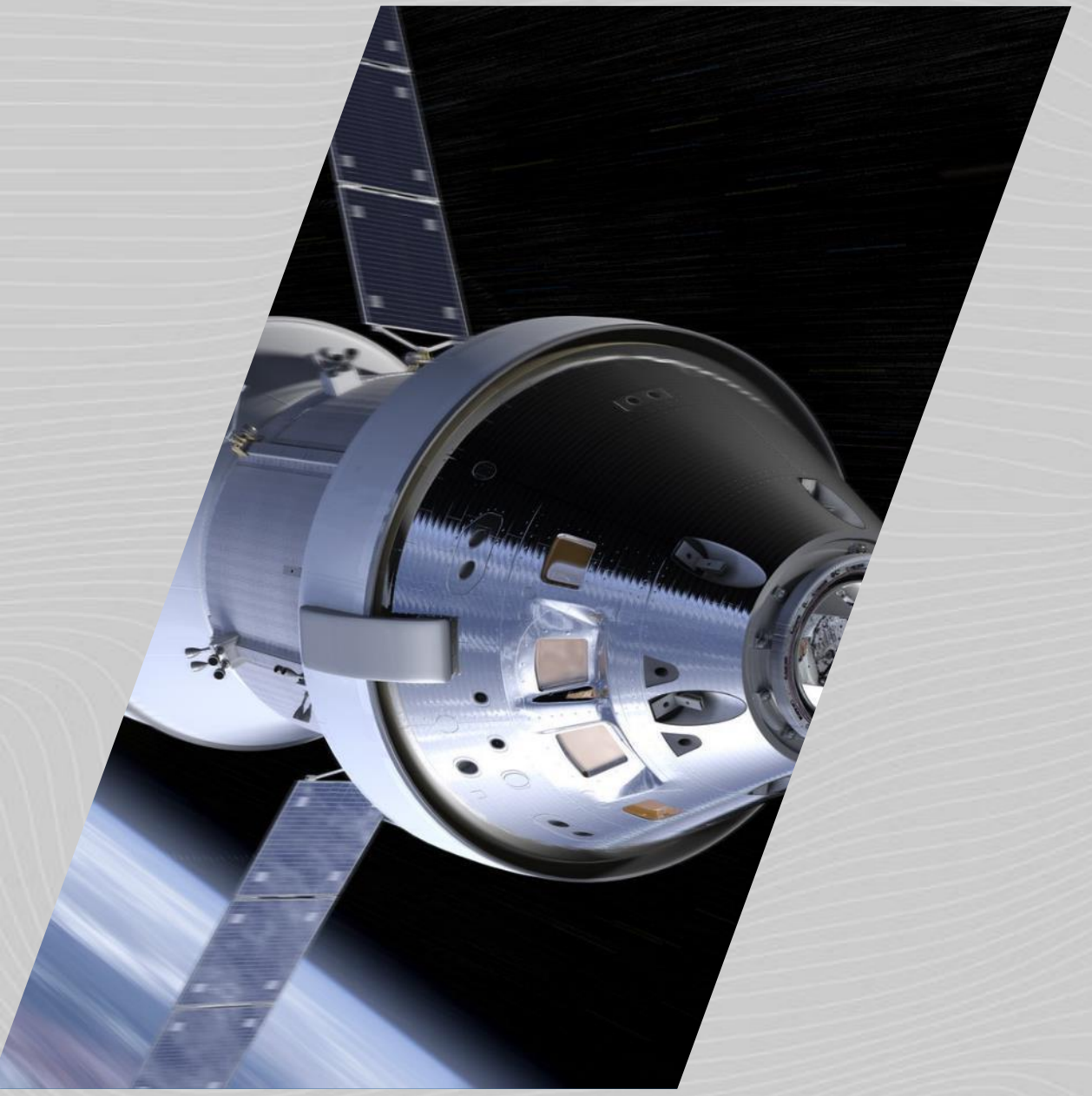


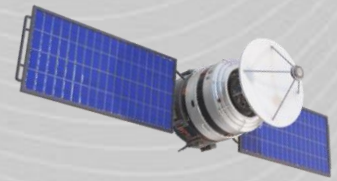
CAES PIONEERING ADVANCED ELECTRONICS

GR740 Qualification Results

Overview Presentation

Date: 2021-03-10

Abstract



- The GR740 is one of ESA's flagship parts.
- It has been selected for multiple missions, including ESA's Copernicus and NASA's WFIRST.
- The completion of the qualification phase marks the conclusion of a long and complex path.
- This presentation covers some of the technology challenges faced along the way and presents the results of the qualification tests that have been completed.

Agenda

- About Cobham Gaisler (CG)
- Introduction to GR740
- Technology challenges
  - Package development
    - OPM
    - Wire bonding
    - Column Selection
  - ESD performance
- GR740 qualification results
  - QML-V specific tests
  - Complementary (Delta ESCC) tests
- Conclusion

CAES PIONEERING ADVANCED ELECTRONICS

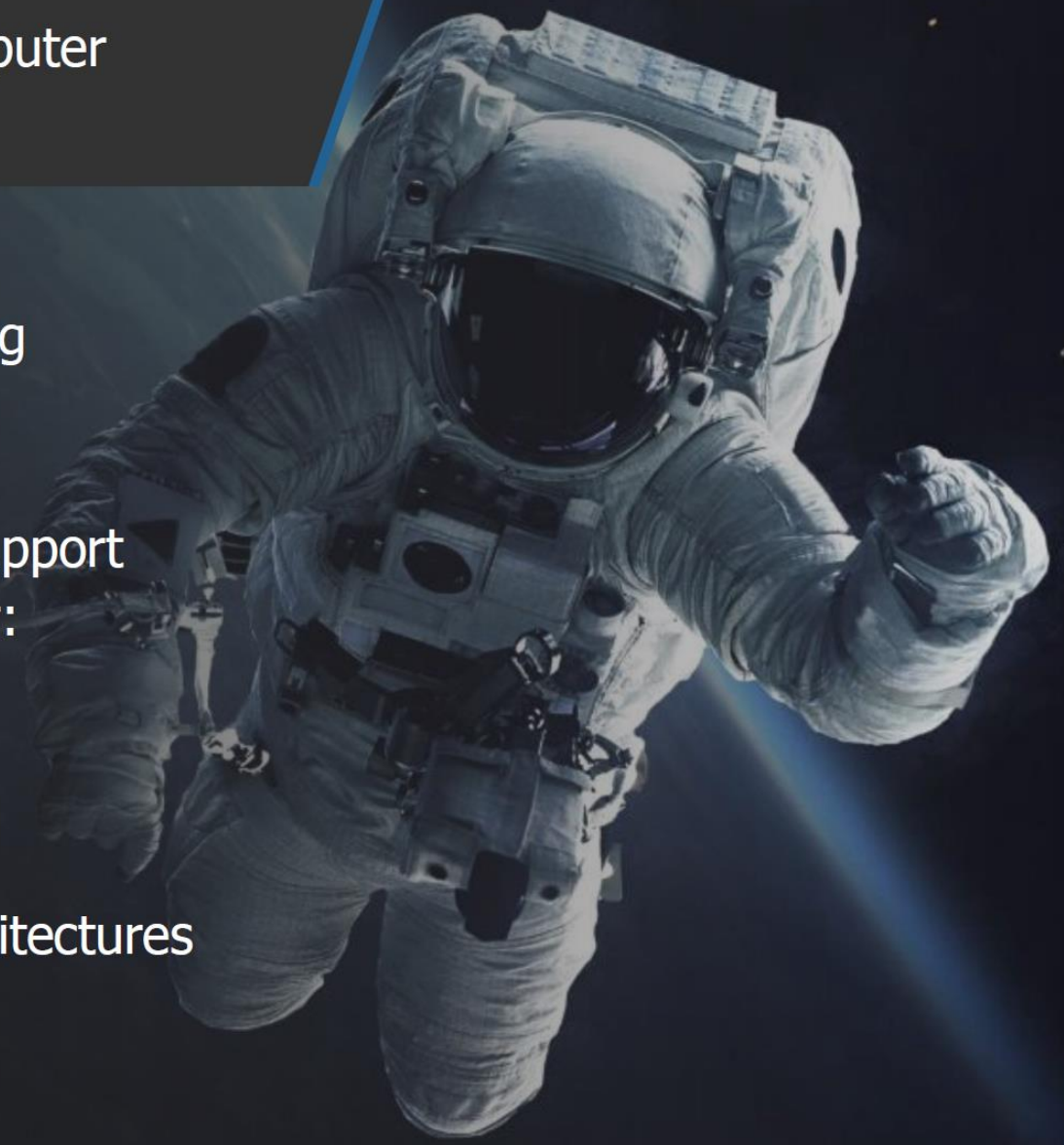
A world leader in embedded computer systems for harsh environments

Experts in fault-tolerant computing

We provide a full ecosystem to support hardware and software design for:

- Standard components
- Semi-custom FPGA
- Full custom ASIC

Based on SPARC and RISC-V architectures



CAES PIONEERING ADVANCED ELECTRONICS

Established 2001, 20-year anniversary!

- Acquired by Aeroflex in 2008
- Acquired by Cobham in 2014

Located in Gothenburg, Sweden

40 employees

In-house facilities

- ASIC and FPGA design
- Software
- Component lab

Components

High-reliability

- Radiation hardened
- Space qualified
- Fault-tolerant

NOEL Processor Family

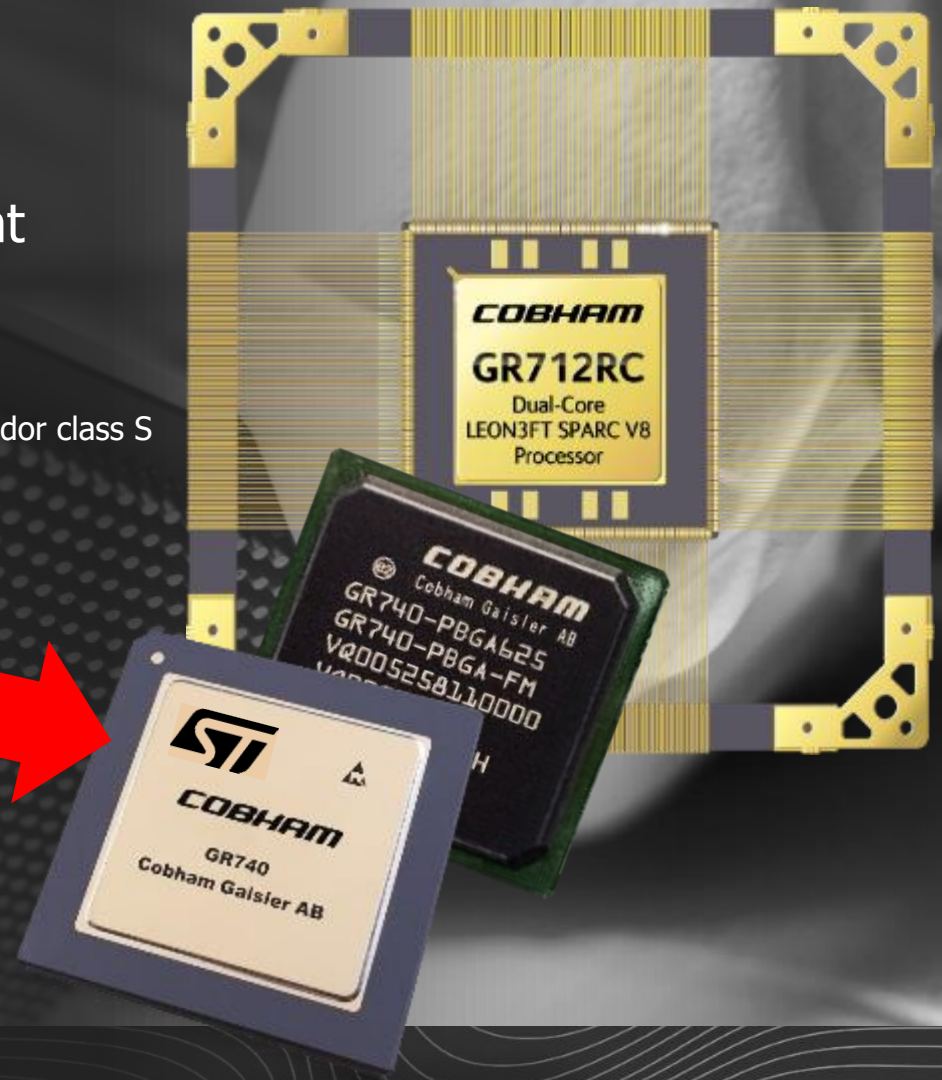
- GR7xv, NOEL-V, 16-Core, in development

LEON Processor Family

- GR765, LEON5FT, in development
- GR740, LEON4FT, quad-core, 250 MHz, QML-V approval exp. Q2 2021
- GR740 PBGA, LEON4FT, quad-core, 250 MHz, prototypes Q1 2021
- GR716A, LEON3FT, single-core, 50 MHz, ESCC 9000 screening exp. Q2 2021
- GR716B, LEON3FT, single core 100 MHz, in development
- GR712RC, LEON3FT, dual-core, 100 MHz, Vendor class S
- UT700, LEON3FT, single-core, 166 MHz, QML-Q, QML-V
- UT699E, LEON3FT, single-core, 100 MHz, QML-Q, QML-V
- UT699, LEON3FT, single-core, 66 MHz, QML-Q, QML-V

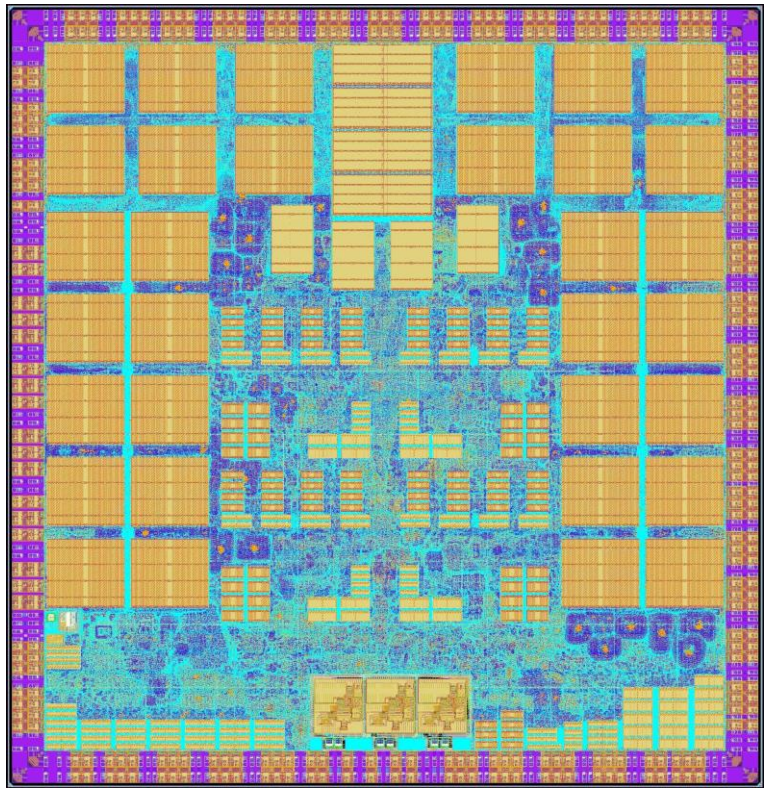
Interconnect

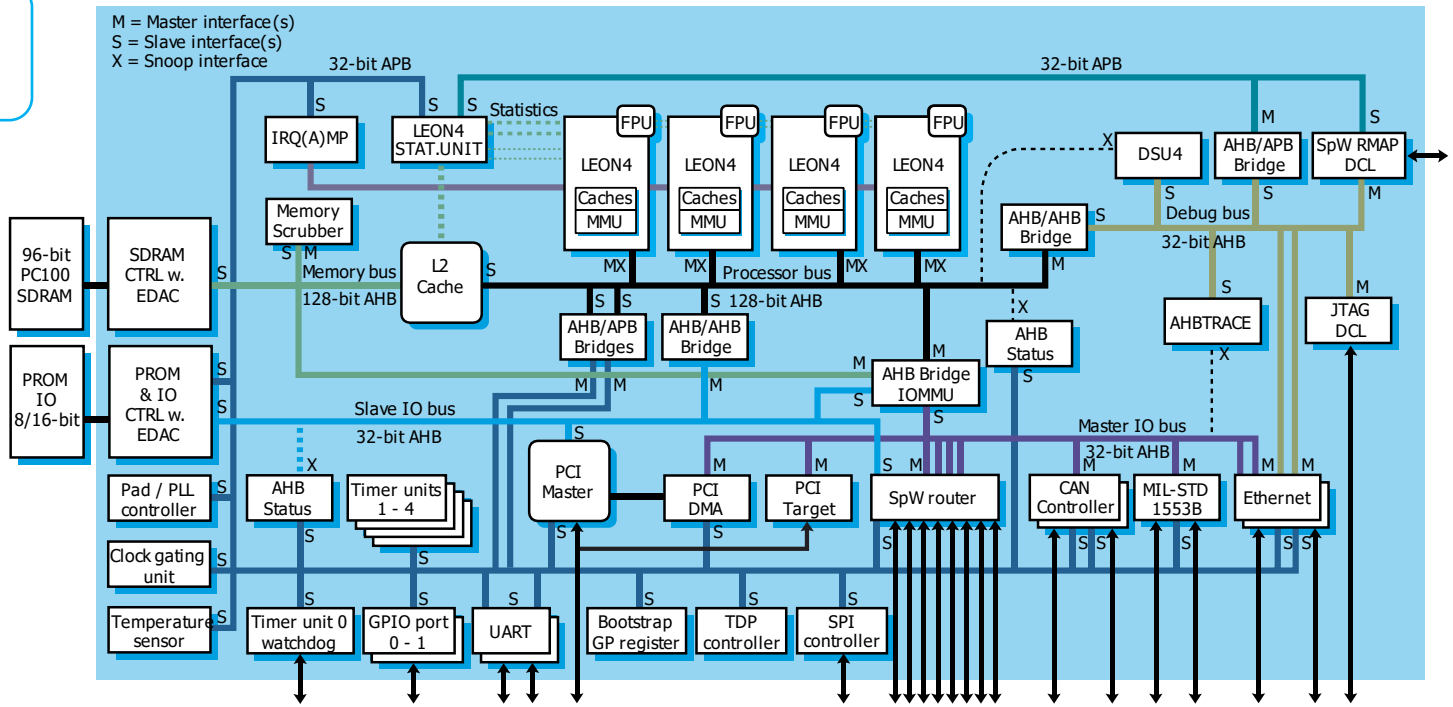
- GR718B, Vendor class S



Introduction to GR740

Radiation-hard system-on-chip quad-core fault-tolerant LEON4 SPARC V8 processor





Cobham Gaisler digital IP: LEON4FT and IO peripherals

STMicroelectronics C65SPACE technology platform

Complete software toolchain and debuggers are available

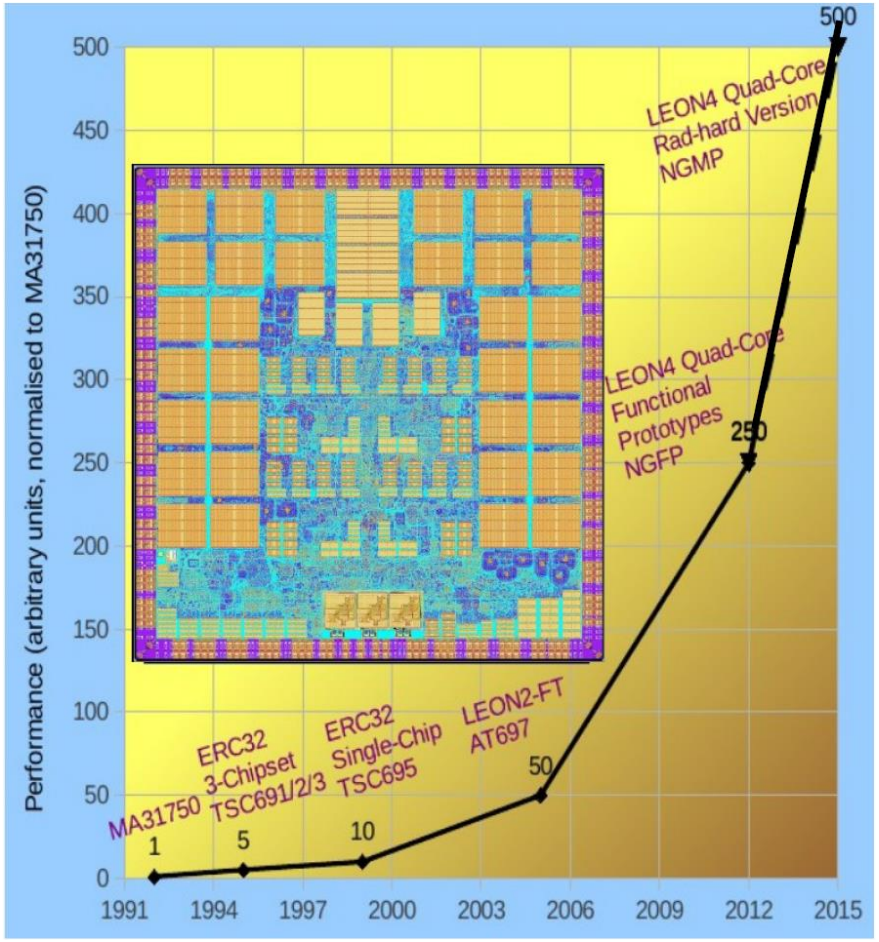
https://www.gaisler.com/

Introduction to GR740

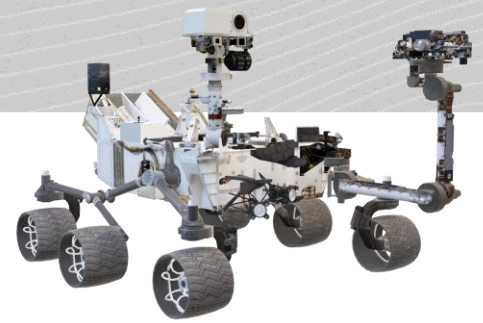
- ESA's next generation Microprocessor (NGMP) development time-line:
  - 2009, Start of the development under a TRP contract with ESA (VHDL design and verification by simulation on FPGA).
  - 2014, Implementation of NGMP into a space chip technology (C65Space).
  - 2016, Engineering models of the GR740 were evaluated.
  - 2018, Flight Silicon manufactured and validated (including radiation).
  - 2020, All QML-V related qualification tests successfully completed.
  - 2021:
    - 2021-Q1 -> All complementary tests (Delta ESCC) successfully completed.
    - 2021-Q1 -> QML-V / QML-Q equivalent flight parts made available.
    - 2021-Q2 -> Constructional analysis on CLGA & CCGA package by ESA completed.
    - Expected 2021-Q2 -> QML-V and QML-Q certification by the DLA.

Introduction to GR740

Power <2.0W, Performance >1700 DMIPS



Ref: Roland Weigand. GR740 User day presentation: "from concept to product NGMP to GR740"



GR740 - IPAC Computer for the Platino mission

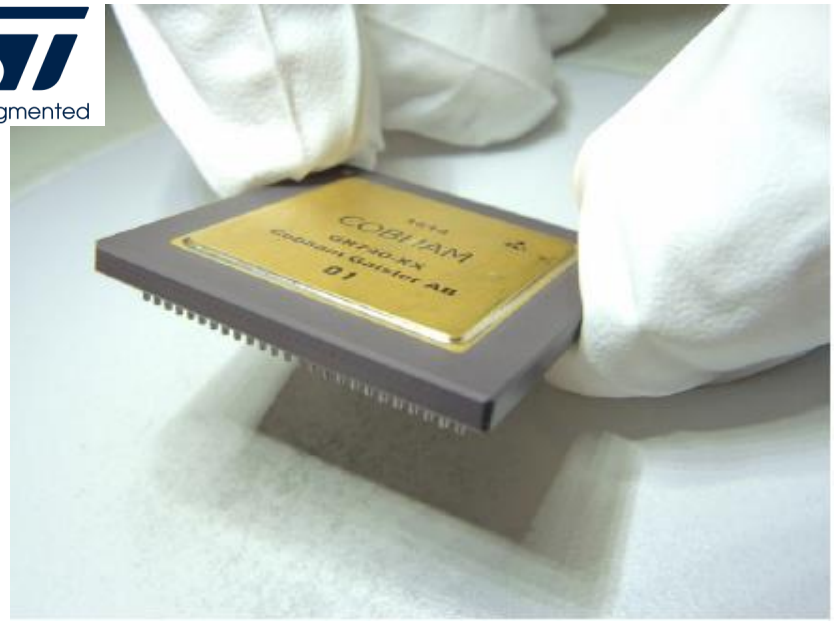
ThalesAlenia Space

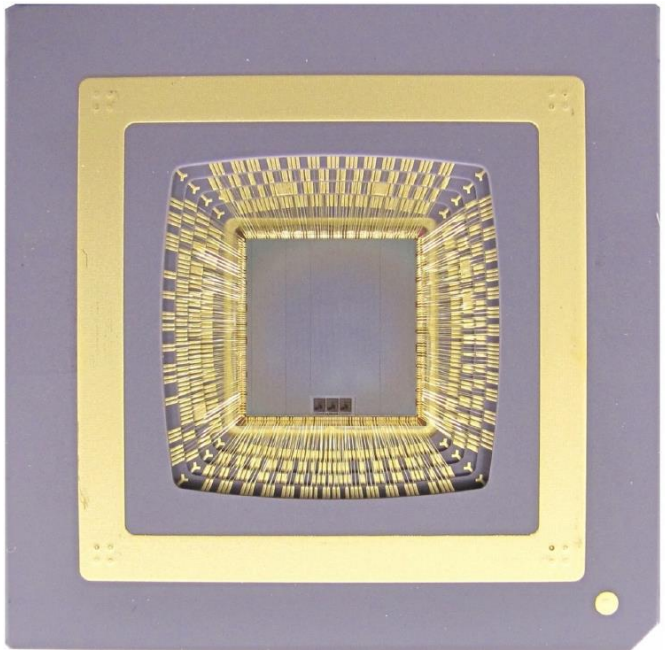
GR740 - WFIRST Processor Board

NASA

Goddard SPACE FLIGHT CENTER

Technology challenges



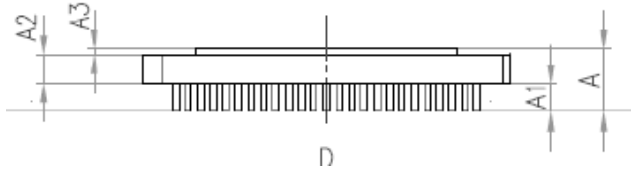


Package development:

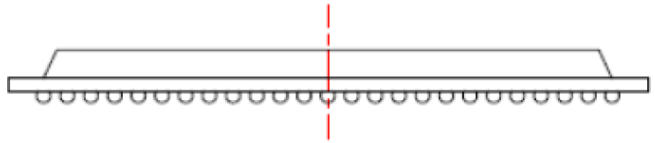
625 pins Package:

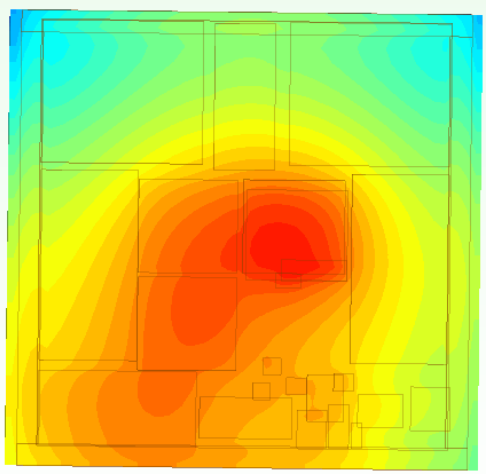
- CLGA

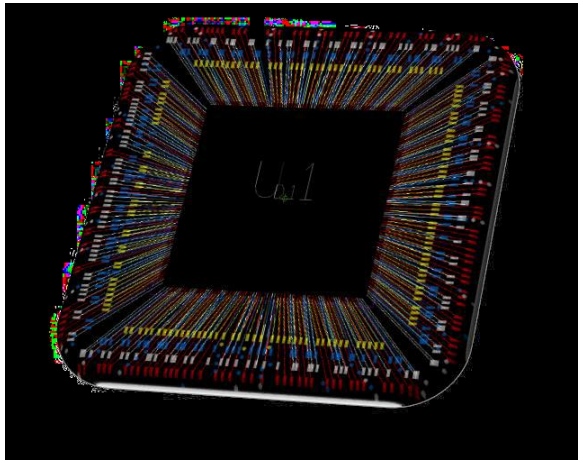
- CCGA



- PBGA (Soon available)







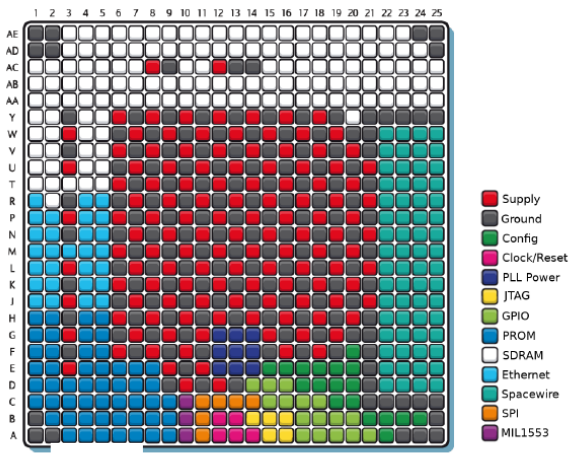


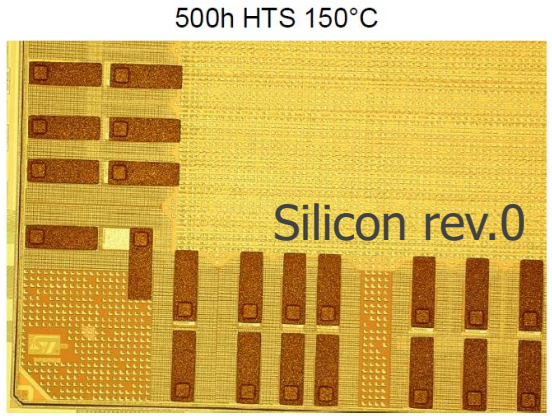
Figure 77. Placement, bottom view

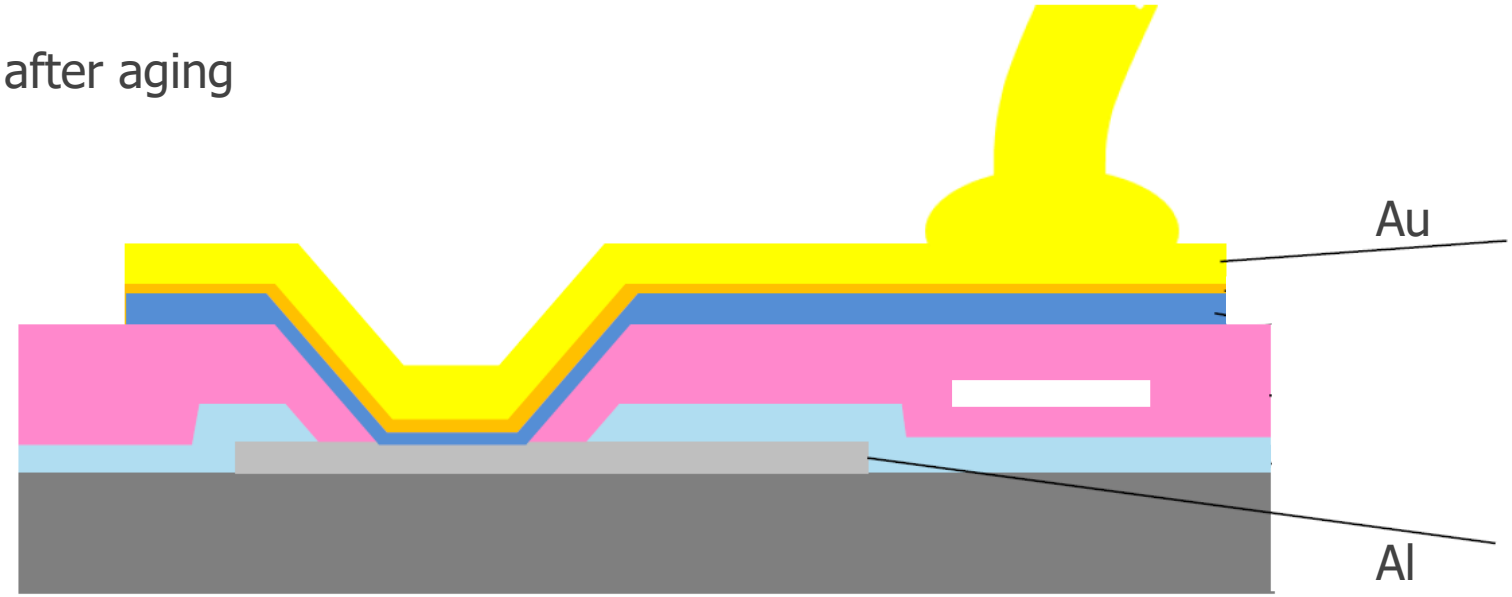
Images courtesy of ST Microelectronics

Technology challenges

OPM qualification:

- Al wedge bonding was not possible for the C65Space library due to pad size compatibility and the complexity of the GR740. Au wire had to be used instead.
- Because of the Al pad – Au wire metal interface, an OPM layer was implemented
- Bond pad validation on nominal OPM thickness and on corner case (low OPM thickness)
- Wire bonding validation after die aging on corner case (500h 150C / 500h 85C/85%RH)
  - Ball dimension
  - Bond wire pull
  - Ball shear
- Metallisation integrity check after aging
- Constructional analysis



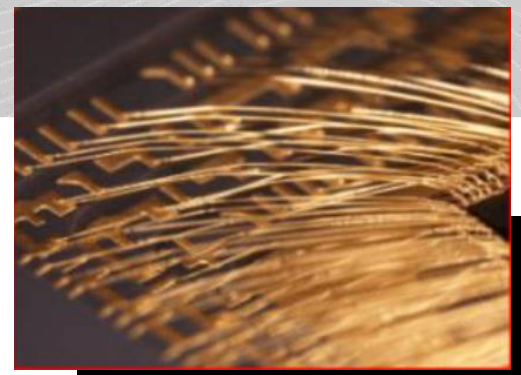


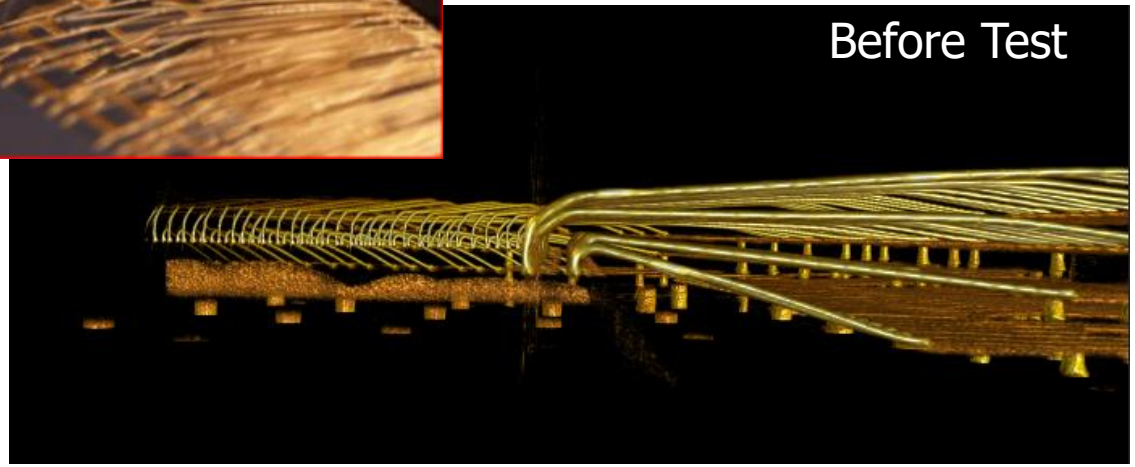
Images courtesy of ST Microelectronics

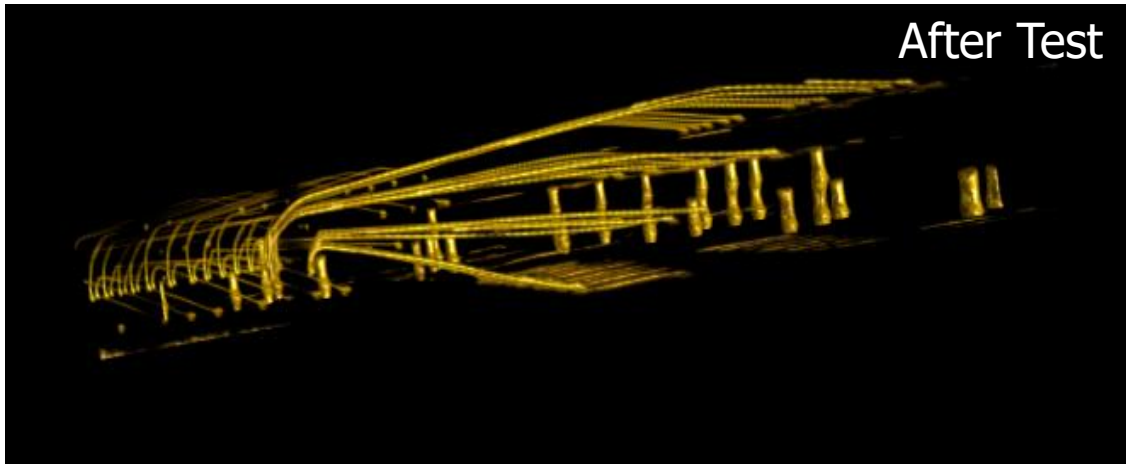
Technology challenges

Wire bonding:

- C65Space library imposed the used of Au ball bonding
- Device complexity imposed the use of thin bond wires, 20nm in diameter
- 4 decks were necessary to accommodate all bond wires. Package validation included:
  - Vibration, TM 2007 Condition A
  - Mechanical Shocks, TM 2002 Condition B
  - Constant acceleration, TM 2001 Condition D
  - PIND test, TM 2020 Condition A.
  - Electrical test & X-ray before and after each test.

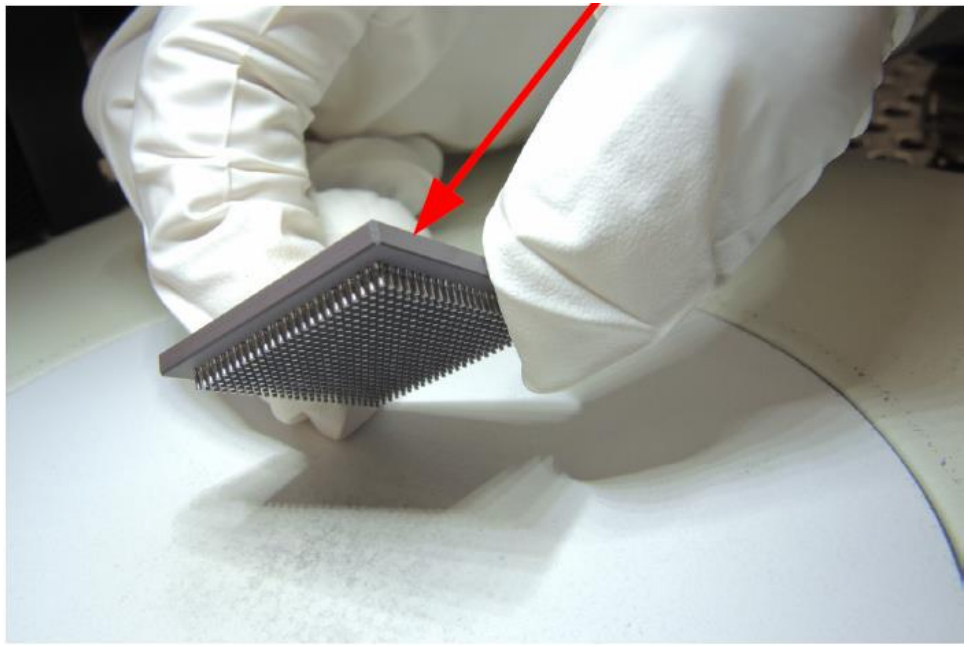


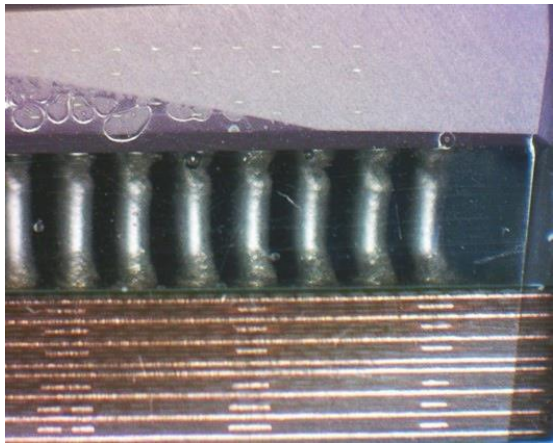


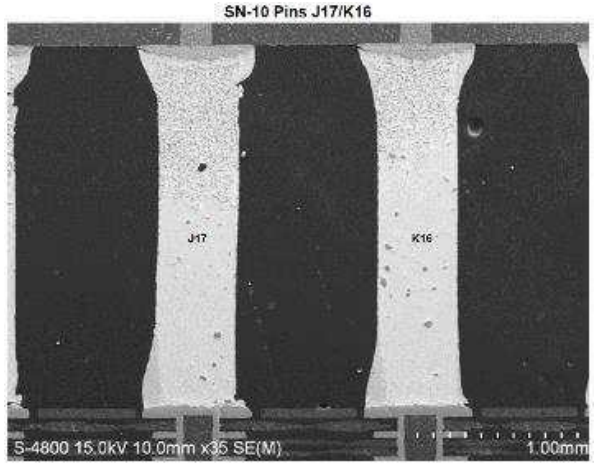


X-ray based 3D reconstruction of the GR740 bonds.
Images courtesy of ST Microelectronics.

Technology challenges







Images courtesy of ST Microelectronics

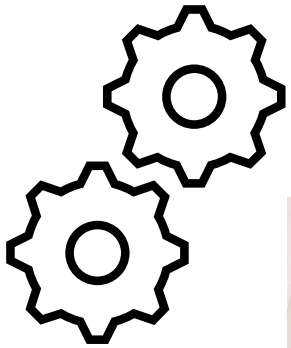
Column Selection:

- The GR740 package is compatible with various columns types:
  - Sn/Pb IBM type (Micross Crewe UK)
  - Sn/Pb copper wrapped (e.g. Serma, SixSigma)
- The QML qualification has been run with Micross IBM type columns
- Micross Crewe UK is currently QML-Q/V/Y certified by the DLA
- A board level reliability study of the IBM columns has been completed by ST & Micross.
  - FIT FOR PURPOSE
- A comparison study between Micross and Serma type columns has been carried out by ESA/Thales I.

ESD performance

- ST reported ESD failures on a test chip on certain type of I/Os
- The GR740 silicon (revision 0) was revised to ensure suitable ESD performance

Die revision 1



- The GR740 silicon revision 1 was ESD verified:

Description	Reference	Level
HBM	JS-001-2017	2000 V
CDM	JS-002-2014	500 V

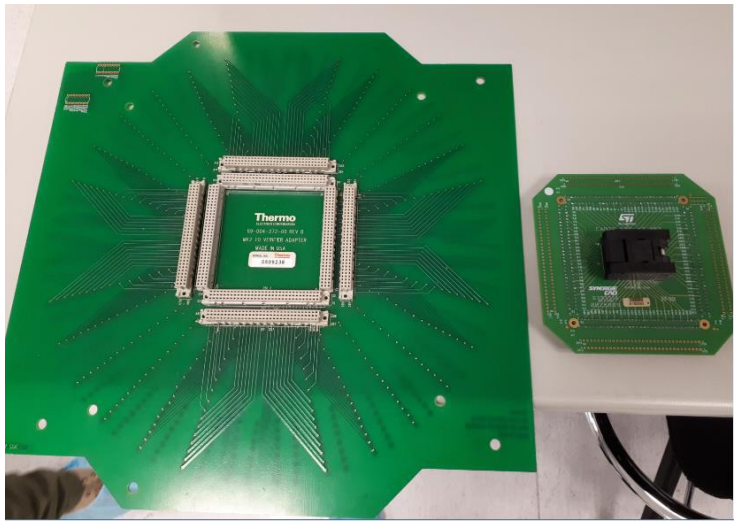
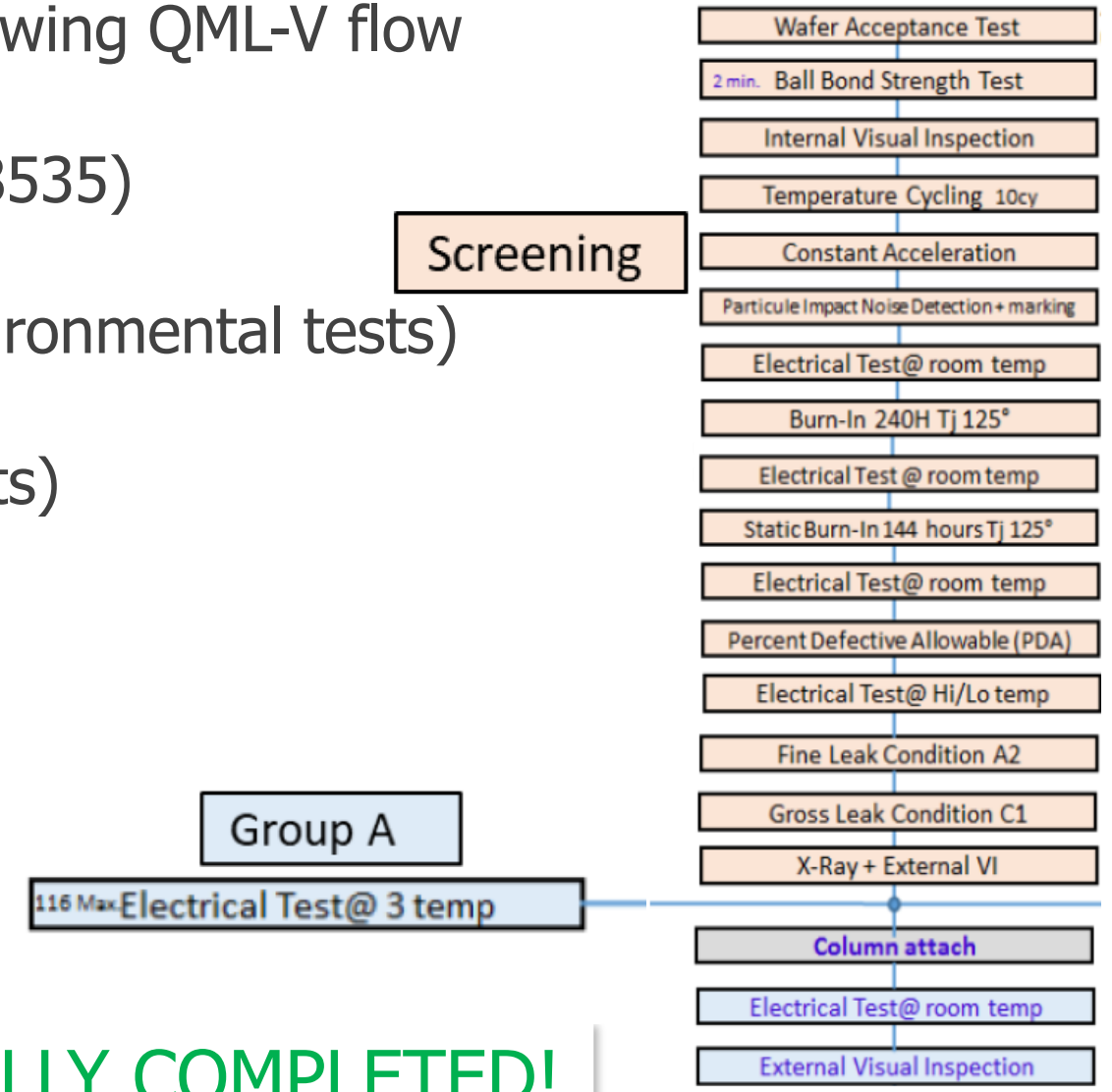


Image courtesy of ST Microelectronics

GR740 qualification results

GR740 qualification performed following QML-V flow

- QML-V Screening (MIL-PRF-38535)
- Group A (Electrical tests)
- Group B (Mechanical and Environmental tests)
- Group C (Life test)
- Group D (Package related tests)
  - CLGA
  - CCGA (IBM type columns)
- Group E (Radiation tests)



ALL TESTS SUCCESSFULLY COMPLETED!

GR740 qualification results

Solder column pull test for CCGA performed in Group D

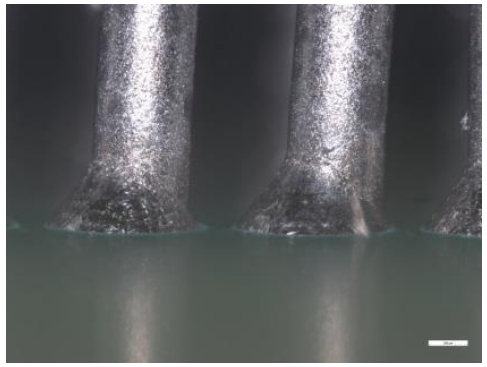
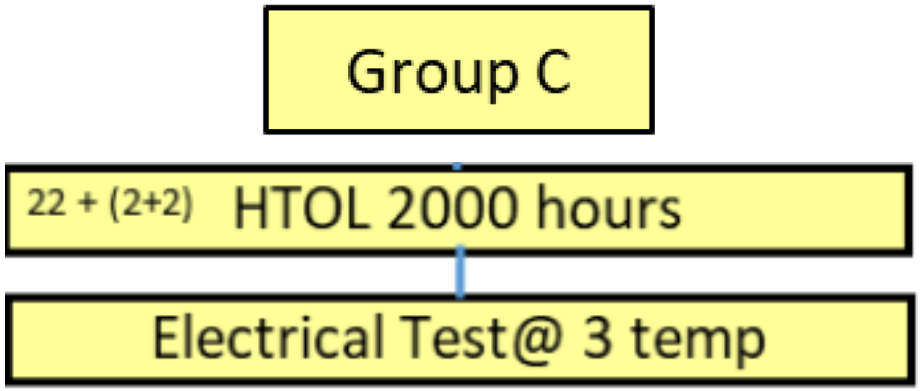


Image of solderability test courtesy of ST Microelectronics and Micross Crewe UK



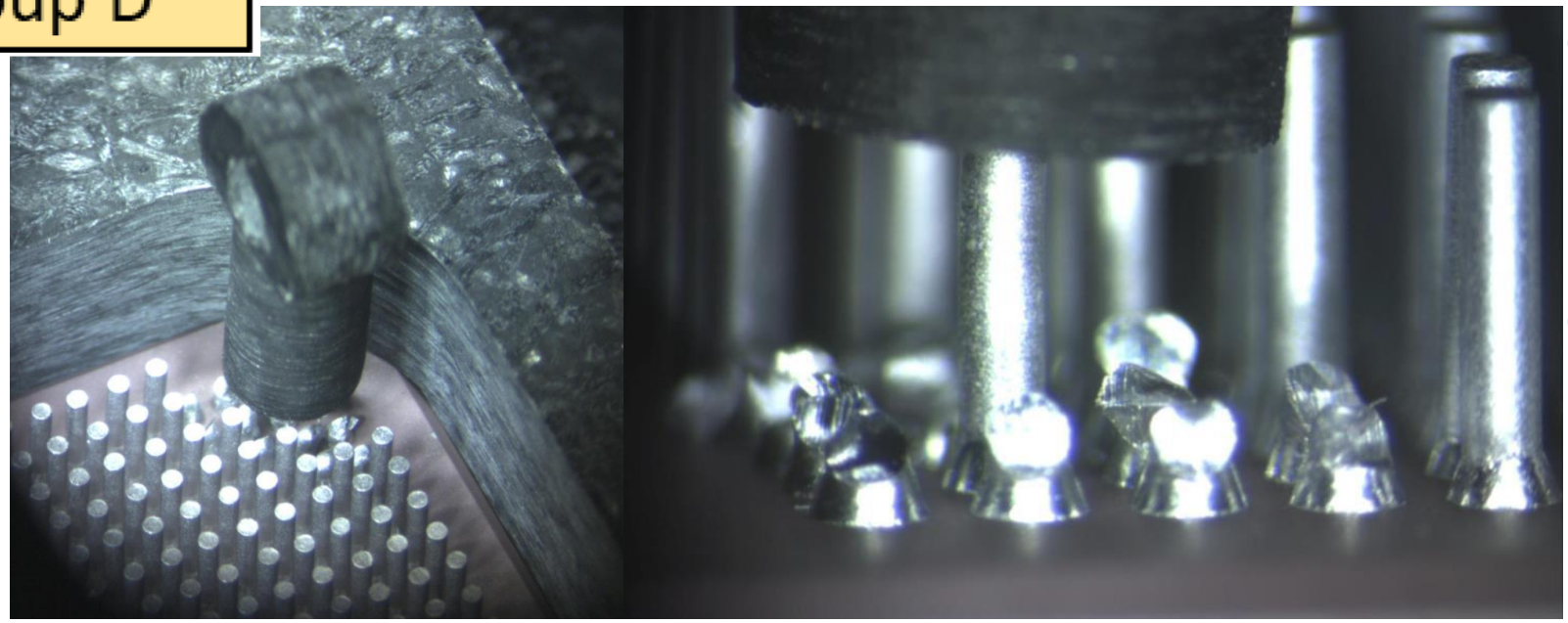
Extensive Life test data has been collected by ST for test vehicles manufactured with same library to calculate the failure rate of the GR740 silicon.

Mission profile	FIT result
Tjunction in use: +125°C, Vuse= Vmax (1.32V)	17
Tjunction in use: +125°C, Vuse= Vnom (1.2V)	3

ALL TESTS SUCCESSFULLY COMPLETED!

GR740 qualification results

Group D



Images of solder column pull test courtesy of ST Microelectronics and Micross Crewe UK

Group D

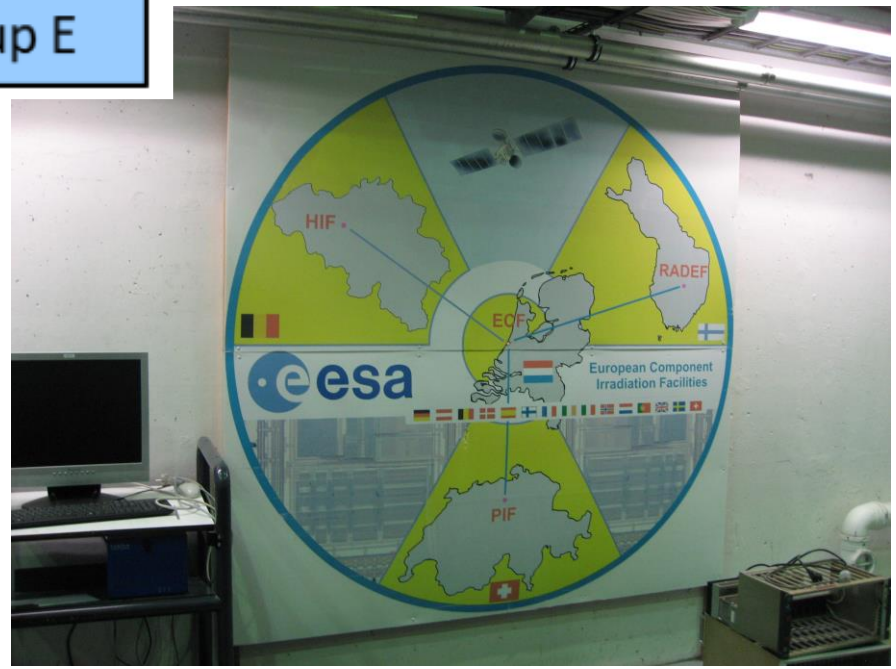
- 3 Internal Water Vapor Test
- 15 Thermal Shock 15 shocks
- Temperature Cycling 100 cy
- (15) Moisture Resistance
- Electrical Test@ room temp
- Visual Inspection
- Seal Test (fine & Gross)
- 15 Mechanical Shock 5 shocks
- Vibration 12 sweeps
- Constant acceleration
- Seal Test (fine & Gross)
- Visual Inspection
- Electrical Test@ room temp
- 15 Physical Dimension
- (15) Physical Dimension
- (15) Salt Atmosphere
- Visual Inspection
- Seal Test (fine & Gross)
- 2 Solder Column Pull Test
- 3 Soldering Heat
- Seal Test (fine & Gross)
- External Visual Inspection
- Electrical Test@ room temp

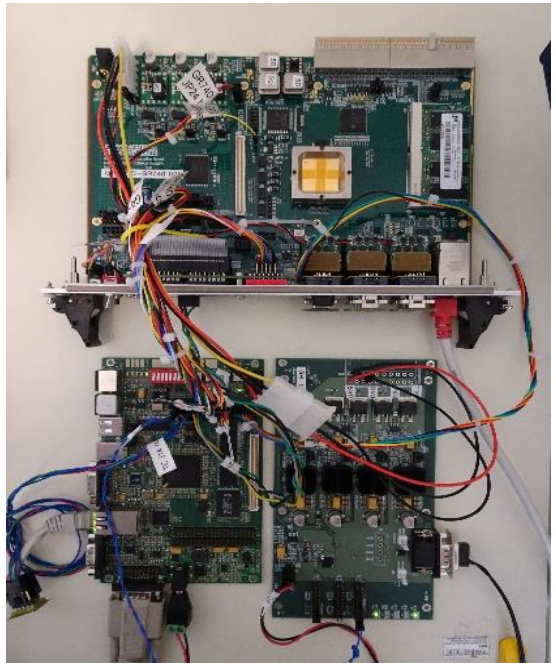
Resistance to soldering heat (subgroup D9) performed under both conditions I and J

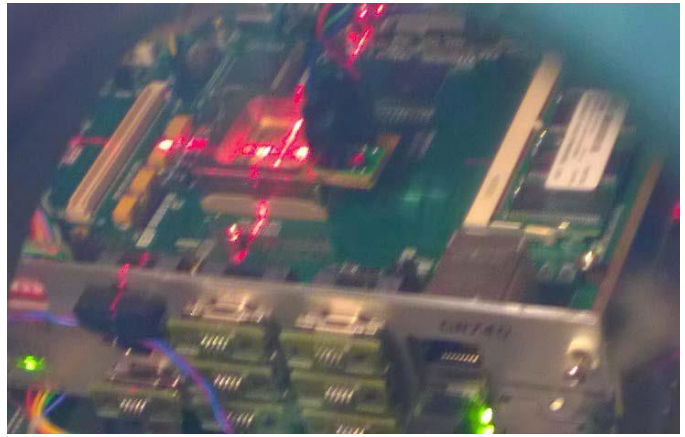
ALL TESTS SUCCESSFULLY COMPLETED!

GR740 qualification results

Group E



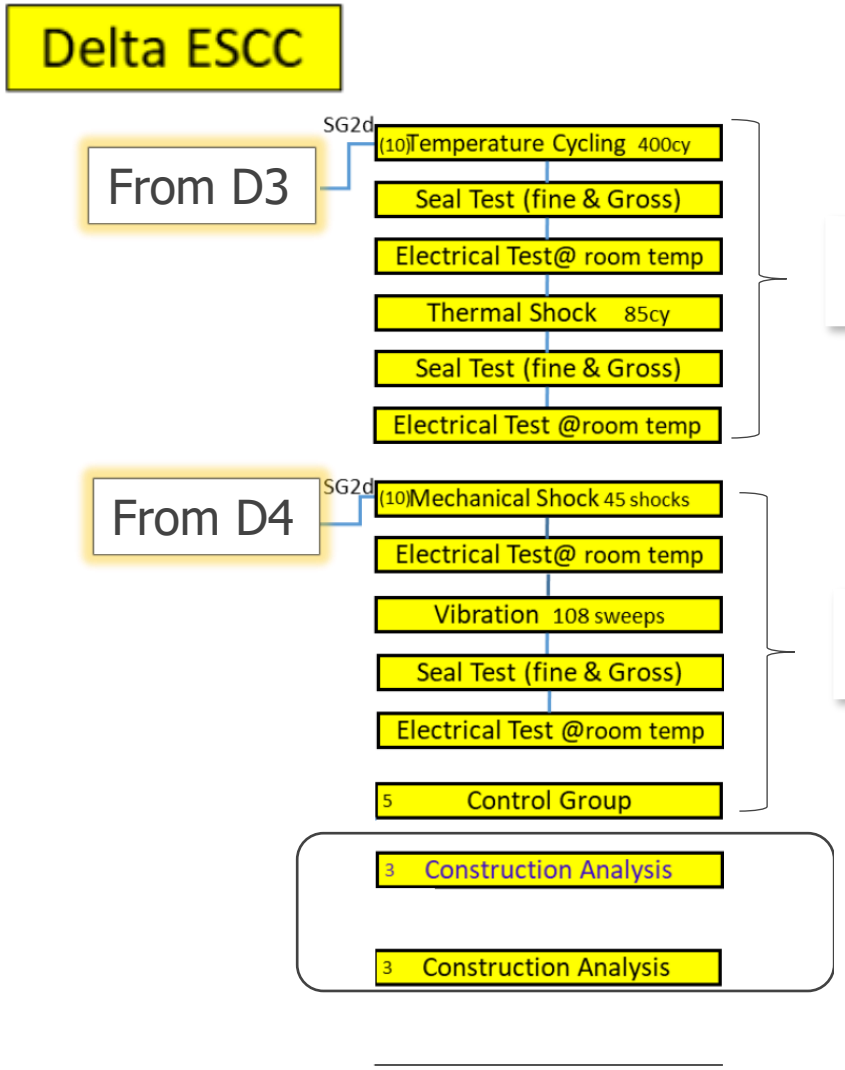




- TID tolerance of 300 krad(Si)
- Overall SEE rate below $1x10^{-5}$ events/device/day (GEO)
- SEL > 125 MeV.cm^2/mg (T>85ºC & max supply)

ALL TESTS SUCCESSFULLY COMPLETED!

GR740 qualification results



TESTS SUCCESSFULLY COMPLETED!

TESTS SUCCESSFULLY COMPLETED!

Expected end of March!

Conclusion

- GR740, ESA's flagship Next Generation Microprocessor, is ready for service!
- All QML-V qualification testing for the GR740 has been successfully completed.
- All Delta ESCC tests also successfully completed.
- Great market interest for the GR740
- The GR740 has already been selected for the Platino and WFIRST missions.

Conclusion

- QML-V / -Q equivalent flight parts currently available. Many already delivered to world-wide customers
- QML-V / -Q certification expected by end of Q2-2021 (SMD 5962-21204)
- More info at https://www.gaisler.com/

Thank you for your attention!

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