# Practical Best Practices in Total Ionizing Dose Testing for Space Applications

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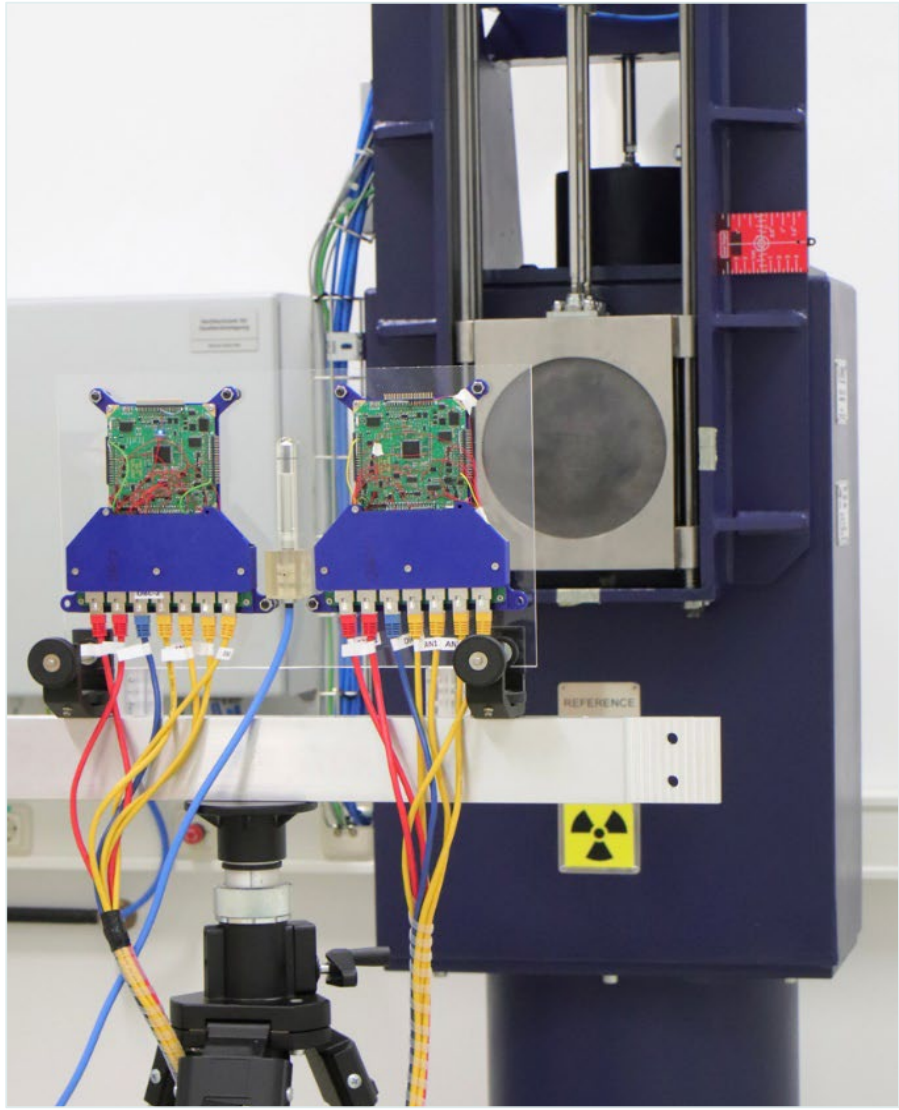
Seibersdorf Laboratories

**Workshop on Small Satellites: Environmental Testing in New Space**
Wiener Neustadt, 10.03.2026

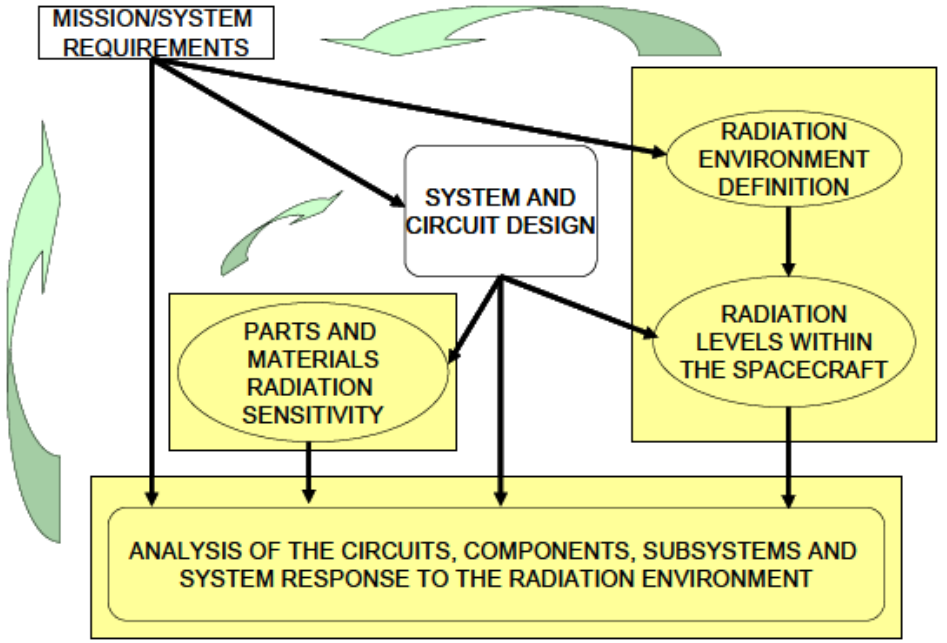


# What is Radiation Hardness Assurance (RHA)?

"*RHA consists of all activities undertaken to ensure that the **electronics** of a space system perform to their **specification** after exposure to the space **radiation** environment.*"

RHA has implications on

- part selection
- system requirements and operations
- system and subsystems circuit design
- spacecraft layout




RHA process overview

*From: ECSS-Q-ST-60-15C*

# Space Radiation Environment

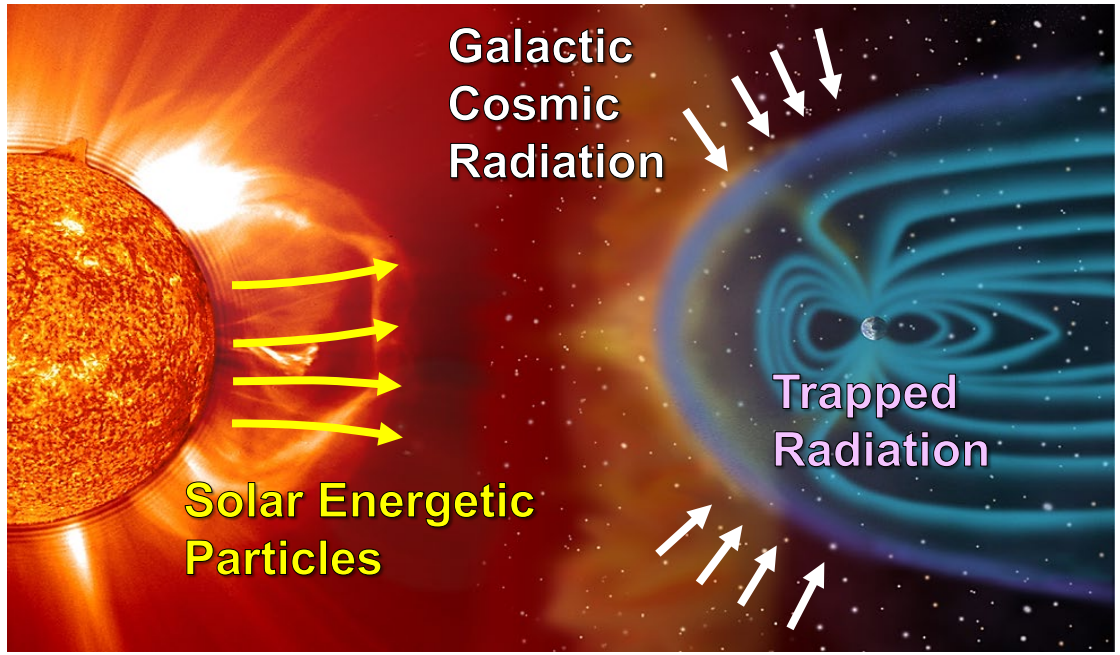
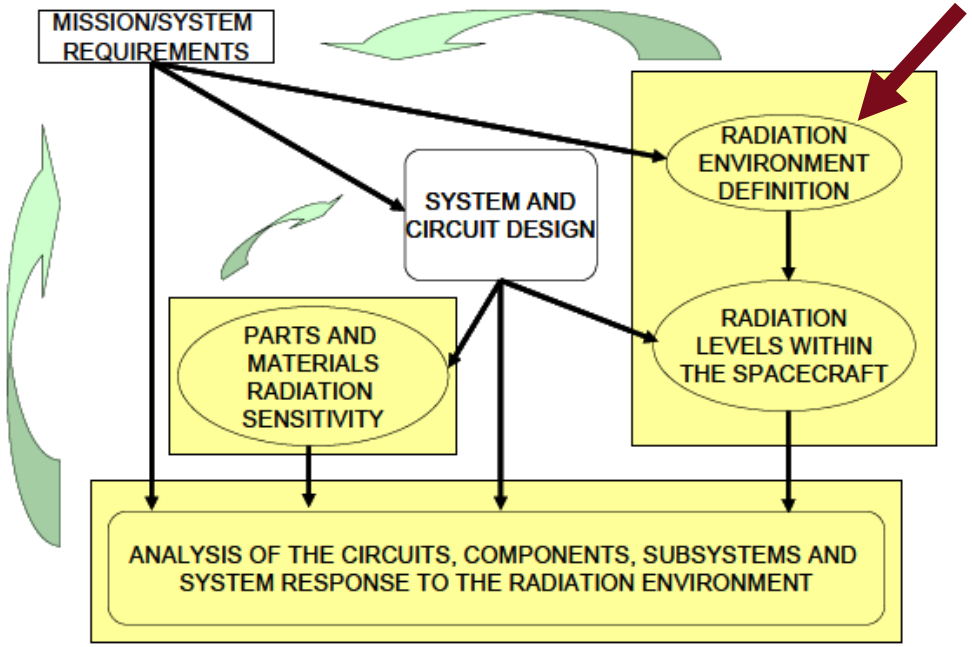



*Image Credit: NASA/SOHO*

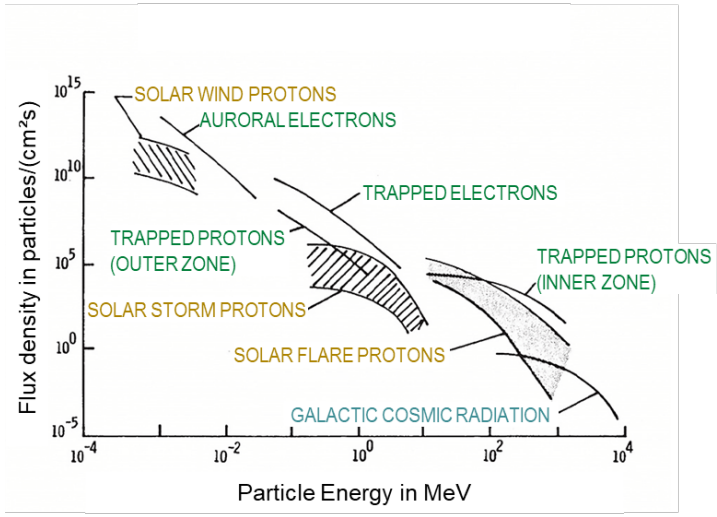



RHA process overview

# Main Radiation Effects on Components

## Solar Particles

*Image Credit: ESA*




*Wilson (1978) University of California, 15 Sept 1978, pp 33–116*

## Cosmic Radiation

*Image Credit: NASA*

## Trapped Particles

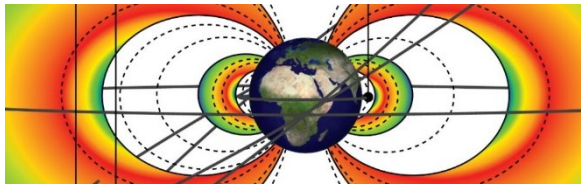
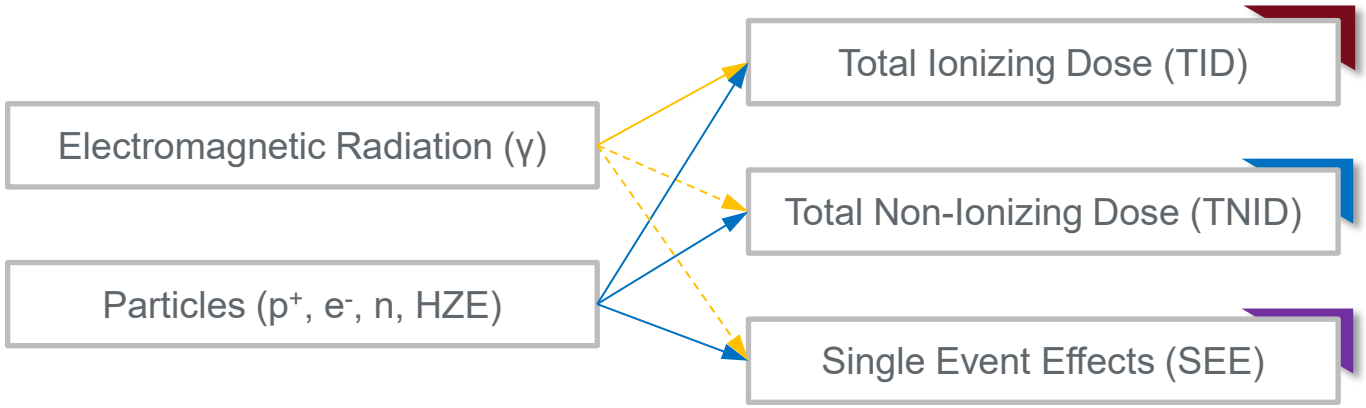


*Image Credit: fp7-spacecast.eu*

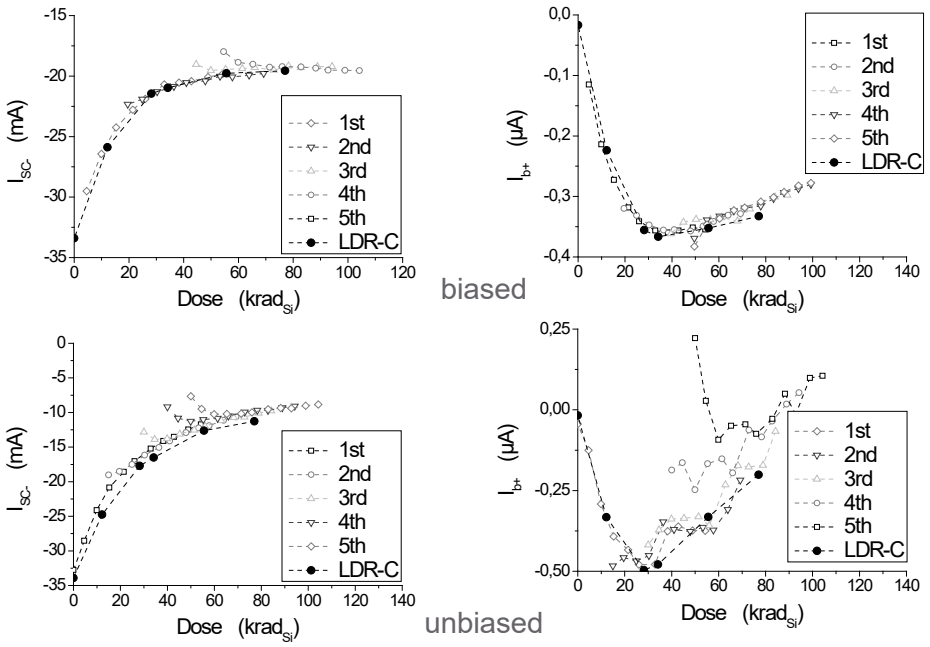


# Total Ionizing Dose (TID) Effects

## Electric Effects

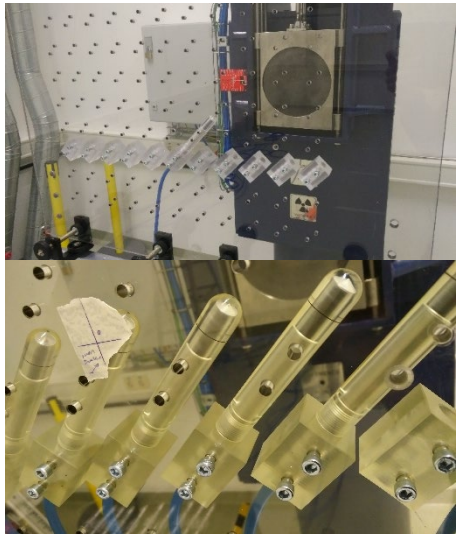
LM324AN: $I_{SC-}$, $I_{b+}$

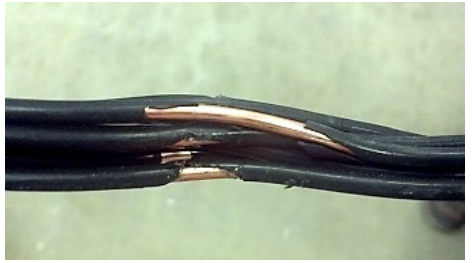
Parameter Degradation




http://eldrs.net/

## Optical /Mechanical Effects





*https://allthingsnuclear.org/dlochbaum/fission-stories-144-not-minding-the-fort?*

# Radiation Testing Standards

**ECSS**
*European Cooperation for Space Standardization*

**MIL-STD**
*U.S. Department of Defense*

**JEDEC**
*Solid State Technology Association*

**IEC**
*International Electrotechnical Commission*

**ASTM**
*(formerly) American Society for Testing and Materials*

**ANSI**
*American National Standards Institute*

**ESCC**
*European Space Components Coordination*

# TID Hardness Assurance (ESCC-Q-ST-60-15C)

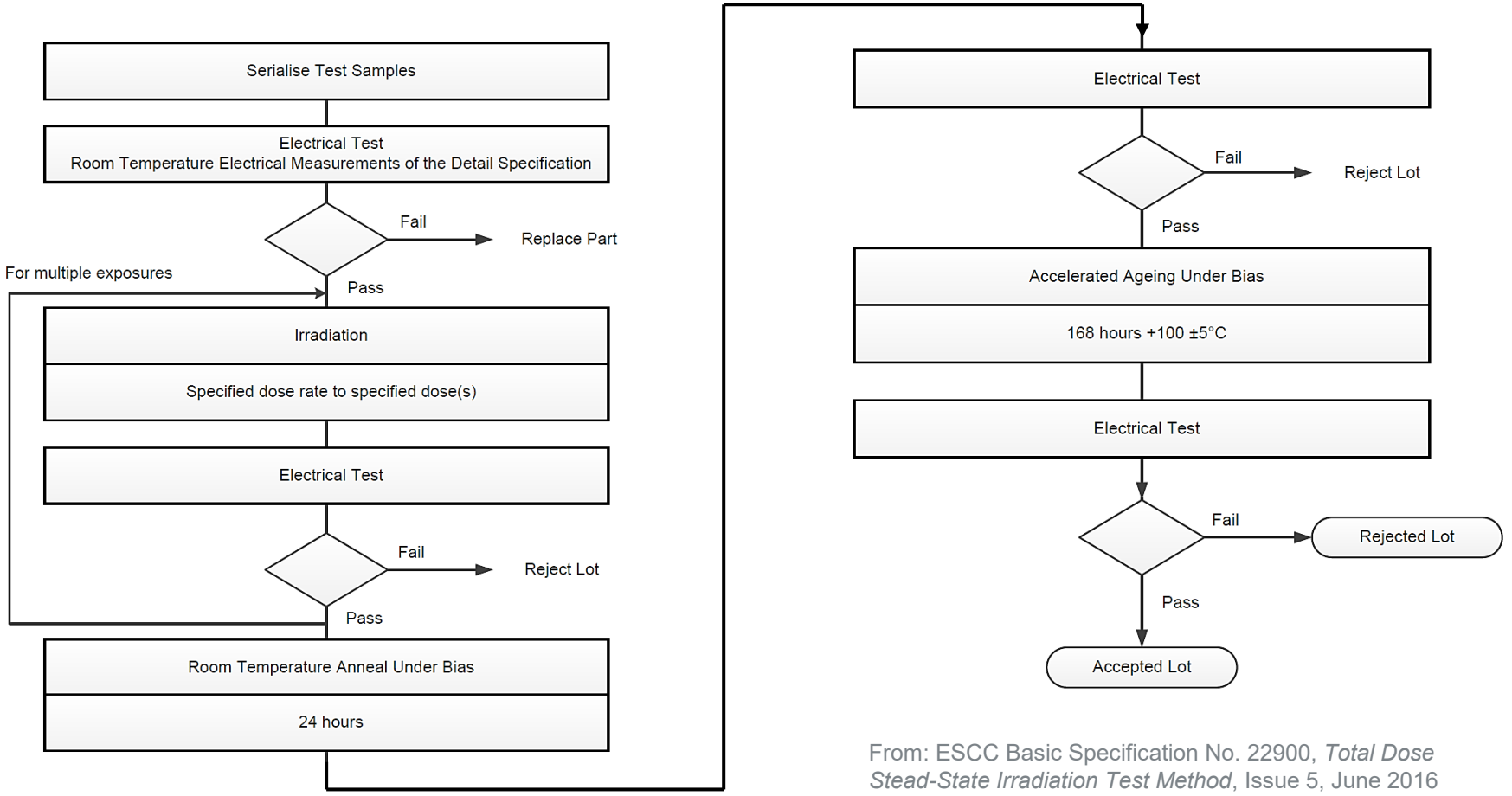
- TID test data used to assess TIDS shall comply with the following rules to be acceptable:
  - Tests are performed in conformance to **ESCC 22900, MIL-STD 883 method 1019, or MIL-STD-750 method 1019**, and
  - Devices that contain **bipolar transistors** are tested at a **dose rate** of 36 rad/h to 360 rad/h, and
  - **Tested** parts are manufactured with technology **identical** to the technology of **flight** parts: same process, same diffusion mask, and same wafer fabrication facility
  - **Bias conditions** are worse or equivalent to the application
- If acceptable component TID test data does not exist, ground testing shall be performed in conformance to **ESCC 22900**
- **Radiation Source: Co-60** (ESCC, MIL-STD) or electron beam (ESCC)

# TID Sensitive Components (ESCC-Q-ST-60-15C)

**Table 5-1: EEE part families potentially sensitive to TID**

| EEE part family | Sub family | TIDL |
|---|---|---|
| Diodes | Voltage reference, Zener | all |
| | Switching, rectifier, Schottky | > 300 krad-Si eq. |
| Diodes microwave | | > 300 krad-Si eq. |
| Integrated Circuits | | all |
| GaAs Integrated Circuits | | > 300 krad-Si eq. |
| Oscillators (hybrids) | | all |
| Charge Coupled devices (CCD) | | all |
| Opto discrete devices, Photodiodes, LED, Phototransistors, Opto couplers | | all |
| Transistors (MOS and bipolar) | | all |
| GaAs Transistors | | > 300 krad-Si eq. |
| Hybrids containing active parts | | all |

# TID Hardness Assurance Testing Procedure




From: ESCC Basic Specification No. 22900, *Total Dose Stead-State Irradiation Test Method*, Issue 5, June 2016

# TEC-Laboratory (**T**esting of **E**lectronic **C**omponents)

EN ISO/IEC 17025 Accredited TID Assurance Testing at Seibersdorf Laboratories



SEIBERSDORF LABORATORIES

# AEROSPACE RADIATION COMPETENCE CENTER

by Seibersdorf Laboratories

16.03.2026

# Space Service Portfolio

## RHA Testing Laboratory

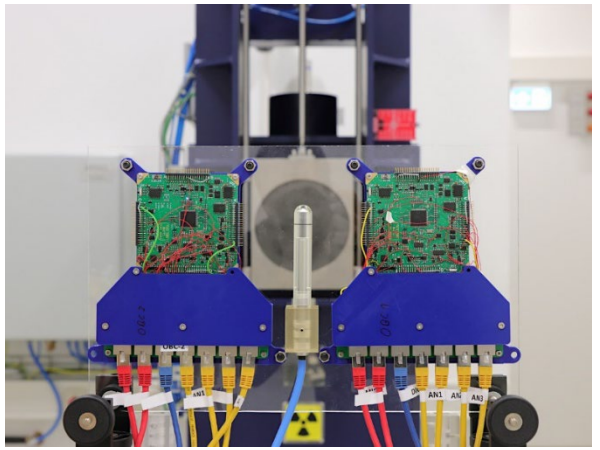
- TID – Testing at SL TEC-Laboratory
- TNID – Testing with partners
- SEE – Testing at SL and partners

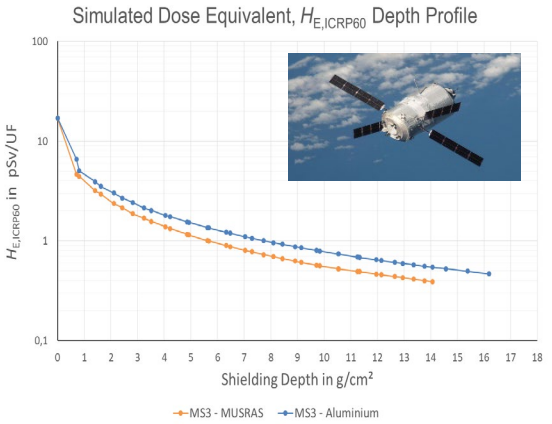
## Radiation Analyses

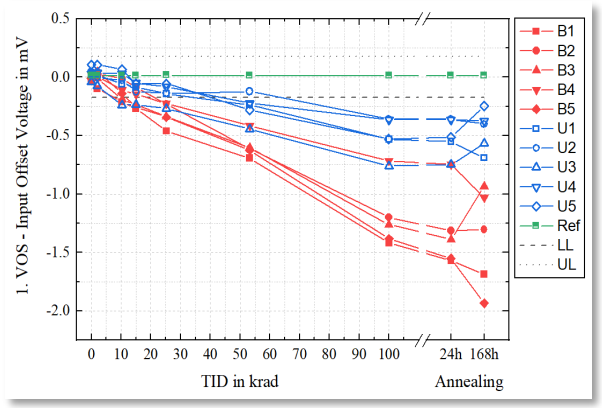
- Environment analysis
- Shielding & dose assessment
- Radiation simulations

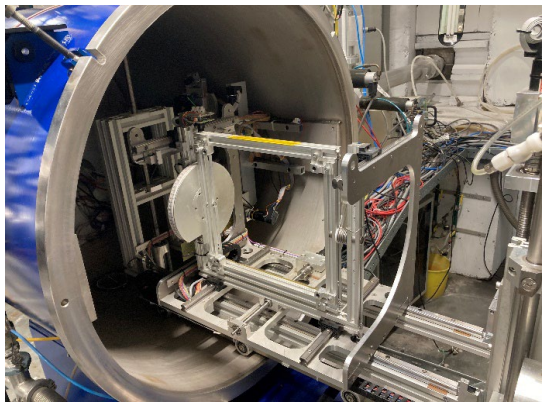
## Electronics and Consulting

- PCB production (irradiation, testing)
- Set-up and testing equipment
- Support with standards
- Training





# Accredited Test House **0312** - Seibersdorf Laboratories EN ISO/IEC 17025

## TEC – Laboratory Test of Electronic Components


- Last successful accreditation audit: October 2025
- Next accreditation audit: 2026-2027

Bundesministerium
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Forschungszentrum, 2444 Seibersdorf

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als / *as* **Prüflaboratorium / *Testing Laboratory***
gemäß / *according to* **EN ISO/IEC 17025:2017**
Datum der Erstakkreditierung / *Initial date of accreditation*: **01.10.2009**

Standorte/Organisationseinheiten / *sites/units*:
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**Seibersdorf Labor GmbH - Dopinganalytik, Forschungszentrum, 2444 Seibersdorf**
**Seibersdorf Labor GmbH - EMV, Forschungszentrum, 2444 Seibersdorf**
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REPUBLIK ÖSTERREICH

**Dipl.-Ing. Dr. Norman Brunner**
Wien, am 20. August 2021

# TEC – Laboratory
# Accredited Testing EN ISO/IEC 17025:2017

## EN ISO/IEC 17025 Accredited

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Identifikationsnummer / *ID-number*: **0312**

als / *as*

**Prüfstelle / *Testing Laboratory***
**gemäß / *according to* EN ISO/IEC 17025:2005**

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31.05.2016
Datum / *Date*

Dipl.-Ing. Dr. Norman Brunner
Leiter Akkreditierung Austria / *Head Akkreditierung Austria*

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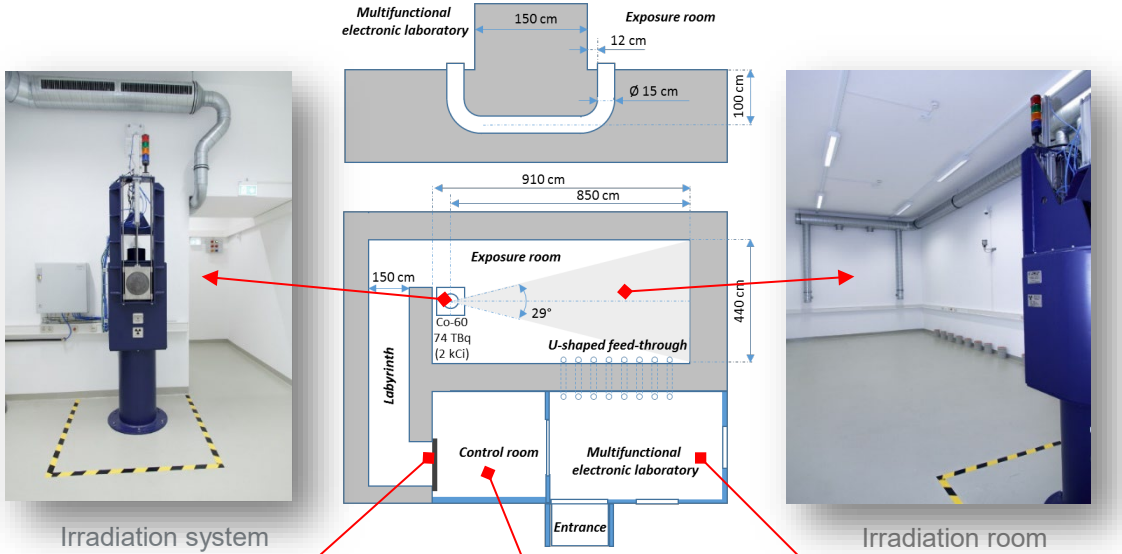





Irradiation system



Irradiation room

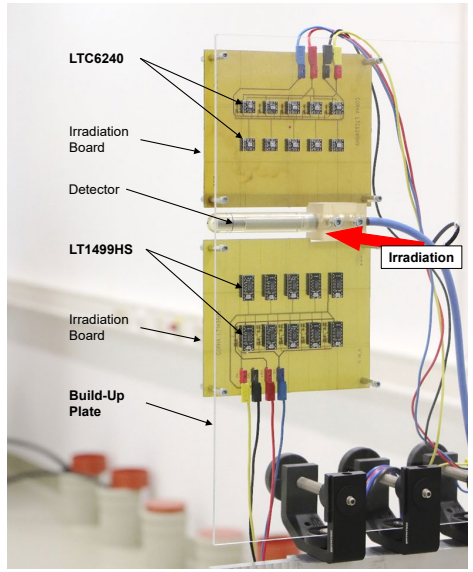
Labyrinth, radiation protection door

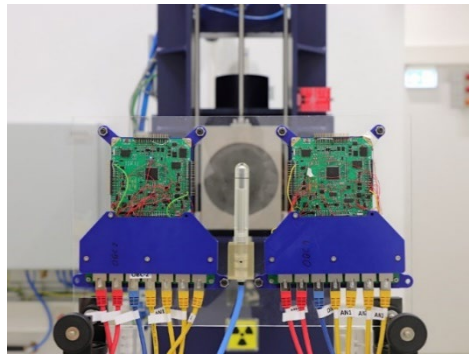
Controlling

Electronics- and analysis room

# TEC-Laboratory

- 24/7 radiation testing services
- Cobalt-60 source 64 TBq
- Dose rate: 50 Gy/h (5 krad/h) ⇨ 0.3 Gy/h (<30 rad/h)
- Field size: 10 cm x 10 cm ⇨ 100 cm x 100 cm
- ELDRS: 6 months low-dose rate exposure
- Electronic Laboratory attached
- EN ISO/IEC 17025, ECSS, ESCC, MIL-STD



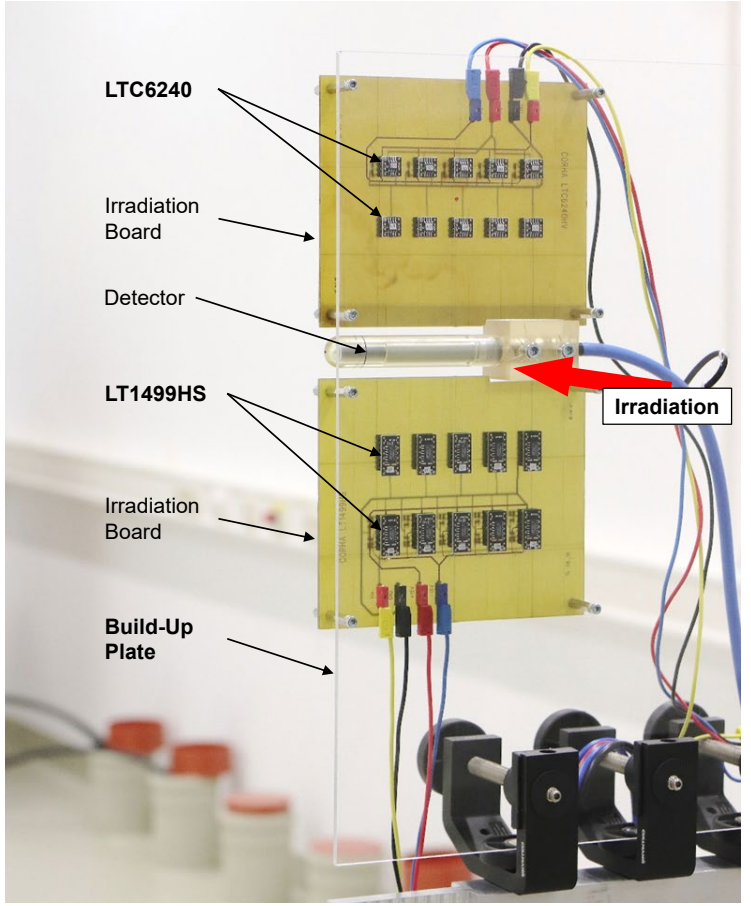



# Example: TID Testing of OpAmps

| Irradiation Step | Applied Total Dose | Applied Dose Rate |
|---|---|---|
| 1 | 2 $krad_{(Si)}$ | 0.6 $krad_{(Si)}/h$ |
| 2 | 10 $krad_{(Si)}$ | |
| 3 | 15 $krad_{(Si)}$ | |
| 4 | 25 $krad_{(Si)}$ | |
| 5 | 53 $krad_{(Si)}$ | |
| 6 | 100 $krad_{(Si)}$ | |

| Annealing Step | Annealing Time | Annealing Temperature |
|---|---|---|
| 1 | 24 hours | room temperature |
| 2 | 168 hours | 100°C |

Reference: C. Tscherne, M. Wind, M. Bagatin, S. Gerardin, M. Latocha, A. Paccagnella, M. Poizat, P. Beck, *Testing of COTS Operational Amplifier in the Framework of the ESA CORHA Study*, Radiation Effects on Components and Systems Conference, **RADECS 2020**, Nov 2020



SEIBERSDORF LABORATORIES

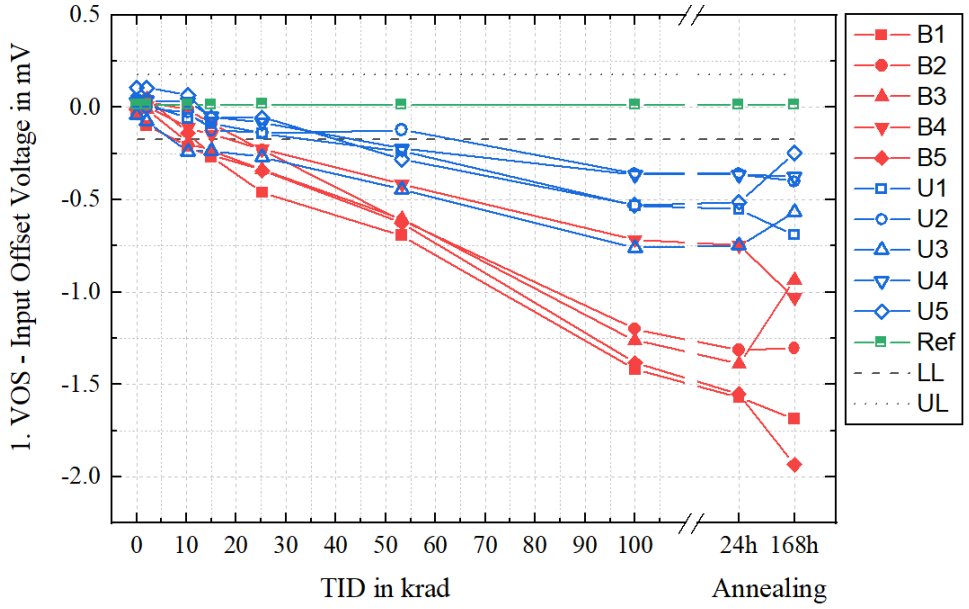
# Example: Parameter Tests

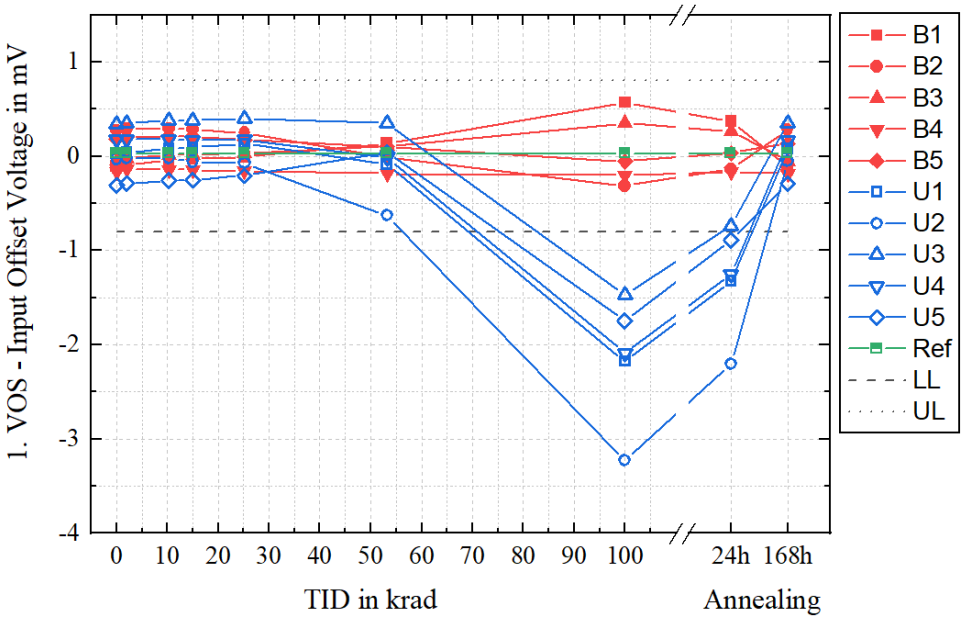
| | Symbol | Parameter | LT1499HS | | LTC6240 | | Unit |
|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | |
| 1 | $V_{OS}$ | Input Offset Voltage | −800 | 800 | −175 | 175 | µV |
| 2 | $I_S^+$ | Positive Supply Current | - | 10 | - | 3.3 | mA |
| 3 | $I_S^-$ | Negative Supply Current | - | 10 | - | 3.3 | mA |
| 4 | $I_B^+$ | Input Bias Current at the non-inv. input | - | 715 | - | 0.025 | nA |
| 5 | $I_B^-$ | Input Bias Current at the inverting input | - | 715 | - | 0.025 | nA |
| 6 | $I_B$ | Input Bias Current | - | 715 | - | 0.025 | nA |
| 7 | $I_{OS}$ | Offset Current | - | 70 | - | 0.01 | nA |
| 8 | $A_{VO}$ | Open Loop Gain | 120 | - | 55 | - | dB |
| 9 | CMRR | Common Mode Rejection Ration | 93 | - | 80 | - | dB |
| 10 | PSRR+ | Positive Power Supply Rej. Ratio | 89 | - | 83 | - | dB |
| 11 | PSRR− | Negative Power Supply Rej. Ratio | N/A | N/A | 40 | - | dB |
| 12 | $V_O^+$ | Positive Output Voltage Swing | 14.99 | 15.00 | 4.97 | 5.00 | V |
| 13 | $V_O^-$ | Negative Output Voltage Swing | -15.00 | -14.97 | -5.00 | -4.97 | V |
| 14 | $I_{SC}^+$ | Positive Short Circuit Current | - | -15 | - | -15 | mA |
| 15 | $I_{SC}^-$ | Negative Short Circuit Current | 30 | - | 15 | - | mA |
| 16 | SR+ | Positive Slew Rate | 3.5 | - | 5 | - | V/µs |
| 17 | SR- | Negative Slew Rate | 3.5 | - | 5 | - | V/µs |

UNIMET Parameter Analyzer

Reference: C. Tscherne, M. Wind, M. Bagatin, S. Gerardin, M. Latocha, A. Paccagnella, M. Poizat, P. Beck, *Testing of COTS Operational Amplifier in the Framework of the ESA CORHA Study*, Radiation Effects on Components and Systems Conference, **RADECS 2020**, Nov 2020

# Example: TID Test Results – Input Offset Voltage




Biased devices in red
Unbiased devices in blue
Non-irradiated reference device in green

Reference: C. Tscherne, M. Wind, M. Bagatin, S. Gerardin, M. Latocha, A. Paccagnella, M. Poizat, P. Beck, *Testing of COTS Operational Amplifier in the Framework of the ESA CORHA Study*, Radiation Effects on Components and Systems Conference, **RADECS 2020**, Nov 2020

# Example: TID Test Results – Summary

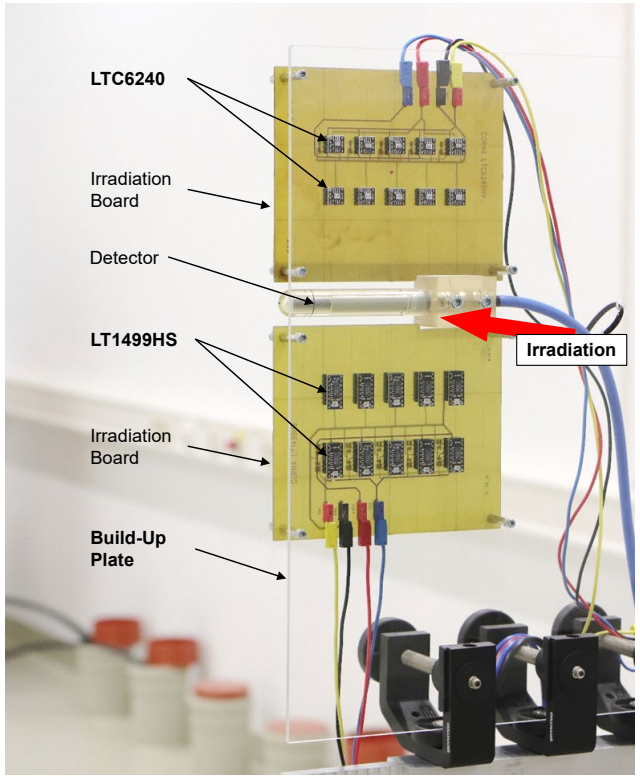
| | LTC6240HVCS8 | | | | | | | | | | | | | | | | LT1499HS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Applied Dose in krad(Si) | | | | | | | | | | | | Annealing | | | | Applied Dose in krad(Si) | | | | | | | | | | | | Annealing | | | |
| Symbol | 2 | | 10 | | 15 | | 25 | | 53 | | 100 | | 24h R.T. | | 168h 65°C[1)] | | 2 | | 10 | | 15 | | 25 | | 53 | | 100 | | 24h R.T. | | 168h 100°C | |
| $V_{OS}$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_S^+$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_S^-$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_B^+$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_B^-$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_B$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_{OS}$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $A_{VO}$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| CMRR | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $V_O^+$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $V_O^-$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_{SC}^+$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| $I_{SC}^-$ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| SR+ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| SR- | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** | **B** | **U** |
| PSRR+ | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U |
| PSRR- | B | U | B | U | B | U | B | U | B | U | B | U | B | U | B | U | | | | | | | | | | | | | | | | |

A green cell color indicates that all biased (B) and unbiased (U) devices are within the specification limits, otherwise the cell is marked red.

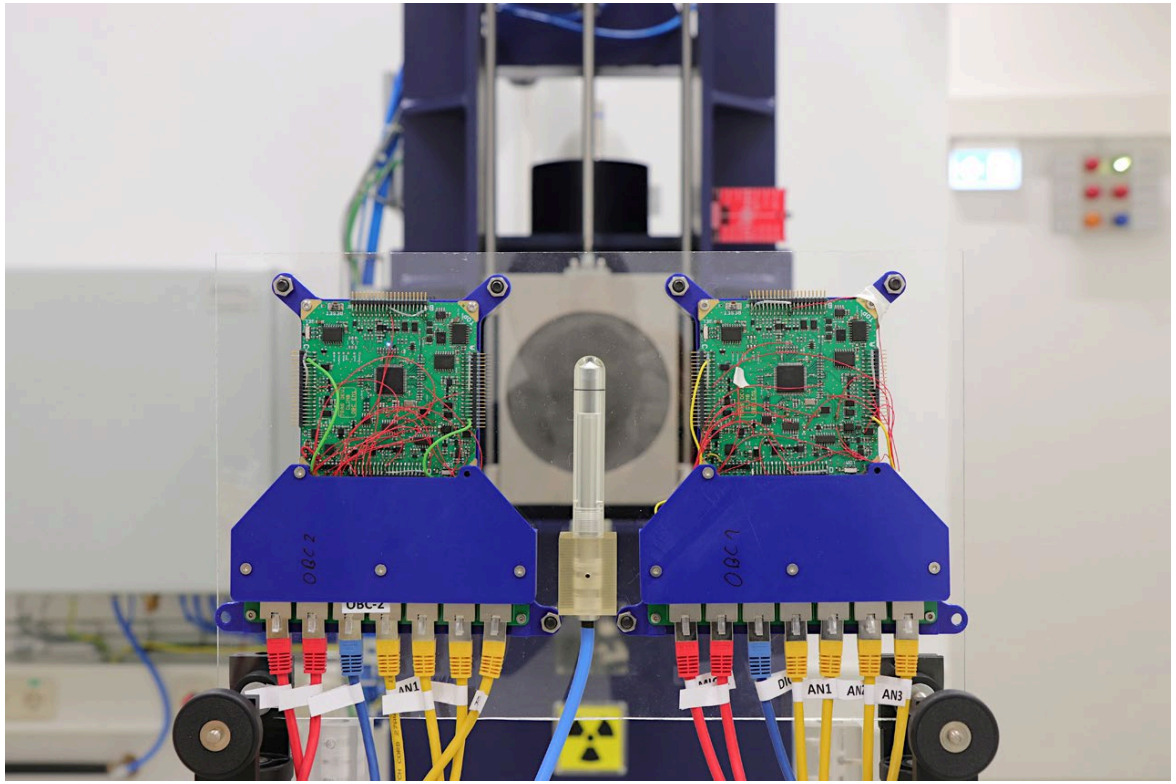
[1)] 168 hours annealing is performed at 65°C in order not to exceed the maximum guaranteed operating temperature of 70°C specified in the device's datasheet.

Reference: C. Tscherne, M. Wind, M. Bagatin, S. Gerardin, M. Latocha, A. Paccagnella, M. Poizat, P. Beck, *Testing of COTS Operational Amplifier in the Framework of the ESA CORHA Study*, Radiation Effects on Components and Systems Conference, **RADECS 2020**, Nov 2020

# TID Testing on Part and System Level




…On Part Level



…On System Level

# Thank you for your attention!

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