

**Alexander V. Achkasov,
Vladimir F. Barabanov,
Mikhail E. Pashkovskiy**

**HARDNESS SIMULATION
AND EVALUATION FOR ELECTRONIC
ENGINEERING PRODUCTS IN THE SPACE**

Monograph

**Science Book Publishing House
Yelm, WA, USA
2013**

UDC 621.3; 539.11

Reviewers:

Kurgalin S.D. Dr.Sc. (Phys.-Math.), Professor, Voronezh State University;
Gromov Yu.Yu. Dr.Sc. (Techn.), Professor, Tambov State Technical University

Achkasov A.V., Barabanov V.F., Pashkovskiy M.E. Hardness simulation and evaluation for electronic products in the space: Monograph/ Ed. by S.L. Podvalniy. – Yelm, WA, USA: Science Book Publishing House, 2013. – 172 p.

ISBN 978-1-62174-045-2
SAN 920-3230

This monograph discusses the actual issues of the prompt simulation and evaluation of hardness and fault tolerance of microelectronic means of the on-board equipment operating in the space. We've performed a development of the special mathematical software and interactive simulation system for product characteristics evaluation. The basic software interfaces of the problem-oriented system are set out herein.

The publication is intended for the work of researchers, professionals and graduate students in the field of software development for simulation and design of electronic means having a special purpose.

UDC 621.3; 539.11

ISBN 978-1-62174-045-2

© **Alexander V. Achkasov,**
Vladimir F. Barabanov,
Mikhail E. Pashkovskiy, 2013

CONTENTS

Introduction	6
Chapter 1. Analysis of the simulation problems of local radiation effects of the charged space particles.....	8
1.1. Local radiation effects in the products of the semiconductor electronics because of the charged space particles.....	8
1.2. Evaluation and ensuring of the failure and fault tolerance of spacecraft onboard equipment under the influence of charged space particles.....	14
1.2.1. Evaluation of the semiconductor product sensitivity to the Single Event Effects (SET) under the influence of heavy charged particles and high-energy protons of the space.....	14
1.2.2. Evaluation of the sensitivity semiconductor products to the Single Effect Latch-up (SEL) under the influence of heavy charged particles and high-energy protons of the space.....	16
1.3. The automatization of evaluation of hardness to the Single Effect from the influence of charged space particles for the onboard equipment.....	20
1.4. Analysis of the known mathematical evaluation methods for the semiconductor product tolerance to the influence of charged space particles.....	24
1.5. Methods to increase the radiation hardness of semiconductor electronics products	26
Chapter 2. Development mathematical model for the evaluation of semiconductor product hardness.....	33
2.1. Implementation of evaluation analysis and of failure and fault tolerance providing of the spacecraft onboard equipment under the influence of charged space particles.....	33
2.2. Simulation of local radiation effects in the semiconductor products.....	36
2.2.1. Interaction between the charged particles and the matter.....	36
2.2.2. Elastic scattering of high energy charged particles	37
2.2.3. The local radiation effects from the charged space particles in semiconductor electronics products as a result of non-equilibrium energy release.....	39
2.3. Mathematical software evaluation of local radiation effect tolerance for the semiconductor products.....	42

2.3.1. Standard model evaluation of hardness characteristics semiconductor products to the effects of charged space particles.....	42
2.3.2. Special mathematical model development to evaluate the semiconductor product hardness to the effects of heavy charged space particles	43
2.3.3. Special mathematical model development to evaluate the hardness of semiconductor products to the effects of high-energy protons of the space	49

Chapter 3. Development and debugging of software modules for the prompt complex evaluation of hardness semiconductor products to local radiation effects under the space charged particle influence 57

3.1. Development of automated information system to simulate and evaluate the hardness characteristics of radioelectronic equipment under influence separate charged space particles	57
3.2. Development of the software complex evaluation of hardness characteristics onboard equipment of spacecraft under influence separate heavy charged particles and high-energy protons of the space.....	59
3.3. Synthesis integrated database structure of semiconductor products.....	66
3.4. Development of the integrated information simulation and object characteristics evaluation support environment software module.	70
3.5. Development of the software module to evaluate the hardness of semiconductor products to the effects of heavy charged space particles.....	74
3.6. Development of the software module to evaluate the hardness of semiconductor products to the effects of high-energy space protons	79
3.7. Development software module evaluation for the configuration check the board equipment blocked being developed to meet the hardness requirements on the basis of known and calculated indicators.....	83
3.8. Development of the software module of the Help system	86
3.9. Development of the software module of the integration projects	91
3.10. Development of the algorithms to optimize the selection of semiconductor products and functioning mode of software module to optimize the selection of semiconductor products	94

Chapter 4. Software implementation of complex to characterization the equipment hardness to the Single Effects under influence separate the charged space particles	102
4.1. Development of the GUI of the functional scheme of subsystem interaction based software complex	102
4.2. GUI of the software complex characterization of equipment hardness to the Single Effects under influence of separate charged space particles	106
4.2.1. “Main graphical form” GUI.....	106
4.2.2. “The help system” GUI.....	107
4.2.3. “The integration of the projects” GUI	112
4.2.4. “The evaluation of hardness of the semiconductor products under the influence of heavy charged particles (HCP)” form GUI.....	114
4.2.5. “The evaluation of hardness of the semiconductor products under the influence of high-energy protons (HEP)” form GUI.....	118
4.2.6. “The checking for compliance with the hardness requirements” form GUI.....	122
4.2.7. “Theoretical information” subsystem GUI.....	127
4.2.8. “Product selection optimization” subsystem GUI.....	129
4.3. Software complex user’s manual.....	131
4.4. Approbation of the calculated values of semiconductor product hardness from the space charged particle influence	143
 Conclusion	 149
 Keywords.....	 150
 List of the references	 151
 List of the useful references	 157

INTRODUCTION

Relevance of the topic. Nowadays the space exploration is the one of the priorities for the most developed countries of the world. Operating conditions and the presence of external radiation exposure factors impose stringent requirements on the equipment and element base of systems for special purposes (rocket and space technology, communication systems, physical experiment, etc.), which hampers the development and use of onboard equipment spacecraft.

With current microelectronics development level, increasing packaging density of the circuitry and decreasing design rules of sensitive element placement on a chip we have a problem of evaluating results effects of individual charged particles of high energy on the functioning equipment in outer space. Of particular interest is the consideration of single effects in semiconductor electronics products (SEP), as there is an urgent need to review approaches to the construction of spacecraft, making the design of additional means of ensuring reliability, taking into account information about the technology, the topological dimension of sensing elements, critical parameters SEP.

Complexity of the integrated mathematical simulation and evaluation of hardness characteristics of equipment to the single effects under the influence of charged space particles is the lack of special purpose hardware designer unified software environment modeling and design. Software complexes to model the processes and make the calculations to assess the hardness of onboard equipment (OE) spacecraft (SC) and SEP accessories are not widespread and virtually inaccessible.

The solution of this problem is to develop the software complex for evaluation of hardness onboard equipment based on special mathematical models intended for implementation as part of software algorithms. This model is based on the experimental data on the hardness of SEP with different design technology and data on the characteristics of the flow of charged particles (CP).

Thus, the relevance of this research topic is a result of the need to develop mathematical and software tools to obtain the data of hardness individual SEP, OE blocks in general and verify configuration of spacecraft for compliance with the correct choice of the circuitry.

Contents of the task. In the first chapter we've analyzed the problems of local simulation radiation effects from the charged space particles. The substantiation of the need to develop a system of special mathematical and software

tools for determination of hardness characterization equipment to the single effects under influence the separate charged particles (CP) of the space. The requirements for the system are set out herein.

In the second chapter, the special adaptive mathematical model is developed. This model takes into account the mass-energy characteristics of the affecting charged particles in the space and product structure of semiconductor electronics (SEP) on the basis of system analysis under creating the software complex calculation of hardness to the single effects for the onboard equipment (failures and faults). The model described is based on the experimental data on the SEP hardness with the different process layouts and data on the characteristics of the charged particle flow.

The third chapter describes a modular structure of the automatic information system of simulation and evaluation of hardness characteristics radioelectronic equipment. In addressing issues of automated calculation of hardness for the semiconductor elements SEP following results were obtained:

- the structure of software complex is proposed;
- generalized structure of an integrated database SEP is described;
- the composition, requirements and purposes of the developed software are defined.

The fourth chapter describes software implementation of complex evaluation of hardness radioelectronic equipment to the single effects from exposure to charged space particles. This section includes:

- the main purposes of the project technical implementation;
- the methodology for calculating the characteristics of equipment tolerance to the single effects under the influence of separate charged particles (CP) of the space, based on the virtual OE block including the sensitive semiconductor products.

Conclusion includes the basic scientific and practical results of the dissertation research.

The annex contains the tables of comparative analysis and reference materials for experimental and calculated data about the hardness of SEP, implementation acts and the approbation examples of hardness evaluation for the different types of SEP to the influence charged space particles.

The body text of the monograph is written by Russian.

and clustering// American Journal of Control Systems an Information Technology, N2, 2013. – P. 33-35.

262. Trakhtenberg B.E., Solomakhin A.N. Expert analysis procedure to specify strategically priorities of municipal entity social and economical development// American Journal of Economics and Control Systems Management, N2, 2013. – P. 37-40.

Scientific publication

Alexander V. Achkasov
Vladimir F. Barabanov
Mikhail E. Pashkovskiy

**HARDNESS SIMULATION AND EVALUATION FOR
ELECTRONIC ENGINEERING PRODUCTS IN THE SPACE**

Monograph

Issue is published in author's edition

Cover designed by Sofia A. Kravets

Assigned to print 25.12.2013. Format 60x84 1/16.
CPP 11,4. Order 0000. Circulation 500.

Science Book Publishing House
17200 153rd Ave SE, Yelm, Washington, 98597 USA
<http://www.sbook.us/>