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Space Passive Component Days 2016

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Connector Press-Fit Technology for Space-Flight Applications

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50 years
1966 - 2016

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Presentation outline

1- Introduction

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1

INTRODUCTION

In 2015 CNES and Positronic started discussions regarding the suitability of press-fit technology for space-flight applications.

Since Positronic’s press-fit technology has been already adopted by some users for space and aerospace applications, the subject became interesting enough to initiate performance testing to ECSS requirements in order to determine if press-fit has merit to be considered for future space-flight specification.

This presentation introduces press-fit technology to the audience, describes the testing performed and outlines the conclusions and future road-map for this technology.

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1.1 Advancement of press-fit technology to space-flight

Why is it inevitable that space-flight specifications will adopt new technologies such as press-fit?

- Trends show increased interest in cost reduction without sacrificing reliability of space-flight systems performance.
- The space industry is becoming more commercialized than ever: the next decade will see the greatest numbers of commercial satellites ever launched.
- Commercial missions are focused on economic considerations in all areas and will push innovation driven by cost-cutting.

Therefore, the trend of adopting proven technology from scientific missions to commercial missions will reverse and in the years to come scientific missions will accept new technology based on heritage acquired from commercial missions with the objective to improve competitiveness.

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1.2

Possible trends to improve competitiveness

To have components that perform better

- Yes but connectors performance satisfy the majority of space-flight application requirements

To have lighter components

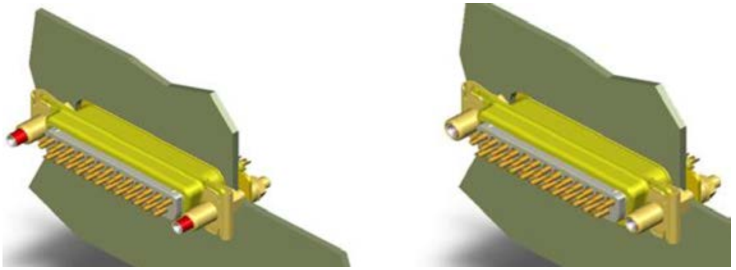
- Yes but most of the time lighter means more expensive

To have cheaper components

- Yes it is a current trend to use lower cost components (for constellation applications mainly) but it also implies to accept lower quality

To have components enabling faster integration time

- Yes it also a current trend (2 examples : fast-locking screw lock, SMP-lock connector)



Connectors being the only components manually mounted on PCB, developing a connector that can be automatically or semi-automatically mounted on PCB is of prime interest

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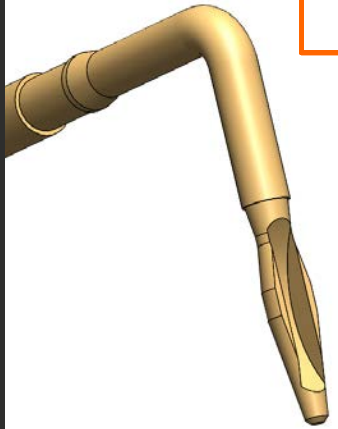
1.3 Contact termination types

Surface mount connectors can be automatically mounted on PCBs

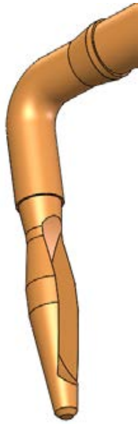
- Yes this technology is part of a CNES ongoing study to evaluate SMT connectors

Press-fit termination connectors can be semi-automatically mounted on PCBs

- Yes this technology is the subject of today's presentation



Are Press-Fit contacts suitable for space-flight applications?

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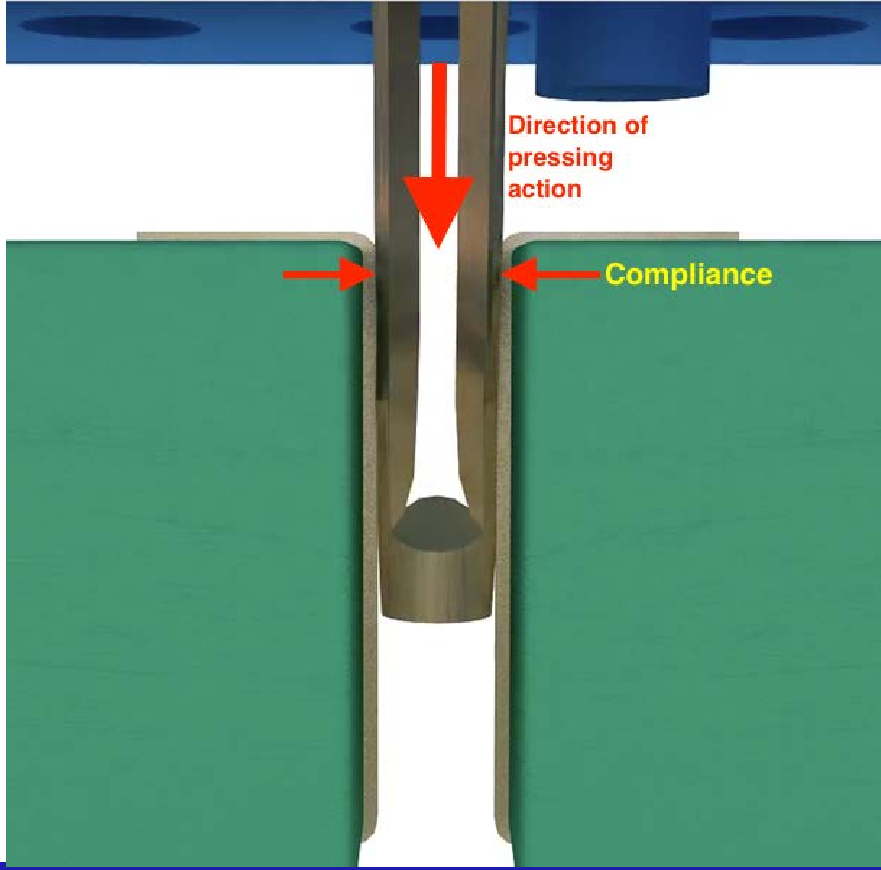
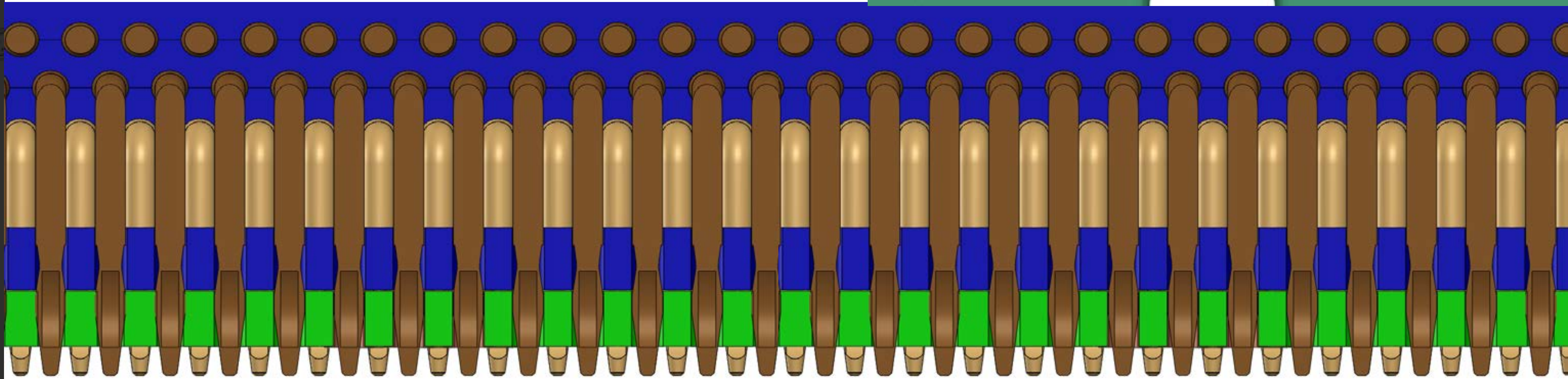
Press-Fit Technology

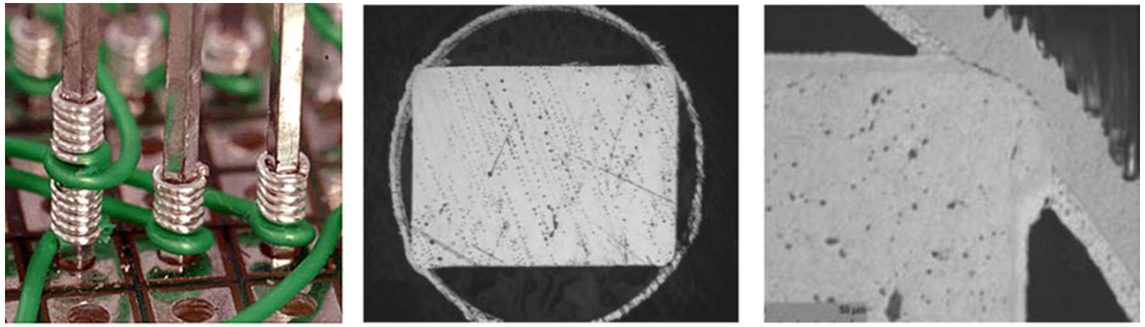
A Press-Fit termination is a valid connection method as long as its insertion in a circuit does not increase the circuit serial resistance or impedance in such way that the circuit's intended electromechanical performance is affected.





2.1 History of Press-Fit

Press-fit technology evolved in the 1960s from square tail "wire-wrap" contact terminations which were forced into round PCB holes notching a square and capturing stretched portions of the copper trace between the wall of the PCB and the body of the contact. Interestingly, this method has been accepted in various applications as it proved a good factor of reliability as long as not much mechanical interference challenged the connection.



The ease of achieving a gas-tight connection by pressing action has led to further innovation of this type of connection.

The telecommunications industry was first to adopt press-fit in large scale applications from the late 1970s onwards and since then, many specifications have been written around press-fit performance requirements by various industry groups such as:

- **IEC (International Electrotechnical Commission)**
- **Bellcore (Bell Communications Research)**
- **PICMG (PCI Industrial Computers Manufacturers Group)**

Product development aimed to meet or exceed conformance to these specifications enabled connector manufacturers to gain significant expertise leading to securing increasing position through the 2000s in military and aerospace applications.

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2.2 Press-Fit advantages and disadvantages

COMPARISON CRITERIA	Press-Fit	Solder through-hole
Assembly time and method	**Simple and rapid** process	**Complex and long** process
Flexibility of assembly	Can be installed on PCBs with components on both sides	In some cases soldering must be performed manually
Limitations caused by PCB thickness	Can be installed on thick backplanes without change in tail length or change in assembly process	Very difficult to ensure proper wetting on thick backplanes, inspection is complex and also custom tail lengths required on connector
Rework - removal from PCB	Simple and rapid process but limited at two removals per connector and cleaning precautions required	Difficult with risk of damage to PCB and Connector insulator due to thermal overload
	Compliant design minimizes plating removal during insertion/extraction but plating erosion occurs	Flux residuals and solder balls may occur
Compatibility with conformal coating	Masking required	Yes, compatible but removal of connector after conformal coating becomes even more difficult
Compatibility with Bus-Bars	Power connectors can be installed on bus-bars	Difficult to solder because of heat conduction
	Can be installed on multi-layered bus-bars	Cannot be installed on laminated bus-bars
Installation Tooling	Special tooling required – Positronic is developing a Tool-Loan program for Press-Fit space products	No additional equipment required
Mechanical Integrity	Repeated mating cycles or strain from mated connector do not affect interface between press-fit tails and PCB since minor movement of tails from stress does not affect electrical connection	Rigid electrical connection between contacts and PCB metallization require provisions to limit the stress transferred to the PCB
	Electrical and mechanical attributes of connection system must always be separated. Mounting screws are required.	Similar requirements are often specified
Performance and weight	Elastic property and compliant design ensures gas-tight fit and sub milliohm resistance maintained between contact and PCB metallization under harsh conditions	Performance of solder method is acceptable to the industry.
		Mass of solder = additional weight
Risk	No risk of whisker growth	Risk of tin whisker growth
		Risk of cold solder joints
Final Inspection	Low level of control	High level of control
Price	10% to 15% higher on standard part numbers	Much higher when longer tails are required
Reliability	IEC1709 shows FIT rate of 0.005 (failure rate) = 100 times lower than that of manual solder	FIT rate of 0.5 for manual solder FIT rate of 0.03 for automatic process

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2.3 Positronic's heritage with Press-Fit connectors

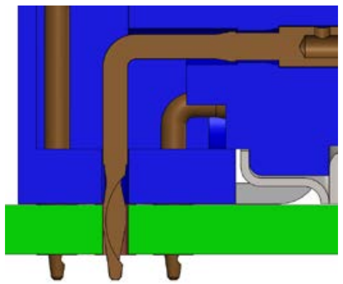


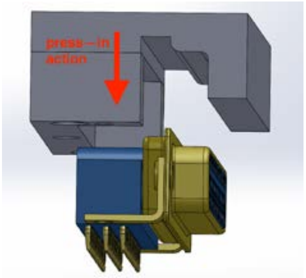
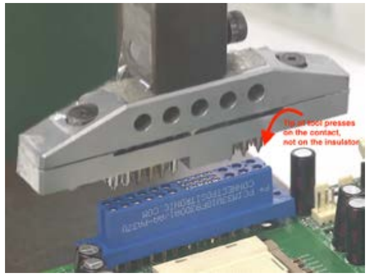

Positronic is a connector manufacturer specialized in high-reliability, high performance machined contact technology offering connectors with the highest power density ratings in the industry.

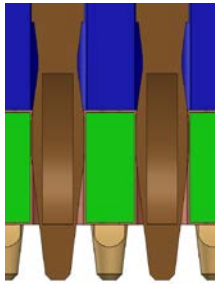
Positronic has been involved with PICMG (PCI Industrial Computers Manufacturers Group) in development work related to press-fit connectors for power and signal applications since the 1990s.

Positronic offers compliant press-fit terminations in various connector packages with high density, power or mixed contact arrangements. The machined contacts always employ a solid one-piece construction from tip to tail for straight and 90º contact configurations.

Positronic press-fit D-Sub connectors are currently flying in the Boeing 787 and Airbus A350 aircraft and have been already utilized in commercial satellite applications.





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Evaluation of press-fit connectors in harsh environment

Alter Technology of Seville, Spain conducted testing in the summer of 2016 following which they provided an 85 page report.

The tests consisted of taking 3 sets of three different assemblies (nine assemblies in total) and subjecting them to the following sequence:

ALTER TECHNOLOGY

SEQUENCE	PARAMETERS	CONCLUSION	
External Visual Inspection	Method: ESCC 20500	Pass: 8 of 9	Fail: 1 of 9
Electrical Measurement	Method: DENG-008-1 Rev.B par.7	Pass: 9 of 9	Fail: 0 of 9
Sine Vibration Test	Method: DENG-008-1 Rev.B + additional	Pass: 9 of 9	Fail: 0 of 9
Random Vibration Test	Method: DENG-008-1 Rev.B par.8	Pass: 9 of 9	Fail: 0 of 9
External Visual Inspection	Method: ESCC 20500	Pass: 9 of 9	Fail: 0 of 9
Electrical Measurement	Method: DENG-008-1 Rev.B par.7	Pass: 9 of 9	Fail: 0 of 9
Temperature Cycling 200 times -55ºC to 100ºC	Method: MIL-STD-202 T.M 107 Condition A & DENG-008-1 & DENG-008-1 Rev.B Par.11	Pass: 9 of 9	Fail: 0 of 9
External Visual Inspection	Method: ESCC 20500	Pass: 9 of 9	Fail: 0 of 9
Electrical Measurement	Method: DENG-008-1 Rev.B par.7	Pass: 9 of 9	Fail: 0 of 9
Temperature Cycling 300 times -55ºC to 100ºC	Method: MIL-STD-202 T.M 107 Condition A & DENG-008-1 & DENG-008-1 Rev.B Par.14	Pass: 9 of 9	Fail: 0 of 9
External Visual Inspection	Method: ESCC 20500	Pass: 9 of 9	Fail: 0 of 9
Electrical Measurement	Method: DENG-008-1 Rev.B par.7	Pass: 9 of 9	Fail: 0 of 9
Cross Sections	Method: DENG-008-1 Rev.B par.17	Pass: 2 of 3	Fail: 1 of 3

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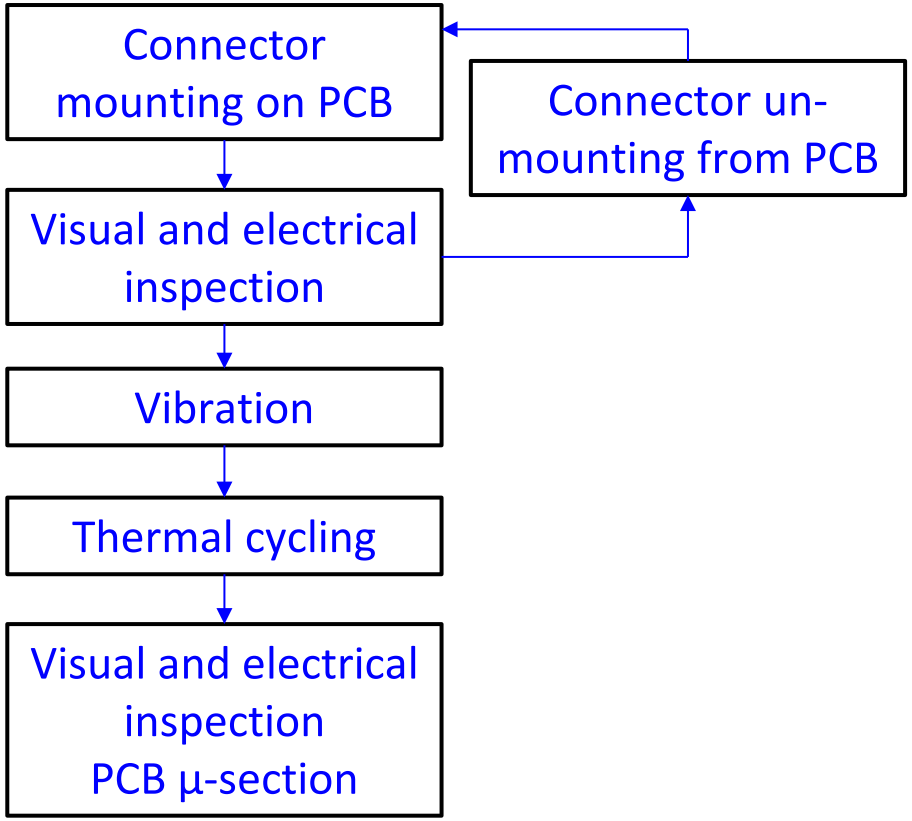
3.1
Test plan evaluation

Test plan (from ECSS-Q-ST-70-38):

- **Up to 3 mounting cycles evaluated**
  - 1 insertion / 0 extractions
  - 2 insertions / 1 extraction
  - 3 insertions / 2 extractions
- **Vibration level higher than 3401**
  - Sine 20g
  - Random 28g
- **300 Thermal cycling**
  - -55/+100°C, 10°/min max
  - Electrical monitoring daisy chain
- **Press-fit contact resistance measurement**
  - Instrument probes



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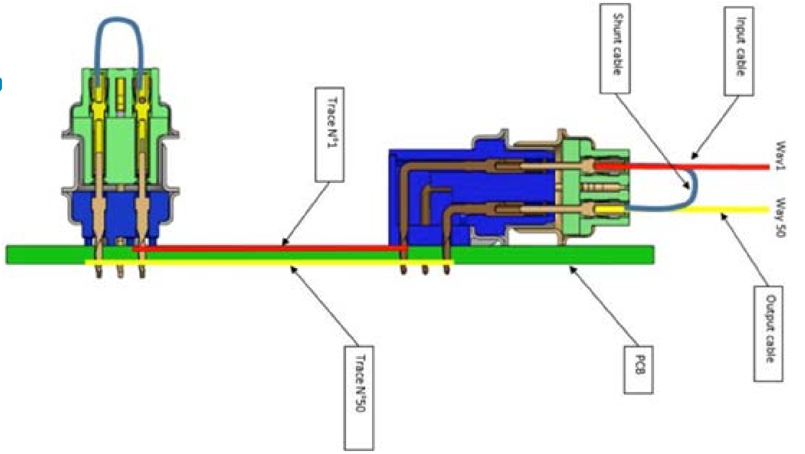
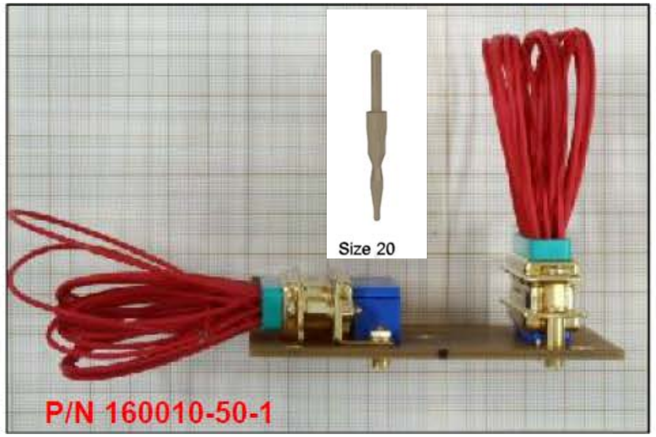
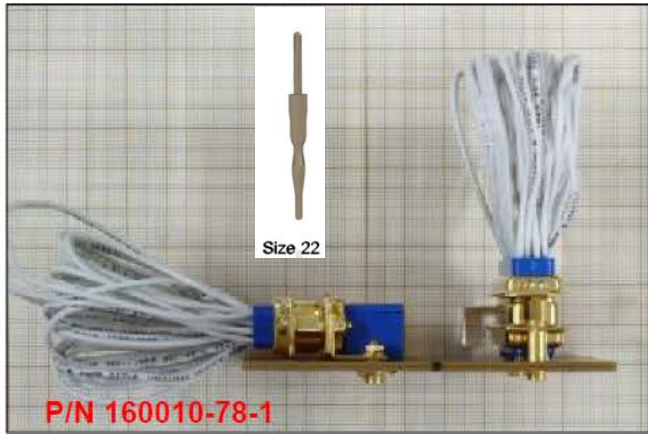
3.1
Test plan evaluation

Test vehicles:

- **D-Sub from Positronic**
  - 8W8 (size 8 cts for high power application)
  - Standard density 50cts, (size 20 cts for low power application)
  - High density 78cts, (size 22 cts for signal)
- **2 Press-Fit connectors & 2 wired connectors per P**
  - Right angle and straight Press-Fit terminations
  - Full Daisy Chain design
- **Polyimide space grade PCB**
  - Glass-polyimide with 4 Cu layers (2.4mm thick)
  - ENIG finish (Electroless Nickel Immersion Gold)
  - Finish thickness: Au=5µm







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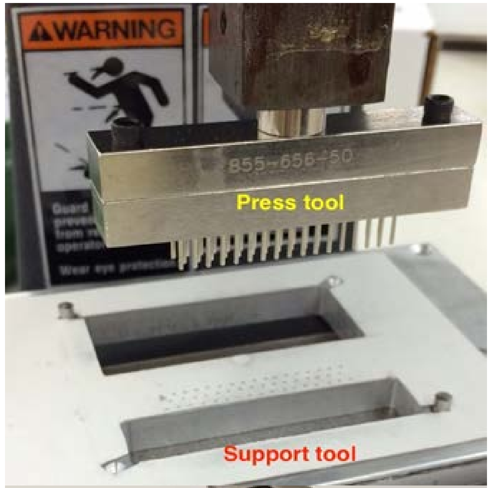
3.1
Test plan evaluation

Mounting observation:

- **Insertion / Extraction process made with dedicated tools:**
  - Press-in equipment
  - Press-fit tools to accommodate connector shape
  - PCB support
- **Insertion / Extraction force measurements on single contacts:**

Contact Size	Range of Insertion Forces in N (Newton)	Average Insertion Force in N (Newton)	Range of Extraction Forces in N (Newton)	Average Extraction Force in N (Newton)
8	128 to 141	132	46.5 to 53.5	54
20	21 to 24	22.5	11 to 19	15.0
22	25 to 28	26.5	17 to 23	20.0

- **Insertion and disengagement force computation for connectors:**
  - Insertion and extraction forces for connectors are not linearly proportional with the single contact insertion and extraction forces.
  - Positronic will provide insertion / extraction forces for each connector size on request.



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3.2 Electrical Test Results

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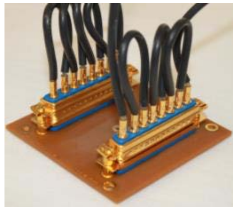
ALTER TECHNOLOGY specializes in engineering, procurement and test for EEE components and equipment within the space and other high technology markets.



	Min	Max	Average	Sin	Random	200 cycles	300 cycles	Min	Max	Average
1	0.121	0.861	0.447	✓	✓	✓	✓	0.209	0.535	0.380
2	0.166	0.428	0.239	✓	✓	✓	✓	0.238	0.529	0.388
3	0.161	0.509	0.358	✓	✓	✓	✓	0.191	0.562	0.392
1	0.204	0.687	0.390	✓	✓	✓	✓	0.103	0.658	0.264
2	0.115	0.841	0.778	✓	✓	✓	✓	0.108	0.563	0.268
3	0.128	0.778	0.316	✓	✓	✓	✓	0.207	0.891	0.434
1	0.156	0.956	0.342	✓	✓	✓	✓	0.116	0.863	0.408
2	0.125	0.597	0.234	✓	✓	✓	✓	0.112	0.877	0.305
3	0.135	0.692	0.316	✓	✓	✓	✓	0.105	0.836	0.306

✓ = Pass X = Fail

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3.2 Electrical Test Results

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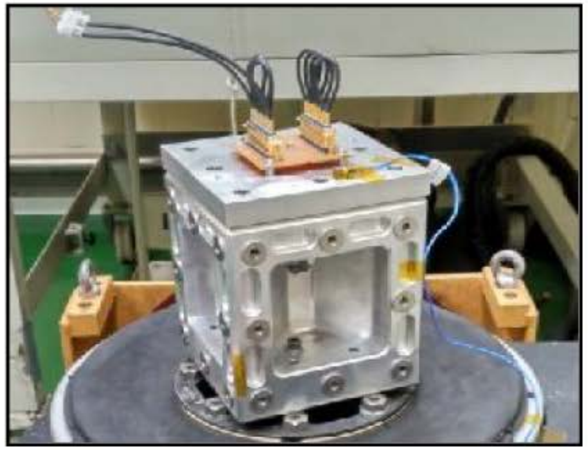
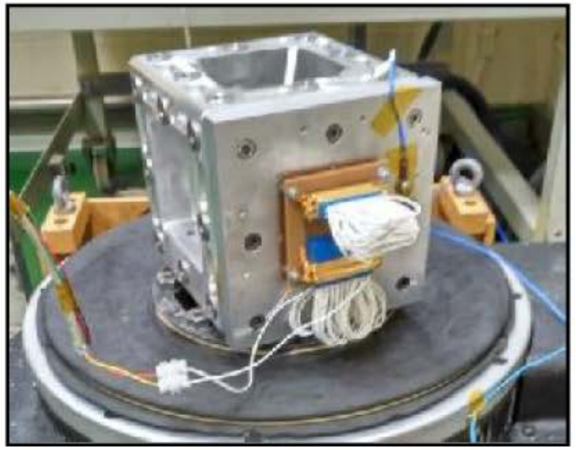
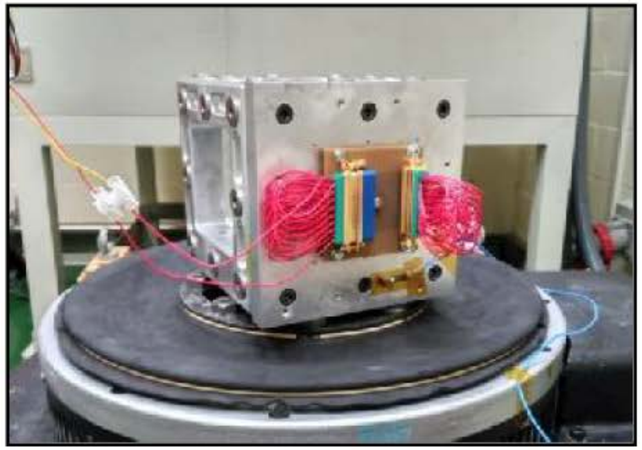




Sinusoidal Vibration test results: No µ-cuts detected

Range (Hz)	PSD level	Sweep rate (Oct/min)	Duration
25 to 100	20g	1	5 min per axis
100 to 200	15g	1	5 min per axis

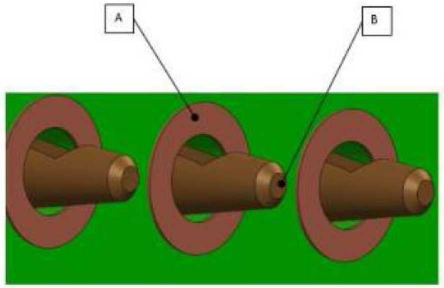
Random Vibration test results: No µ-cuts detected

Perpendicular to PCB		Parallel to PCB	
Range (Hz)	PSD level	Range (Hz)	PSD level
20 to 100	+6 dB/oct.	20 to 100	+3 dB/oct.
100 to 500	1 g /Hz	100 to 800	0.5 g /Hz
500 to 2000	-6 dB/oct	800 to 2000	-3 dB/oct
Global: 28.5g r.m.s		Global: 27.1g r.m.s	
Duration: 5 minutes per axis			

Electrical resistance measurements between PCB and contact terminations using probes:

- No evolution

Contact resistance µΩ	Initial	Post Vibration	Post thermal cycling
Min Value	115	125	103
Max Value	841	986	891
Average	365	343	322



3.2 Electrical Test Results

Thermal cycling:

- No circuit open detected
- Temperature effect on serial resistance was uniform

Assembly with size 8 contacts	
23ºC	Ri (initial series R)
-55ºC	0.73 x Ri
+125ºC	1.31 x Ri

Assembly with size 20 contacts	
23ºC	Ri (initial series R)
-55ºC	0.71 x Ri
+125ºC	1.35 x Ri

Assembly with size 22 contacts	
23ºC	Ri (initial series R)
-55ºC	0.72 x Ri
+125ºC	1.30 x Ri

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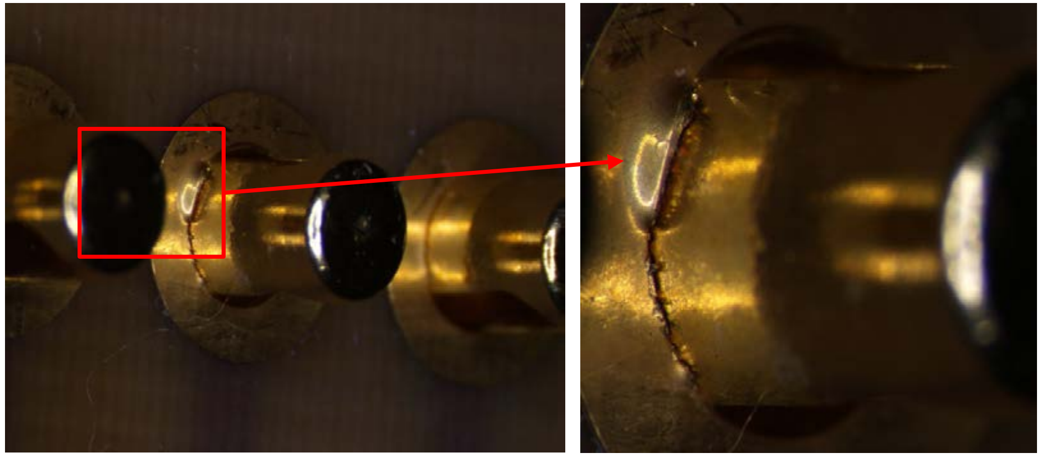
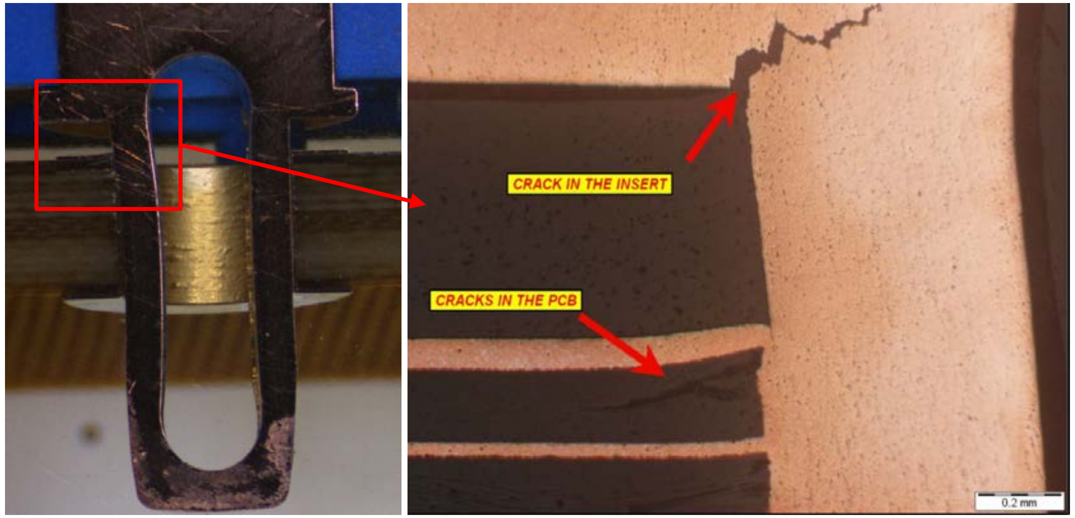
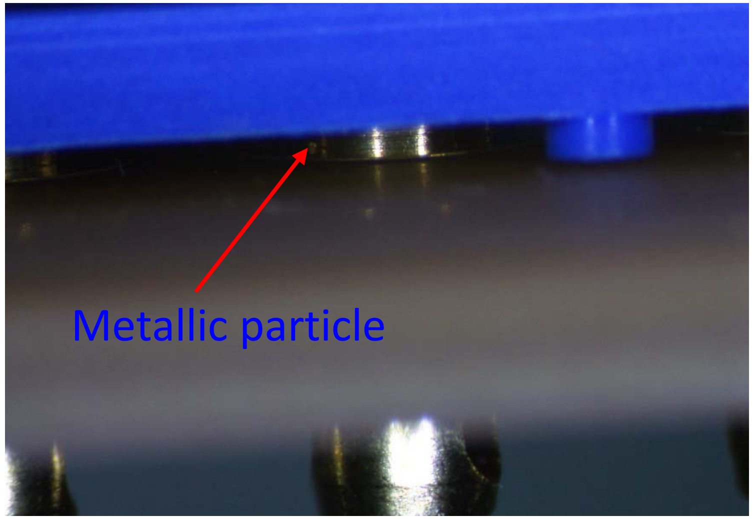
3.3 Physical Test Results

Physical characterisation on 8W8 connector: worst case observed

- **PCB visual inspection:**
  - Damages in PCB plating
  - Plating lift off after thermal cycling
  - Metallic particle
- **PCB µ-section:**
  - Damages in PCB insulator (8W8)
  - Damages in contact termination







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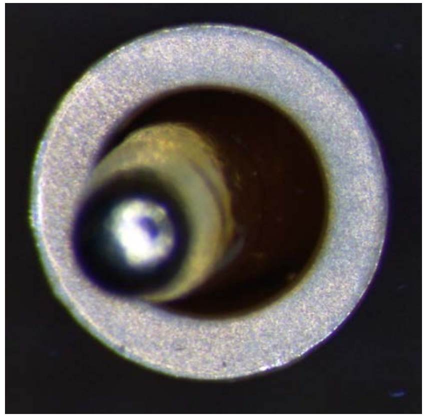
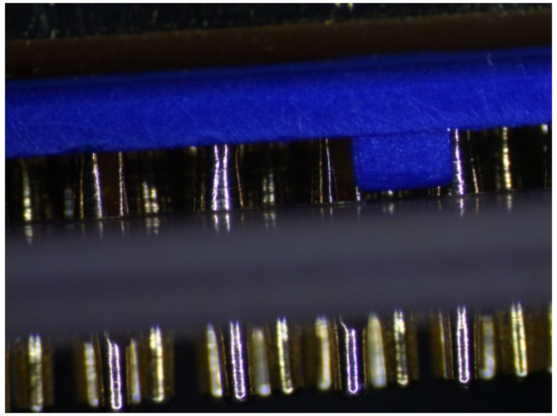
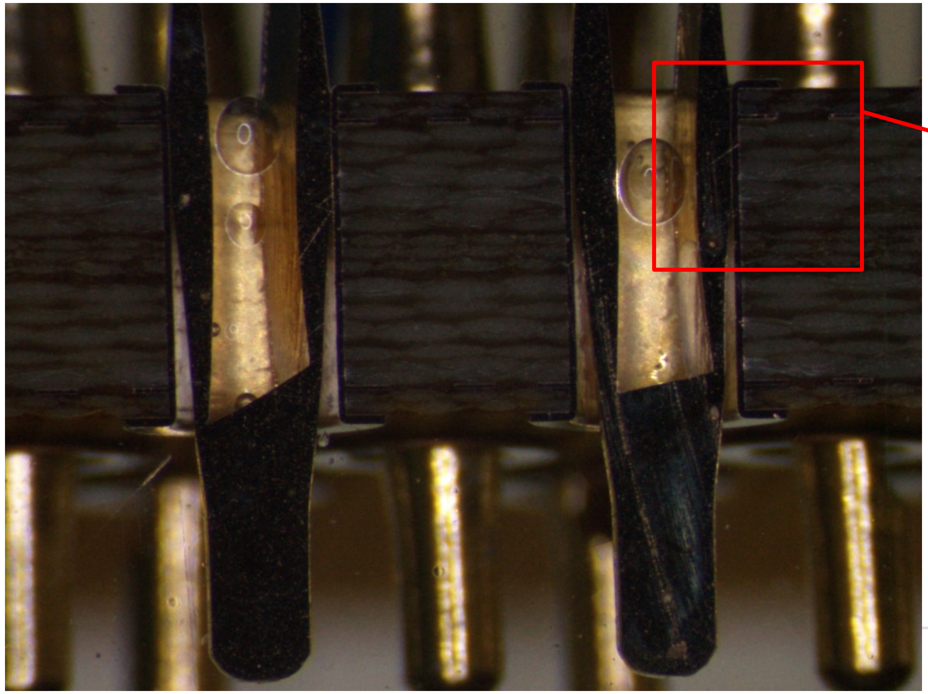
3.3 Physical Test Results

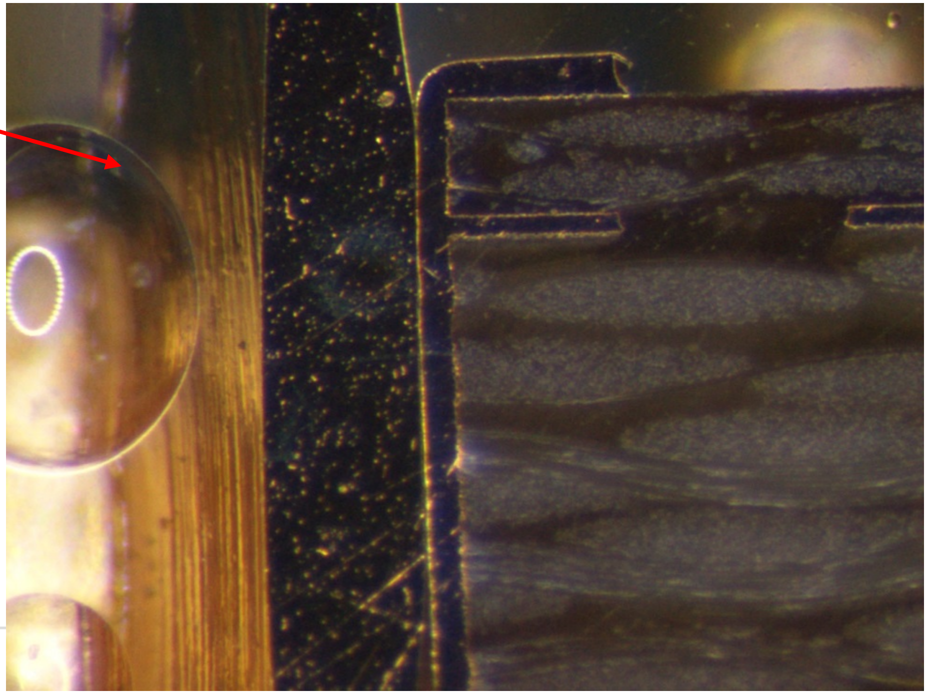
Physical characterisation on Standard Density 50 positions & High Density 78 positions Connectors:

- **PCB visual inspection:**
  - No damage observed
- **PCB µ-section:**
  - No damage observed





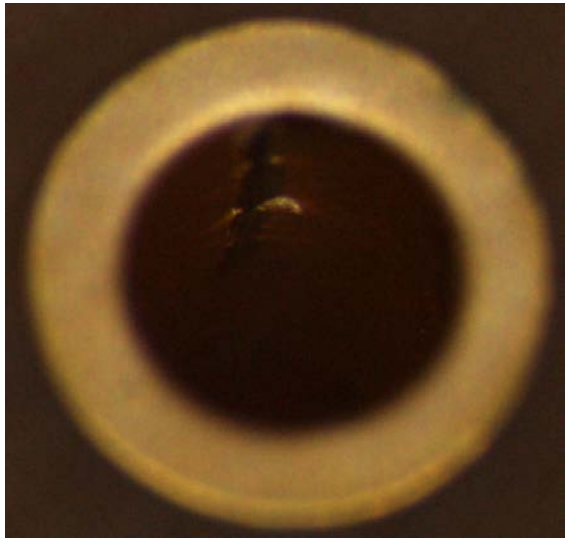


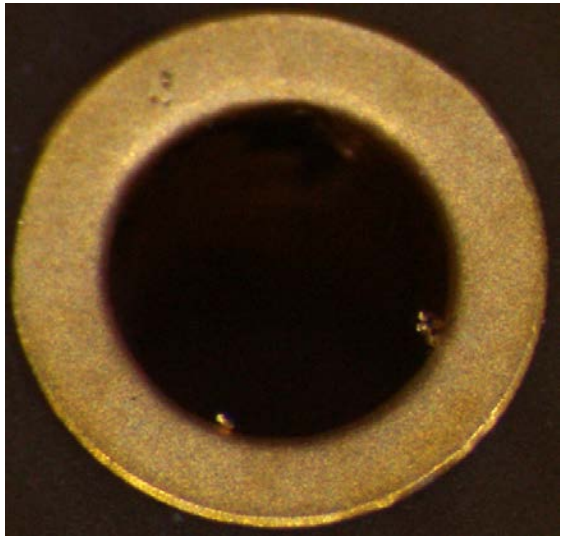


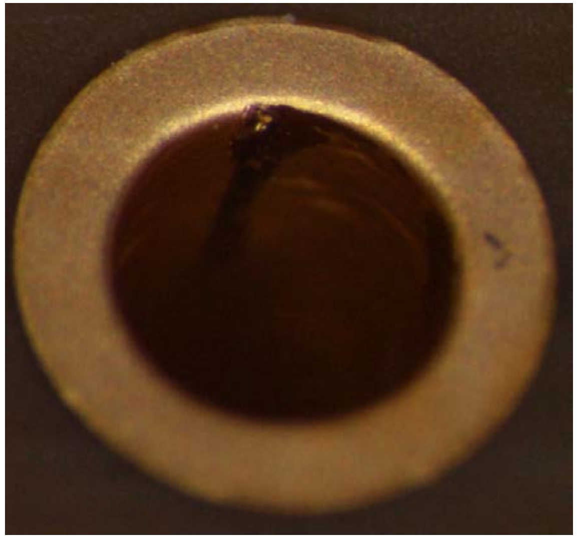
3.3 Physical Test Results

PCB inspection after disengagement

- **PCB visual inspection:**
  - Some gold plating flakes observed in almost all PTH after removal







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4 Conclusions and Future Work

Mechanical and environmental testing demonstrate that press-fit terminations of size 20 and size 22 contacts conform to electrical and mechanical performance requirements of harsh environment conditions.

Mechanical and environmental testing demonstrate that press-fit terminations of size 8 contacts conform to electrical performance requirements in harsh environment conditions however the design needs further improvement to meet the mechanical performance requirements of harsh environment conditions.

Physical observation of one sample has revealed a major defect on one size 8 contact installed in an 8W8 connector and revealed visible deformations on the PCB traces near the perimeter of the through-holes.

- Consequently, the monitoring and the specification of the insertion force appears to be a key parameter to guarantee a reliable connection.
- Positronic is committed to continue development to perfect size 8 contact mechanical performance.

The metallic particles created after connector extraction from PCB are of particular concern.

- Consequently, a procedure to reinstall a press-fit connector shall be defined.
- This procedure will have to define the operations needed to inspect and remove particles from the PCB through-holes.

Further evaluation studies are necessary before completing a specification for Press-Fit terminations in connectors for space-flight applications. Such further studies may encompass the following areas:

- Interaction of press fit termination with PCB varnish and/or masking requirements.
- Effect of several connector mating sequences on press-fit terminations.
- Requirements on the separation of electrical and mechanical actions in the elements of the interconnect system.
- Other potential evaluation requirements may be proposed by users who have experience and already employed press-fit technology for space-flight applications.

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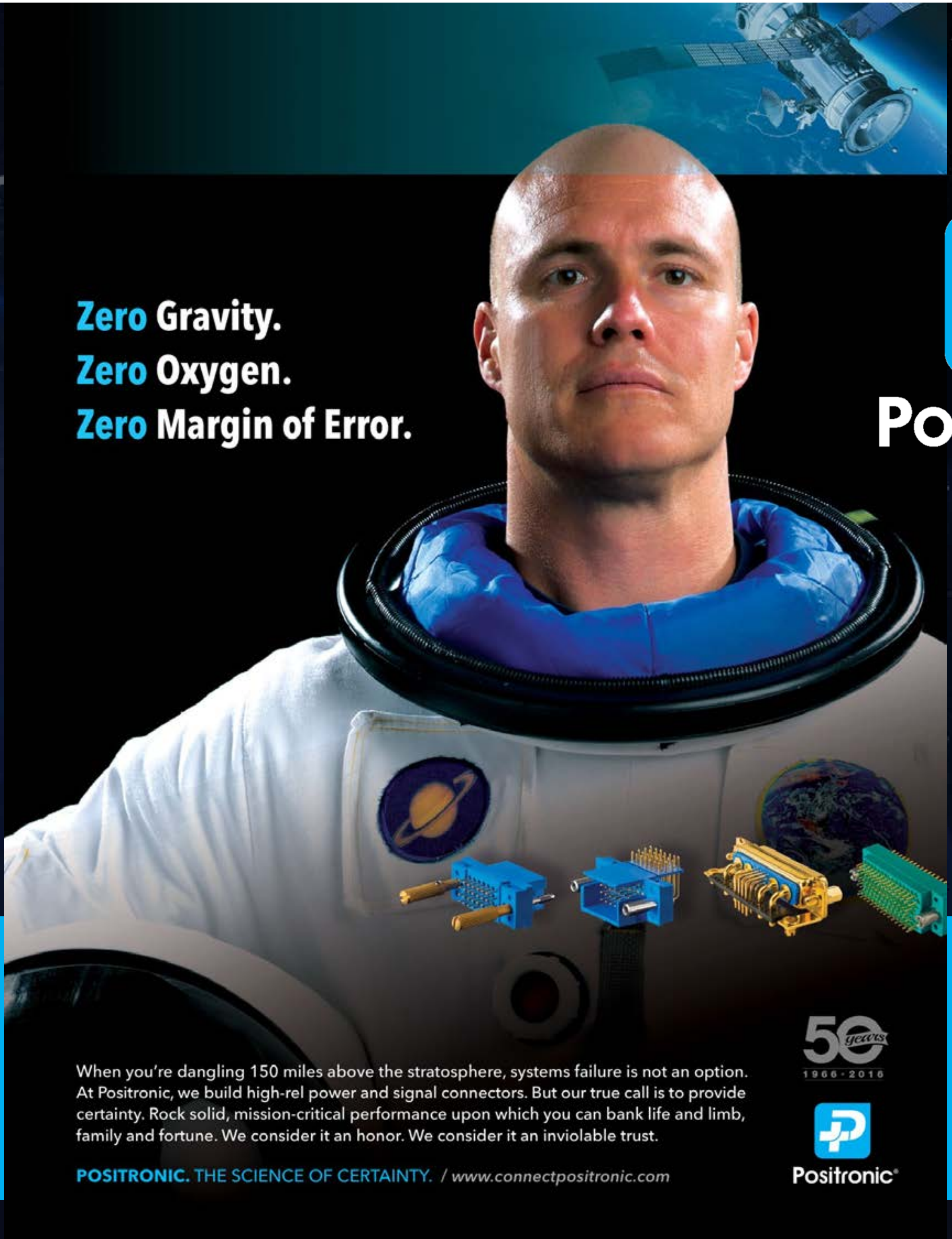
THANK YOU

If you have any questions you are welcome to ask!



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Connector Press-Fit Technology for space-flight applications

12-14 October 2016
ESA/ESTEC, Noordwijk, The Netherlands

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