SPARTAN 6 Evaluation for Space Application

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Acknowledgements

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  - DCT/AQ/EC-2012/0019591, 12/10/2012, Utilisation DSP FPGA Xilinx Spartan 6 pour application spatiale (covering the Justification File and the SEE test)

  - DCT/AQ/EC-2014/01646, 23/01/2014, Fiabilité d'un module de processing haute performance à base de FPGA CMP Xilinx Spartan 6

  - DCT/AQ/EC-2015/01158, 21/01/2015, Spécification Technique de Besoin pour évaluation en dose cumulée d'un FPGA CMP en Co60 (covering the current TID test)

Selection : Needs, Hypothesis, Criteria

❑ FPGA selection table *(Cell in orange : bad / in green : good compromise)*

Family/sub-family		Virtex5 QV	Virtex5	Spartan6	Artix7	Artix7	Kintex7
Reference		XQR 5VFX130T	XQ 5VLX155T	XC/XQ 6SLX150T	XQ 7A100T	XQ 7A200T	XQ 7K325T
Proccess (nm)		65	65	45	28	28	28
SEL derisk		ok	TBD	ok laser	TBD	TBD	TBD
Price		☼	☼☼☼☼	☼☼☼☼	TBD	TBD	TBD
Logic cells		130k	155k	150k	100k	200k	325k
Memory	Mbits	10,7	7,6	4,8	4,8	13,1	16
Blocks DSP		380	128	180	240	740	840
DDR3		0	0	4x16	0	0	0
ARM core		no	PPC	no	no	no	no
HSSL		18	16	8	4	8	16
Consumption WC Benchmark	W	☼	☼	☼☼	☼☼☼	☼☼☼	☼☼
Package (Flip Chip or Wire Bound)		FC	FC	WB	WB	FC	FC
Grade&Temperature range		Space	-40/+100	Mil-40/+125	Mil-55/+125	Mil-55/+125	Mil-55/+125
Defense Grade Availability		Space	ok	Q3 2011	Q3 2013 TBC	Q3 2013 TBC	Q2 2013 TBC
Conclusion				good compromise			

❑ Part selected : SPARTAN6 XQ6SLX150T-2FG676

Present Status

Test	Source	Trace code	Conditions	Availability
Construction analysis	AGI	same trace	6 mission profiles (temp, duty cycles)	✓
Heavy ions	ADS	same trace	SEL at high temperature & SEU/MBU & SEFI	✓
SEE Laser	AGI	XC6SLX9	SEL at ambiant temperature	✓
TID	ADS	Procured	3 ON (dynamic) + 3 OFF, 200 rad/h up to 100krad	Results available soon
Electrical characterization @3t	ADS	same trace	during lifetest, frequency margins	
HAST/THB	Xilinx	XC6Sxxx	130°C, 85% RH	✓ quarterly report
T/C & CSAM	Xilinx	XC6Sxxx	-55°C to +125°C; CSAM tbd	✓ quarterly report
Life test & DPA	ADS	same trace	4800h 125°C V max ratings	✓ Life test plan
Ageing (endurance test)	AGI		7000h 125°C & -40°C Vmax ratings	On-going
Reliability Analysis	AGI	-	-	✓
Assembly Evaluation report	ADS	same trace	Vibrations, shocks, thermal cycles	First evaluation report available

Radiation : Heavy Ions, SEE

❑ Test Conditions

- **SEL**
  - – @ 85°C, VccMax Rating
  - – Real Time Monitoring Current & Temperature
  - – Periodic Reload

- **SEU** Characterization
  - – @ 25°C, VccNom
  - – Software preloaded in DUT but static design
  - – Read back Select MAP
  - – SEU/MBU CRAM
  - – SEU/MBU BRAM

❑ Results Synthesis

- No SEL up to 65 MeV.cm²/mg @85°C – Vmax rating up to 2E07 particles/cm²,
- SEU & SEFI characterized, periodic reset needed,
- No need to Power OFF the device .

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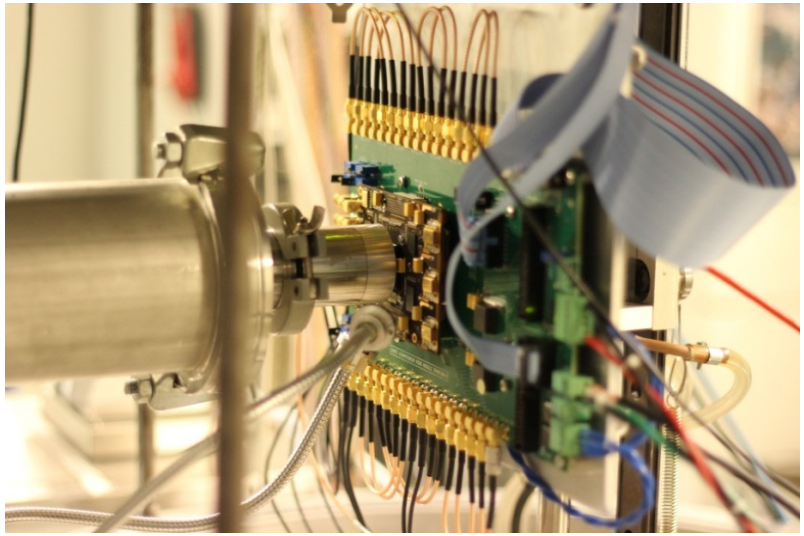
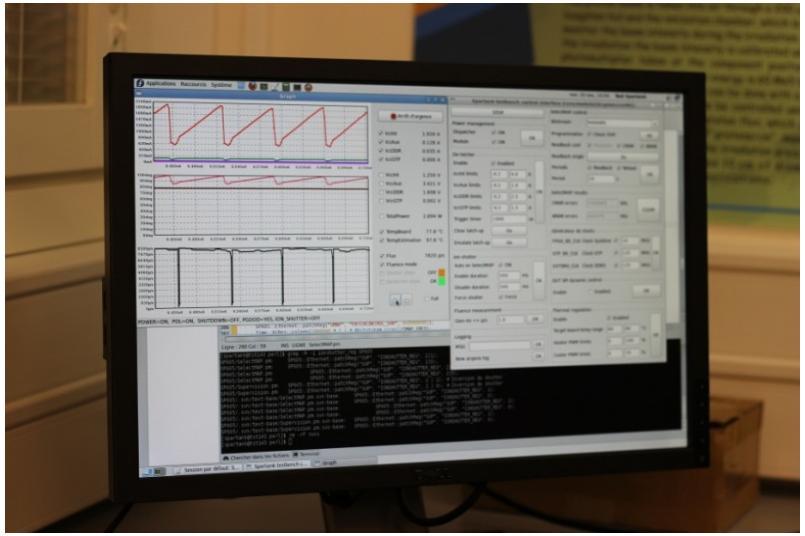
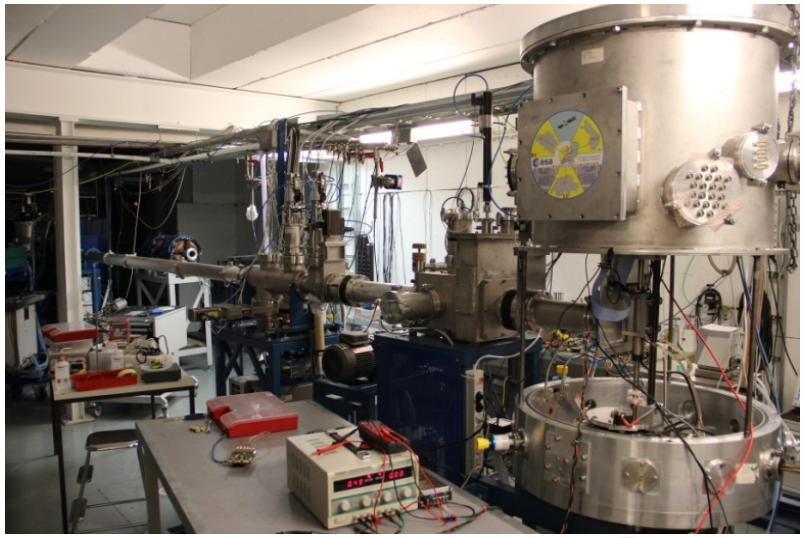
Radiation : Heavy Ions, SEE

- Test @ Jyväskylä







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Reliability :Reliability Analysis

- Plan of experiment has been set up to investigate the long term reliability of Spartan6 FPGA in aerospace applications for several Mission Profiles
- This plan is exclusively dedicated to the silicon failure mechanisms previously identified as relevant for space application by the construction analysis
- The test conditions to assess the reliability towards electro migration (EM), High Carrier Injection, (HCI) and Bias Temperature Instabilities (BTI) have been defined,
- Endurance Test will be done on 2 primitives: I/O, BRAM
  - at cold temperature -40°C – 3800h
  - at hot temperature +125°C – 7000h

  → Results in Q2 2017.

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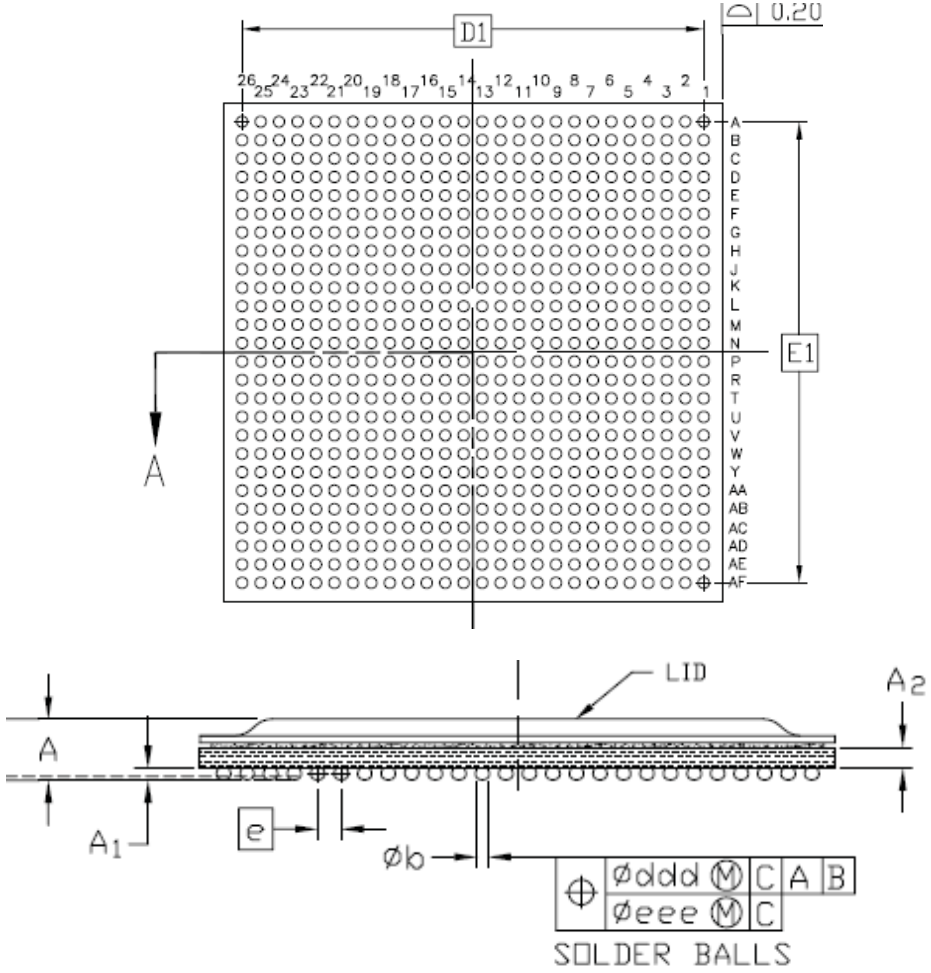
Spartan 6 assembly evaluation

- Description of Spartan6 package

Characteristics	PBGA 676
Type of package	plastic
matrix	26 x 26
Dimensions (mm)	27 x 27
Pitch (mm)	1
Interconnection • Diameter (µm) • Alloy	solderballs 600 Sn63Pb37

PBGA 676



- Assembly evaluation was conducted through CNES Study in 2014, « Comparative analysis of PBGA and CCGA assembly »
  (Marché sous cadre CNES n°130980)

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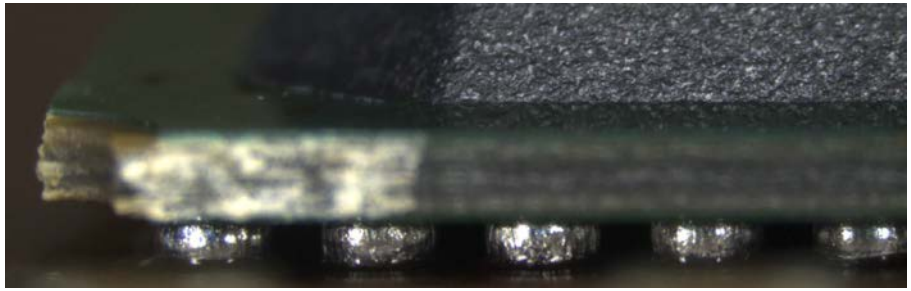
Spartan 6 assembly evaluation

- Printed circuit board characteristics :
  - HDI technology was used
  - Material : polyimide
  - Finishing of boards : fused SnPb

- 6 PBGA packages were mounted on polyimid board according to automatic process assembly in Elancourt

- X-Ray inspection and electrical test of components was achieved on all boards



Side view of PBGA 676 mounted on polyimid board

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Spartan 6 assembly evaluation

- Description of test conditions for environmental tests :
  - achieved on 5 boards

	PBGA 676
Vibrations	**ECSS-Q-70-38** 28,5G rms en ⊥ 27,1G rms en //
shocks	2000g en ⊥ 1500g en //
Thermal cycles	1500 cycles [-55°C ; 100°C] with electrical monitoring
DPA	T0, 500cycles

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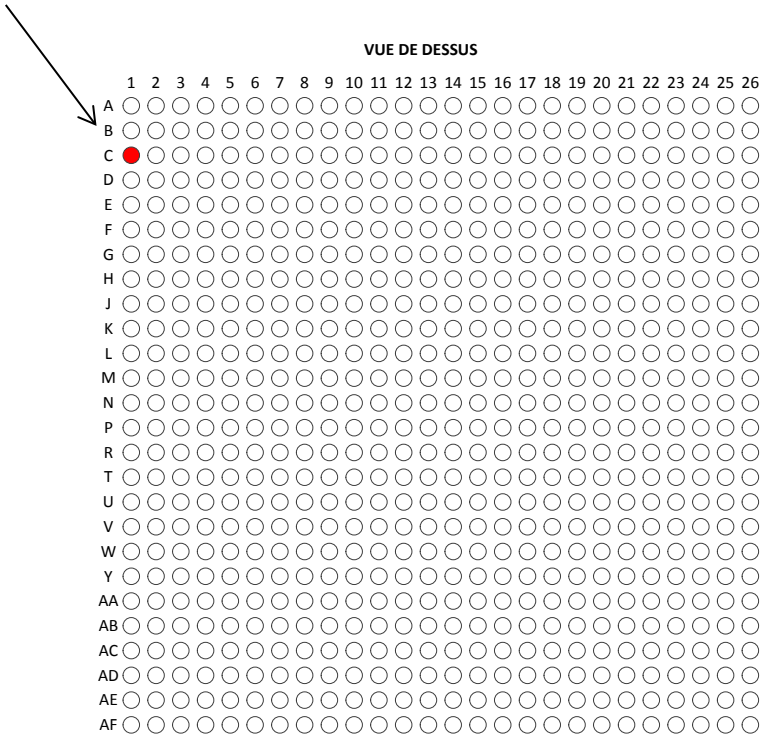
Spartan 6 assembly evaluation

- Results through environmental tests

- After vibration and shocks
  - 4 /5 assembled PBGA passed successfully vibration and shocks
  - 1 assembled PBGA presented one open circuit which was detected on one external solderball => this board was kept apart



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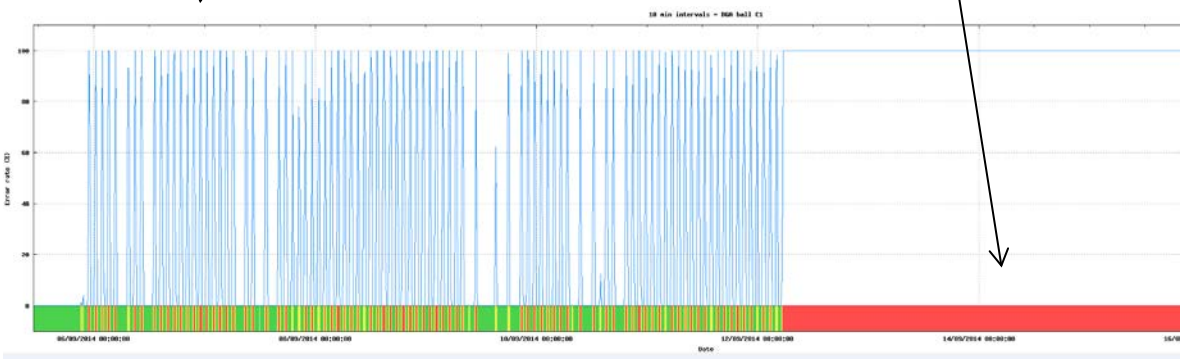
Spartan 6 assembly evaluation

- Results through environmental tests
  - Through thermal cycles :

Nb thermal cycles	4 tested boards
200	OK for 2 boards Early electrical drifts on 2 boards
500	OK for 2 boards Previous failures remained permanent
1500	OK for 1 board 1 new failed board (after 639 cycles) + failed board (detected before 500 cycles)



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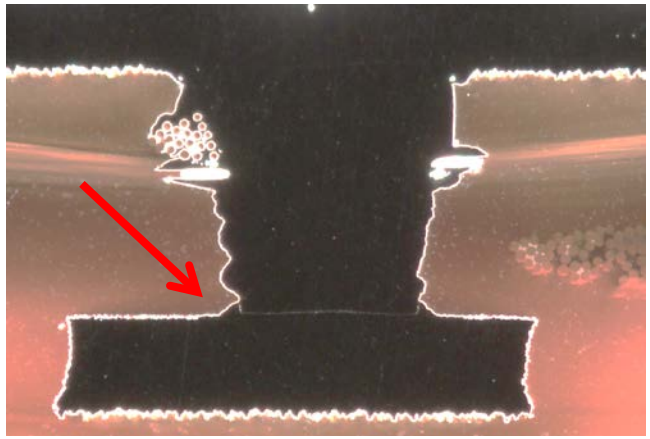
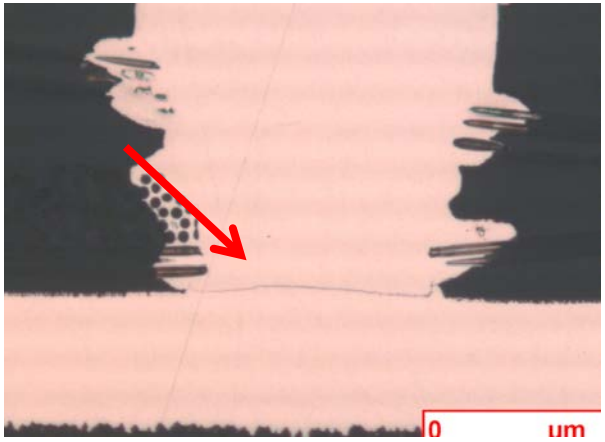
Spartan 6 assembly evaluation

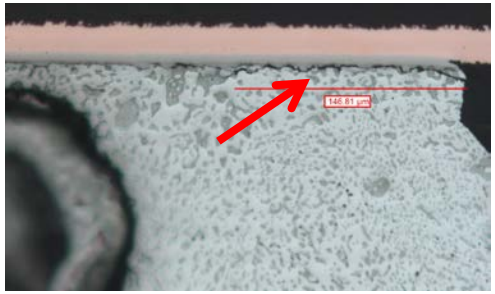
- Investigation:
  - Microsection revealed after 500 cycles:
    - thin cracks on top of solderballs => no impact on electrical continuity
    - Severe cracks in microvias of printed circuit board
      - Confirmed on board only submitted to vibration and shocks

Microsection of board n°3 after shocks : crack in microvia



Microsection of board n°4 after 500 cycles: crack in microvia and thin crack at solderball level





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Spartan-6 assembly summary

- 6 PBGA676 were assembled on HDI board using standard automatic assembly process at Airbus DS Elancourt.
- Boards were submitted to vibration, shocks and thermal cycles.
- Except one assembled PBGA, all boards passed successfully mechanical tests.
- Electrical failures were detected earlier on PBGA assemblies
- Investigations highlighted significant cracks in PCB microvias.

  - PCB manufacturer improved its process manufacturing and delivered new printed circuit boards with successful IST test results.
  - New assembly evaluation is on going with reliable PCB.

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THANK YOU

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