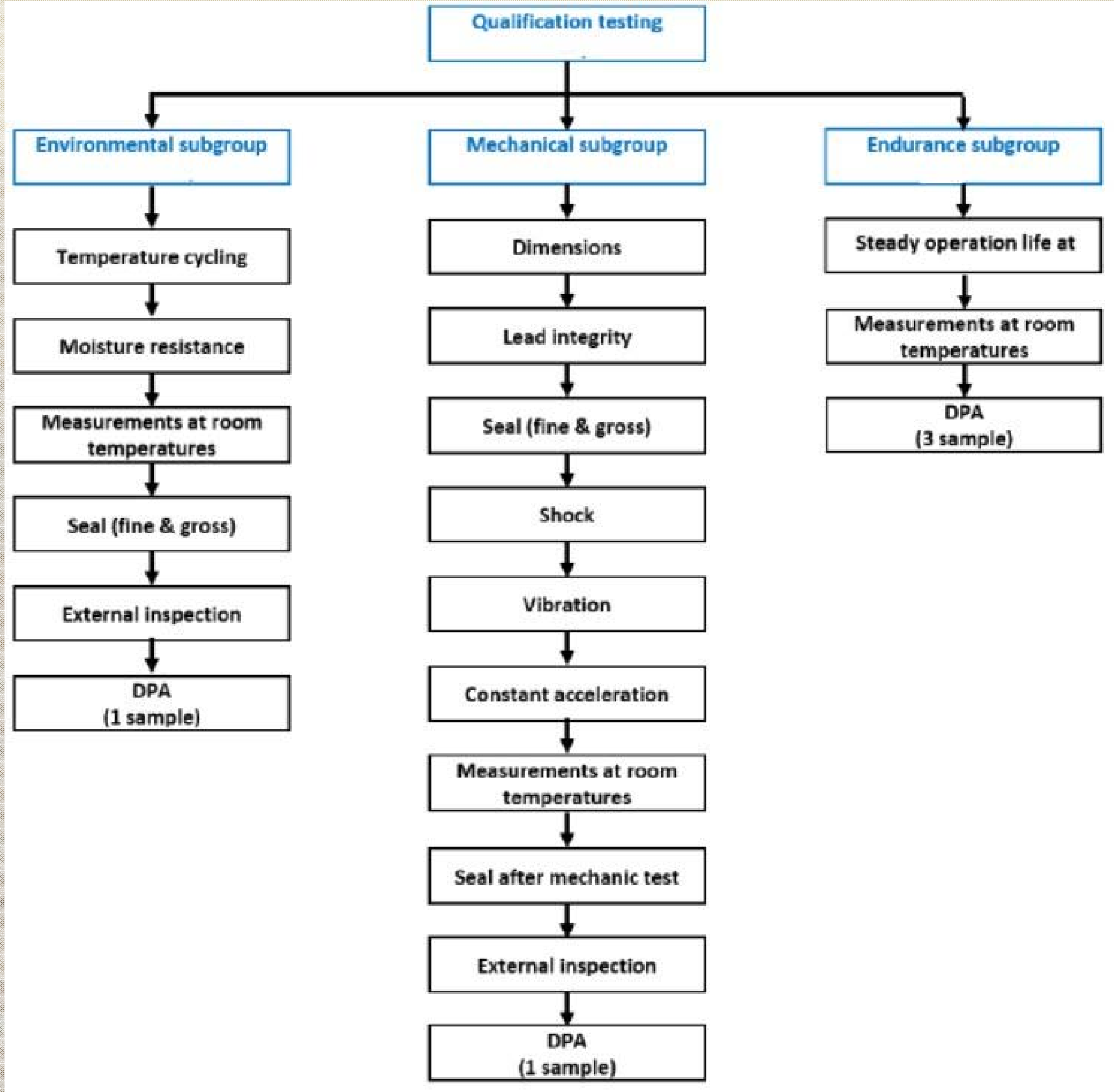
Postcap test	Sampling plan	Methods
Constant acceleration	100%	MIL-STD-883 Method 2001, condition 30000g, Y1 direction only
PIND	100%	MIL-STD-883 Method 2020, condition A
Measurements at room temperature	100%	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Temperature cycling	100%	MIL-STD-883 Method 1010 condition C. Tmax = 125°C / Tmin = -135°C / 10 cycles Dwell time: 5 min
Measurements at room temperature	100%	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Power burn-in	100%	MIL-STD-883 Method 1015, 160h, Temp =50°C
Final measurements at room temperatures	100%	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Measurements at high & low temperature	100%	At maximum and minimum operating temperatures, Tmax = 50°C / Tmin = -128°C According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Seal (fine & gross)	100%	MIL-STD-883 Method 1014
External visual	100%	MIL-STD-883 Method 2009
Lot failure calculation:	Acceptability lot 10%	

FM-units selection

Parameter	Criteria
Dispersion IH/IS at -128º & 1mA.	Minimize the maximum error
Dispersion IH/IS at -128º & 10mA.	
Dispersion IH/IS at -128º & 15mA.	
Error ADC: dispersion between characterization at three temp. (-128/25/50ºC)	Minimize differences between the codes measured at different temperatures
Dispersion Ixs (See three temp.)	Minimize the relative error
VREF TILT (-128 to 50ºC)	To analyze the graphics to assure the change of slope.
VREF OFFSET (in the range)	See the best TILT, see if the medium voltage in range.
DACs (See three temp.)	Minimize the relative error
IBDAC (lineality) -> error relative error respect to rated value	Minimize relative error.
Comparators	See changes from 16382 a 0
Power	<400mA

Qualification: by **Alter Technology TÜV Nord**

Qualification Test Plan



Qualification: Environmental Tests

Test	Sampling plan	Methods
Thermal cycling	15	MIL-STD-883 TM 1010 Cycles: 100, dwell time: 5 min, Condition C Tmax = 125°C / Tmin = -135°C
Moisture resistance	15	MIL-STD-883 TM 1004 10 cycles 24h (>90% HR / 65°C)
Final measurements at room temperature	15	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Seal test after environmental group	15	MIL-STD-883 Method 1014
External visual	15	MIL-STD-883 Method 2009

Qualification: Mechanical Tests

Test	Sampling plan	Methods
Mechanical shock	15	MIL-STD-883 TM 2002 5 shocks for qualification, 1500 g at 0.5 ms, 3-axis
Measurements at room temperature	15	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Vibration, variable frequency	15	MIL-STD-883 Method 2007, Condition A 20-2000 Hz, 20grms with the modification according the project requirements
Measurements at room temperature	15	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Constants Acceleration	15	MIL-STD-883 Method 2001, Condition E, Only orientation Y1
Measurements at room temperature	15	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2
Seal test after mechanical shock	15	MIL-STD-883 Method 1014
Final external visual inspection	15	MIL-STD-883 Method 2009
Dimensions	2	MIL-STD-883 Method 2016
Lead integrity	2	MIL-STD-883 Method 2004
Seal (fine & gross)	2	MIL-STD-883 Method 2014

Qualification: Endurance (life) Tests

Test	Sampling plan	Methods
Operating life test at Tmax = 70°C	8	MIL-STD-883 TM 1005 1000h at 70°C Vcc=3.3V Intermediate temperature: 168 h, 500 h
Measurements at room temperature	8	According to MEDA ASIC Validation Report IMSE-MEDA-RPT-0012 Issue 2

Qualification: Destructive Physical Analysis (DPA)

Test	Sampling plan	Methods
External visual inspection	5 3 after life test 1 after environmental sequence 1 after Mechanical sequence	MIL-STD-883 TM 2009
Seal		MIL-STD-883 TM 1014
Radiography		MIL-STD-883 TM 2012
RGA		MIL-STD-883 TM 2018
Terminal strength		MIL-STD-883 TM 2004
Internal inspection		MIL-STD-883 TM 2010
Destructive pull test		MIL-STD-883 TM 2011
SEM inspection		MIL-STD-883 TM 2018
Die shear test		MIL-STD-883 TM 2019

Summary

- The MEDA WS ASIC is:
  - A Mixed-signal front-end ASIC
  - For a meteorological instrument (Wind Sensor) to be used on Mars surface (NASA Mars 2020)
  - Designed using RHBD techniques in a standard 0.35µm CMOS technology (AMS)
- Operative and within specs down to -128ºC
- No latch-up up to 81.6 MeV/(mg/cm^2). SEUs & SEFIs within specs. TID effects negligible.
- Qualified by Alter Technology TÜV Nord: Low Temp., Radiation, environmental, endurance, mechanical, DPA
- Samples have been screened, and Flight-Module units have been selected.
- System integration is underway.