RADIATION CHARACTERIZATION AND FUNCTIONAL VERIFICATION OF COTS COMPONENTS FOR SPACE APPLICATIONS (RACOCO)

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Fraunhofer

INT

OVERVIEW

- Introduction
  - Who are we?
- Using COTS in space
  - Some thoughts (not only related to radiation)
- RACOCO activity
  - What will we do?

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Fraunhofer INT
Overview

Fraunhofer SPACE

- Employees: about 110
  (incl. about 50 scientists)
- Budget: approx. 10.0 million €
  (incl. approx. 4.0 million € contract research)

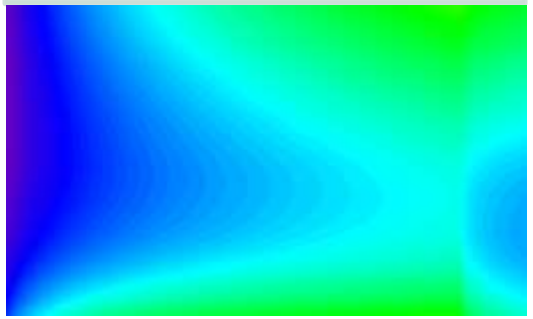
Business Unit Nuclear Effects in Electronics and Optics (NEO) at Fraunhofer INT

Areas of actvity

Investigation and application of effects of radiation on optical and electronic components and systems

Experimental Investigations

- Planning, execution and analysis of irradiation tests
- Characterization of the radiation sensitivity
- Extensive measurement equipment for optics and electronics



Radiation effects consulting

- Consulting on the execution of standard conform tests
- Consulting on the selection of appropriate parts
- Consulting on the hardening of components and systems

Operation of irradiation facilities

- Three Co-60 facilities in-house for TID tests
- Neutron generator in-house for SEE and displacement tests
- Pulsed Laser system for SEE tests

Simulation of radiation environment

- Radiation transport
- Model calculations
- Definition of environment
- Determination of mission dose
- Calculation of shielding

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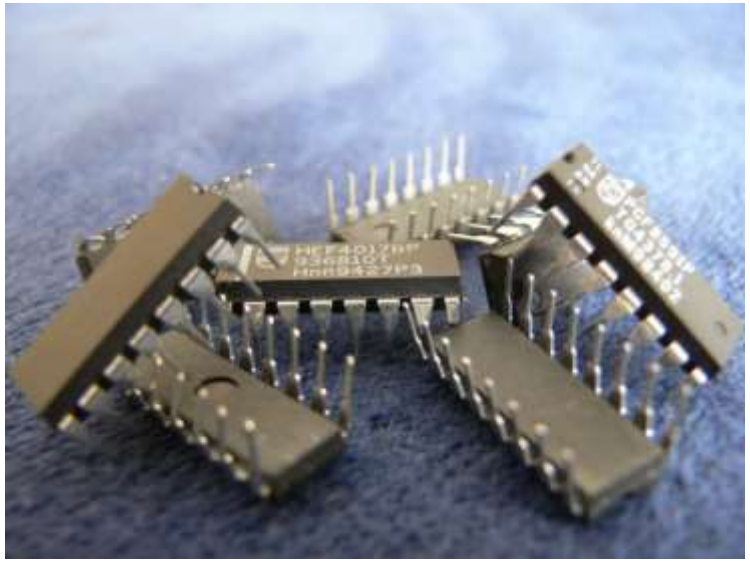
Getting started
What are “Commercial of the shelf” (COTS) components?

- *“COTS products are packaged solutions which are then adapted to satisfy the needs of the purchasing organization, rather than the commissioning of custom-made solutions.”* (en.wikipedia.org)
  - Wikipedia mostly refers to software products, no definition is given for components
- Commercial components are produced to serve
  - Volume mass-markets with high availability
  - Universal purpose
  - At very low prices
- Typical characteristics are
  - Cutting edge technologies available
  - Very wide range of available products
  - No specific optimization for (very) challenging environments



https://www.stockvault.net/photo/103091/integrated-circuits

Getting started – ESA Technology Development Targets

Why is there a topic “Commercial of the shelf components”?

ESA Technology Strategy

Version 1.0
08/11/18
ESA unclassified – releasable to the public

space systems much faster.

This will allow the achievement of concrete and measurable ambitious targets:

1. 30% improvement of spacecraft development time by 2023
2. One order of magnitude improvement of cost efficiency with every generation
3. 30% faster development and adoption of innovative technology.

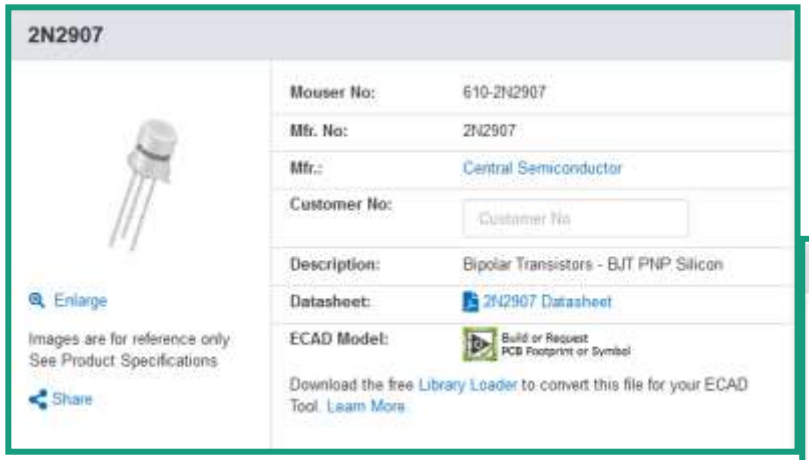
The development of technologies and concepts to enable the sustainable use

Comparison
How could COTS contribute to the ESA Technical Development Targets?

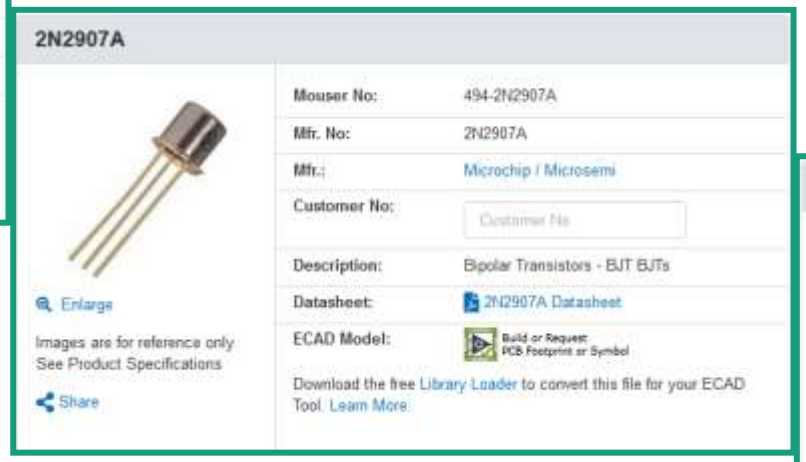
Technical Development Target	HiRel Components	"Perfect" COTS
30% Improvement of spacecraft development time by 2023	• Long delivery times • Slow qualification processes • "Old" industry behavior	• Instant availability • Optimized (delta) qualification • Dynamic manufacturers
One order of magnitude improvement of cost efficiency with every generation	• Expensive components • Backup/spare parts management • Adaption of possibilities	• Very cheap components • Re-buy possible • Extreme flexibility
30% faster development and adoption of innovative technology	• Limited range of available types • Generations behind current status • No intense market pressure	• Huge variation of solutions • Newest technology possible • Very competitive market

Example of COTS vs. HiRel Product

Three versions of bipolar transistor with identical functionality @ Mouser

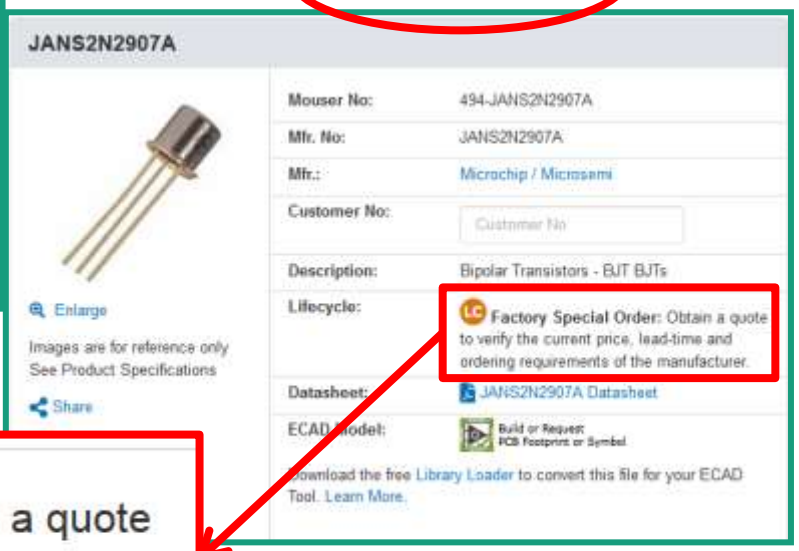


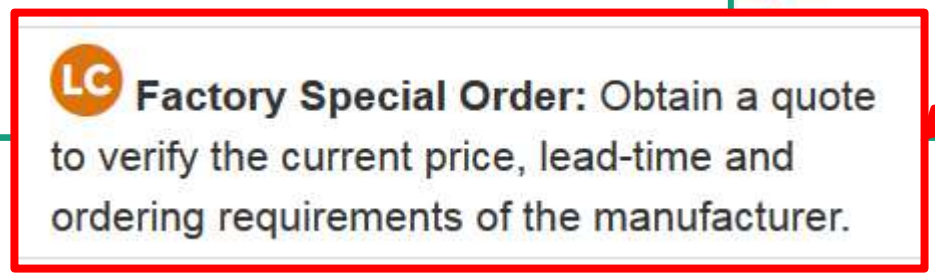
2 €, >2000 tomorrow



~5 €, >400 tomorrow

>60 €, ~50 available ?





Reality check
There is no “Perfect” COTS: Obsolescence

- Example of using COTS for special applications
  - Condor Cluster (500 TFLOPS, 33rd in world)
  - US Air Force supercomputer built out of 1,760 Sony PlayStation 3s running the Linux operating system

- On March 28, 2010, Sony announced it would be disabling the ability to run other operating systems with the v3.21 update due to security concerns
- No replacement units available any more

→ COTS use can wipe out years of work in a day

Reality check
There is no “Perfect” COTS: Price

- Presentation given by Tesat at ESCCON 2019:
  - For qualified parts the procurement is about 25% of the total costs
  - For COTS parts the procurement could be 5% to 10% of the total costs
- Biggest difference:
  - HiRel parts already include the full qualification, maybe no testing needed
  - COTS parts need (at least) radiation qualification for most applications
- Example calculation in table: We buy 200 COTS parts for 10 € each (or 2000 × 1 € or 20 × 100 €)

Price Ratio HiRel/COTS	10 k€ Qualification	100 k€ Qualification	1 M€ Qualification
5	83%	10%	1%
10	167%	20%	2%
50	833%	98%	10%
100	1667%	196%	20%
500	8333%	980%	100%

HiRel cheaper

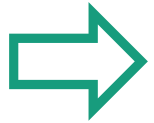
COTS cheaper

Reality check
Potential problems associated with COTS parts

- Traceability
  - No, incomplete or unreliable identification codes to judge lot/lot or wafer/wafer consistance
  - No manufacturer awareness with respect to process changes, silent modifications, fab dependence
- Order considerations
  - Huge minimum order quantities
  - Still large lead times (especially considering necessary qualification)
- Long term effects
  - Very fast generation developments
  - Storage conditions
  - No real heritage possible

Intermediate conclusion
COTS use in future missions

Time	• COTS use as such might not be the major contributor towards faster developments
Price	• The use of COTS could reduce costs substantially, but only case-by-case
Innovation	• Only the use of COTS will enable the integration of newest technologies



What could be done (exemplary with respect to radiation)
Examples of potential aspects

- Traditional way
  - Test conformance with requirements of optimized products developed for radiation environments → Acceptance
  - Test is only successful if all requirements are met defined for all possible applications or missions (GEO, 15 years) → Full spectrum
  - Over-testing on every level (radiation environments, parameter limits, operation conditions) → "300%" margin
  - Don't trust anyone or anything, tests have to be repeated for new lots → No blind spot
- Potential COTS way
  - Test many potential candidates to identify the less suited parts and reduce the list of components → Rejection
  - Tests could be done to aim at specific mission scenarios (LEO, 3 years) and failure is not a fixed definition → Particular case
  - Reducing individual margins and consideration of system-related robustness and mitigation → Some risk is acceptable
  - Don't expect everything to go the worst possible way → Trial and error

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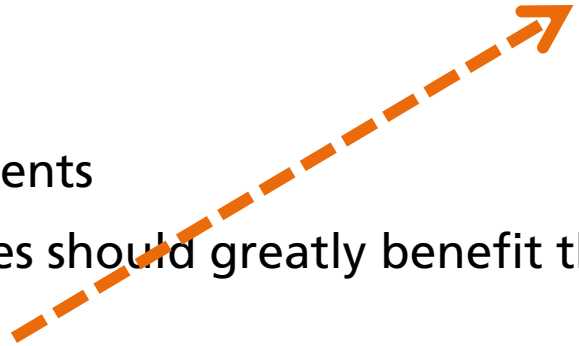
The RACOCO project

http://s.fhg.de/racoco

- Radiation characterization and functional verification of COTS components for space applications
- ESA contract 4000127569/19/NL/FE
- GSTP activity supported by Germany (DLR)
- Awarded to Fraunhofer INT (represented by the Fraunhofer Gesellschaft)
- Technical officer: Gianluca Furano (ESA)
- Budget 1.2 M€
- Timeline: 2019-2022

Aim of RACOCO

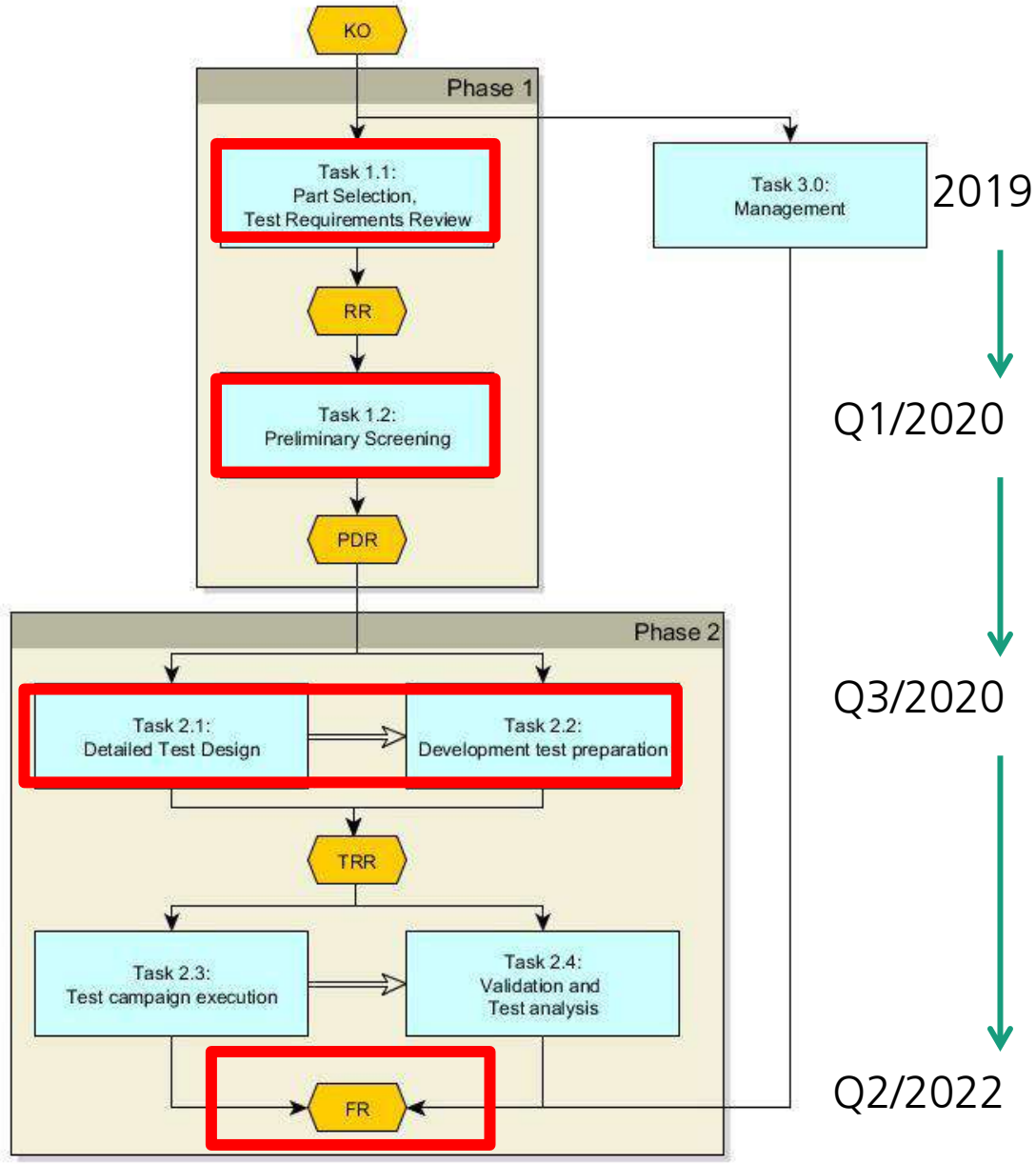
http://s.fhg.de/racoco-survey



- Identify available COTS components
  - Functionality or properties should greatly benefit the space community
    - Call for participation!
  - Will make use of spin-in approach (e.g. AEC-Q)
- Preliminary functional verification and radiation testing of a “long” list of components
- In-depth radiation testing on smaller but comprehensive subset
- Assess test methods and methodology for COTS components in general
  - Data and experience on the specific parts/lots can serve as input to guidelines for future COTS testing. This will be in support of the ESA COTS initiative recommendations.

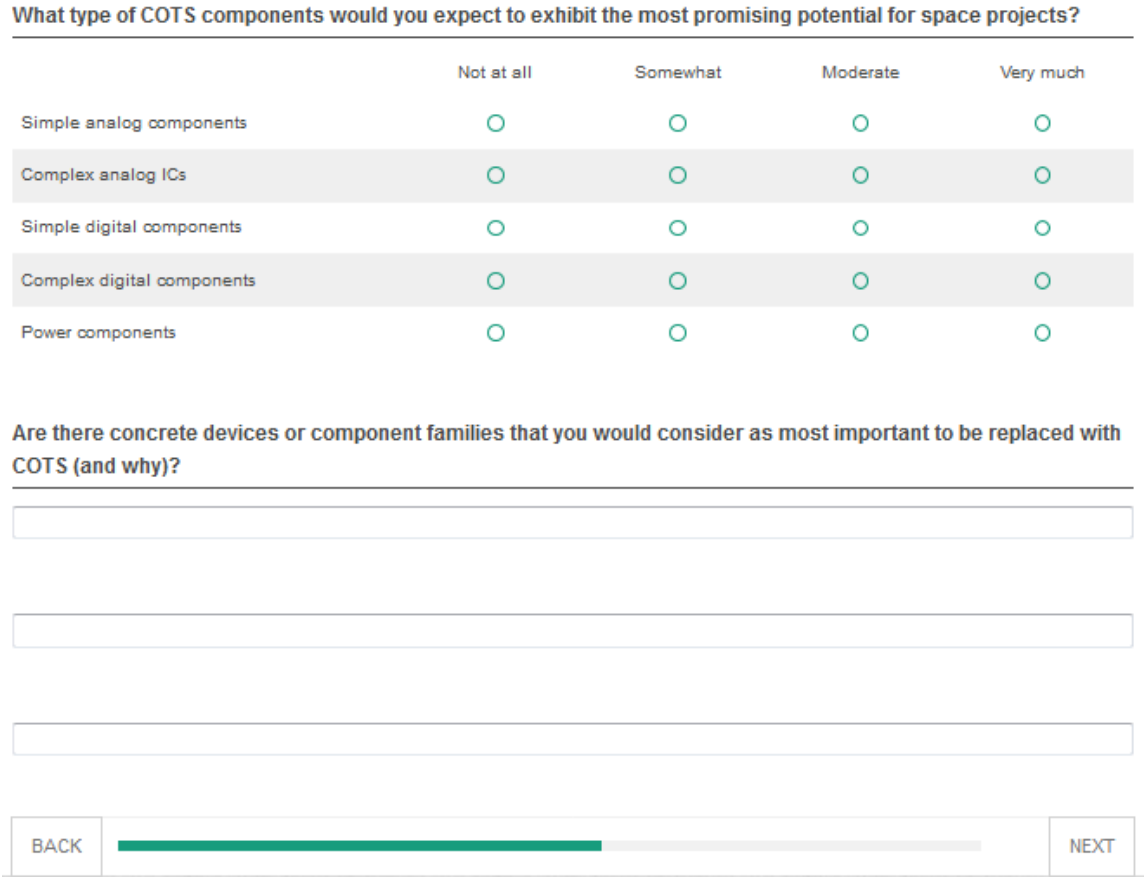
Timeline of RACOCO

- The project is currently in the first phase of test candidate identification.
- The basic suitability is then checked in a preliminary screening campaign
- Components that pass this will be subjected to in-depth testing.
- Suitable devices will be recommended for further qualification tests beyond radiation to enable use in space.



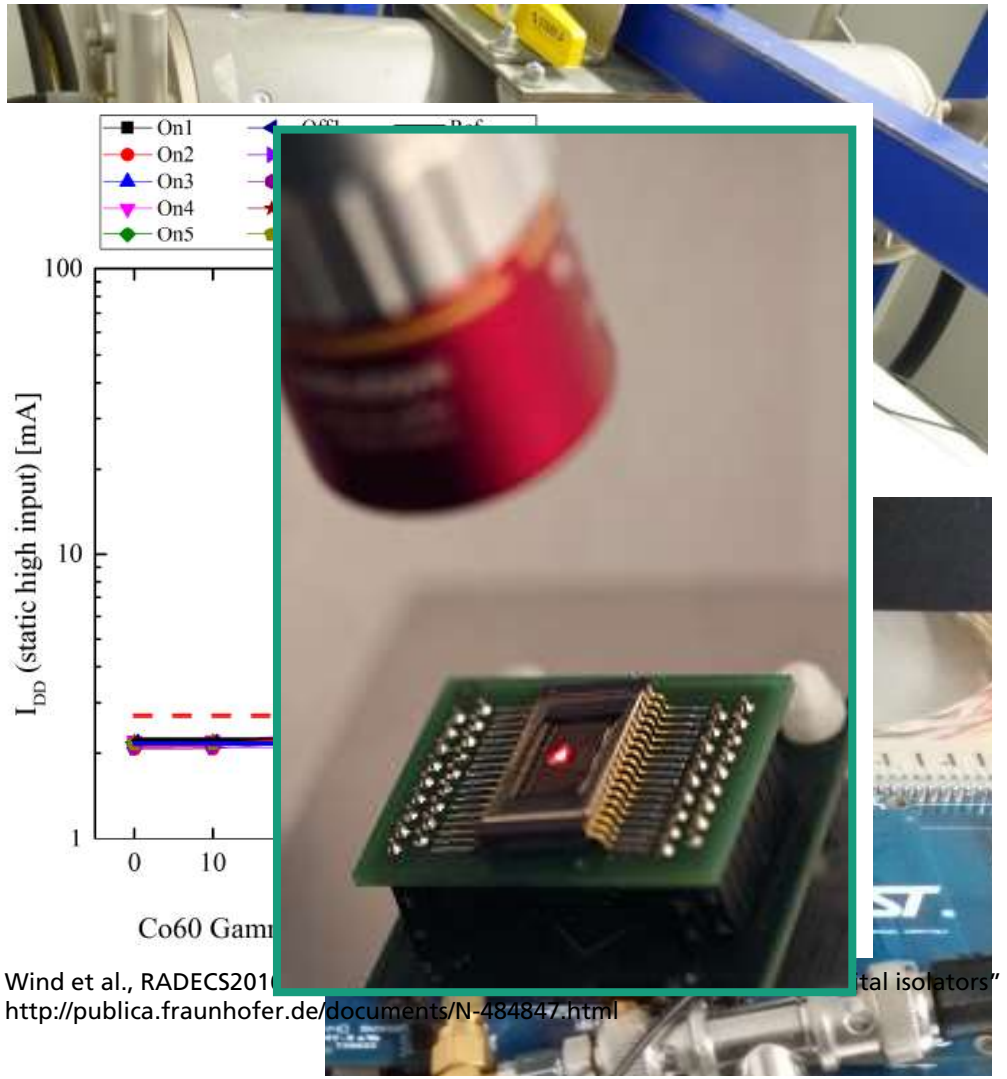
Candidate identification

- Build a „long“ list of candidate devices
  - Functionality or properties should greatly benefit the space community
  - Focus on high integration / high performance / reduced power?
- Why a „long“ list? Examples encountered:
  - Target 100 krad(Si) → Failing at < 10 krad(Si)
  - Target no SEL for LET < 60 MeVcm2/mg → failing with low LET to SEL
  - Decapsulation issues etc.



Preliminary screening

- The „long“ list of test candidates will be preliminary screened
  - focusing on SEL and TID to identify components which allow for a full characterization
  - If possible using evaluation boards and reference designs
  - → „short“ list of components with proven feasibility for further testing



Wind et al., RADECS201 tal isolators"
http://publica.fraunhofer.de/documents/N-484847.html

A. Menicucci et al., 2018 IEEE REDW
10.1109/NSREC.2018.8584279

Radiation testing campaign

- All parts passing the preliminary screening will be subjected to in-depth testing
  - Baseline: SEE, TID according to ECSS 25100 / 22900, DD, ….

- Some components will be subjected to additional tests:
  - Board level or assembly tests: How do component effects scale to a board level test?
  - Array of SEE test campaigns:
    - Assess alternative test methods more suitable for COTS testing.
    - Could a proton test be enough? Or UHE ions, Neutrons?
    - What would the reliability be? (e.g. How applicable is the figure of merit?)
  - TID: Statistics on large data sets
    - Lot to lot, part to part variations

Output of RACOCO

- Data and experience on an array of COTS components for space
- Eligible COTS Components that have passed all comprehensive radiation and functional tests shall be proposed for further upscreening for wide application areas
  - Radiation is the focus of this project, but not the only issue with COTS
- Experiences gained during testing shall be submitted to relevant stakeholders in the form of guidelines for possible inclusion in European normative standards

What we also want to learn from RACOCO

- How can we apply „cheap and easy“ preliminary test methods to first assess radiation hardness on unknown components?
  - Avoid „trial and error“ full-scale tests up to standards
- How representative and reliable can these preliminary test methods be?
  - Can they replace „full scale tests“ for „high-risk“ missions?
- How representative are radiation tests for samples from another lot/date code?
  - Links heavily to the use of heritage information and/or COTS databases

Summary

- Using COTS in space is challenging, but probably unavoidable

- In RACOCO we will put both COTS components and COTS test strategies to a test (http://s.fhg.de/racoco)
- The project is currently in its initial phase of device selection
  - Test preparations and preliminary screening in 2020
  - „Short“ list of components assembled in Q3/2020
  - In-depth testing from Q4/2020 to Q1/2022
  - Final report and Guidelines Q2/2022

- Please contact me for any other radiation effects related matters!

Last slide ….

Thank you for your attention!

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