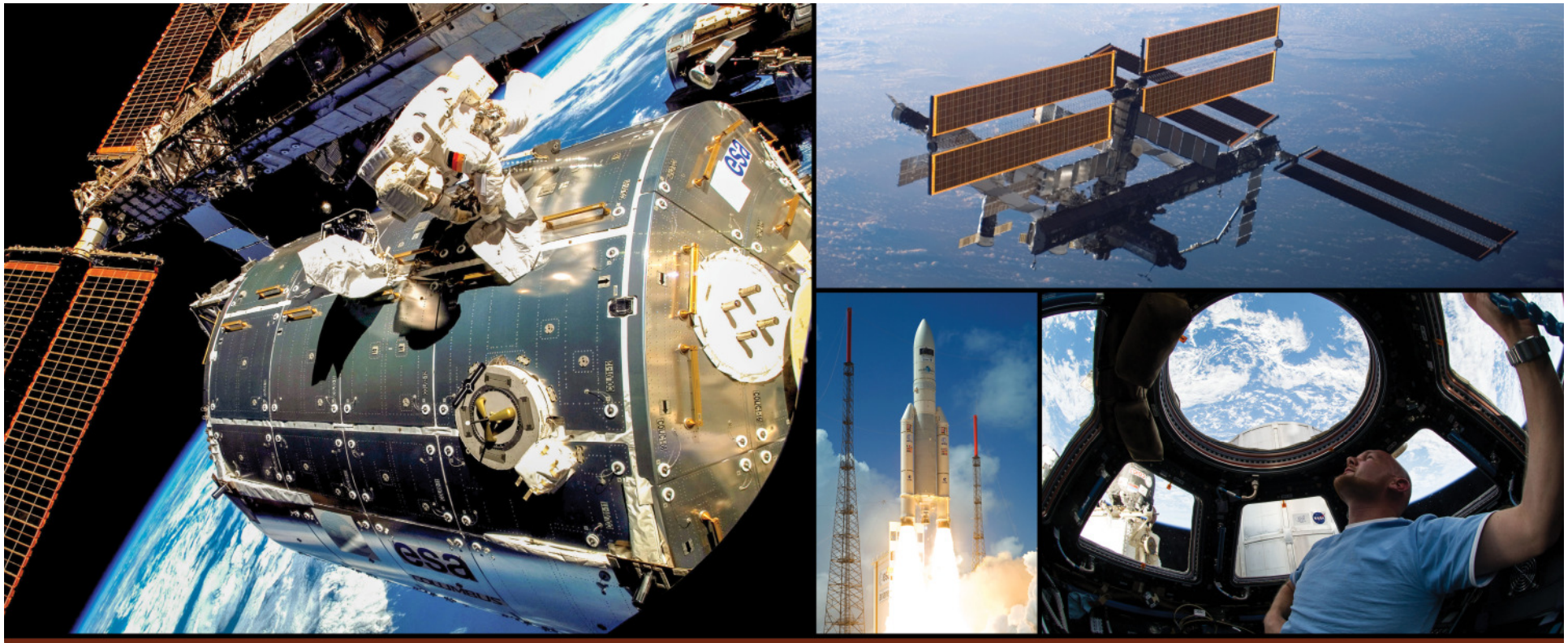

Ruggedized Photonic Components for Aerospace Applications

Dr Ron Logan, Davinder Basuita

Outline

- Problem
  - Space environmental requirements for photonic components in fiber-optic data-transmission applications are difficult to meet
- Solution
  - Ruggedized optical transceivers with high radiation tolerance
- Approach
  - Apply rigorous aerospace design & manufacturing processes
- Results
  - Performance and qualification data
- Summary and conclusions

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Requirements for Aerospace Photonic Components

- More severe environments than for commercial photonic components
  - Operating temperature range: -40C to +85C or wider
  - Storage temperature: -55C to +125C, 1000 cycles
  - High levels of mechanical shock and vibration while operating
  - High humidity environments (pre-launch)
  - Operation in vacuum (outgassing)
  - Radiation: gamma, neutron / proton, heavy ion SEE
- Commercial manufacturers do not address these requirements very well
  - Do not have required capabilities, engineering expertise, qualification data
  - Quantities are low (10's-100's) compared to commercial datacom/telecom (millions)
  - Program lifecycles are very long therefore obsolescence is an issue

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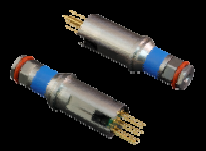
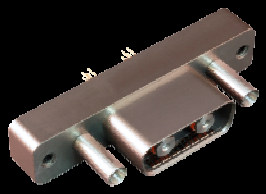
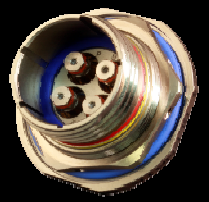
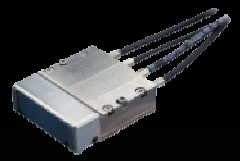
Solution: Radiation-Tolerant Aerospace Transceivers

- Apply MIL / aerospace design and manufacturing practices
  - Use best-available COTS photonic and electronic device technology
  - Ruggedize the packaging
  - Manage parts obsolescence issues
- "Form follows function"
  - Commercial standard form-factors are not required for aerospace
  - Design products to survive the environment
  - Select components with inherently high radiation tolerance
  - Simple design with no microprocessors or EEPROMs
  - GaAs lasers / photodiodes; SiGe / CMOS driver ICs
- Maintain electrical and optical interoperability with commercial products
  - Eases integration, testing









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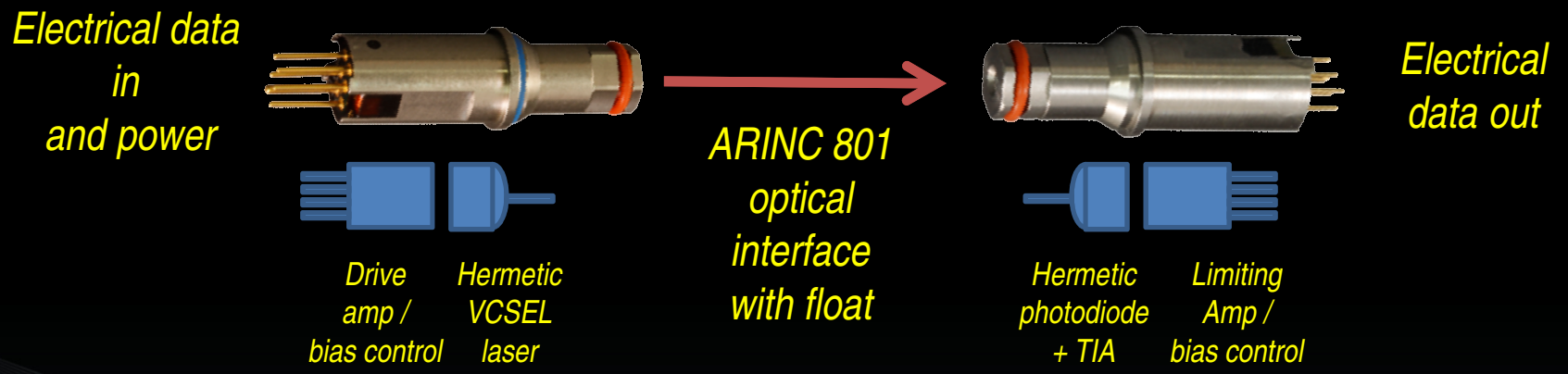
Size #8 Opto-Electronic Contact

- Fiber-Optic transmitter and receiver in a size #8 contact
- Simplest possible design
  - No microprocessor or EEPROMs
  - Hermetic GaAs laser and photodiode; non-hermetic SiGe / CMOS drive and limiting amps



Patent Pending

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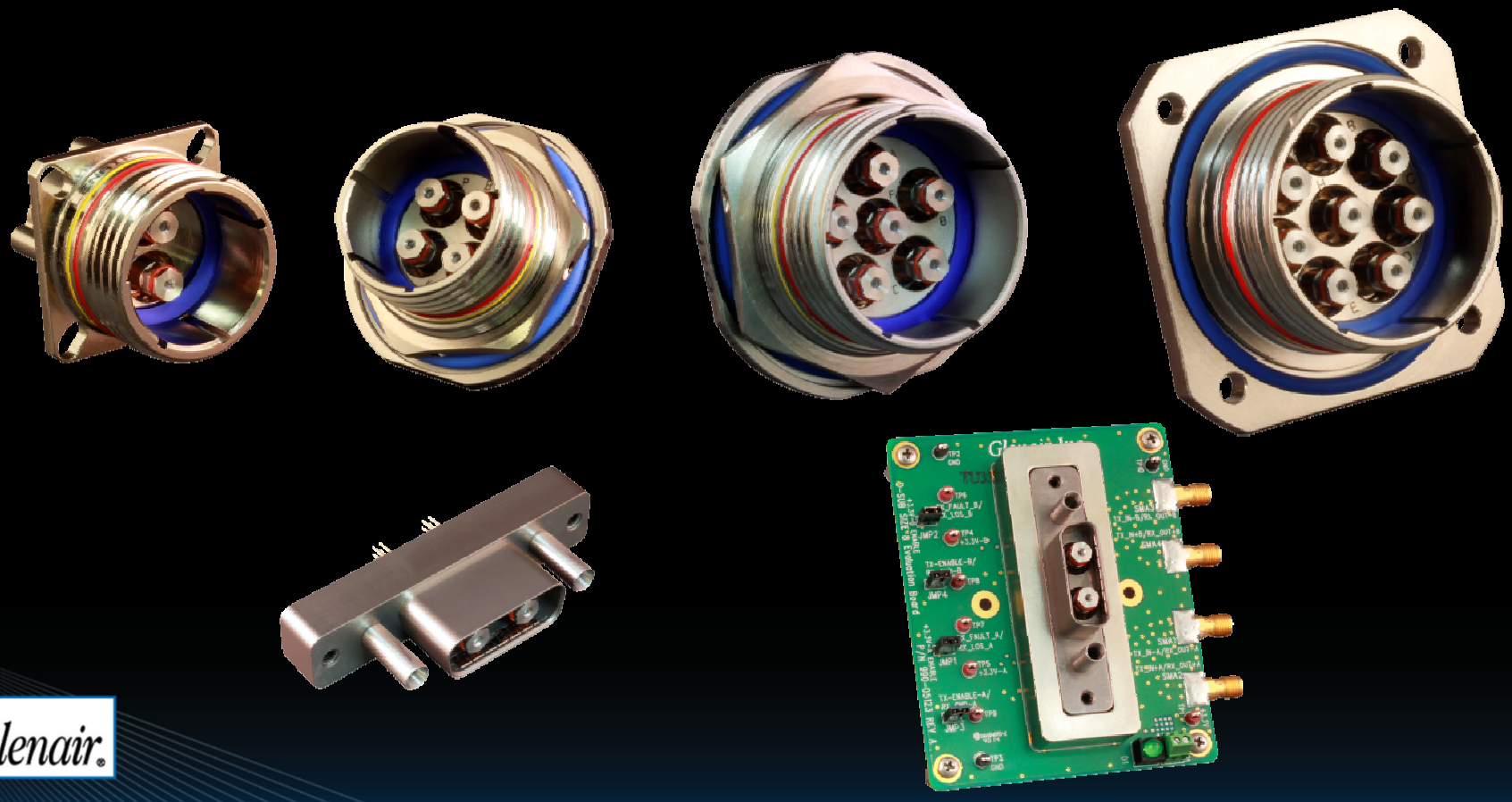
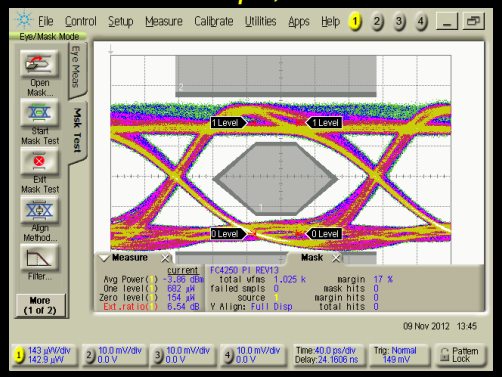
Size #8 Opto-Electronic Contacts in Aerospace-Grade Connectors

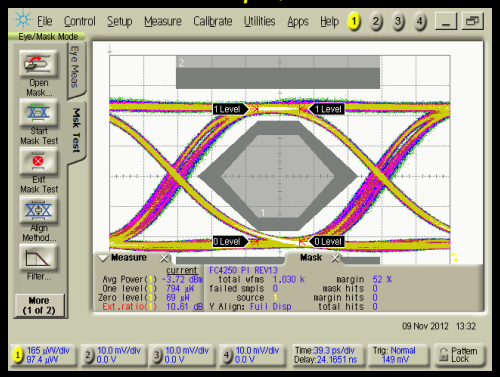


Size #8 Optoelectronic Contacts 100% Production Test

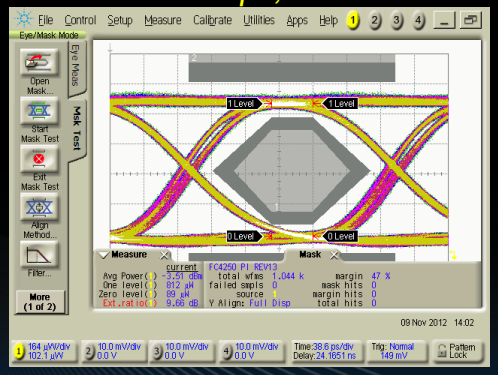
4.25 Gbps, -40C



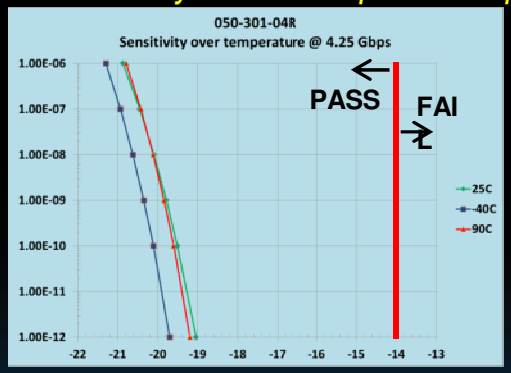
4.25 Gbps, +25C



4.25 Gbps, +90C



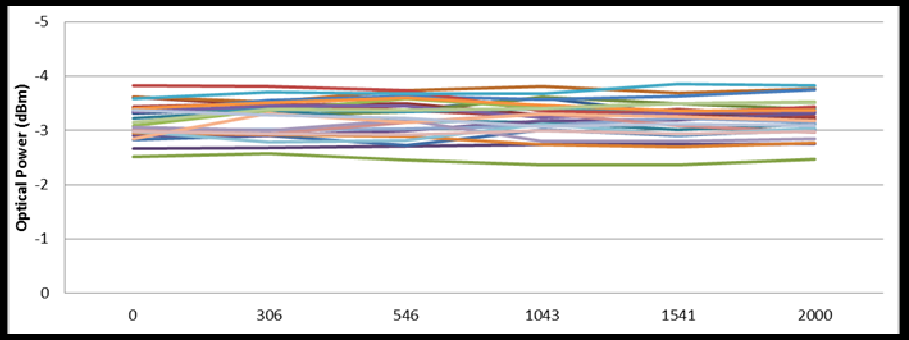
RX Sensitivity @ 4.25 Gbps vs Temp

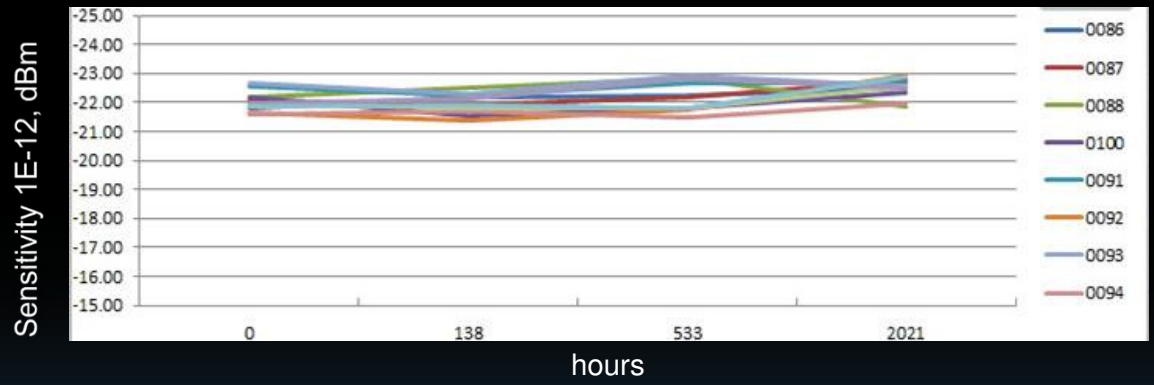


Automated Temp Cycle Test System

Accelerated Aging – Size 8 Optoelectronic Contacts

- Output power and receiver sensitivity over 2000 hours at 85C





Results Glenair 050-301

Technische Universität München

Experiment in gamma cell II

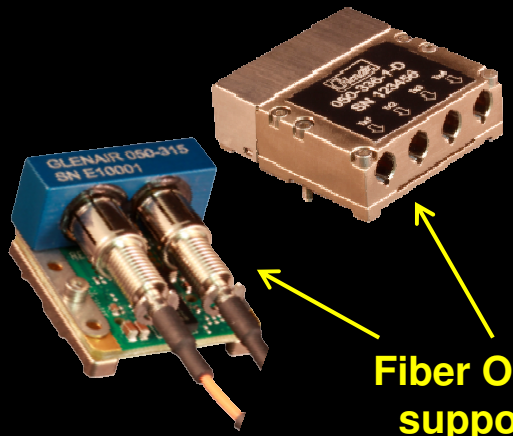
	Dose(krad)	Time(min)	Accumulated Dose(krad)	Status
Step 1	168.3	187	168.3	✓

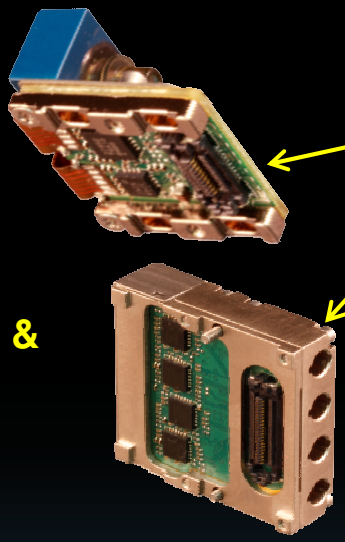
Neutron irradiation at room temperature 25°C

	Dose(neutron/cm^{-2})	Time(s) + 13s[1]	Accumulated Dose	Errors
Step 1	$62.5 \cdot 10^{10}$	2718 + 13	$62.5 \cdot 10^{10}$	No
Step 2	$62.5 \cdot 10^{10}$	2718 + 13	$125 \cdot 10^{10}$	No
Step 3	$125 \cdot 10^{10}$	5435 + 13	$250 \cdot 10^{10}$	No

Glenair Radiation-Tolerant Transceivers

- Same circuitry and photonics as rad-tolerant Size #8 optoelectronic contacts
- No microprocessors or EEPROMs
- Selected for use in particle physics detector systems





Fiber Optic connectors support high vibration & shock applications

850nm GaAs hermetic VCSEL, PIN-TIAs

30Gbps High Speed electrical connector retained with 4 mounting screws to support high Vibration & Shock Applications

Easily installed and replaceable

Glenair Transceiver features compared to COTS

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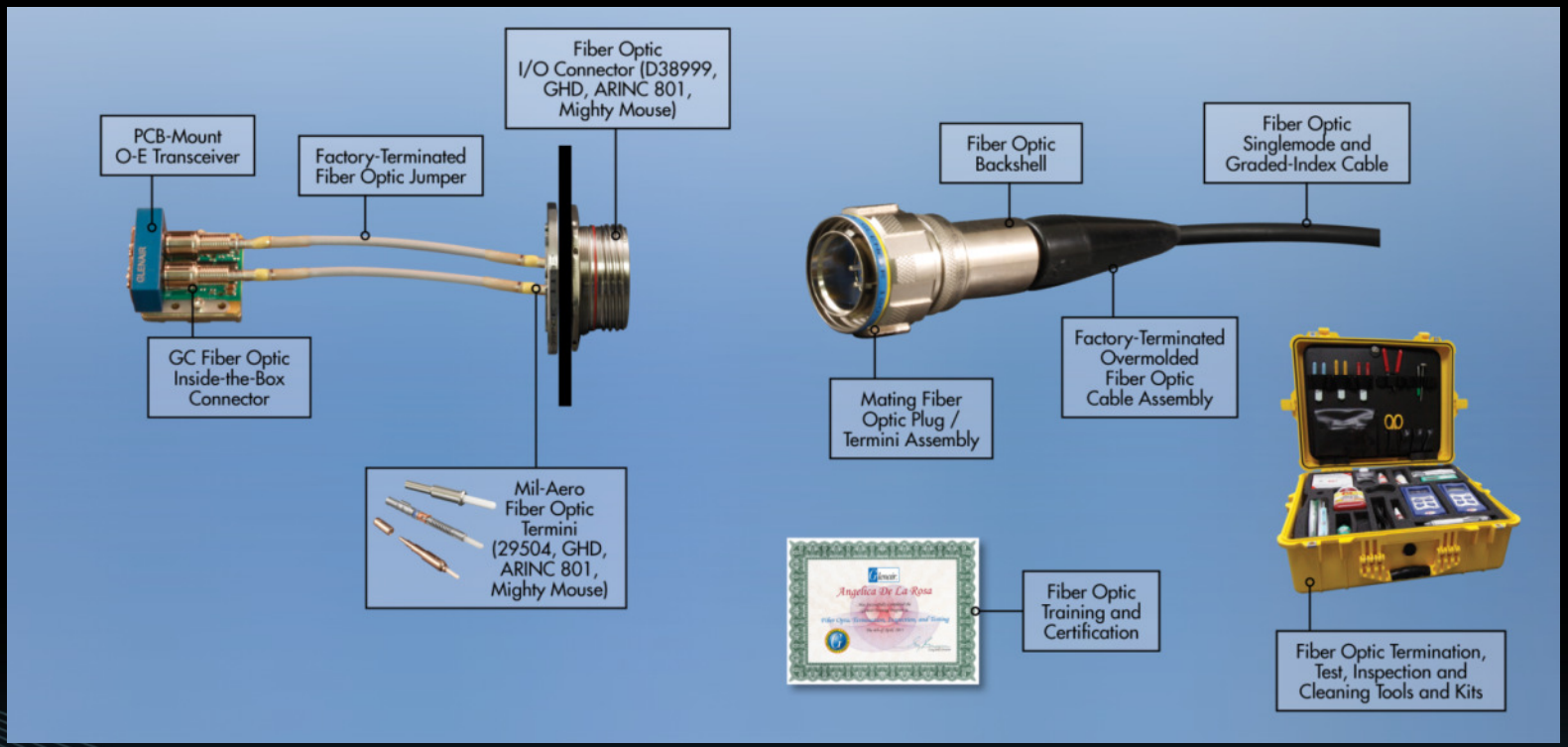
SFP

- Aerospace XCVR
  - Secure mounting to PCB preferred
  - Rugged optical and electrical connector
  - Compatible with SFF I^2C standard
- COTS SFP, SFP+, QSFP+, etc.
  - Pluggable, commercial grade connectors
  - Not ruggedized for vibration or temperature – some non-hermetic
  - Larger footprints
  - Off-shore mfg and firmware loading
  - SFF XCVRs require soldering to PCB

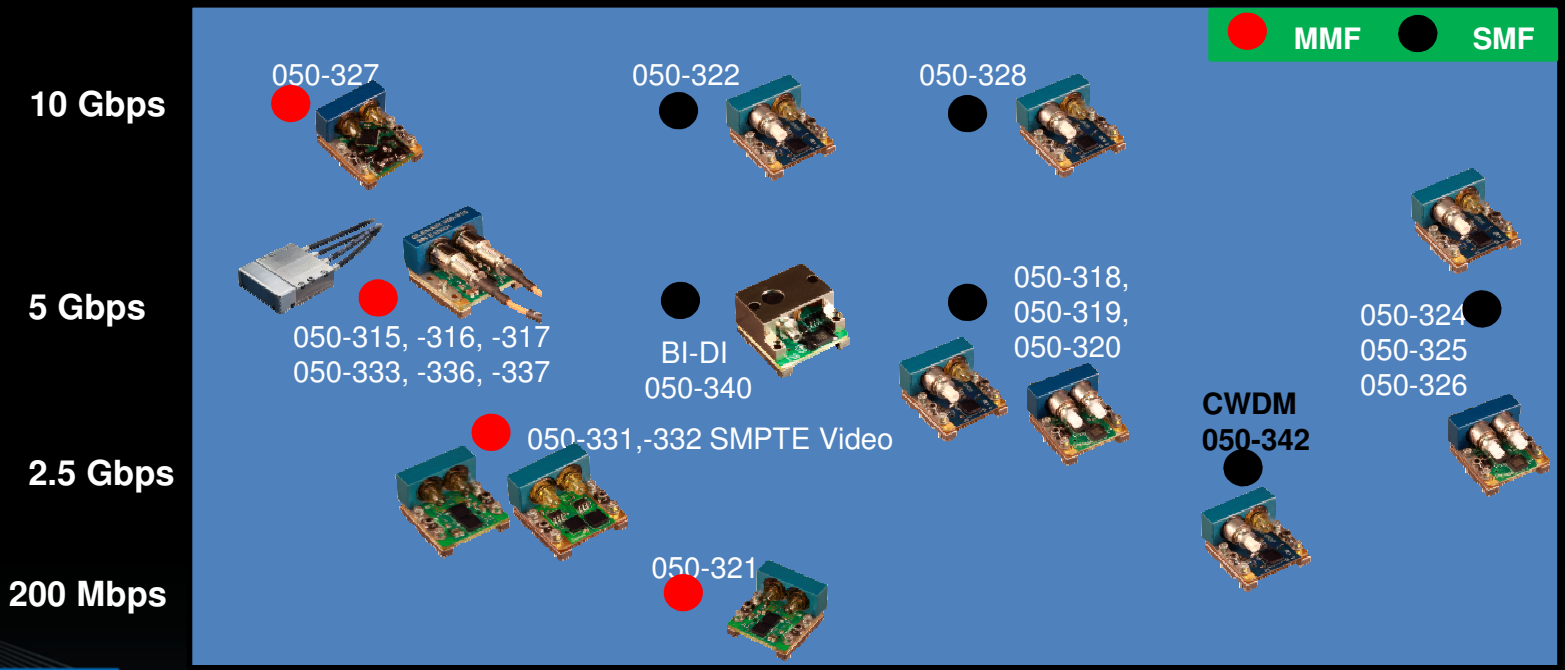
Typical Implementation of Aerospace Transceiver

- PCB-mounted XCVR to panel connector to aerospace fiber plant



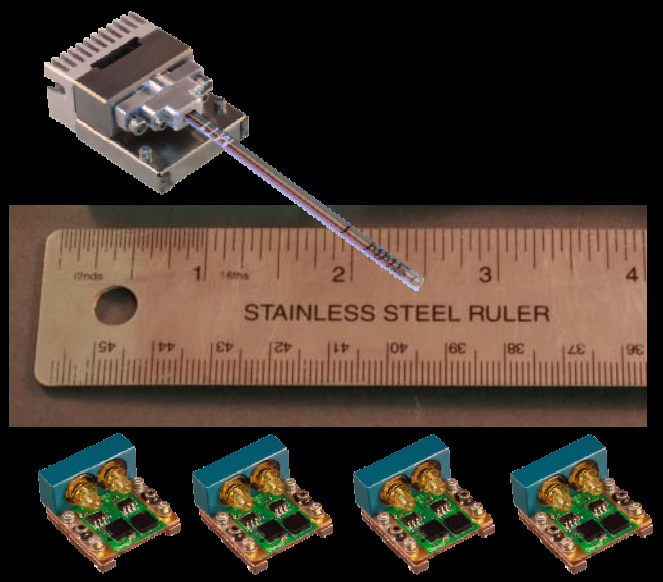
PCB-Mount Transceivers

Wide range of digital and video signal types supported



Parallel Optical Transmitter

- In final stage development
- 850nm GaAs laser and photodiode arrays and drive electronics in a hermetically-sealed hybrid package
- Electrical and optical MT removable connectors – no soldering required
- High-speed volume robotic assembly for die-attach / pick-place / wirebonding
  - Low cost and high-reliability



Replaces four 10G XCVRs

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Quality System, Design and Production Environment

- AS9102C quality system
- ANSI 2020 ESD-controlled manufacturing and inventory facilities
- IPC-610 certification of all operators
- NADCAP planned 1H'16

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Engineering Design Elements

- Design features to enable operation in rugged environment
- Parts selection, qualification and source control
- Documentation and control of manufacturing process
- MTBF calculations based on MIL-HDBK-217F

Manufacturing Methodology

- Use of qualified / audited component suppliers
- Control of all design information, supply chain, assembly procedures, test software
- IPC Class 2/3 PCBAs with conformal coating
- Operator training
- 100% Production Testing to weed out early failures
  - 100% thermal cycling, -40 to +85C, 10 cycles
  - 100% operating burn-in at 85C
  - 100% operational test over temperature -40C to +85C
- Computerized database of all production test data
  - Monitor trends in data to spot potential problems
- Over 15,000 opto-electronic transceivers produced to date

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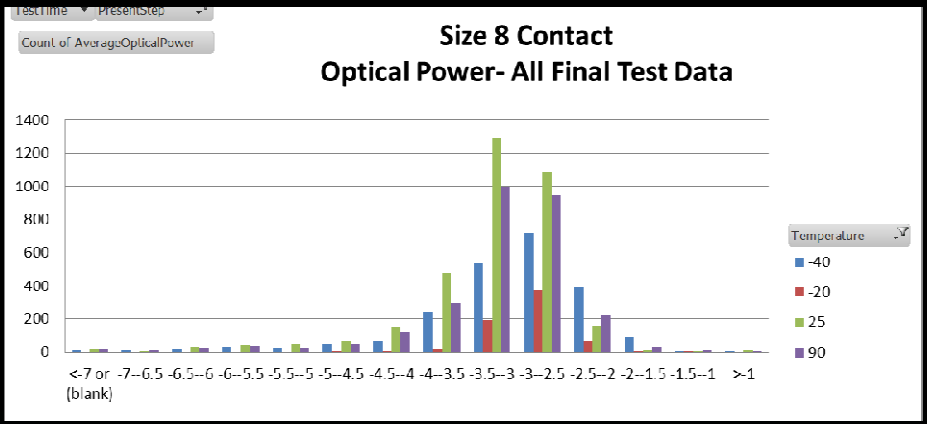
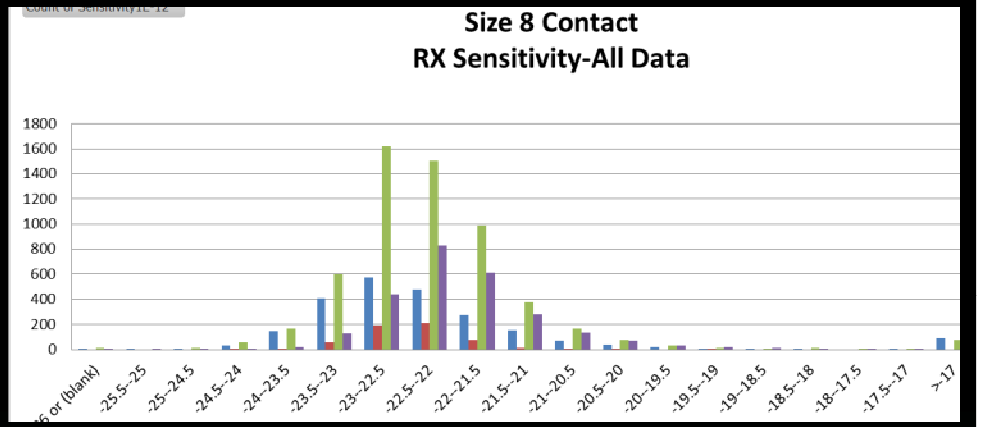
Size #8 Opto-Electronic Contact Production Data

- Production data by serial number on every part
- >10K parts data collected to date
- Continuously monitor data trends to identify potential problems early



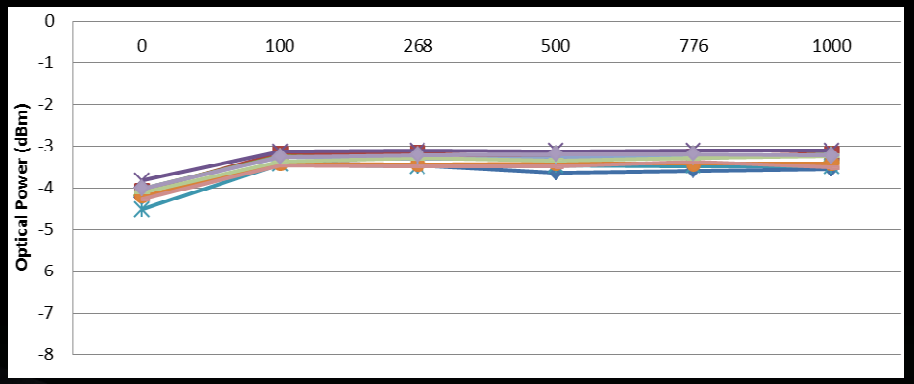


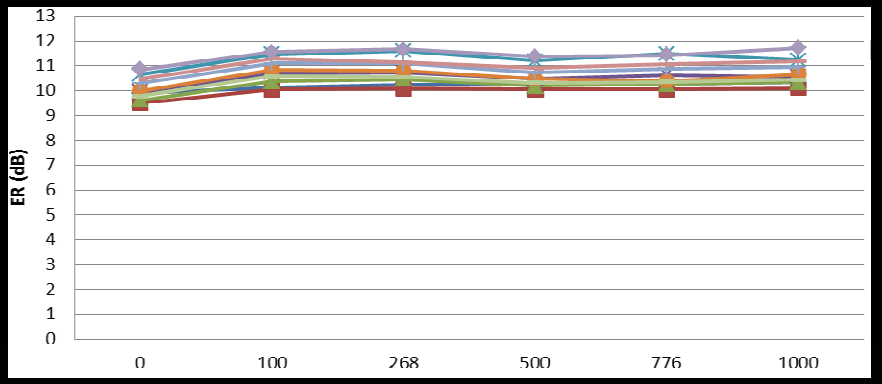
Qualification Testing

- Qual testing of parts produced under stable and controlled manufacturing processes
  - Qualify the Process and the Product
  - Continuous qualification testing as new products are introduced
- Qualification testing driven by customer requirements
- Thermal cycling, mechanical vibration / shock, high-temp operation, altitude, ESD, EMI/EMC, humidity, radiation

5.0 Gbps Transceiver - 1000 Temperature Cycles -55C to +125C

- Optical Output Power and extinction ratio





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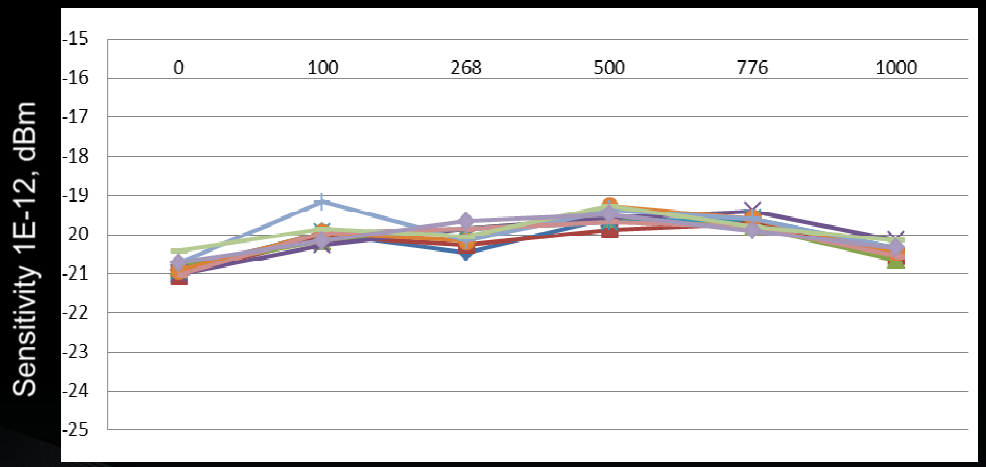
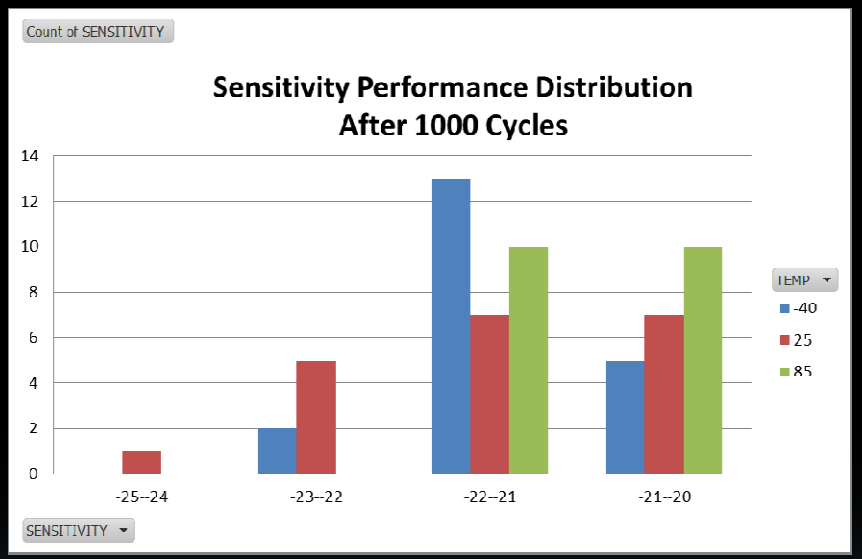
5.0 Gbps Transceiver - 1000 Temperature Cycles -55C to +125C

- Receiver sensitivity at 4.25 Gbps





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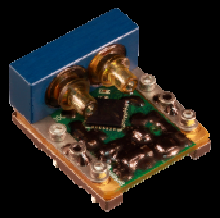
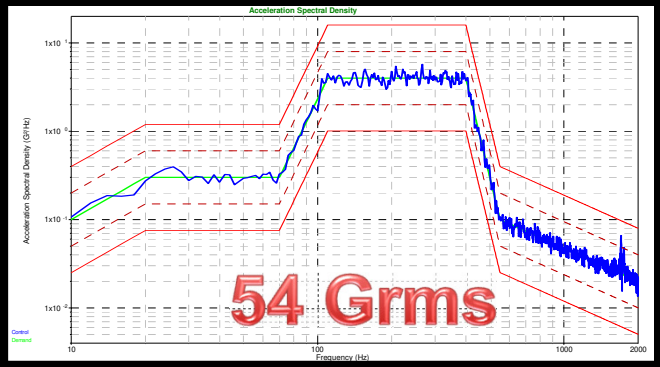
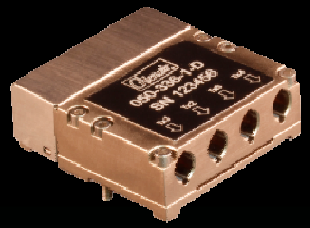
5.0 & 10.0 Gbps Transceiver Modules - Operational Vibration & Shock

- Random vibration, operational
  - 38grms 2 hours per axis
  - 54Grms 2 hours per axis
- Operational shock
- BIT error free

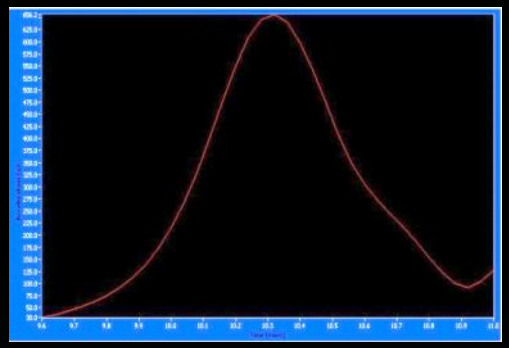






Shock Test Levels					
X-Axis		Y-Axis		Z- Axis	
Shock (G)	Time (ms)	Shock (G)	Time (ms)	Shock (G)	Time (ms)
180	1.4	180	1.4	650	0.9
78	12	78	12	55	40

10 Shock pulses applied to each axis,
5 shocks positive & 5 shocks negative



650G Shock

Summary and Conclusions

- Glenair transceivers are employed in a wide range of military aircraft applications
  - AS9102C manufacturing facility
  - Multiple versions for data / video up to 10 Gbps, SM & MM
- Radiation-tolerant transceivers
  - Simple 5 Gbps hermetic GaAs / SiGe / CMOS design
  - No microprocessors or EEPROMs
  - 165 Krad Gamma and 2.5x10E12/cm^2 neutrons
  - Heavy ion testing still required and planned
- Hermetic 4x10G optical transceiver in development
- Topics for further discussion
  - Hermetic vs. non-hermetic
  - MIL-PRF-38534 requirements
  - Systems requirements (SpaceFibre, other protocols?)
  - Opportunities for heavy ion testing or space flight insertion
  - Collaboration opportunities

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