**Lifetime study of electronic devices for extreme radiation conditions**

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**Background**
- Radiation technology development and its applications bring new requirements on related electronic devices.
- The study of radiation effect on electronic devices is important for increasing their lifetime and the reliability of the whole technology, when used in radiation harsh environment like space, large accelerators, nuclear reactors etc.
- We have studied the effect of the X-rays and the high energy electrons on lifetime of devices used in radiation extreme conditions:
  - the CERN accelerator component (by electrons)
  - the semiconductor devices for the first Slovak satellite (by X-rays)
  - the semiconductor detectors for radiation imaging and dosimetry (by electrons)

**Methodology**

**Method of lifetime study**
1. Monte Carlo simulations of irradiation geometry and device tested together with dose-depth distribution in it
2. Irradiation of phantom of tested device
3. Irradiation of tested device
4. Electrical and/or mechanical functional tests of irradiated device in collaboration with Slovak University of Technology in Bratislava, SK, ZTS VÚ VÚSECE Ltd., SK
5. Periodical of measurements for longer device operational life in real radiation fields

**Irradiation**

**Linear electron accelerator UELR 5-15**
- Producer NIEFA, St. Petersburg
- Maximum beam power: 3 kW
- Electron energy (3.6 - 6.2) MeV
- Beam repetition rate 5, 10, 20, 40, 120 or 240 Hz
- Converted X-rays, up to 8.2 MeV
- Beam scanning width: 40, 45, 50 cm
- Beam diameter at window 11 mm
- Convered velocity: 0.1 mm/s - 100 mm/s
- Three modes of irradiation:
  i. the static scientific irradiation
  ii. the in-line routine irradiation on conveyor
  iii. the rotational irradiation

**CERN accelerator component**

- Engine for precise positioning of dipole magnets in Super LHC accelerator in CERN
- Made by ZTS VÚ VÚSECE Ltd., SK
- Tested by PC controlled tester at ZTS VÚ VÚSECE Ltd, SK
- Beam repetition rate 10 Hz, scanning width 27.4.80
- Monte Carlo simulations of irradiation geometry and device tested together with dose-depth distribution in it
- Irradiation of phantom of tested device
- Irradiation of tested device
- Electrical and/or mechanical functional tests of irradiated device in collaboration with Slovak University of Technology in Bratislava, SK, ZTS VÚ VÚSECE Ltd., SK
- Periodical of measurements for longer device operational life in real radiation fields

**Simulation of operating radiation environment**
- Stray radiation fields are created at high-energy particle accelerators by the intentional interaction of the accelerated beam with targets, beam dumps, collimators and by unintentional beam losses on structural components of the machines.
- At electron accelerators (UEDA) the most important secondary radiation is bremsstrahlung photons and high-energy electrons produced in electromagnetic cascades.
- At proton accelerators (CERN), interaction of the beam with materials generates a hadron cascade containing neutrons, charged hadrons, muons, photons and electrons. Dominant are neutrons.
- Simulations of secondary particles of 200 MeV protons of various depths of carbon shield ionizing one on non energy deposit than the proton range and electron energy distributions in test after various carbon thicknesses penetration 20

**Semiconductor devices for skCUBE**

- **SKCUBE**, the first Slovak satellite:
  - made by Slovak Organization for Space Activities
  - made for launch in 2015
  - Circular Earth’s orbit with 500 km altitude with an inclination angle of 98° gives estimated surviving dose exposure of 400 Gy/year (40 Mrad/yr)
  - Mean ionisation from 1 to 2 years
  - Commercial semiconductor devices for the skCUBE power supply unit were chosen according to their radiation hardness evaluated by X-ray irradiation

**Results**:
- After 250 kGy – convector mechanically destroyed
- After 750 kGy – significant color change of plastic parts
- After 2 kGy – device still functional

**Graphs**
- **Accumulative dose applied to detectors:**
  - Dose rate 20 kGy/h
  - Doses obtained in 13 steps

**Conclusion**
- The CERN accelerator component, the engine for dipole precise positioning, tested up to 2 Mgy of electrons, only its plastic were mechanically destroyed.
- The commercial semiconductor devices for skCUBE satellite power unit from various manufacturers were tested up to a dose of 1200 Gy of X-rays, representing the dose obtained by satellite on its orbit during about 3 years.
- The semiconductor detectors were irradiated up to 120 kGy of electrons preserving the functionality with initial improvement of energy resolution followed by its degradation.

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**ICARST 2017**