RADSAGA review introduction and objectives

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RADSAGA System Level Test Review
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RADSAGA

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Review Panel Composition

- Jonathan Pellish (NASA) [review chair]
- Markus Brugger (CERN) [review chair]
- Francoise Bezerra (CNES)
- César Boatella (ESA)
- Tony Sanders (NASA)
- Jyotika Athavale (Intel)
- Renaud Mangeret (Airbus)
- Federico Faccio (CERN EP-ESE)
- Enrico Chesta (CERN IPT-KT)

Review Agenda: Introduction

Tuesday, 12 November

08:45 → 10:15 **Introduction session** — 774/R-013

- 08:45 **Welcome coffee** — 30m
- 09:15 **RADSAGA review introduction and objectives** — 30m
  Speaker: Ruben Garcia Alia (CERN)
- 09:45 **System level testing status in radiation effects community** — 30m
  Speaker: Andrea Coronetti (CERN)

Review Agenda: Facilities and Environment

10:30 → 12:15 **Facilities and radiation environment considerations** — 774/R-013

10:30	**Radiation field representativeness, homogeneity and penetration requirements** **Speaker**: Ruben Garcia Alia (CERN)	20m
10:50	**System level testing in CHARM** **Speaker**: Salvatore Danzeca (CERN)	25m
11:15	**System level testing in ChipIr** **Speaker**: Carlo Cazzaniga (Università Milano Bicocca)	25m
11:40	**Board and system level testing in other RADSAGA facilities and beyond** **Speaker**: Daniel Paul Soderstrom	25m

Review Agenda: Study Cases and Related Methodology

13:15 → 16:35 **Study cases and related methodology** — 774/R-013

13:15	**ESR7: Wide-bandgap DCDC converter** **Speaker**: Kimmo Niskanen	30m
13:45	**ESR12: 3D Point-of-load DCDC** **Speaker**: Tomasz Krzysztof Rajkowski	30m
14:15	**ESR14: Software Defined Radio for space applications** **Speaker**: Jan Budroweit	30m
14:45	**ESR13: FPGA modules for avionic and new space applications** **Speaker**: Israel Da Costa Lopes	30m
15:15	**Coffee**	20m
15:35	**Round-table discussion**	1h

Wednesday, 13 November

10:00 → 10:30 **ESR15: On-Board Computer and camera for space applications** — 30m — 774/R-013

Speaker: Andrea Coronetti (CERN)

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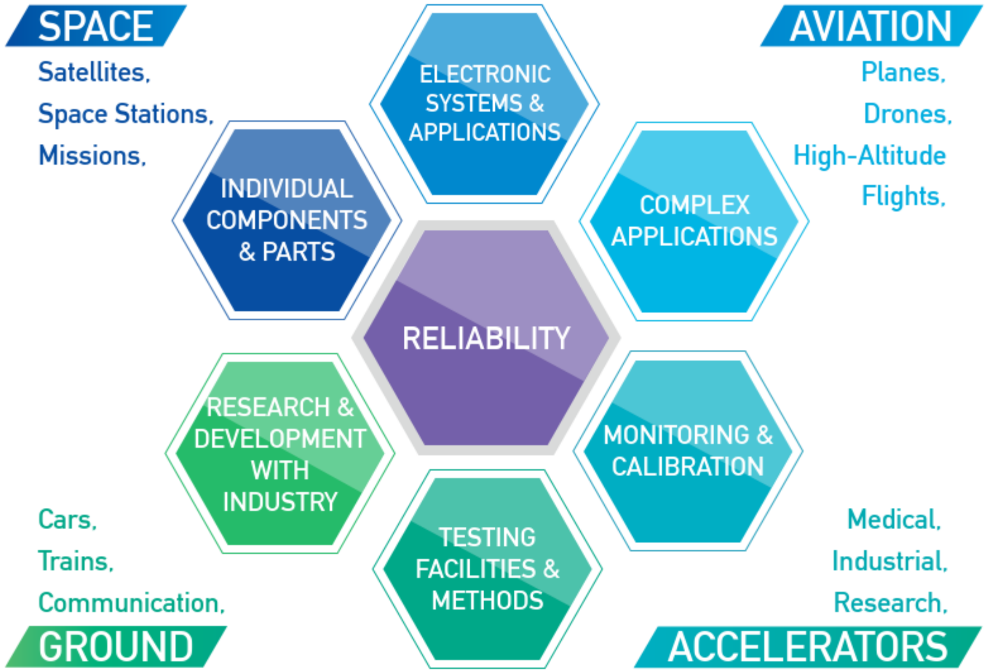
Review Agenda: Summary and Outlook

10:30 → 11:00	**Summary of methodology aspects derived from system level testing** **Speaker**: Andrea Coronetti (CERN)	30m	774/R-013
11:00 → 11:20	**Coffee**	20m	774/R-013
11:20 → 11:50	**Roadmap for future activities, including guideline structure and outline** **Speaker**: Ruben Garcia Alia (CERN)	30m	774/R-013

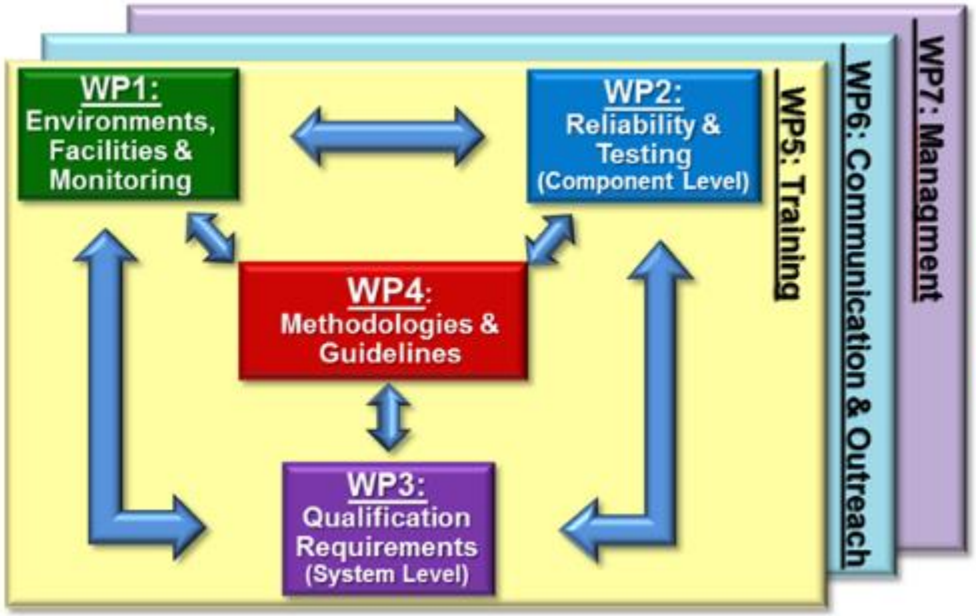
RADSAGA Introduction

RADSAGA is an Innovative Training Network created to train 15 young scientists and engineers in all aspects related to electronics exposed to radiation.



cern.ch/radsaga

RADSAGA Work Package Structure and Training Cycle



RADSAGA Early Stage Researchers

RADSAGA 2018 Summer School in Jyvaskyla

RADSAGA Mid-Term Review (September 2018)

- Focused on ESR training, dissemination and outreach aspects
- Very positive feedback from European Commission Project Officer and external expert

RADSAGA 2018 Mid-Term Review in Saint Etienne

RADSAGA Work Package 3 (System Level Testing)

Closely linked to WP2, WP3 will address the decisive question of ***how system tests will be able to provide reliability information as opposed to the standard bottom-up individual component characterization****, which is hardly practical for modern digital integrated circuits hosting a vast amount of devices. This WP will also make use of the results obtained in WP1, as the feasibility and preparation of a full-system test will largely depend on the radiation facility parameters (i.e. beam size, beam energy, etc.) as well as the interaction of the radiation environment with the system components (i.e. stopping particles, generation of secondary particles, etc.) all of which need to be carefully considered through Monte Carlo simulations.*

Name	Subject
ESR 12 WP3.1	System-In-Package (SiP) radiation qualification requirements
ESR 13 WP3.2	Bridging methodology from component to system-level for the assessment of coupled radiation and degradation constraints in digital systems
ESR 14 WP3.3	Radiation tolerant communication links to be used for distributed systems and mixed-field radiation environments

RADSAGA Work Package 4 (Handbook)

*Furthermore, WP4 will make use of the research progress in the first three WPs to develop a **handbook of guidelines and tools for rad-hard design and radiation testing of components and systems in complex environments**. This document will serve as a decisive input for engineers across the European industry working on the design and characterization of electronic systems in a broad range of application fields. It will combine fundamental radiation aspects (i.e. particle interaction with matter, synergetic and coupled effects, etc.) and practical aspects (i.e. predictive tools, test facility information, etc.) providing an insight to radiation reliability otherwise inaccessible even for the most experienced radiation expert. It is intended to serve as basis for a new European radiation testing standard*

Name	Subject
ESR 15 WP4.1	Relevance, Guidelines & Tools for rad-hard design and radiation testing of components and systems in complex environments

RADSAGA Deliverables

WP	Deliv. N.	Title	Lead Benef.	Deadline of submission
WP1	D1.1	Summary of RHA approaches in European irradiation test	JYU	28.Feb.19
WP1	D1.2	Design status report and prototype of SRAM radiation monitor	JYU	31.Aug.19
WP1	D1.3	Facility dosimetry procedure and dedicated monitors	JYU	31.Oct.19
WP1	D1.4	Documentation of test setups practical for mixed-facilities	JYU	29.Feb.20
WP2	D2.1	Report on hardening by design rules, tools and modelling	UM	30.Apr.19
WP2	D2.2	Status report on coupled effects and predictions tools	UM	31.Oct.19
WP2	D2.3	Design status report and prototype of the rad-tolerant CMOS imager	UM	31.Dec.19
WP2	D2.4	Combined status report on modelling techniques and tools	UM	29.Feb.20
WP3	D3.1	Progress Report on system level test methodology compared with component test results	BTU	30.Apr.19
WP3	D3.2	**Final Report on system level test methodology compared with component test results**	BTU	**30.Apr.20**
WP3	D3.3	**Collection and documentation of testing tools and facilities required for system level tests**	BTU	**30.Jun.20**
WP3	D3.4	**Risk assessment and application procedure of system test methodologies**	BTU	**31.Aug.20**
WP4	D4.1	Evaluation report of 14 MeV test methodology	CERN	30.Jun.19
WP4	D4.2	**Handbook of test methodologies and applicable facilities for advanced systems**	CERN	**31.Oct.20**

System level testing: some general considerations

- Already well established for some applications (e.g. high reliability ground level, avionic), but knowledge and procedure is typically kept in-house
- Example in space community: systematically performed for non-critical ISS applications (Proton Board Level Test Method [PBTM] – see later on)
- Increasing interest for new space applications (reduced launch cost, increased use of COTS, risk evaluation and acceptance, etc.)
- Typically, not to be seen as an alternative to component level qualification, but rather as an alternative to not testing at all
  - Importance of evaluating investment and return of investment
- Lack of existing best practice/guideline/handbook for system level testing
  - Inefficient for system engineers without radiation effects background
  - Risk of not being able to compare different results, use work from other groups, transfer/accept risk between system tester and end users, etc.

Traditional Radiation Hardness Assurance (RHA): radiation testing at component level

Equipment/system response against radiation is estimated via analysis, based on results from component testing

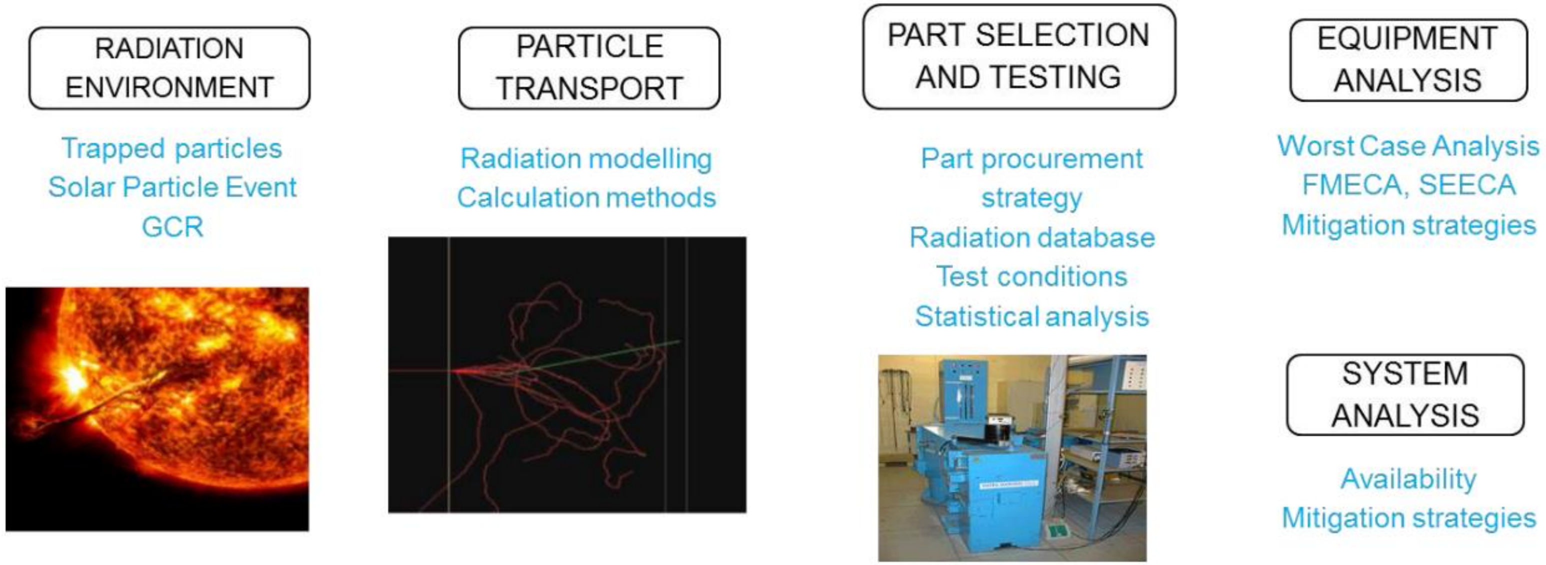


Figure 1: top level description of the Radiation Hardness Assurance coverage

Why is standard RHA performed at component level?

- Device-centric isolation provides clear boundary between device behaviour and system design that makes it relatively easy to define system response [1]
- Device-centric radiation data provides clear delineation that enables system-level understanding and empowers designers with **boundaries of the performance of individual devices** [1]
- The requirement for system operation allows for a **failure definition that is determined by the application of the part in the system** [4]
- The requirement to meet a specified radiation level allows us to test parts as a function of a radiation environment and compare the radiation failure level of the part to the specification level [4]

Top-down: system requirements can define type of radiation tests to be performed at component level
Bottom-up: component level response used to determine whether it is acceptable for a given system

Indenture level

- Proposal for review:
  - We will define as **system** the subject being considered (with regards to its response to radiation)
  - We will define as **electronic component or part** an electronic device that cannot be taken apart without destruction or impairment of its intended use (e.g. discrete transistors, integrated circuits, system-on-chip…)
  - The part and system are at the lowest and highest level in terms of hierarchy. Possible levels in between are defined through the **indenture level**, which will depend e.g. on the item's complexity, accessibility of sub-items, etc.
  - Examples:
    - system, sub-system, assembly and component
    - system, sub-system, equipment, functional unit, device and component
    - system, sub-system, box, board, component
- The cases covered in the review will have two (system, component) or three (system, sub-system, component) indenture level
  - System-on-Chip: combination of system (high hierarchical/complexity level) and chip (i.e. part that cannot be taken apart without destruction). A lower indenture level can be defined as **processing unit** (e.g. application processing unit, on-chip memory…)

Failure modes and fault tolerance

- If at a high enough level, system level failures will typically manifest as functional failures. In this sense, the main purpose of system level testing is:
  - Defining the **failure modes** (qualitative)
  - Determining their **occurrence likelihood/rate** (quantitative)
- System level mitigation/protection of radiation effects (typically referred to as **fault tolerance**) may be implemented either prior the radiation tests, or as a consequence of previous radiation test results. In this sense, system level radiation testing can serve the purpose of:
  - Validating the mitigation measures/fault tolerance
  - (In case they have an impact on the system performance or availability) Determining their occurrence likelihood/rate
  - Examples: switching of redundant component or function, error correction system, specific memory organization, latch-up protection circuitry, etc.

System Level Testing Categorization

- **Custom/commercial**

- **By effect:**
  - TID
  - TID + DDD (*)
  - SEE (**)
  - SEE + TID + DDD

- **By application:**
  - Space (ISS, LEO)
  - Atmospheric
    - Avionic
    - High reliability terrestrial
  - Accelerators

- **Number and type of active components**
  - Sensitive to destructive SEEs and/or soft SEEs
  - Previous information about radiation response?

- **Critical/non-critical applications**

- **By indenture level:**
  - 2 (system, component)
  - 3 (system, sub-system, component)
  - 3 (system, component, processing unit)
  - 4 (system, sub-system, component, processing unit)

- **By test environment (high penetration)** (***):
  - Cobalt-60
  - High energy (200 MeV) protons
  - Intermediate/high energy neutrons
    - Spallation
    - 14 MeV
  - Mixed-field
  - Very high energy heavy ions

- **By main test objective:**
  - System level lifetime and SEE rate characterization
  - Fault injection and failure mode definition (i.e. qualitative)

(*) Boards/systems sensitive to DDD will typically also be sensitive to TID
(**) With TID levels below 1 krad
(***) Laser and x-ray could also be considered, but typically more as qualitative fault injection rather than quantitative rate prediction/bounding

System Level Testing Categorization

- For example, the **proton board-level test method (PBTM)** introduced in [1] covers mainly systems that are:
  - Commercial
  - For SEE effects, with SEE rate estimation/upper limit as main purpose
  - With 2 indenture levels (board, component)
  - For non-critical ISS applications
  - Using 200 MeV proton beams with a 10^{10} p/cm^2 fluence
  - Considering 65 active components
    - 45 of which are triaged as having SEE rates below 0.1% in 10 years
    - 20 devices with destructive/permanent failure risk

Importance of scope definition when referring to "system level testing"

System Level Testing: Pros and Cons (as so far identified in radiation effects community)

Pros	Cons
Cost, time (**)	Observability (go/no-go)
System level failure mode and rate	Traceability, part-to-part variation
	Same irradiation conditions for all technologies
	Limited information about destructive SEE sensitivity to heavy ions (*)
	System-level application specific

(**) In some cases, it might be the "only option"

(*) only applicable to space environments

To be developed and discussed during the review…

References

- [1] Guertin, Steven M. Board level proton testing book of knowledge for NASA Electronic Parts and Packaging Program. Pasadena, CA: Jet Propulsion Laboratory, National Aeronautics and Space Administration, 2017.
- [2] http://www.electropedia.org
- [3] NSREC 2017 Short Course
- [4] NSREC 2018 Short Course