R2E Radiation Hardness Assurance

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With input from the R2E equipment groups

Possible BE-CO/EPC common requirements

- Mechanical form factor: 6U rack for EPC, 3U rack for BE-CO?
- AC/DC module: 230V/48V
- DC/DC module: 48V/+5V, ±15V
- Timeline: LS2/Run3/LS3

Key building blocks

Radiation Monitoring and Calculation

Rad-hard component design
(experiments)

Rad-tol system development based on COTS

(accelerator)

Radiation Hardness Assurance

Qualification Approach

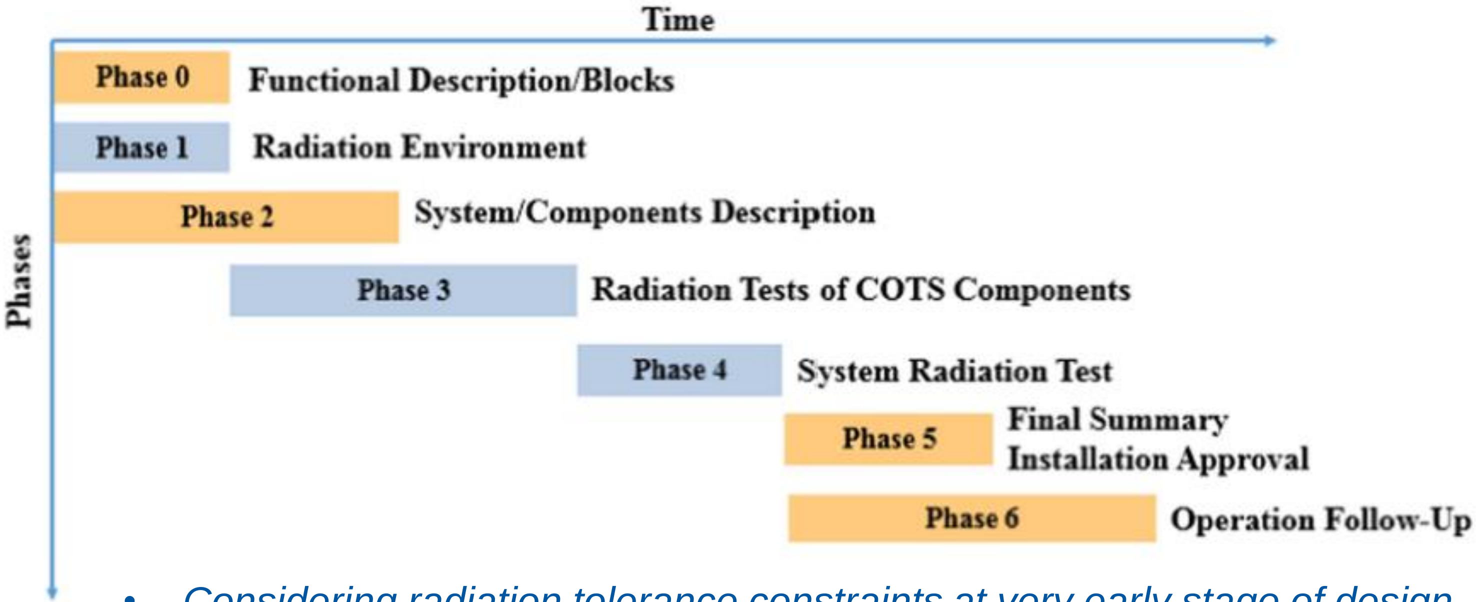
Radiation Test Facilities

R2E RHA scope

- R2E RHA mainly applies to **COTS-based systems** that are designed in-house, allowing for:
  - Selection of individual COTS components according to both electrical and radiation tolerance considerations (and sometimes used in combination with radiation hardened parts)
  - Possibility of having high observability during system level test (i.e. self-diagnose, modular design)
  - Possibility of re-design in case of unsatisfactory performance against radiation at system level

RHA guidelines for COTS-based systems

(and high-energy accelerator applications)



- *Considering radiation tolerance constraints at very early stage of design*
- *Validation of radiation tolerance at system level before final production*

RHA guidelines for COTS-based systems

(and high-energy accelerator applications)

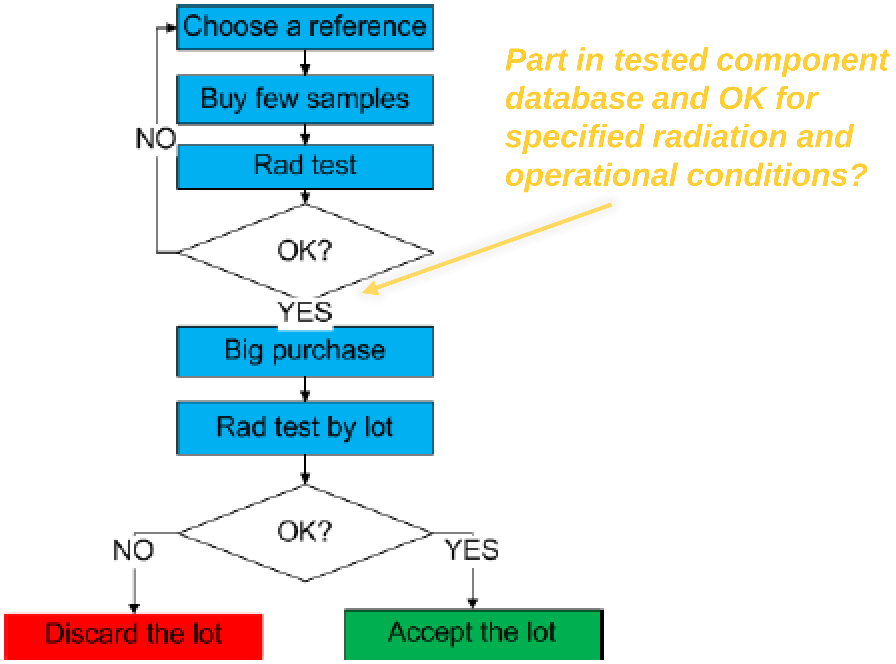
Class	Radiation response	Sourcing	Test methodology
Class-0 (potentially sensitive)	Resistant or moderately sensitive	Easily replaceable, different manufacturers available	Selection of already tested component when possible. Only integrated in system test.
Class-1 (potentially critical)	Potentially susceptible to radiation, not in system's critical path	Substitution possible (list of preferable replacements defined)	Sensitivity screening, if possible of several candidates. If passed, integrated in system test.
Class-2 (highly critical)	Potentially susceptible to radiation, on system's critical path	Difficult to replace, no equivalents on the market	Sensitivity screening and if passed, lot/batch testing. If accepted, integrated in system test.

+ *impact of component failure at system level*

Not possible to test all parts at same level, therefore different classes according to criticality need to be considered

Screening and lot acceptance

- Components purchased through vendors which obtain them from different foundries
- Dedicated production follow-up (i.e. full traceability) is expensive
- We rely on the assumption that COTS samples belong to same lot when they have same date code

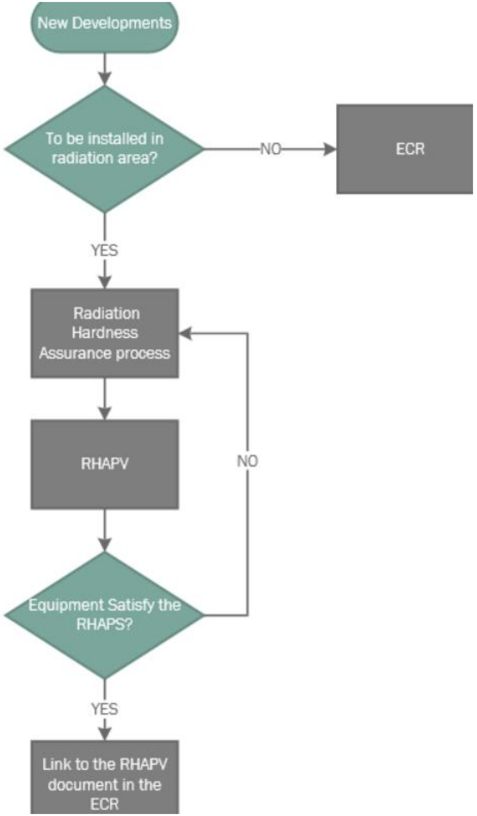


R2E RHA documents

- **RHAPS: Process Structure** → Pure RHA guideline which give information on the process and guide the user through the testing method and effectiveness.
- **RHAPV: Project Validation** (new project) → report of the project information, radiation environment, radiation tests [linked to Engineering Change Request]
- **RHACD: Check document** (existing equipment) → report the cards changed and if they are conform with the RHAPS.

New Developments	System already installed
• Have to follow a radiation assurance procedure RHA • The criticality needs to be assessed • The system has to be tested in a representative radiation environment	• Their fault rate should be assessed • The relocation should be notified • The integration document will have a field pointing at the RHA document • Any system change should be notified

RHAPV – Process Structure



- Endorsed during 2017 R2E review
- Linked to LHC Engineering Change Request (ECR)
- Contains the RHA Project Validation document as cornerstone for equipment exposed to radiation

RHAPV – Project validation

- Example: GEFE BPM FE system

CERN CH-1211 Geneva 23 Switzerland

EDMS NO.	REV.	VALIDITY
0000000	0.0	DRAFT

REFERENCE
XXXX

Engineering Department

To be sent to: ecr.ENDEPT@cern.ch Date: 201x-xx-xx

Radiation Hardness Assurance Protocol Document

GBT-based Expandable Front-End (GEFE)

Brief description of the project(s):

EQUIPMENT CONCERNED:	DRAWINGS CONCERNED:	DOCUMENTS CONCERNED:

PE IN CHARGE OF THE ITEM:	PROJECT LEADER:
< Name >	< Name >
DECISION OF THE PROJECT ENGINEER: ☐ Rejected. ☐ Accepted by the Project Engineer, no impact on other items. *Actions identified by the Project Engineer.* ☐ Accepted by the Project Engineer, but impact on other items. *Comments from other Project Engineers required. Final decision and actions by the Project Management.*	DECISION OF THE PROJECT LEADER: ☐ Rejected. ☐ Accepted by the Project Leader
DATE OF APPROVAL:	DATE OF APPROVAL:

ACTIONS TO BE UNDERTAKEN:
< ACTIONS >

DATE OF IMPLEMENTATION: < DATE >

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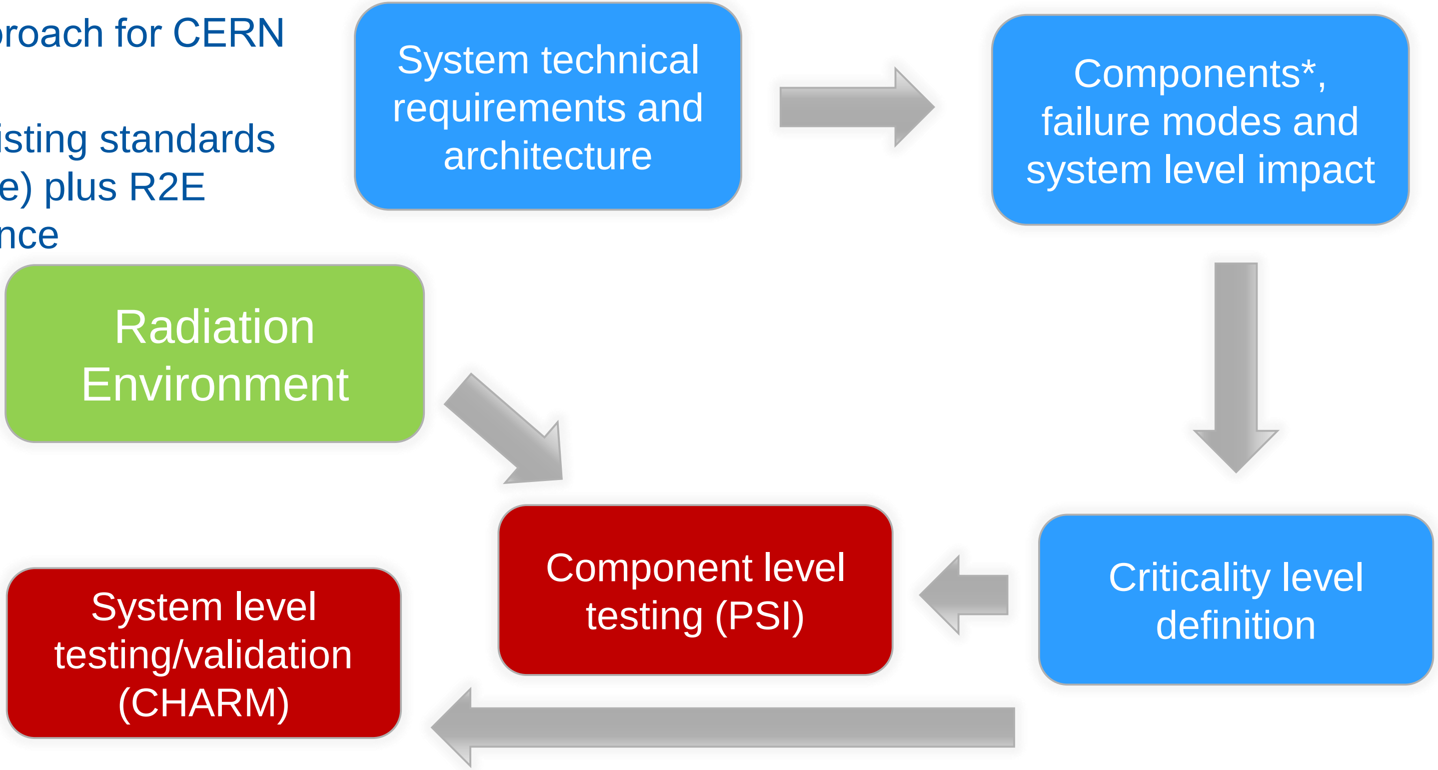
1. PROJECT DESCRIPTION 1.1.1 TECHNICAL REQUIREMENTS AND MAIN SPECIFICAITONS 1.1.2 ARCHITECTURE 1.2 CRITICALITY	**Equipment group**
2. RADIATION ENVIRONMENT	**MCWG chair**
3. RADIATION TESTING 3.1 COMPONENTS LIST AND CRITICALITY 3.2 RADIATION TEST AT COMPONENT LEVEL	**Radiation test service**
4. RADIATION TEST AT SYSTEM LEVEL	**Equipment group + Radiation test service**
5. FINAL SUMMARY 6. COMMENTS	**R2E project leader**

RHA project validation

**importance of structured database for tested COTS component; further testing still needed to determine batch response and if applicable adapt test conditions (radiation + component operation)*

- Formalization of R2E “best practice” approach for CERN equipment
- Based on existing standards (mainly space) plus R2E LHC experience



Typical qualification limits and facilities

- Project specific, as they will depend on the respective radiation environment and system criticality
- Example: critical system (i.e. one R2E failure per year) in HL-LHC ARC/shielded area, ~1000 system units
  - Cumulative effects: **200 Gy**, **$2 \cdot 10^{12}$ n_{eq}/cm^2**
  - Stochastic effects: **$\sigma_{failure} < 10^{-12}$ cm^2** (at system level)
- Facilities:
  - At component level: 200 MeV protons at **PSI** (SEE, TID, DD)
  - At component and system level: **CHARM** (high-energy accelerator mixed-field)

CHARM R2E facility for system-level testing

- Unique facility for radiation testing at component, board and **system level** in **high-energy accelerator environment**
- Facility makes use of available beam (PS East Area) while being specifically tailored for accelerator electronics qualification
- Similar approaches outside CERN at **board level**: neutron spallation (e.g. LANSCE, ChipIr), proton cyclotrons (e.g. PSI, KVI, TRIUMF), very-high energy heavy ions (GSI, NSRL)

System-level testing during LS2

- Global situation:
  - LS2 systems already qualified
  - LS3 systems mostly in phase of design and component level testing, to be qualified at system level beginning of Run 3
- Rad-tol systems presently under development and required before end of LS2/by start of Run 3 (spares, etc.):
  - Possibility to perform board/system level test during LS2 in **Cobalt-60** source (TID) and **ChipIr** neutron spallation facility (SEEs with large, highly penetrating beam)

General considerations on DCDC converters

- COTS-based in-house design or commercial module?
- Isolation principle for feedback loop: photo-coupler or magnetic transformer?
- Possible synergies with EP activities/know-how and/or industrial applications?

Associated applications/radiation environment

- Bi-Volt/Tri-Volt EPC:
  - FGClites (tri-volt): RR areas, possibly also needed for 60A in LHC arc?
  - DCCT(bi-volt)
- DIOT:
  - Potentially used in broad variety of applications/environments, therefore radiation tolerance target should be compliant with most LHC areas hosting electronics
  - Applications already confirmed: PIC, WIC