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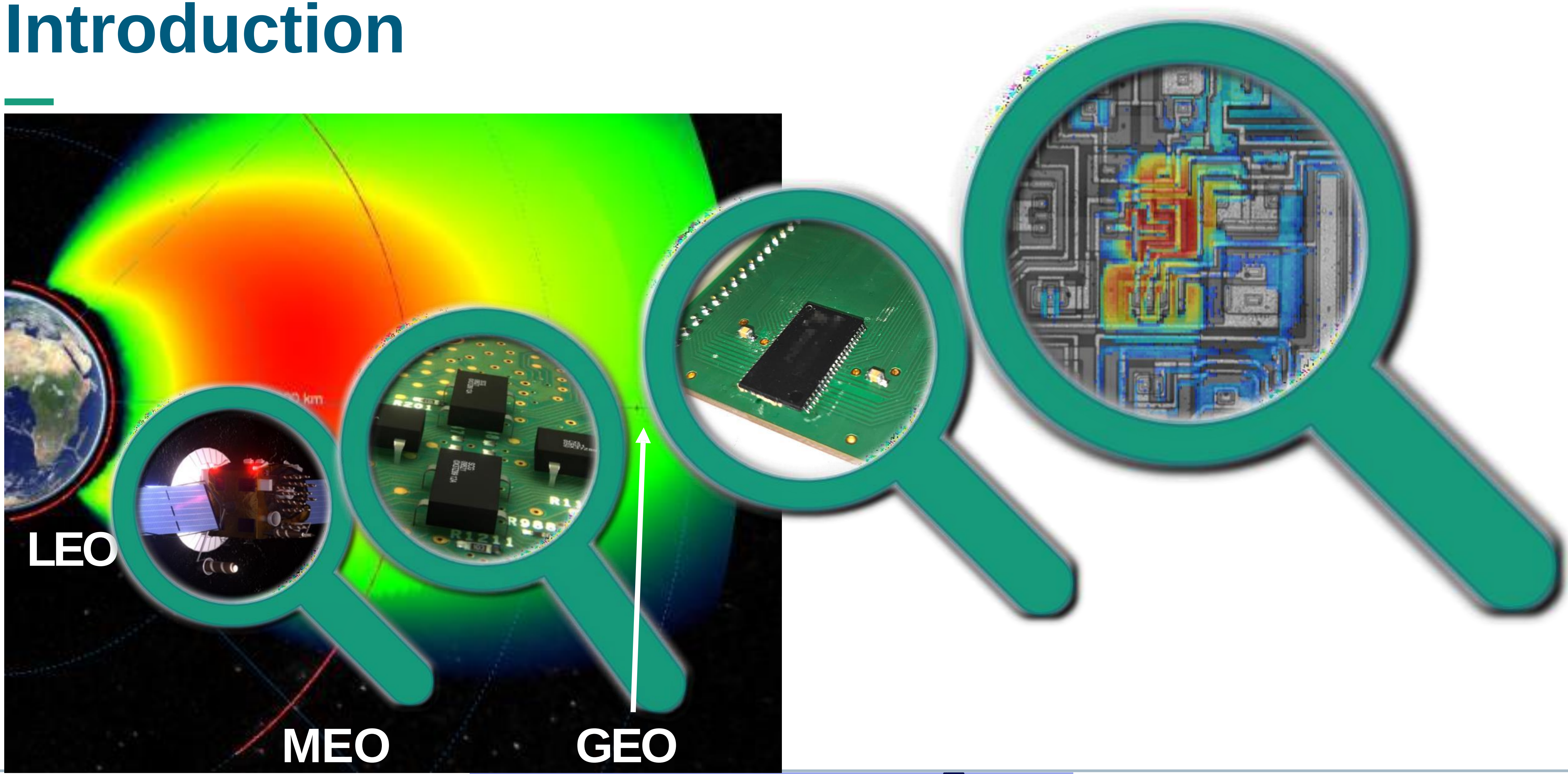
Radiation characterization and functional verification of COTS components for space applications (RACOCO)

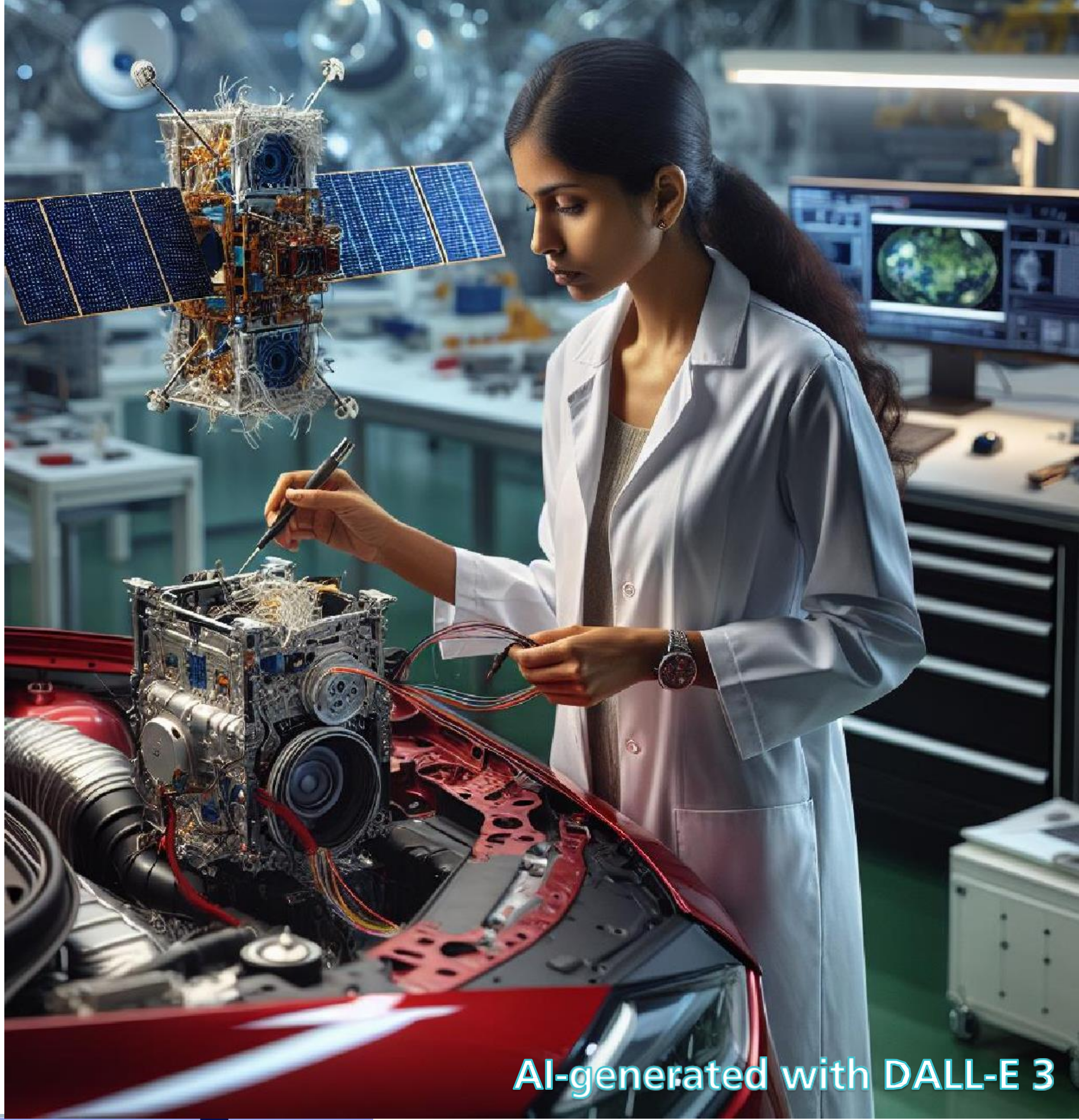
Contract number 4000127569/19/NL/FE

Introduction



COTS use for Space

- Components designed for commercial ground applications are not optimized w.r.t. radiation
- Not „per se“ unsuitable but behaviour is unknown
  - TID / SEE sensitivity
  - Dependency part-to-part
  - Dependency lot-to-lot
  - Die revision



Components under investigation

Contract number
4000127569/19/NL/FE

Component	Description
IRF9540NPBF	MOSFET
TSV992IQ2T	Op. Amp
TSZ182HYDT	Op. Amp
THS4032MDGNREP	Op. Amp
REF5050MDREP	Voltage Reference
INA169QPWRQ1	Current Sensor
ADUM7440CRQZ	Digital Isolators
TMP423AQDCNTQ1	Temp Sensor
LTC4303IMS8PBF	I2C buffer
MR2A08ACYS35	NVRAM
IS42S86400B-7TLI	SDRAM
LMG3410R050RWHT	GaN with integrated gate driver and protection
SM7244XMTE/NOPB	Power Management Specialized IC (X = 2 and 5)

Especially SEE campaigns with Heavy Ions and Pulsed Lasers ongoing

To be submitted for RADECS

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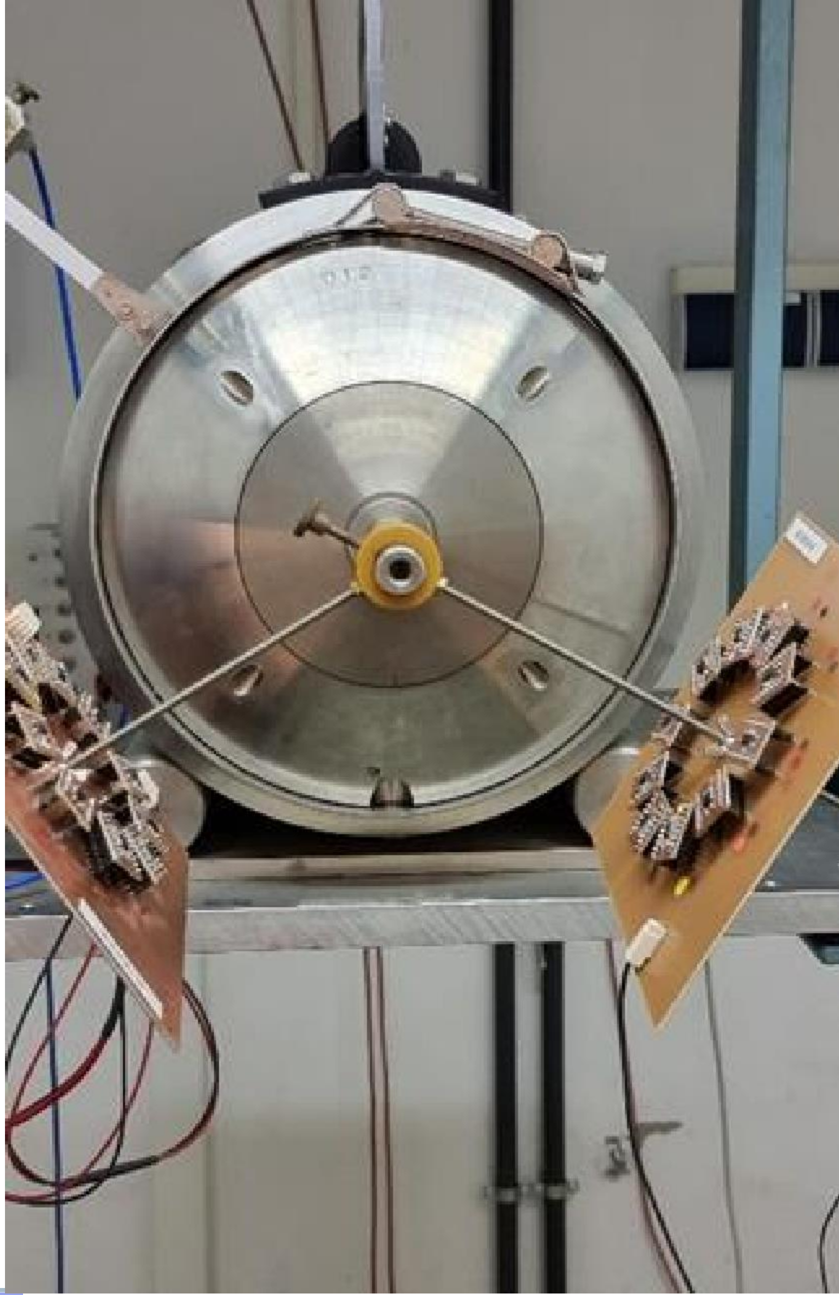
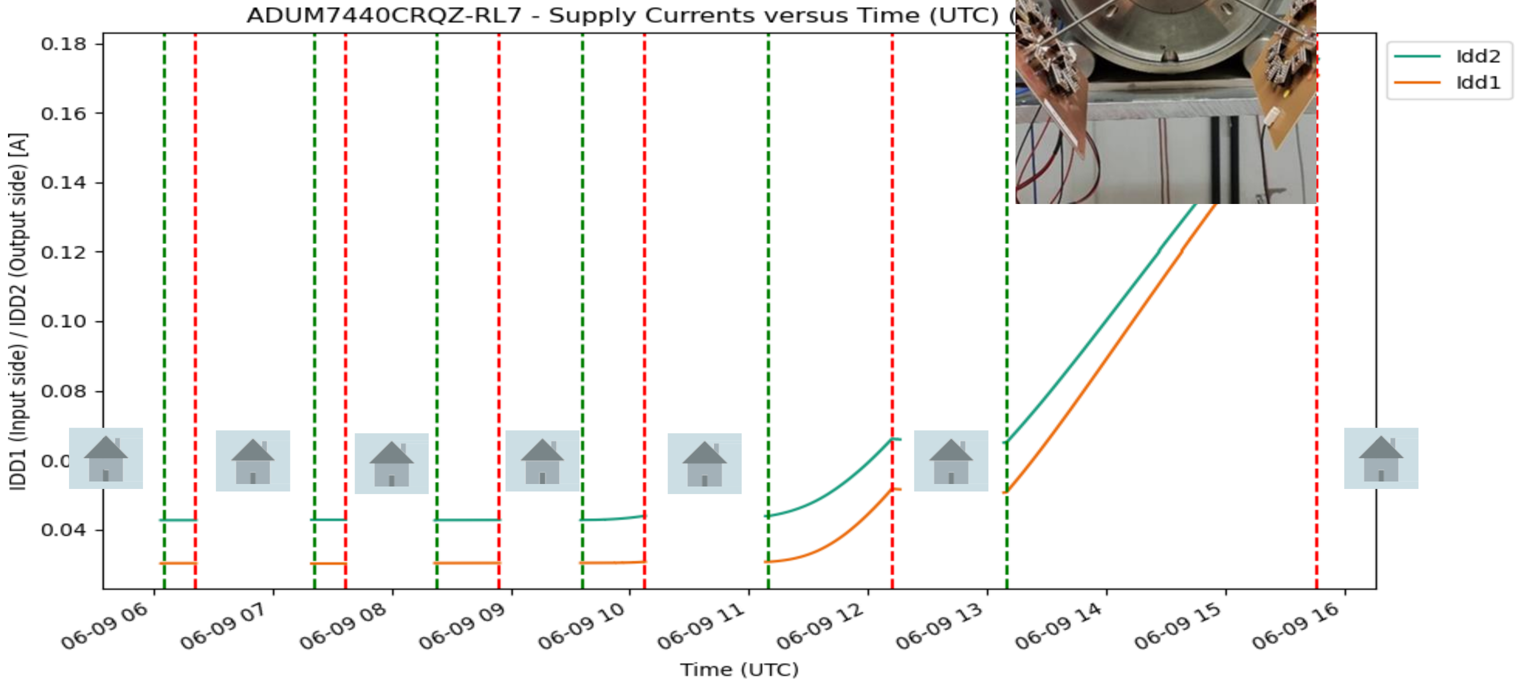
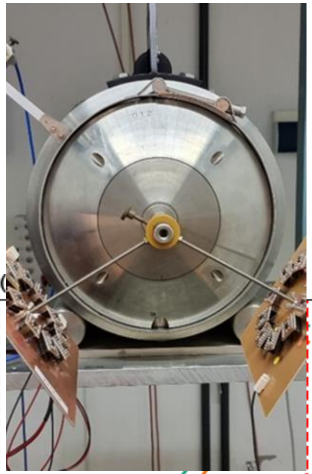
Total Ionizing Dose Testing

- Tests performed at the Co-60 facilities at INT
- Target dose level: 100 krad(Si)
- Dose rates between 0.36 to 25 krad(Si)/h
- Dose steps of 5, 10, 20, 30, 50, 100 krad(Si).
- In-situ tests during irradiation of basic parameters
- Parameteric characterization at first, last and intermediate steps
- Testing of 10 biased and 10 unbiased samples
  - With exceptions



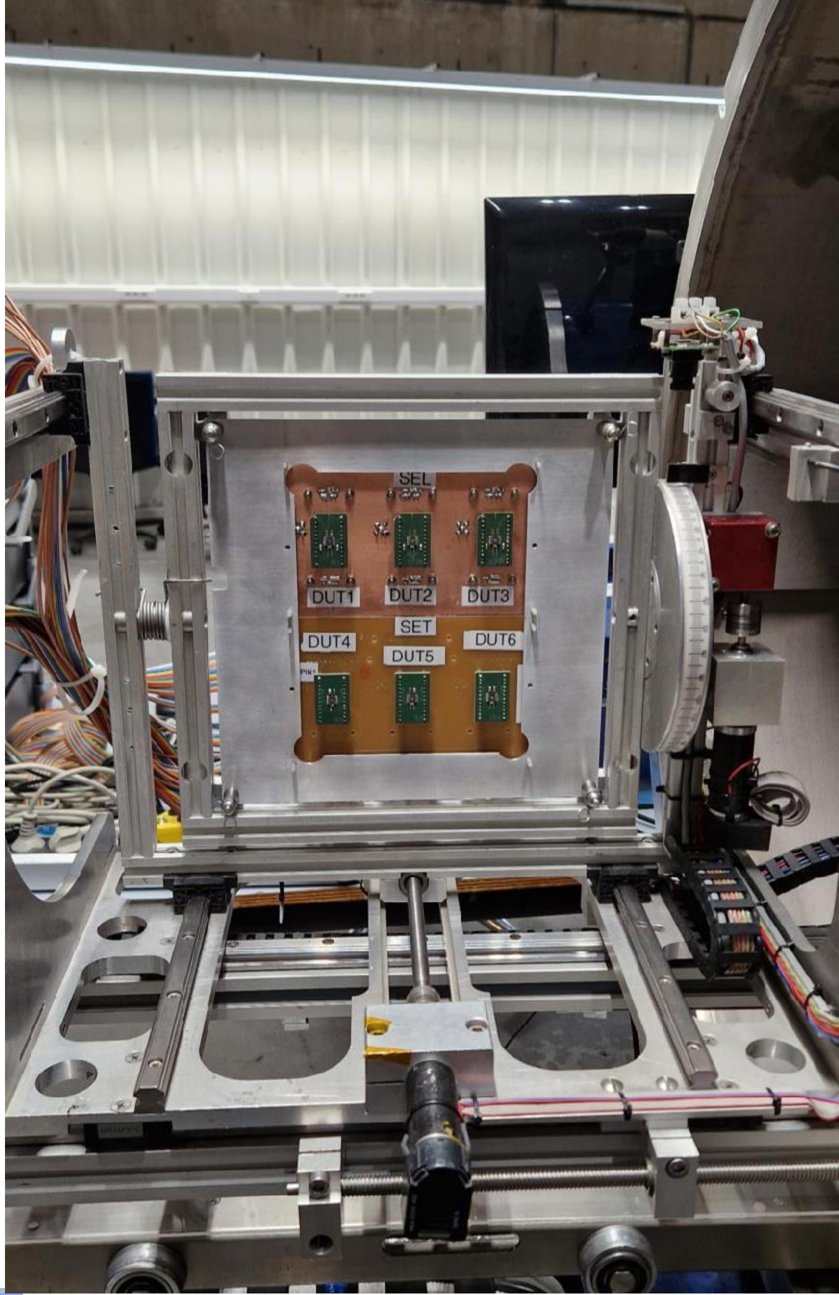
Total Ionizing Dose Testing





Single Event Effect Testing (HI)

- HIF @ UCLouvain
- LETs from 1.6 → 62 MEV cm²/mg (depending on DUT)
- Tests include SEL, SEFI
- SET/SEB/SEGR… where applicable



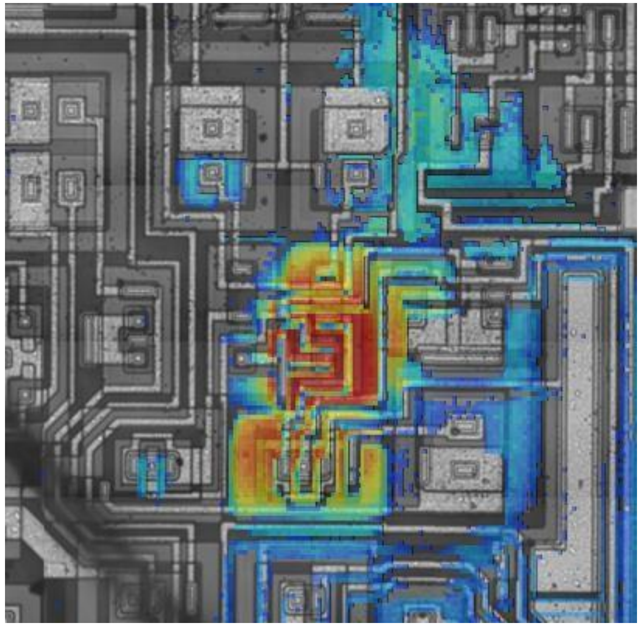
SEE sample preparation

- Decapsulation of the components at INT
  - MW-induced Plasma etcher
  - Precicion milling
  - Wet-chemical etching
  - Laser decapsulation

Selection depending on component

Pulsed-Laser SEE Testing

- For the current project: Pulscan PULSYS-RAD
- Wavelength 1064 nm (1.17 eV)
- Pulse duration 30 ps
- Automatic scanning of the die and acquisition of SEE at any scan point
- Front-side testing (not best practice but compatible with the HI setups)



THS4032MDGNREP / TSV992IQ2T / TSZ182HYDT

TIDL > 30 krad(Si) → good for many missions

>30krad(Si): Results / TIDL depend on operating conditions

- irradiate the device in worst case bias, then run at different operating conditions
- TIDL can be 30 krad(Si) → 100 krad(Si) just depending on Vcc

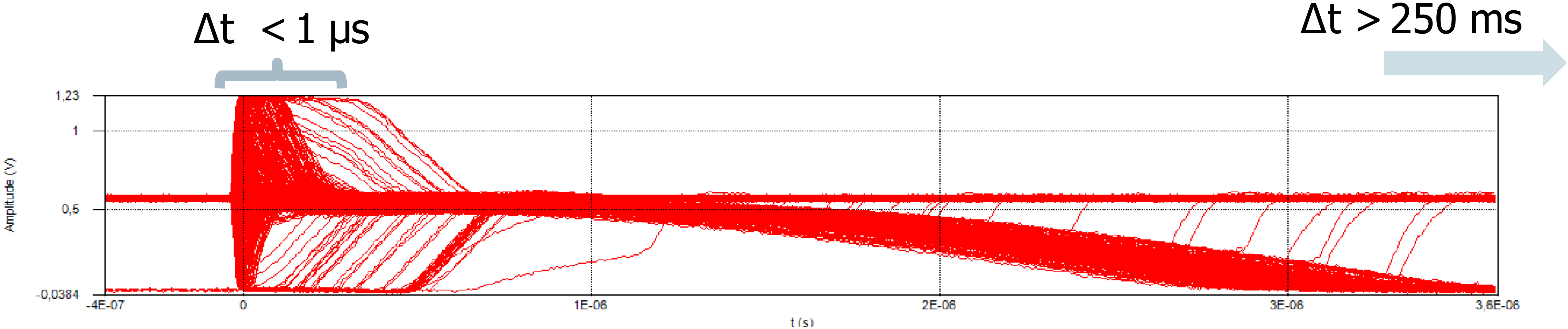
SEE: No destructive events @ LET 62.5 MeV cm²/mg
(as expected for bipolar techn.)

SET @ THS4032MDGNREP / TSZ182HYDT: LET_{thresh} > 20 MeV cm²/mg

THS4032MDGNREP / TSV992IQ2T / TSZ182HYDT

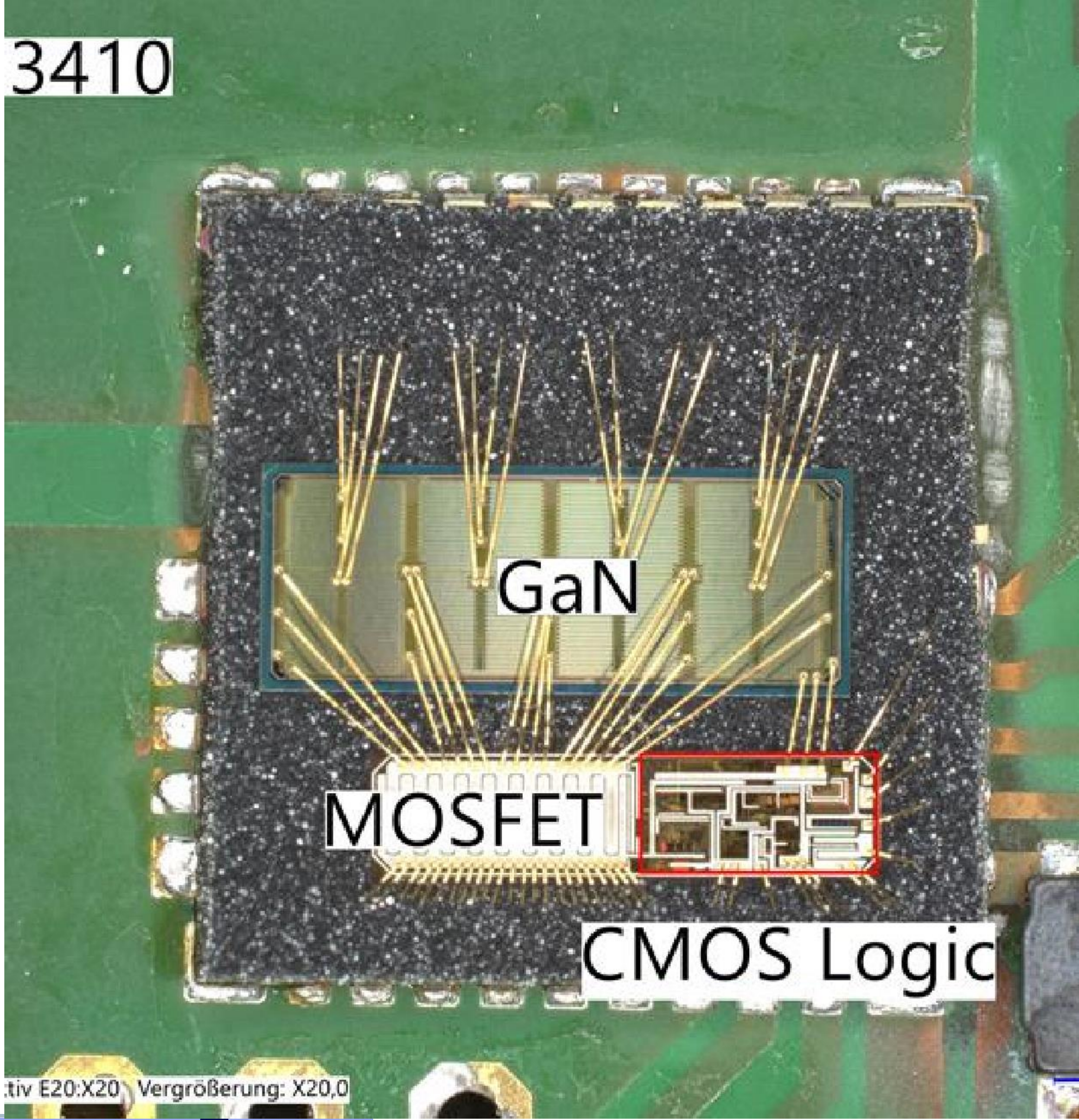
SET @TSV992IQ2T

- Performing Laser Tests before going to Heavy Ion improved the results / use of beam time massively
- Early identification of SETs being 5 orders of magnitude apart → adapt test plan



LMG3410R050RWHT

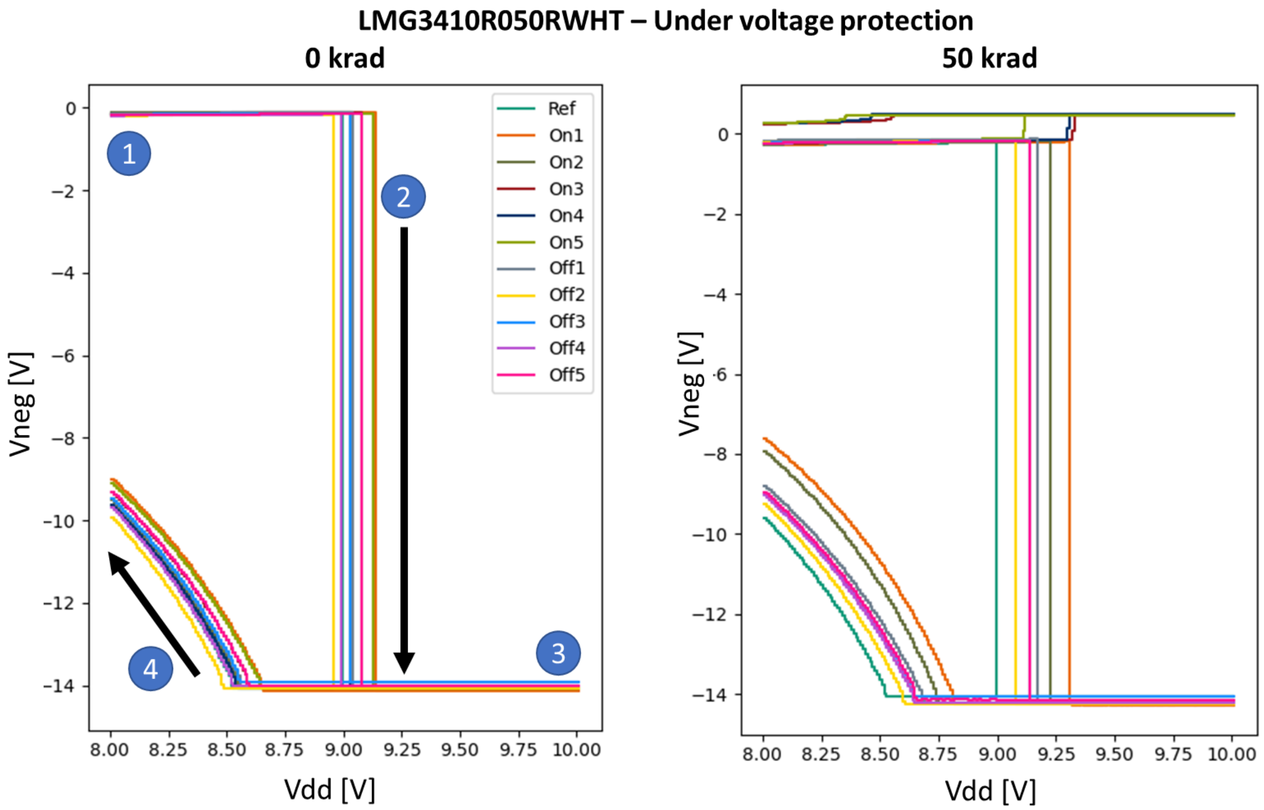
- Integrated design of a 600 V GaN
  + gate driver
  + overcurrent, overtemperature, undervoltage protection



LMG3410R050RWHT

- All devices within specs at **30 krad(Si).**
- At 50 krad(Si) under-voltage protection failure: some biased DUTs do not turn on as expected and especially do not block the GaN FET.
- Under voltage protection failing not visible during on-going irradiation in static bias (→ False positive results)

→ periodic restarts during irradiation for such parameters recommended



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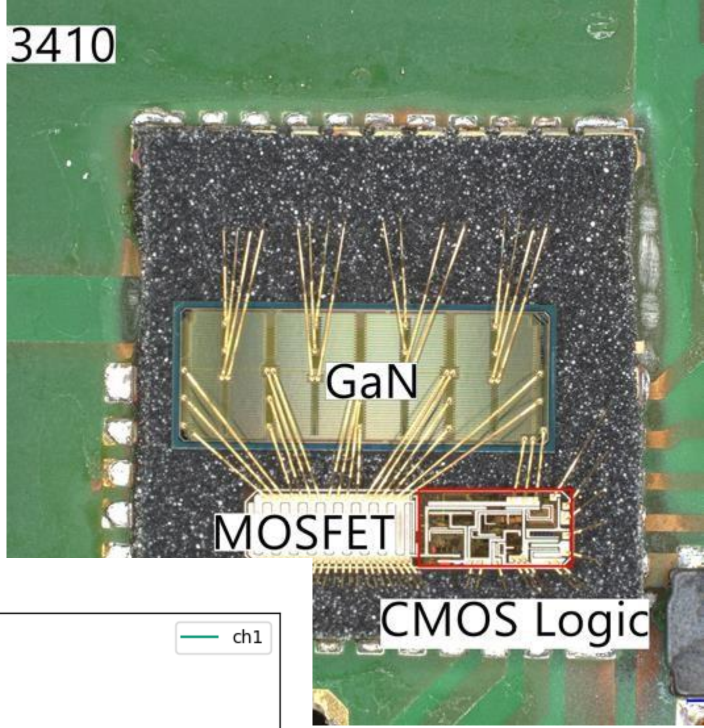
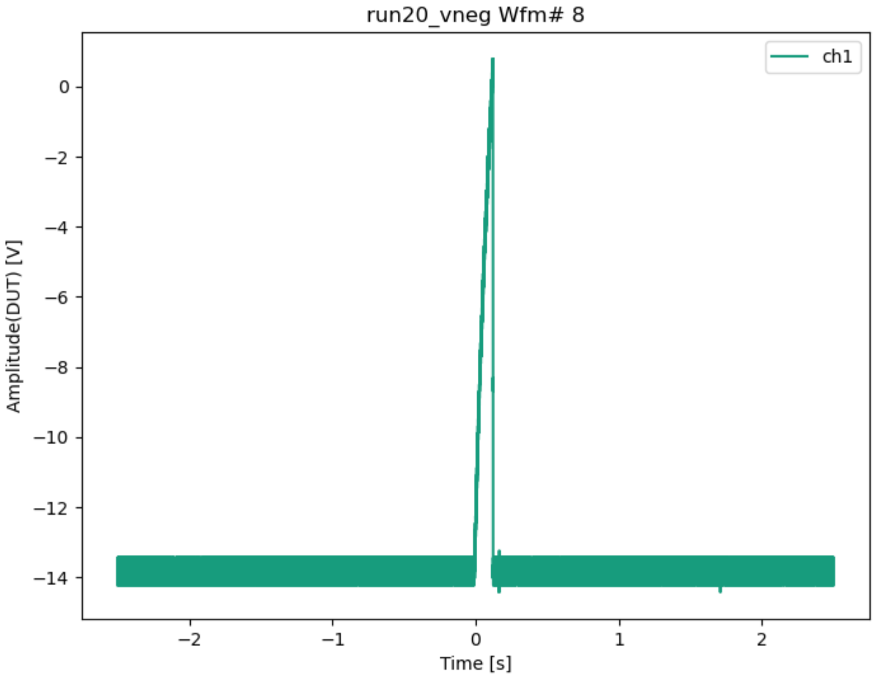
LMG3410R050RWHT

- Sample preparation for HI SEE:
  - Full die exposed
  - Only MOSFET+CMOS logic exposed
- All SEL/SEB/SEGR are non-mitigatable and immediately destructive
  (there is no control on the GaN gate by the experimenter)
- GaN encapsulated: SEE on the gate driver can make GaN conductive
- GaN exposed: huge σ for destructive events even if derated (600 V → 60 V)





What is our experience with COTS

Over the course of the years we encountered several of the well discussed caveats when using COTS

- Procurement affected by „chip crisis“ in 2021/2022, low availability of candidates
- Availability of date codes/procurement lot codes. Wafer lots only for some
  - At some vendors, even getting the date code is non-trivial
- Obsolescence: SM7244XMTE/NOPB
  - SM72442 was originally intended for testing. Now replaced by SM72445
  - Luckily these are pin and interface compatible → we can compare these

What is our experience with COTS

Over the course of the project we encountered several of the well discussed caveats when using COTS

- Lack of documentation
  - Experienced once: highly integrated component with on-die MCU
    - MCU documentation was only available to large-scale automotive customers
  - Several times: errors / inaccuracies in data sheets
  - Relevant information on more advanced protective functions can be hidden somewhere or not medtioned in the data sheet (irrelevant for the intended use, but relevant if you want to drive the DUT out of its comfort zone)

What is our experience with COTS

What of the well discussed caveats did we not see

- Destructive SEE events are an issue but relevant for fewer devices than anticipated
  - High Current Events (which can be mixed-up with SEL) are more frequent

- Most devices we observed have TIDL ≥ 30 krad(Si)
- TIDL ≤ 10 krad(Si) only observed quite rarely (once in RACOCO)

Summary

Commercial-off-the-shelf components tested with TID, SEE

For low-profile / high-risk missions, nearly all tested components could be considered

- For these missions, low SEE thresholds are the main blocking point
- From experience in this and past projects:
  - Protective functions (undervoltage….) are suprisingly often the weak spot (TID+SEE)

At least due to SEE, radiation test data is required

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