Customized PCB and Equipment Manufacturing at Astrium - Space Transportation

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I. **Astrium-ST as manufacturer of PCB's and equipment for space applications**

- **EADS**
  - **Airbus / Airbus Military**
  - **Eurocopter**
  - **EADS Defence & Security**
  - **Astrium Satellites**
  - **Astrium Services**

**Astrium Space Transportation**

- **4 Business Divisions**
  - Launchers
  - Orbital Systems & Space Exploration
  - Defence
  - Propulsion & Equipment

- **1 Competence Centre**

- **Product Design TE56, Bremen**

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All the space you need
TE56 PCB assembly and equipment manufacturing shop Bremen

- ESA-certified manufacturing line for PCB's
- 170 m² of manufacturing, integration and repair facilities
- 5 manual soldering workplaces
- 1 vapour-phase soldering machine (lead base) FSL MRT52
- 1 vapour-phase soldering machine (lead base) ASSCON VP6000
- Cleaning equipment
- Furnaces, climate chambers, etc

Capacity

- ca. 150 PCB's in flight quality p.a.
- ca. 200 PCB's for ground use p.a.
- Supporting services in parallel
We have a long heritage of flight proven electronic equipment for space, e.g. for ATV

3-Lane Fault Tolerant Computer
FTC
(1x3 per ATV)

Propulsion Drive Electronics
PDE
(2 per ATV)
We design and manufacture harness and equipment for transport systems & payloads, e.g.; Integrated Cargo Carrier ICC

Power Distribution Box, Fuse Box, Harness for ICC (STS-127)
We supply the International Space Station and its experiment racks with computer power.

- Standard Payload Computer (SPLC) inside various experiment racks inside Columbus (5x at ISS, 50 in total)
- Microgravity Science Glovebox (MSG) Experiment Rack inside US-Lab "Destiny"
- Data management computer for the ISS (DMS-R), Control of the ISS since July 2000 (1x3 FTC at ISS, 63 in total)
There is a need for a new generation of space computers

- SPLC is in place as the standard solution for European „Class 1“ µG-Payload controllers aboard the ISS.

- The gap is a standard COTS computer solution for „Class 2“ µG-Payload controllers which fulfils the needs of experiment developers regarding
  - size (tiny)
  - performance (high),
  - interfaces (as used in a laboratory environment, e.g. USB).
II. The "SPAICE" demonstrator as the new generation space computer to fill this gap

- SPAICE - SPAce Infrastructure ComputEr
- Significant gain of performance w.r.t. previous computer generation
  - Fast control loops (~ 50 s⁻¹) require new CPU technology (LEON II AT697)
  - Fast backplanes, e.g. Compact-PCI bus as VME successor
  - Large memory arrays (256 – 1024 MByte)
- Obsolescence of parts requires new designs
  - ERC32, RAM, EPROM etc. of last generation computers become obsolete
- Modular system (industry compatible) for cost effectiveness
  - Tailor system to needs of mission (environment, safety, cost...)
  - Compatibility with industry standards (e.g. cPCI, 19”) to incorporate COTS
  - Configurable redundancy concepts
- Modern & fast interfaces (but also legacy I/F to stay compatible)
  - Spacewire, CAN, Ethernet, AFDX
  - MIL-STD-1553B, RS-422
The "SPAICE" concept: COTS and High Rel. components to achieve new functionalities

- Core system is hi-reliable
- Availability even after breakdown of COTS H/W
- S/W architecture is adapted, e.g. interrupt service routines are always in SRAM
- Shell functions can partly be accommodated in an FPGA
- Radiation Mitigation for COTS components by Latchup-Protection and Redundancy
"SPAICE" single board computer with LEON II: mixed COTS and High Rel. for multivalent use

LEON II FT AT697

32 Mbyte flash memory double redundant

PMC slot for extension card (FME, MIL-1553 w/ coprocessor)

Compact PCI backplane connector

256 MByte fast RAM triple redundant

SoC I/F controller LAN, CAN, PCI bridge

Reverse side: 4 banks with 2 Mbyte Hi-Rel SRAM each

Spacewire (not assembled)

Radiation mitigation by design

Compact PCI backplane connector

256 MByte fast RAM triple redundant

SoC I/F controller LAN, CAN, PCI bridge

Reverse side: 4 banks with 2 Mbyte Hi-Rel SRAM each

Spacewire (not assembled)
Compact PCI connectors to achieve high data transfer rates

- The application of cPCI connectors enable a large number of connections

- The design and manufacturing of backplanes with cPCI connectors provide very compact PCB solutions
Tailored usage of components to fit to reliability needs

- Spacecraft (High Availability)
  - COTS
  - High-Rel.

- Primary Payloads
  - COTS
  - High-Rel.

- Secondary Payloads
  - COTS
  - High-Rel.

EEE parts used

Safety critical

Safety uncritical
IBM Power PC 104 processor board as an example for less safety critical applications

Environmental conditions:

- extended operating temperature range (-40° to +85°C)
- minimum power dissipation (< 3W, 5V single supply), no active cooling necessary
- radiation tests verify good performance for LEO / ISS level
  (=> NASA report (ref.: JSC-63014) & Astrium own re-tests)

PC/104 Dimensions:

- Dimensions: 96 * 90 (+2 *12,7) mm (PC104 standard)
- 110 gr., fully equipped board
Configurable redundancy concept through fault-management elements

Fault-Management Element
- (FME) mezzanine add-on card
- provides fast data exchange for redundancy management
- SpaceWire-based
- Byzantine algorithm implementation
- Configurable number of processor boards
Successful demonstrator flight on STS-122 and on-orbit performance

- ppcBOX on ICC pallet (PC104, temperature acquisition)

- in Columbus (LEON II, Record of radiation effects, assess radiation mitigation, acquire sensor data (milli-g))
There is now a need for a full flight qualification

**ERNObox**
- Successful vibration / thermal / offgassing / EMC tests
- Successful interface tests in the Columbus Model / at ESTEC / at KSC
- Successful data acquisition over a 14 months period in the Columbus Module
- Loss of data due to failure of qualified EEE-parts (S-RAM, engineering samples)
- Refurbishment in progress for 2nd Launch in 2010 as payload controller for AIS experiment

**ppcBox**
- Launch with STS-122 on ICC, permanently powered by ICC
- Non-stop operation for the whole duration of the STS-122 mission (17 days on orbit)
- Successful acquisition of environmental data (temperature distribution) and storage on USB-Sticks.
III. **Next developments at Astrium-ST for full flight qualification**

- Flight-worthiness of the PC-104 computer demonstrated
- Flight-worthiness of LEON II computer demonstrated
- On-orbit verification led to successful initial results
- Exchange of SRAM necessary (use radiation-qualified Samsung type)

- However, full verification / flight acceptance quality needs to be granted for future applications

- New board design shall incorporate:
  - ceramic CGA's
  - plastic or ceramic BGA's
  - design w/o solder stop mask
  - new raw board materials for a wider operational temperature range
Improvements through better raw board characteristics:

<table>
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<tr>
<th>Manufacturer</th>
<th>Material</th>
<th>CTE (x/y axis, &lt; Tg)</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Lamitec</td>
<td>15193-60 Laminate / Prepreg</td>
<td>13 ppm/°C</td>
<td>obsolete</td>
</tr>
<tr>
<td>Panasonic</td>
<td>R-1755C Laminate / R-1650C Prepreg</td>
<td>13 - 15 ppm/°C</td>
<td>in application</td>
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<td>ARLON</td>
<td>Thermount</td>
<td>9 - 10 ppm/°C</td>
<td>obsolete</td>
</tr>
<tr>
<td>NN</td>
<td>?</td>
<td>&lt; 8 ppm/°C</td>
<td>needed</td>
</tr>
</tbody>
</table>

... but there is still a need for new materials
Adapted board design to avoid micro-VIAs...

- 1.27 mm pitch CGA is possible without micro VIAs:
...leads to a successful application of CGAs

- As successfully flown in the SPAICE Erno-Box demonstrator
The process know-how and adapted new equipment is available…

- Ceramic BGAs successfully assembled and lab-tested (ground-quality)
- Successful soldering results

- New vapour phase soldering equipment ASSCON VPM6000 ready and tested
- Relaxed soldering induced stress for new generation of PCBs due to better control of temperature profiles
- ESA process qualification is going to start

…to enable a successful application of C-BGAs
Improvement of raw board manufacturing technology is necessary

- A looming pitch shrinkage at BGAs/ CGAs would reach the present design technology limits

- Microvia technology will become unavoidable

- At present, this technology is available for commercial and military applications, but not in a qualified manner for space equipment

- The obsolete status of Thermount and the currently missing replacement material for low CTE PCBs is grave and disabled the application of some ceramic component housings. ESA should support the space equipment manufacturers to find a suitable replacement material.

- We recommend that the raw PCB manufacturers continue investing further for the future and that ESA provides the necessary support for a space qualification of the raw boards with advanced technologies.
Summary & Conclusion

● Astrium ST in Bremen is a space qualified manufacturer of PCB's and electronic equipment.

● We have already demonstrated the potential usage of new designs and modern EEE components.

● We have taken the first steps for a new generation of space computers and will continue the related qualification activities.

● Improved raw board materials, improved processing, and adapted raw PCB manufacturing technology would lead to a new functionality and quality of space products.

● We are looking forward to any development in this area.
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