Russian SEE test approach: available standards, test variables, difficulties and future trends

Head of Department Branch of URSC - ISDE
Pavel Chubunov

Outline

- The Branch of URSC – ISDE
- Roscosmos testing aids
  - Test facility
    - Heavy ions
    - Protons
    - Laser
  - Standards and guidelines
  - Software
- Future trends
- Conclusion

Pavel Chubunov npk1@niikp.org

The Branch of URSC – ISDE and The Test Laboratory for Hardness to Radiation Effects

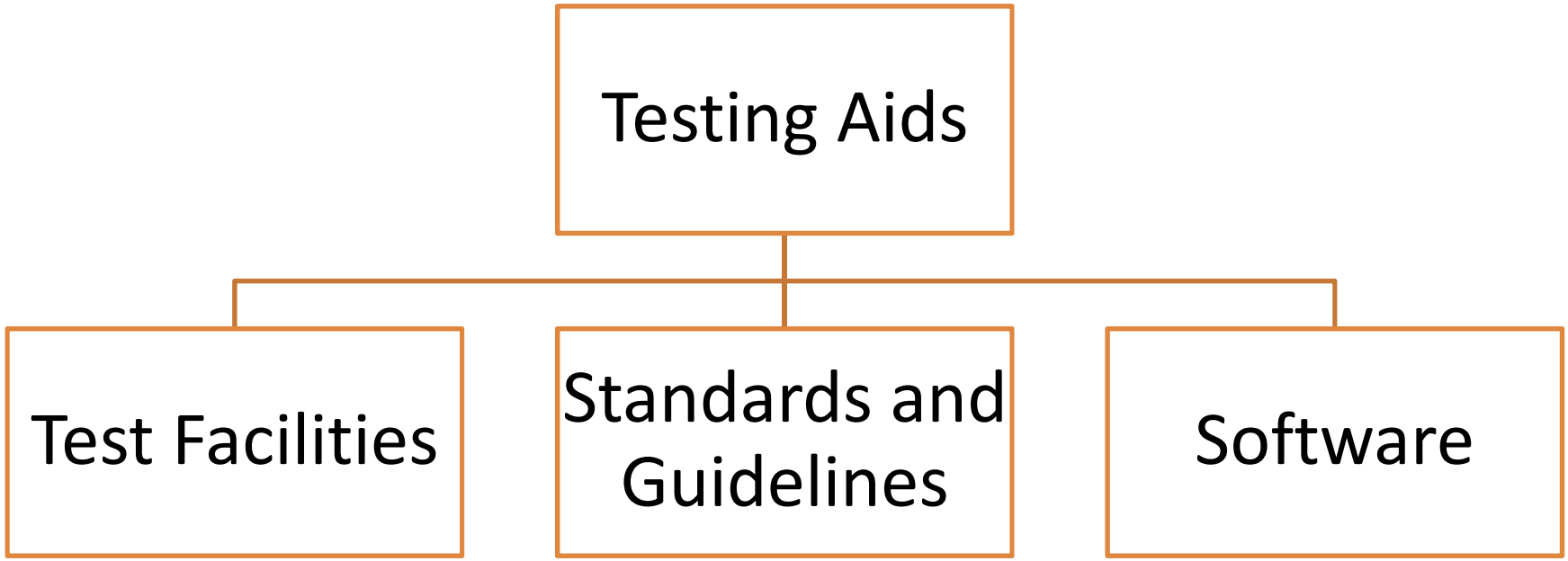
The Branch of URSC – ISDE is a coordinator of Roscosmos activities which cover the creation and introduction of manufacturing methods for radiation hardness control, including:

1. Function implementations as a head company of the Russian Inter-agency Component Radiation Testing Center from the Roscosmos side
2. Creation and operation covering of testing aids:
   - Test facilities (heavy ion, proton and neutron (SEE, DD), gamma, laser)
   - Standards and guidelines
   - Software
3. Creation and operation covering of the Database for Components and Systems
4. Creation and operation covering of the Space Radiation exposure on electronic components Monitoring System
5. Scientific and technical conferences co-organization

The official websites are www.tlisde.org, www.kosrad.ru

Pavel Chubunov npk1@niikp.org

Roscosmos Testing Aids



Pavel Chubunov npk1@niikp.org

Roscosmos Testing Aids

Dose Effects

- Test Facilities

(created ones - 8)

- Standards and Guidelines

(created ones - 24)

- Software – DSG

Single event effects

- Test Facilities and Test Facility Construction

(created ones - 13)

- Standards and Guidelines

(created ones - 20)

- Software – OSOT

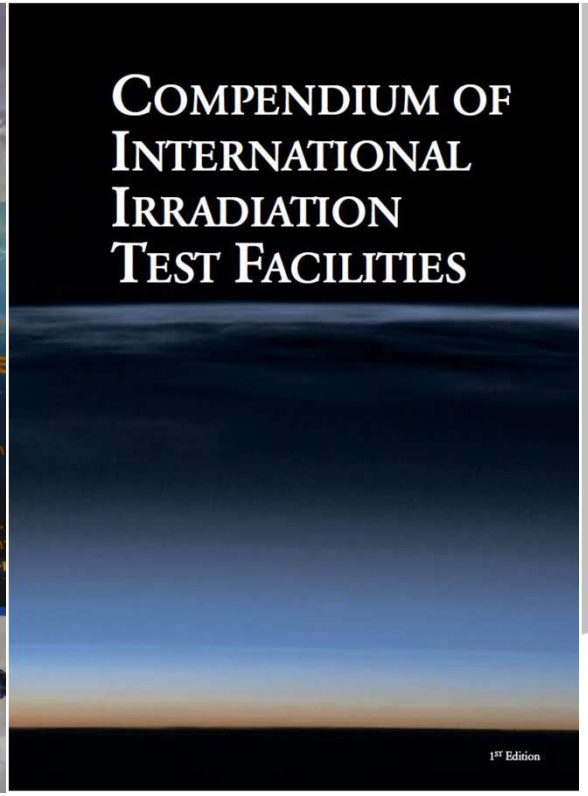
- The Roscosmos Testing Aids provide tests for all types of dose and single event effects
- More than 3000 components were tested to SEE in 2010-2015

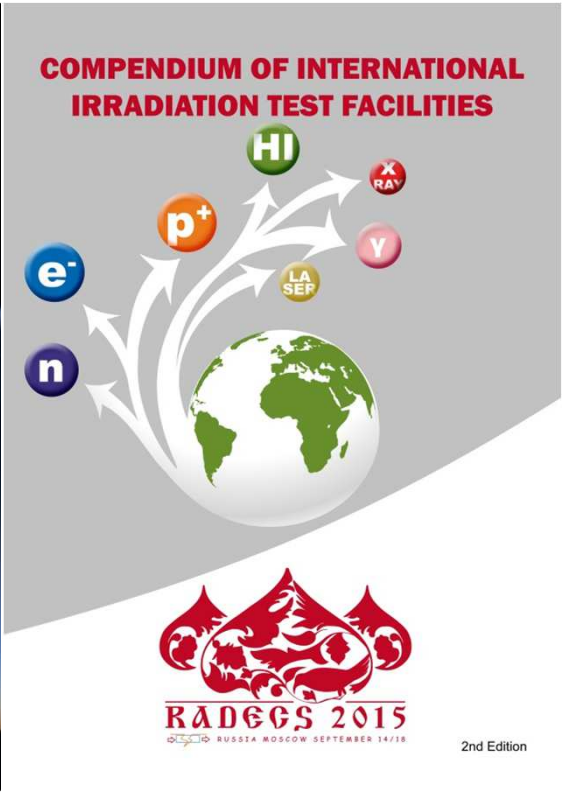
Created and planned test facilities in conformity with international standards

- It was confirmed at the international conferences like RADECS, NSREC, SEES, ISROS
- Test Facilities were included in the 2011 and 2015 Compendium of International Irradiation Test Facilities
- SEE Test Facilities were rewarded in the 2014 International Exhibition of Inventions in Geneva

Pavel Chubunov npk1@niikp.org

Recognition of High Scientific and Technical Level





URSC

TL ISDE

ROSCOSMOS

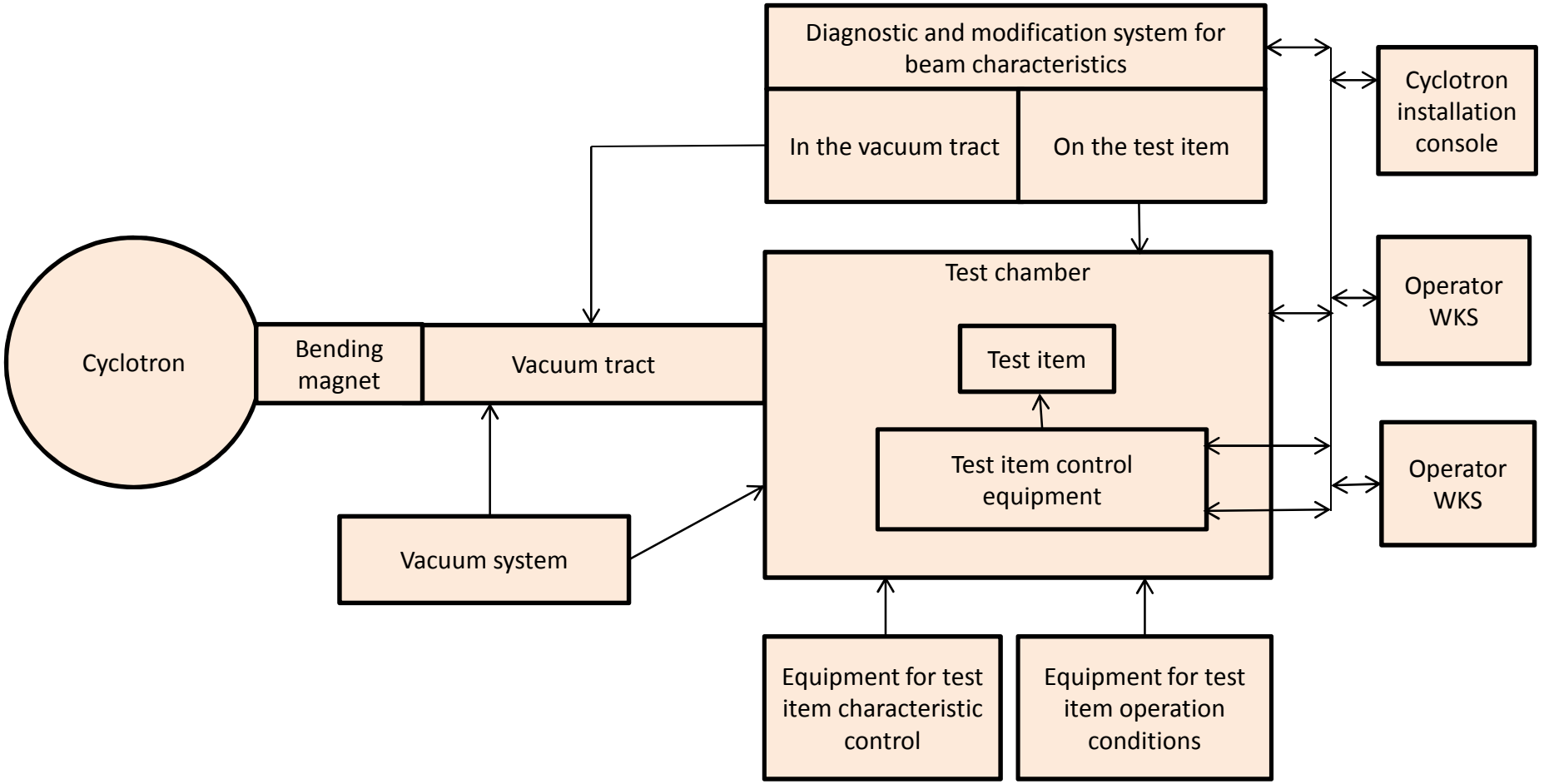
Pavel Chubunov npk1@niikp.org

Variables of SEE Testing

- **SEE testing is carried out with**:
  - Ion accelerator (dominating)
  - Proton accelerator
  - Laser simulator (result calibration on the ion or proton accelerators is necessary!)
- **The Testing Plans are developed on typical Program and the Procedure for corresponding type of facility:**
  - SEE test procedure for electronic devices which are being tested on Roscosmos Test Facilities with the usage of U-400 and U-400M accelerators
  - SEE test procedure for electronic devices which are being tested on the PNPI proton synchrocyclotron
  - SEE test procedure for electronic devices which are being tested on the laser simulators with focused radiation

Pavel Chubunov npk1@niikp.org

General Structure of the SEE Test Facilities Based on Ion Sources



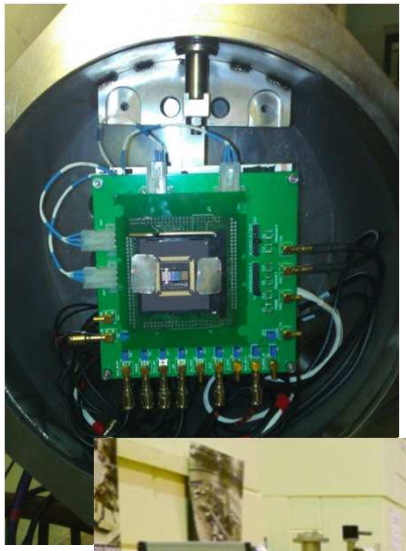
Pavel Chubunov npk1@niikp.org

Technical Features of the SEE Test Facilities based on ion sources

Technical features	IS OI (400)/ IS KOE	BIS OI-A (400M)/ IS OE PP	IS OE VE	IS OU 400-N
Ion source	Cyclotron U-400/ U-400M FLNR JINR	Cyclotron U-400M FLNR JINR	Cyclotron U-400M FLNR JINR	Cyclotron U-400 FLNR JINR
Energy, MeV/nucleon	3 .. 6	3 .. 6	20 .. 40 (60 for light ions)	3 .. 6
Flux density, particle/(cm² × s)	10 .. 10^5	10 .. 10^5	10 .. 10^5 (10^4 for Bi)	10 .. 10^5
Nonuniformity, %	± 15	± 15/ ± 10	± 15	± 10
Suit of ions	C, O, Ne, Ar, Fe, Kr, Xe, Bi	C, O, Ne, Ar, Fe, Kr, Xe, Bi	Ne, Ar, Kr, Xe (C, O, Fe, Bi)	Ne, Ar, Kr, Xe (C, O, Fe, Bi)
LET (Si), MeV × cm²/mg	1 .. 100	1 .. 100	1 .. 80(with using degraders)	1 .. 100
Range in Si, µm	>30	>30	130 .. 2000	> 30
Irradiation area, mm	100 x 100	100 x 100/ 200 x 200	Ø 60 (Ø 40 for Bi)	150 x 200
Operational pressure, Pa	2,2 x 10^{-3}	2,2 x 10^{-3}	Forvacuum/atmosphere	2,2 x 10^{-3}
Chargeover time for gaseous ion, hour	8	8/ 6	6	6
Chargeover time for metal ion, hour	24	24/ 18	18	18
Vacuum pumping time, min	8/ 10	10/ 6	5	8
Temperature range, °C	+25/ +25 .. +125	+25/ +25 .. +125	+25 .. +125	+25 .. +125

Pavel Chubunov npk1@niikp.org

Ion SEE Test Facilities



URSC

TL ISDE

ROSCOSMOS

Pavel Chubunov npk1@niikp.org

Some practical aspects for heavy ion testing

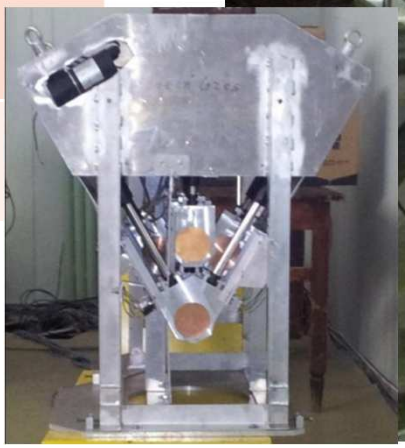
- Number of samples – not less than 3 (SEL, SEU, SEFI, SET); 12 (SEB, SEGR)
- LET from 1 to 60 (100) MeV ×cm^2/mg (4 (5) type of ions is needed – Ne,Ar, Kr, Xe (Bi))
- Range of ions in Si – more than 30 µm
- Decapsulation is needed
- Tilted irradiation for investigation only
- Test norms – Fluence not less than10^7 (taking into account possible errors) or 100 SEE
- Safety operation area for SEB, SEGR
- Maximum supply voltage and temperature for SEL
- Minimum supply voltage for SEU
- Worst case biasing conditions
- UI-curve for SEL, SET
- Survivability test for SEL (holding in SEL for 5 min)

Pavel Chubunov npk1@niikp.org

Proton SEE Test Facility

Based on synchrocyclotron accelerator SC-1000 PNPI

Technical features	
Energy, MeV	200 .. 1000
Energy nonuniformity, %	1 .. 3
Flux density, particle/(cm^2 × s)	10^5 .. 10^8
Nonuniformity, %	10



Pavel Chubunov npk1@niikp.org

Laser SEE Test Facility

Technical features	
Laser type	Picosecond DPSS Nd^{3+}:YAG
Wavelength, nm	1064/532
Pulse duration, ps	20
Max pulse energy on chip, nJ	8000/3000

URSC

TL ISDE

ROSCOSMOS

Pavel Chubunov npk1@niikp.org

The Facility for Preparing Components – Decapsulation and Analysis

Pavel Chubunov npk1@niikp.org

Russia's Regulation Used (Standards and Guidelines) for SEE

20 documents, main ones:

1. Establishing Methods of the Requirements on Hardness of Spacecraft Electronic Devices to the effects of Natural Origin Space Charged Particles
2. Digital Integrated Circuits Test Methods on the impact of Certain High Energy Protons and Space Heavy Charged Particles on Heavy Ion Accelerators
3. Test Methods on the Effects of Analog and Mixed-Signal Integrated Circuits to the Single High-Energy Protons and Space Heavy Charged Particles on Heavy Ion Accelerators
4. Test Methods on the Effects of Power MOSFETs to the Single High-Energy Protons and Space Charged Ions and Heavy Ion Accelerators
5. Integrated Circuits Hardness Calculation Methods to the Effects of Space Charged Ions on Single Errors and Faults Hardness Evaluation Methods to the Effects of Space Charged Particles on Single Event Effects

Pavel Chubunov npk1@niikp.org

Russia's Software

Dose effects

DSG is the set of verified software - dose behind any material shielding calculation

Functionality capabilities

1. Energy spectrum of proton, electron and ion calculation in "outer space" (jointly and separately) in any orbit behind any protection (monomaterial, mixture) which is made of any technology(lamination, sputtering)
2. Modeling of the spacecraft cover, the device case and local shielding
3. Calculation of constructive and technological protection sufficiency of electronic components to space radiation

Single event effects

OSOT – processing of electronic components tests results (covering the electronic components SEE rate calculation)

Functionality capabilities

1. Modeling of space radiation fields in the Natural Earth radiation belt, Solar Cosmic Rays, Galactic Cosmic Ray on the intended orbit (with spacecraft flight time, solar active cycle and other factors)
2. SEE test norm calculation of electronic components
3. Local fields of space radiation calculation in any place in spacecraft
4. SEE test processing
5. SEE rate calculation

Pavel Chubunov npk1@niikp.org

Using Worldwide Standards and Software

Standards

- ESCC 25100 Single Event Effect Test Method and Guidelines
- MIL-STD-750 Test Method Standard — Semiconductor devices
- ASTM F1192-11 Standard Guide for the Measurement of Single Event Phenomena (SEP) Induced by Heavy Ion Irradiation of Semiconductor Devices
- EIA/JEDEC 57 Test Procedures for the Measurement of Single Event Effects in Semiconductor Devices from Heavy Ion Irradiation

Software

- SPENVIS
- OMERE
- CRÈME-MC
- GEANT4

Pavel Chubunov npk1@niikp.org

Roscosmos Testing Aids Directions for the Development

Main future trends:

1. Performance upgrade of test facilities (efficiency, accuracy, reliability, availability) with testing cost reductions
2. The creation of reference ion beam and the system of metrological support
3. The creation of test facilities with milli- and micro- beams for fundamental investigations
4. The creation of technological bench for insuring decapsulation of electronic components
5. The creation of new test facilities (with average energy) based on existing and construction accelerators in JINR

Pavel Chubunov npk1@niikp.org

Conclusions

1. Admissible methods for SEE testing were determined on accounts of their realization at Roscosmos Test Facilities
2. The SEE Testing Aids (based on ions, proton and laser sources) were created and are currently in operation
3. The Roscosmos Testing Aids provide tests for all types of single event effects
4. More than 3000 components were tested to SEE in 2010-2015
5. Directions for the development of SEE Testing aids were defined
6. We invite you to joint research – common application of Roscosmos test facilities for electronic components radiation testing (including software, standards and methods development)

Pavel Chubunov npk1@niikp.org

THANK YOU FOR YOUR ATTENTION!

Pavel Chubunov npk1@niikp.org