Photonics Packaging for Space Environment

Presentation by

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RUAG Space, Switzerland

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RUAG Space at a glance

- Leading European space product supplier to the industry
- Eight sites in four countries (Switzerland, Sweden, Finland, Austria)
- Part of the RUAG group, which is fully owned by the Swiss state
- 1158 employees (end 2014)
- Total revenues (2014): 322 mCHF
- Headquarters: Zurich (CH)

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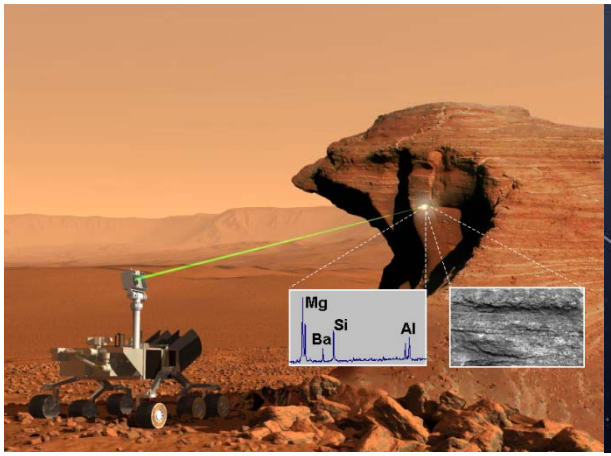
Outline

- Photonics in Space
  - Applications
  - Examples
- Technical Challenges
  - Specific requirements
  - Aspects of packages
- Technical Strategies
  - Design strategies
  - Qualification strategies
- Examples
- Conclusions

SMOS satellite, artist's view

Photonics in Space – Applications

- Scientific instruments on satellites or rovers (cameras, LIDARs, spectrometers)
- Digital optical comms (inter-satellite or satellite-to-ground)
- Signal distribution (MOEMs based switches, mixers, optocouplers, analog or digital intra-satellite comms)
- Sensing purposes (star-trackers, gyroscopes, temperature, strain…)



Spectrometer
CHEMCAM, NASA / CNES

Optical Data Comm
EDRS, ESA

LIDAR
AEOLUS, ESA

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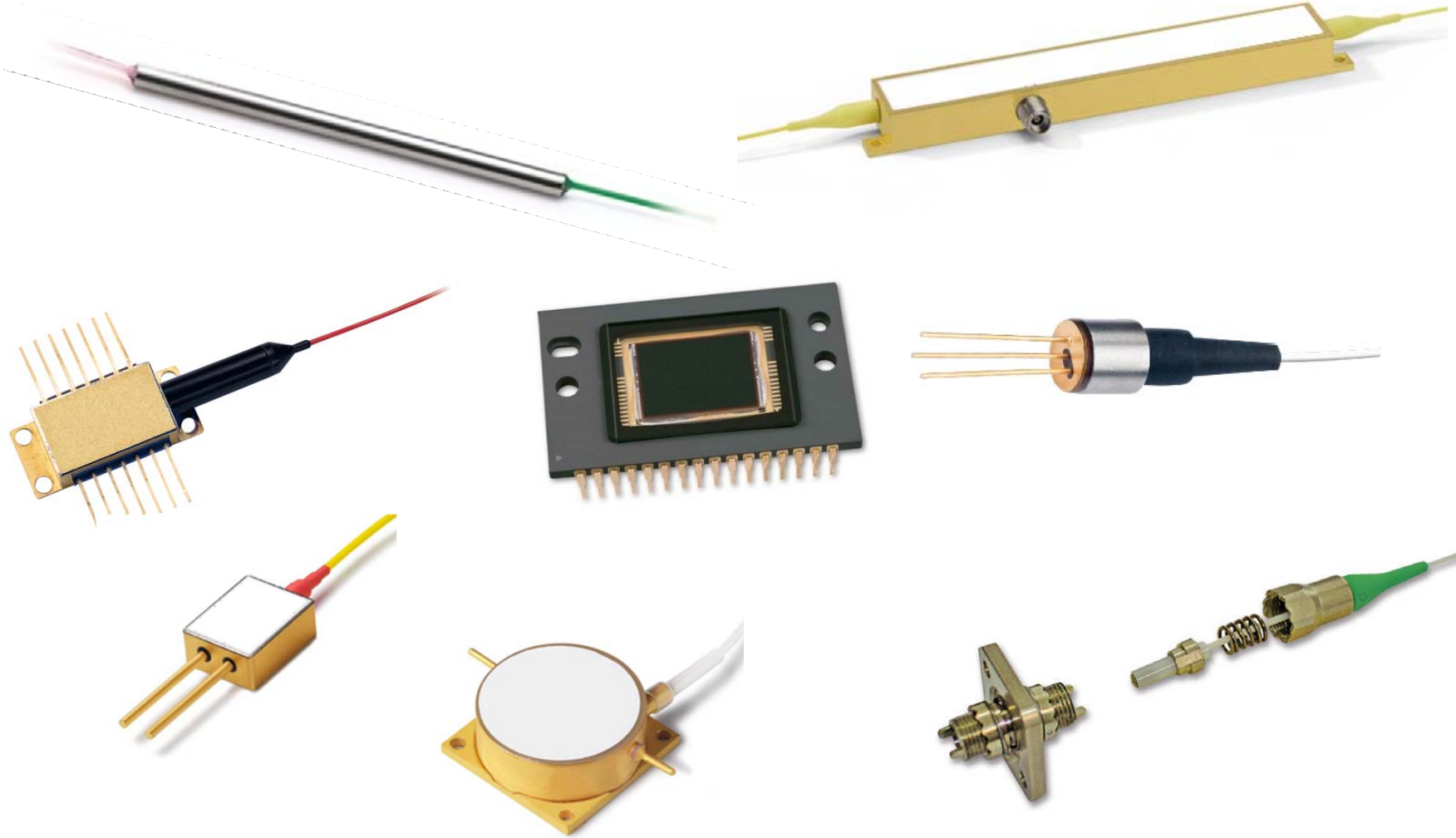
Photonics in Space – Functions of Components

All major photonic components are used or considered for use in space

Considered at RSSZ in previous or current projects:

- **Laser diodes:** High power, low power, all major pump or signal wavelengths
- **Light routing:** passive & active fibers, fiber connectors, optical switches, power/wavelength/polarization - coupler/splitter, isolators, AOMs, MZMs
- **Sensors:** CCDs, CMOSs, photodiodes, APDs

Photonics in Space – Packaging on Component Level



and many, many more

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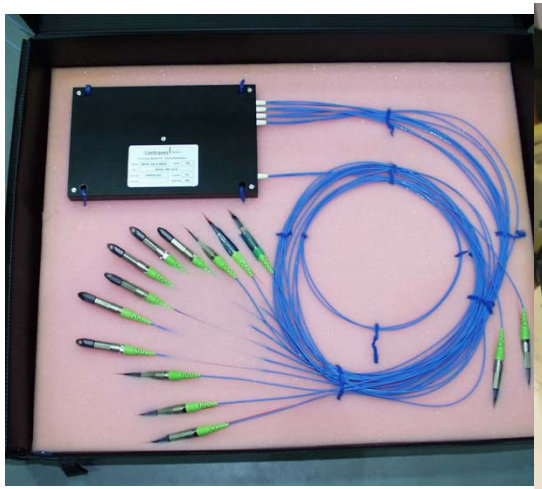
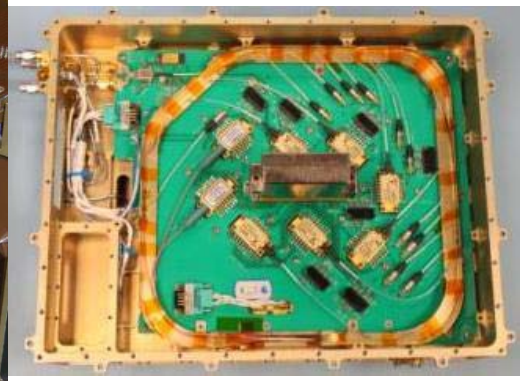
Photonics in Space – Packaging / Integration on Module Level



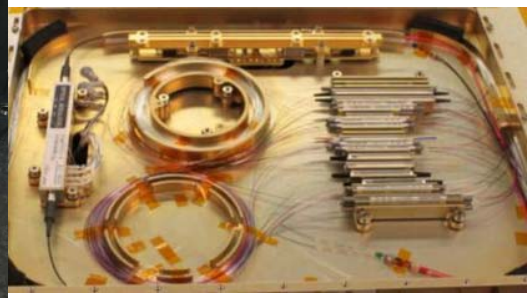
SMOS

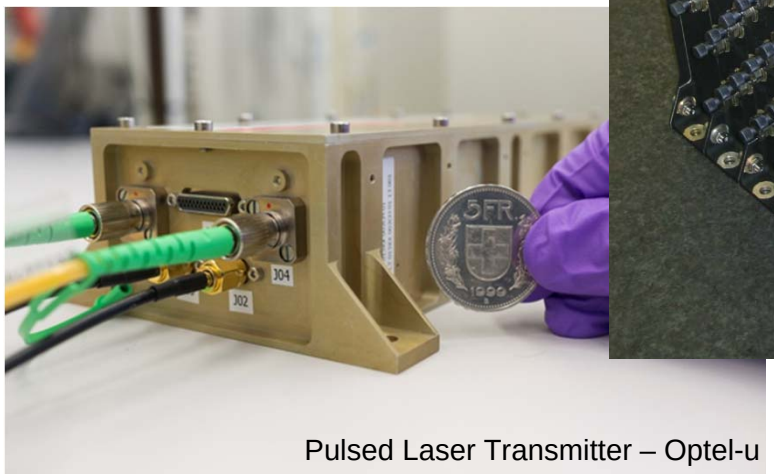
SMOS



LADEE, LLCD

NASA / MIT (picture above and below)





Pulsed Laser Transmitter – Optel-u

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Challenges for Photonics in Space – Specific Space Requirements

Launch:	Shock, vibration
Environment:	Temperatures, radiation, vacuum
Operation:	Power cycling, outgassing, reliability, lifetime

→ **requirements vary strongly** (depending on mission criticality, used launcher, flight orbit, specific accommodation on a satellite)

→ **standards** that cover the requirements of most missions without imposing excessive requirements on many missions are only feasible on a general level

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Challenges for Photonics in Space – Aspects of the Package

Package dominates the component performance in many aspects

- Shock & vibration stability
- Low thermal strain under high absolute temperatures and thermal cycling
- Hermeticity to ensure operation in vacuum
- High reliability & lifetime
- Excellent functional performance
- Low mass & volume
- Reasonable costs at manufacturing & integration

The main functional part of photonic components is often considered very suitable for space. The package makes the difference.

Technical Strategies – Design Development

RUAG Space provides instruments or sub-systems to the satellites. RUAG Space is not a component manufacturer.

→ RUAG Space applies a system engineering approach that targets on low re-engineering on component level.

- Good system design sets best trade-offs for requirements on component level (photonic, electronic and mechanic components)
- Package constraints are considered on upper level system design

- Verification by thermo-mechanical modelling and analysis
- Verification by testing on component, submodule or module level

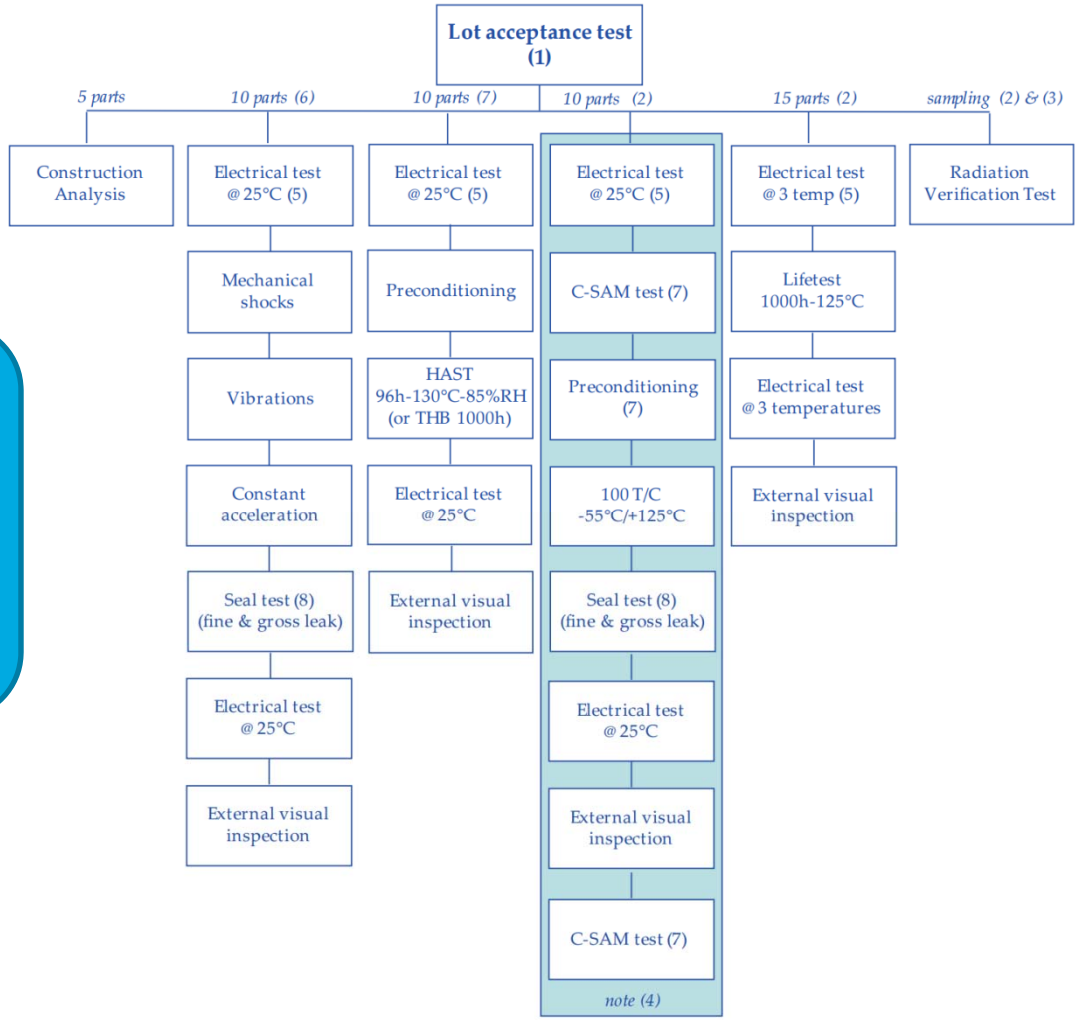
Technical Strategies – Component Qualification

Qualification campaign	Description & Intention
Component evaluation	Early partial qualification to reduce the risk of failure of a later full qualification. (Prevent expensive re-designs)
Screening	Required on all components considered for flight or qualification to remove “infant mortality.”
Qualification of a production line	Full qualification of the entire manufacturing. Only applied for high quantity components (such as standard electronic components) → **Less interesting for photonic components**
Qualification of a production lot	Qualification of a lot that was produced from absolutely equal materials and processes → **Most often applied for photonic components**

Technical Strategies – Commercial Component Qualification

Typically a lot acceptance test is the preferred choice to qualify a particular component for a specific mission.

ECSS-Q-ST-60-13C:



Tailoring needed, depending on available heritage, mission criticality, costs per item, schedule …

Technical Strategies – Commercial Component Qualification

Important tests for the package qualification for space applications

- Shock (typ. 1500g) & Vibration testing (typ. 20g, 10-2000Hz)
- Hermeticity → seal tests (gross & fine leak)
- Thermal cycling (typ. 100 cycles from between -55° C and +125 ° C)
- Highly Accelerated Stress Test (HAST)
- Particle Impact Noise Detection Test (PIND)
- Destructive physical analysis (DPA)
- Visual inspection (screen for abnormalities)
- Life test (typ. 1000h at > 125° C)

Space industry has well established standards for compliance to its harsh environment (see **ECSS-Q-ST-60-13C** / MIL-STD-883).

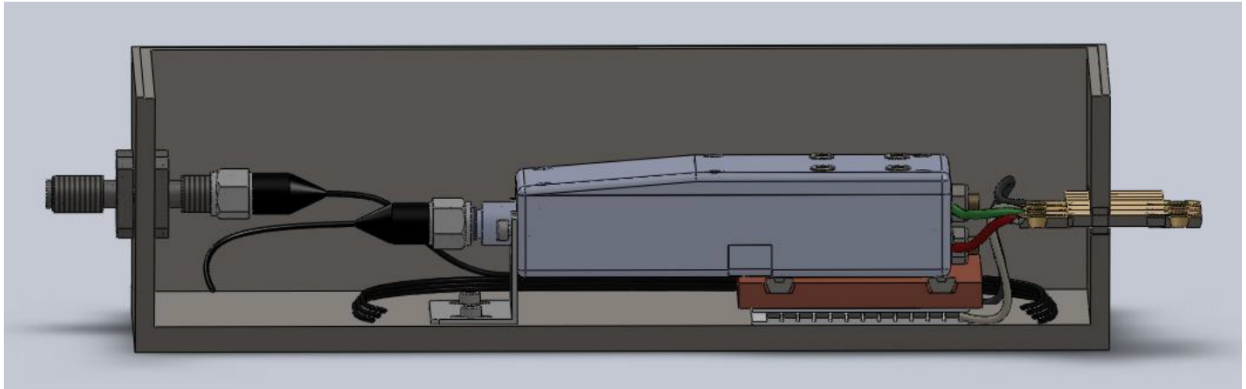
Space industry has well established test facilities and testing expertise.

Detailed Examples – Prototype Study
High Power Pump Laser Diode

Commercial device could fulfill performance requirements with minor modifications, however hermetic sealing required.

Hermetic package built around a pump diode.

- High power multimode fiber feed-through
- Electrical feed through
- Peltier cooler included

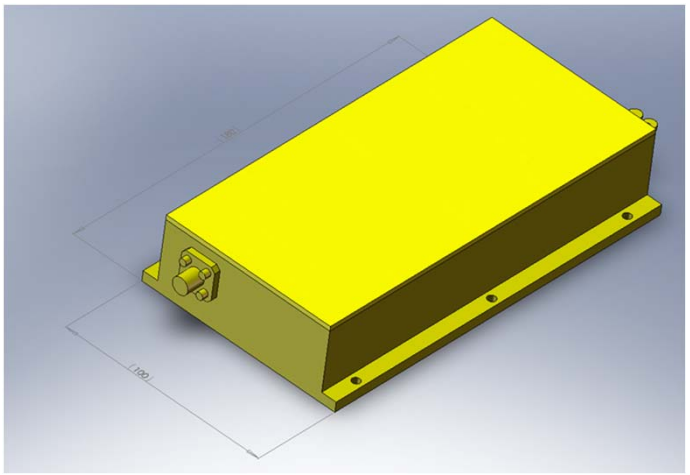


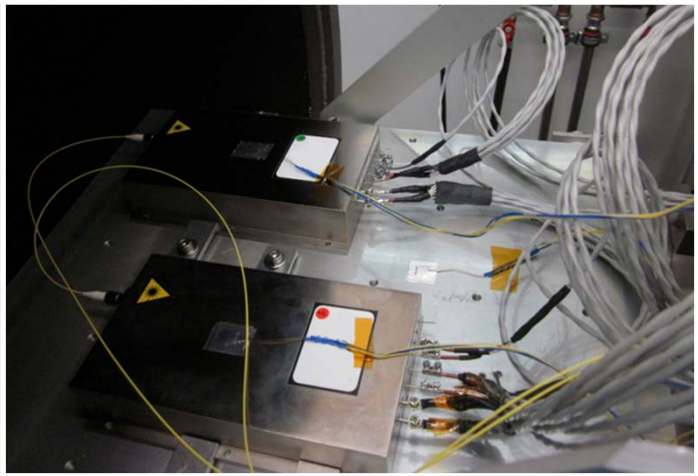
Evaluation test campaign performed.

Detailed Examples – Prototype Study High Power Pump Laser Diode

- Devices passed 500h accelerated testing in vacuum
- Devices passed thermal cycling in vacuum

Package fulfilled all functional requirements





Package adds significant volume and weight

→ For a Flight Unit, further optimizations are required

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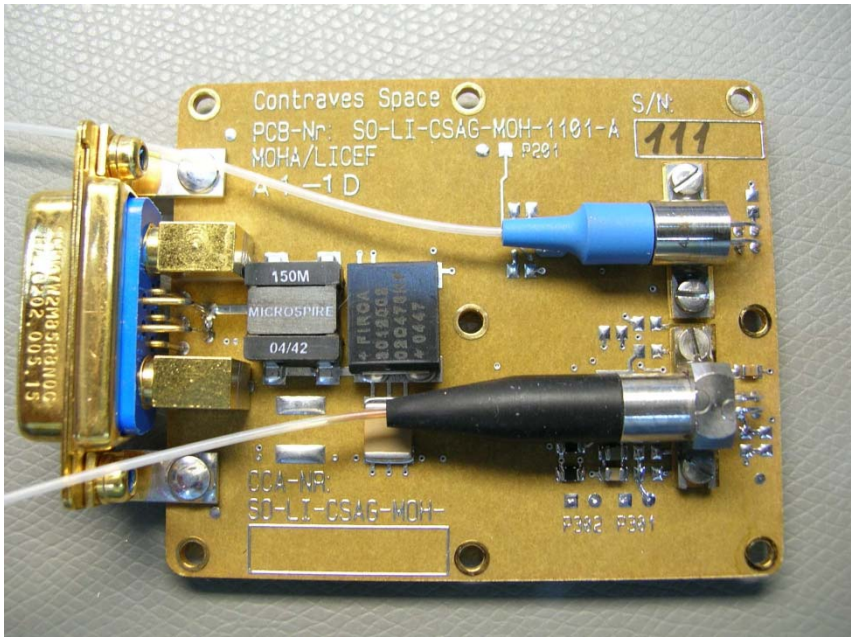
Detailed Examples – SMOS Satellite
RF over fiber network

SMOS Satellite, Main Instrument: MIRAS: Synthetic Aperture Radar

Demanding phase stability required for clock and signal distribution between central unit and 69 individual microwave receivers.

Commercial photonic components used:

- 1300nm laser diodes
- InGaAs photodiodes
- Couplers / Splitters
- Many fibers & connectors
  (> 180 patchcords)



Fibre Optics in the SMOS Mission, K. Kudielka et al., ICSO 2010, Rhodes, Greece

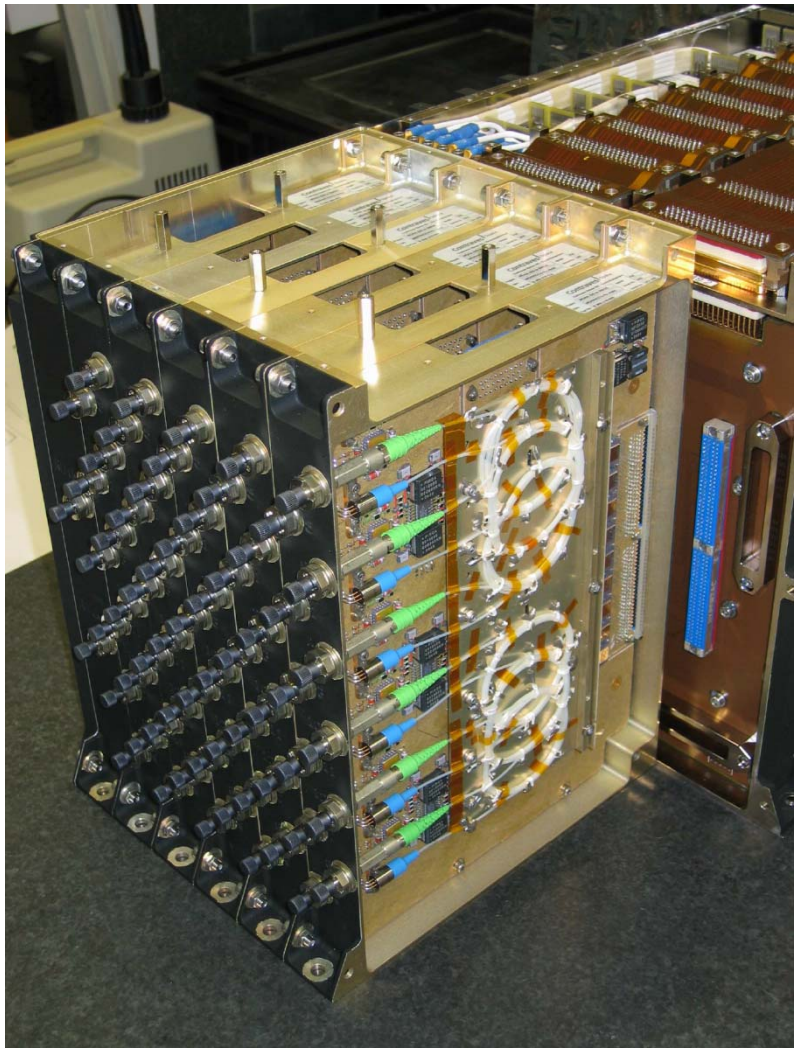
Detailed Examples – SMOS Satellite
RF over fiber network

Qualification program was successfully completed.

Performance 10x better than required.

Satellite since 2009 fully functional in orbit.

Already passed twice its nominal life time without any defects.



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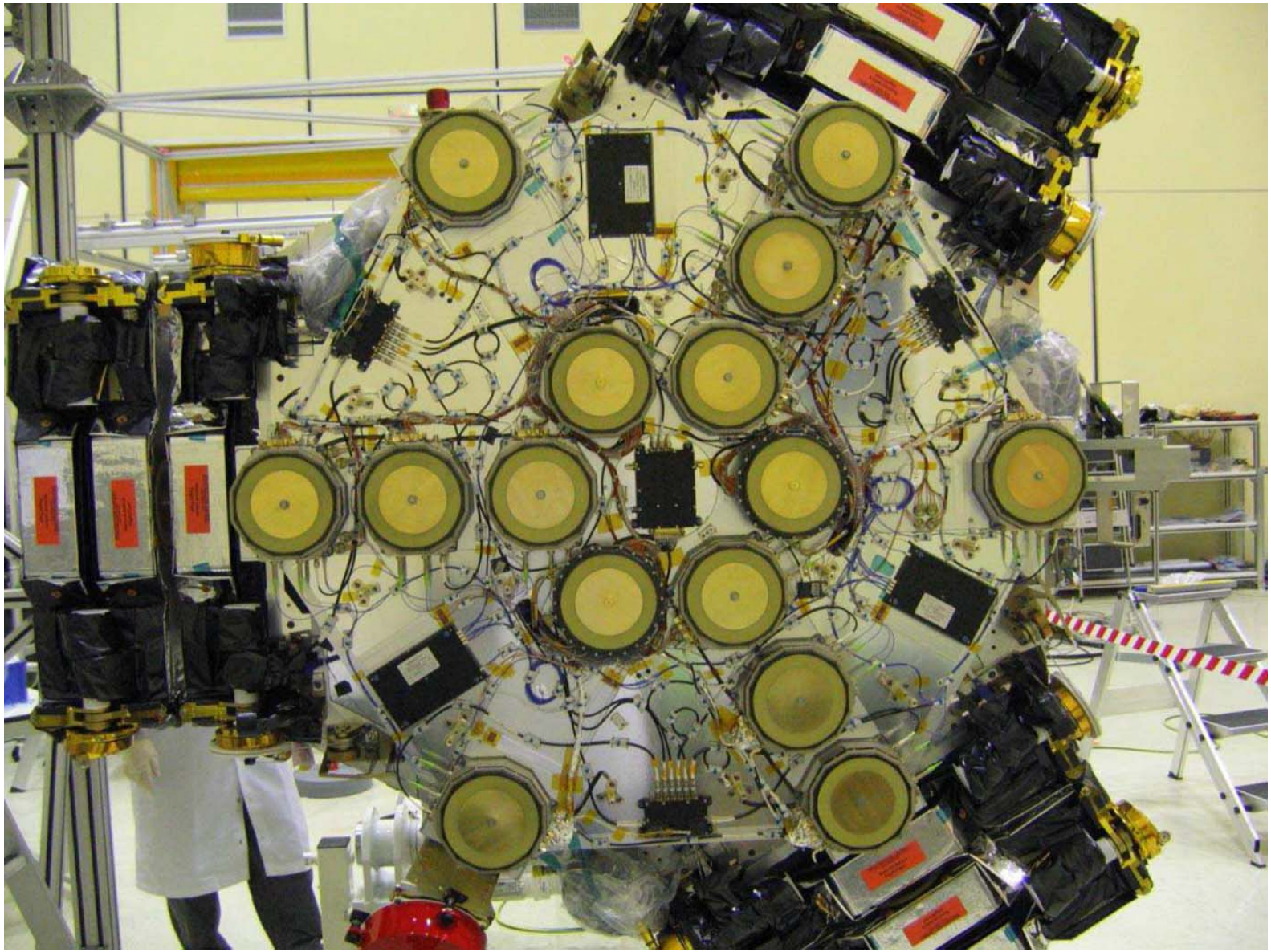
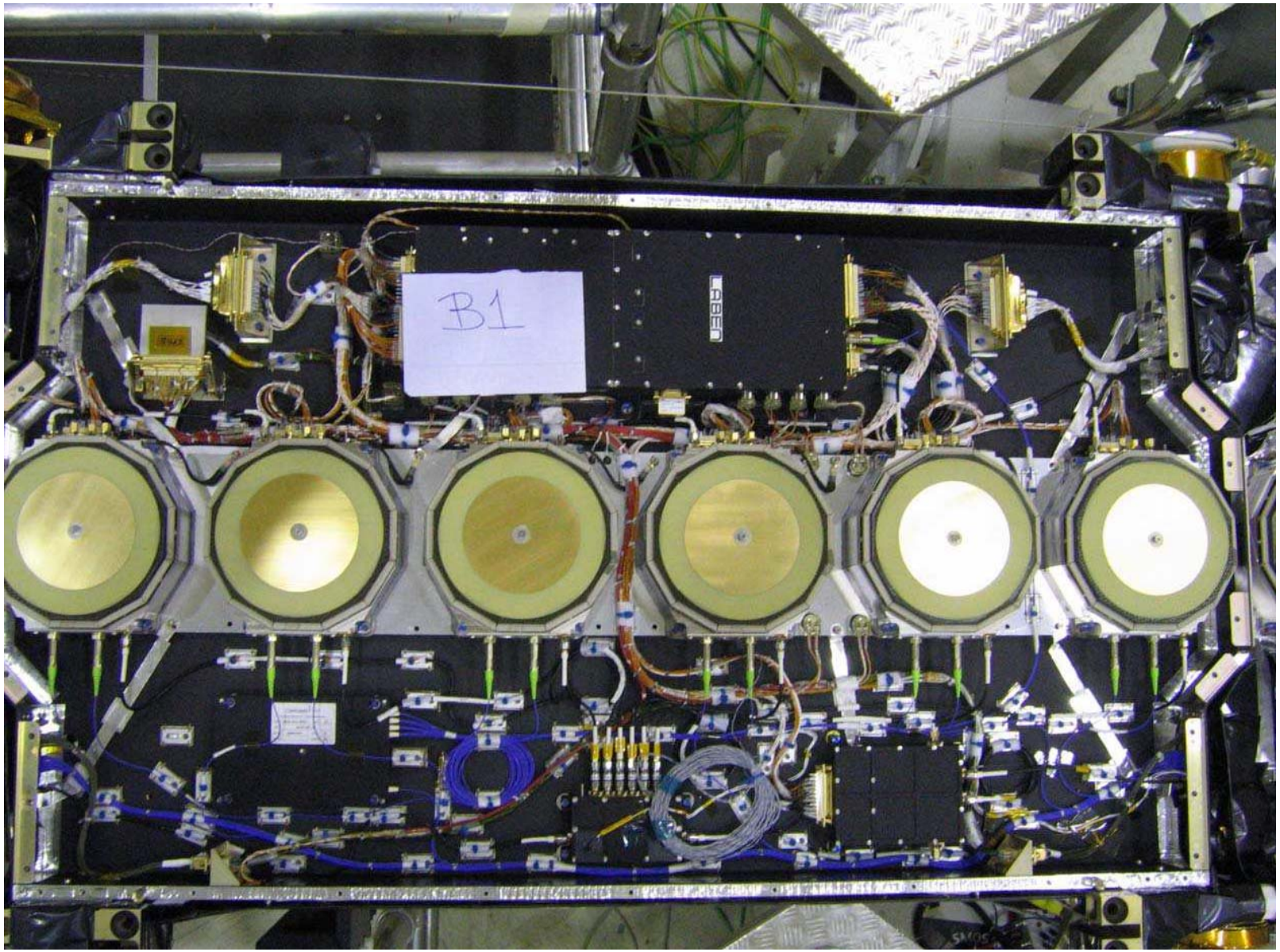


SMOS Satellite, Credits: ESA



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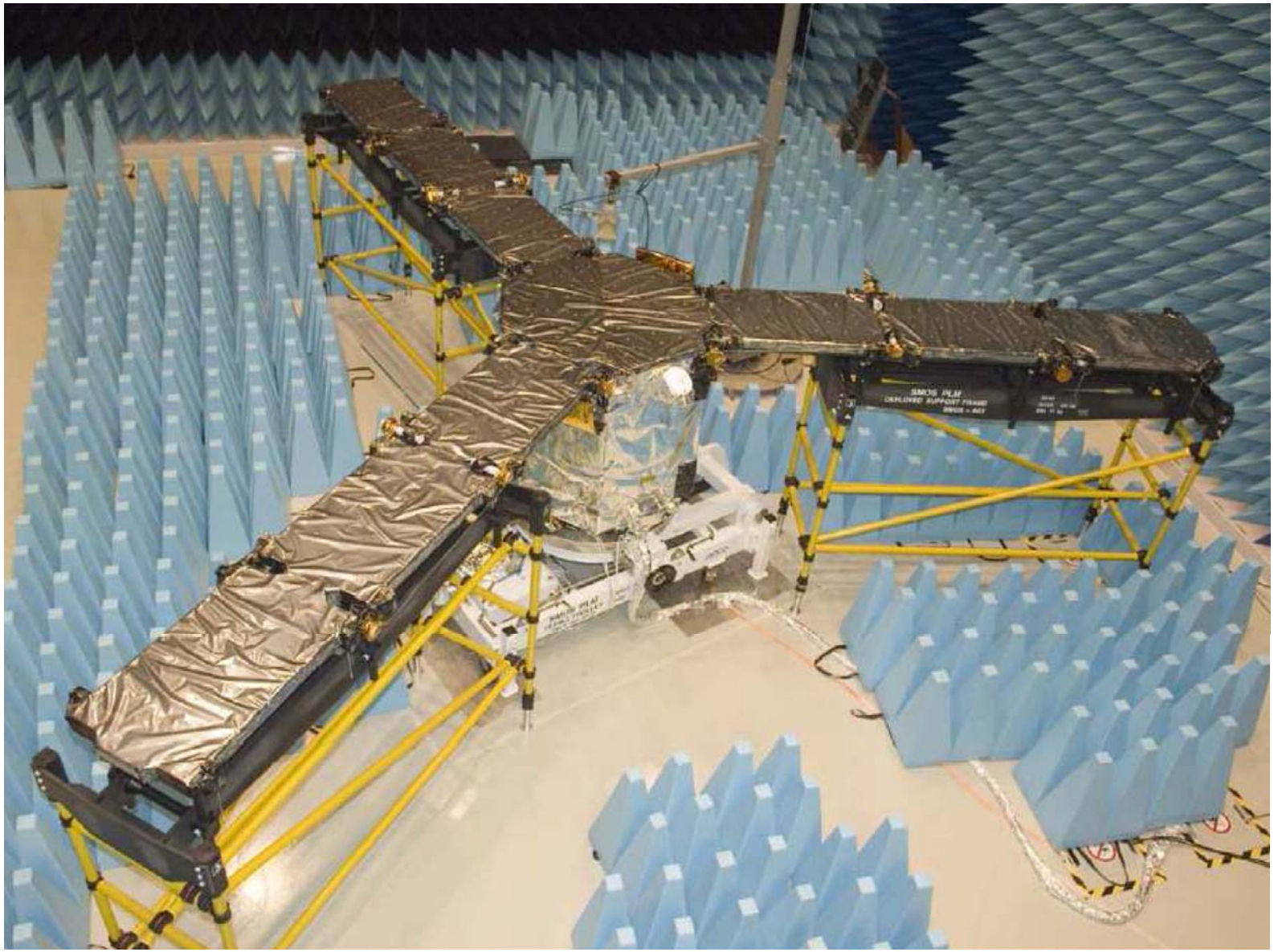

SMOS Satellite, Credits: ESA

Photonics in Space – Market Requirements

Component manufacturers should consider the following aspects

- Open communication to provide understanding on specific performance characteristics, design and manufacturing
- Flexible manufacturing: possibility to apply specific modifications
- Keeping close track of reliability and test levels that were reached or failed
- Interest to raise the robustness of components and to verify so ideally conduct qualification tests on own responsibility → direct commitment to compliance for harsh environments
- Master high quality levels and long-term products

Space can be a very challenging market.

Photonics in Space – Industrial challenges

Opportunities for manufacturers and photonic components.

- Proof of compliance to very harsh environments
- Demonstrated compliance to high PA standards
- Strengthened test and reliability data
- Development projects are eligible for ESA funding / co-funding

→ overcome limited support for small volume markets

Space can be a very challenging market.
But it provides exceptional opportunities and benefits as well.

Photonics in Space – Conclusions

- Tremendous improvements in performance and availability of photonic components has also increased the interest in photonics for space
- Photonics allow new or higher performing instruments
- Photonic solutions are considered or to be used in many missions
- Challenges have to be addressed but successful experiences have been made at RSSZ

Photonic components and their packages are increasingly important for space flight.

Thank you for your attention!

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