Russian Surety Research Projects in the Sandia National Laboratories Cooperative Measures Program

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Abstract

Over forty safety and security related research and development projects have been initiated between Sandia National Laboratories and the Russian nuclear weapons laboratories VNIIIEF and VNIITF. About half of these projects have been completed. All relate to either safety or security methodology development, processes, accident environment analysis and testing, accident databases, assessments or product design of devices. All projects have a potential benefit to various safety or security programs and some may directly have commercial applications. In general, these projects could benefit risk assessments associated with systems that could result in accidents or incidents having high public consequences. These systems typically have already been engineered to have very low assessed probabilities of occurrence of such accidents or incidents.

This paper gives an overview of the Sandia surety program with a focus on the potential for future collaboration between Sandia, three Russian Institutes; VNIIIEF, VNIITF and VNIIA, and other industry and government organizations. The intent is to serve as an introduction to a roundtable session on Russian Safety Collaboration at the 14th International System Safety Conference. The current Sandia collaboration program scope and rationale is presented along with the evolved program focus. An overview of the projects is given and a few specific projects are briefly highlighted with tangible results to date.

Introduction

The nuclear weapons complex of the United States is necessarily concerned with the continuous improvement of weapons and other systems that are designed to have very low failure probabilities. Such failures are, nonetheless, feasible and the resulting consequences can be enormous. Russian institutes associated with the nuclear weapons complex of the Former Soviet Union (FSU) share this concern. Particularly, VNIIIEF, VNIITF, and VNIIA are the primary counterparts to the US weapons national laboratories. It is of mutual benefit and interest for these laboratories and institutes to cooperate in the various safety areas of methodology development, processes, accident environment analysis and testing, accident databases, assessments and product design of devices.

Sandia National Laboratories (SNL) has been sponsoring safety research and development projects with the Russian institutes for the last two years. These projects form a basis for developing future collaboration between Sandia, the Russian institutes and other government agencies or industry, both American and international.

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Background Information on the Institutes

A. RFNC-VNIIEF

The All-Russian Institute of Experimental Physics, or Всероссийский научно-исследовательский институт экспериментальной физики (ВНИИЭФ, or VNIIEF in English), better known as Arzamas-16, was established in 1946, at the site of the village of Sarov, now named Sarovski, Russia. The first of the Russian Federal Nuclear Centers (RFNC), it is located approximately 400 km southeast of Moscow and about 150 km south of Nizhny Novgorod. It was initially established as a research, design, and development facility with two experimental facilities and internal test sites in the surrounding forests. Some of the facilities are available for safety projects. Manufacture of the first Soviet nuclear weapon components and associated laboratory testing was performed here (Ref. 1). Today, VNIIEF is a complete nuclear weapon design organization involving the design of nuclear weapon charges and warheads, as well as various research and testing programs. Currently, VNIIEF is involved in such activities as nuclear weapons work, nuclear power safety, disarmament and nonproliferation activities, industrial technologies applications, and fundamental research (Ref. 2).

B. RFNC-VNIIA

The All-Russian Research Institute of Automatics or Всероссийский научно-исследовательский институт автоматики (ВНИИА, or VNIIA in English) was the second RFNC to be founded, and is located in the Moscow area. VNIIA, also known as Automatics, is heavily involved in the nuclear weapons program and has responsibilities associated with weaponizing warheads designed by VNIIEF and VNIITF. The current main focus of collaboration with the US national laboratories and industry has been neutron generators, oil and gas technology, and mineral research (Ref. 3).

C. RFNC-VNIITF

The third RFNC to be founded was established in 1954 in the southern Ural mountains. This establishment is officially called the All-Russian Institute of Technical Physics, or Всероссийский научно-исследовательский институт технической физики (ВНИИТФ, or VNIITF in English). VNIITF, better known as Chelyabinsk-70, is located about 200 km south of Yekaterinberg (formerly known as Sverdlovsk) at the town that is now called Snezhinsk. VNIITF is also heavily involved in nuclear weapon development work, but is also involved in activities such as experimentation connected with studying and modeling nuclear explosions, development of nuclear and non-nuclear technologies, fundamental research in experimental and theoretical physics, and technology transfer. Like VNIIEF, VNIITF has extensive experimental facilities and test sites that are available for safety related projects (Ref. 4).
The Sandia Safety Program

Sandia has established a Cooperative Measures Program (CMP), with the Former Soviet Union (FSU), with the concurrence of the United States Department of Energy (DOE) and the Department of State. Paul A. Stokes, Organization 5331, is the current Program Manager of the CMP. The CMP sponsors several surety initiatives, primarily in safety and security. The CMP has both sponsored and participated in several surety symposia jointly with the DOE and the other DOE national laboratories, Los Alamos National Laboratory (LANL), and Lawrence Livermore National Laboratory (LLNL), and with the Russian Ministry of Atomic Energy (MINATOM), and the Russian national institutes; VNIIEF, VNIITF and others. The first joint symposium was held at VNIITF in the town of Chelyabinsk-70, now renamed Snezhinsk, on risk assessment technology in October, 1993. Resulting from these symposia is a continuing dialog and specific initiatives on various safety and security issues of mutual interest to the national laboratories and institutes. The safety projects discussed in this paper are one such initiative. The first signed contract for a safety related project between Sandia and a Russian institute was with VNIIEF in May, 1994, entitled “The Development of a Glossary in Surety Terminology.” A similar contract was subsequently signed with VNIITF. Since then, over forty safety projects have been signed, with more that half of these completed. Initial contracts were largely exploratory in nature, where each Russian institute and Sandia learned a little of each other’s culture, interests and capabilities. Later contracts are more substantive in nature and are becoming more collaborative. Some of the future contracts are expected to be joint ventures, with the Russian institutes contributing equally to the project resources and benefiting accordingly. In summary, Sandia now has an ongoing dialog with the Russian institutes which has resulted in a mutual understanding of each institute’s areas of interest and technical capabilities. This knowledge provides a basis for significant future initiatives.

Sandia Safety Program Guidelines

While there are overall guidelines for the CMP, this paper is only focused on the current guidelines associated with the safety part of the program. General surety guidelines are discussed and specific applications to the safety part of the surety program are emphasized. Figure 1 summarizes the surety collaboration guidelines, which have changed over time due to our evolving interests and, more specifically, due to the realistic limitations on funding.
For reasons of perceived significance to Sandia, the surety program has evolved from one including many disciplines to a current focus on safety and security. Within the safety and security disciplines, transportation related issues are perceived to be the most critical to Sandia and as such are the primary focus. Clearly there is always the option to expand this guideline if either Sandia or one of the Russian institutes can identify a compelling reason for change. The broad guidelines given for safety and security projects must be complied with before a contract can be signed with one of the Russian institutes. Sandia's ultimate goal is to reduce the risk of safety and security incidents associated with both countries. Sandia believes that this goal is furthered by actively participating with the Russian counterparts through the funding of actual joint safety research and development projects, and by having an active continuing dialog between safety specialists in both countries.

**Areas of Focus of Safety Projects**

The rationale for identification of areas of focus for the mostly transportation related safety projects can be demonstrated by a review of a typical safety system process as depicted in Figure 2. One must ultimately perform some sort of assessment in order to determine the level of safety of the system, (box 3). In order to perform any assessment, an assessment methodology must be developed or selected, (box 1) and then data must be acquired, (box 2). Given the assessment, additional trade-off studies may be made and ultimately the final system or products critical to the system may be designed and developed with a goal of improving the system by reducing risk, (box 4). While admittedly crude, this depiction helps identify areas of focus for collaborative projects and dialog.

The actual areas of focus for the Sandia safety projects with the Russian institutes are:

I. Assessment Methodology
II. Safety Databases
III. Accident Environment Characterization
IV. Assessments
V. Product Development
Greater attention is given to some areas than others. For example, increasing information in safety databases and accident environment characterization is considered to be of greater importance than improving assessment methodology.

**Contracted Safety Projects**

An overview of the existing safety projects relative to the five areas of focus is provided in Table 1. This table gives a project title and the institute, or institutes, that are collaborating with Sandia on each project. If more than one institute is, or was, working on the same or similar project, a separate contract was signed with each institute. The actual project task commitments were uniquely developed and specified in each contract. Many of the listed contracts have been completed. Task reports were generated and are available based on contract agreements for access to the information. Generally, this requires approval from both institutes. Tables 2-I through 2-V provides a brief description and current status of the various projects. Again, the purpose of this paper is to introduce the broad spectrum of projects that have been contracted with the institutes and not to discuss in detail any specific project. If there is interest in details of a specific contract, the reader is advised to contact the author of this paper or the safety contact person at the Russian institute (Ref. 5,6). A more detailed description of each project is contained in an Official Use Only report that can be obtained with approvals through the CMP.
Table 1. Contracted Safety Projects

I. Assessment Methodology Projects (13 projects)
- Evaluation of Qualitative Risk Assessment Methodologies, VNIEF, VNIITF.
- Acceptable Risk Criteria for Selected Operational States, VNIEF, VNIITF.
- Neural Network Processing for Probabilistic Risk Assessments, VNIITF.
- Russian Methods of Probabilistic Risk Assessment, VNIITF.
- 2 and 3 Dimensional Numerical Simulations of Selected Structural and Thermal Problems, VNIEF, VNIITF.
- Russian Human Factors and Human Engineering Methods, VNIEF, VNIITF.
- Principals and Methods of Russian Surety Training and Certification, VNIEF, VNIITF.
- Methods Development for Statistical Analysis of Censored Data, VNIEF.

II. Safety Database Projects (7 projects)
- Glossary of Terminology, VNIEF, VNIITF.
- Development of a Russian Surety Database, VNIEF, VNIITF.
- Development of a Russian Aircraft Crash Database, VNIEF.
- Railroad Hazardous Materials Databank, VNIITF.
- Hazardous Materials Data Bank, VNIITF.

III. Accident Environment Characterization Projects (17 projects)
- Experiments on the Accidental Dispersion of Surrogate Radioactive Materials, (three contracts to date) VNIITF.
- Railway Car Accident Simulation Tests, VNIEF.
- Development of an Actively Cooled Calorimeter Test Device, VNIEF.
- Environmental Tests of Wood Impact Limiters, VNIEF, VNIITF.
- Container O-ring Seals Environmental Tests, VNIEF.
- Abnormal Environment Penetration Tests on Shipping Containers, VNIITF.
- Aircraft Crash and Fire Test Evaluations, VNIEF, VNIITF.
- Fuel Fire Characterization, VNIITF.
- Numerical Model for Decomposition and Burning, VNIEF.
- International Vibration Standard for Testing, VNIEF.
- Container Materials Aging Tests (three contracts; birch, pine and foam), VNIEF.

IV. Assessment Projects (3 projects)
- Environmentally Clean Materials Recycling, VNIITF.
- Safety of Technical Systems Exposed to Lightning, VNIEF, VNIITF.

V. Product Development Projects (1 project)
- Design and Analysis of Prototype Explosive Resistant Containers, VNIEF.
Table 2-1. Description and Status of Assessment Methodology Projects

- **Evaluation of Qualitative Risk Assessment Methodologies**, VNIIEF, VNIITF.
  Evaluates the usefulness of qualitative risk assessment techniques such as Analytic Hierarchy Process, Fuzzy Logic and others as determined by institute. Received 1st task report from VNIIEF. Negotiations started on a new project, Risk Assessment of a Hazardous Transportation System. Funding uncertain.

- **Acceptable Risk Criteria for Selected Operational States**, VNIIEF, VNIITF.
  Project to provide the technical basis for establishing acceptable risk criteria for hazardous objects or processes such as nuclear power plants, explosive operations and transportation of hazardous materials. Projects are completed.

- **Using Neural Networks to Process Systems Response Data for Probabilistic Risk Assessments**, VNIITF.
  Purpose is to ascertain whether neural networks provide an advantage over interpolation schemes to process system response data for probabilistic risk assessments. Received first task report.

- **Russian Methods of Probabilistic Risk Assessment**, VNIITF.
  Produce a description of risk assessment techniques used in Russia, summarize applications and identify areas for improvement. Project completed. Provided a reliability based analysis methodology. Sandia successfully applied one math process to a computer program. Follow-on merged with, Risk Assessment of a Hazardous Transportation System. Funding uncertain.

- **Two and Three Dimensional Numerical Simulations of Selected Structural and Thermal Problems**, VNIIEF, VNIITF.
  This work benchmarks 2-D and 3-D numerical simulation codes used at Russian and US laboratories. The codes of interest are used for nonlinear, numerical simulation of abnormal environments. Project completed. Seeking follow-on funding.

- **Russian Human Factors and Human Engineering Methods**, VNIIEF, VNIITF.
  Provides a description of human factors and human reliability used at the Russian institutes versus methods used at Sandia. Received first task reports.

- **Principals and Methods Incorporated into Surety Training and Certification Programs**, VNIIEF, VNIITF.
  Information exchange on principals incorporated into surety programs and the educational process used to teach the principals, ensure continuity of standards between designers and users, and preserve the evolution of surety principals and methods. Received first task report from VNIITF.

- **Methods Development for Statistical Analysis of Censored Data**, VNIIEF.
  Data is censored if the value of a measurement is not obtained but is known in a limiting sense. Provides a description of current methods used, assessment of areas of analysis requiring improvement, development of new appropriate methods, and an illustration of the application of these new methods. Received the first two task reports.
Table 2-II. Description and Status of Safety Database Projects

- Proposal for Development of a Glossary of Terminology in Surety Technology, VNIIIEF, VNIITF.
  Purpose is to develop a bilingual glossary of terms used by Russian and US nuclear institutions in surety technology. Project completed. No follow-on projects.
- Development and Improvement of a Russian Nuclear Safety Information Center Database, VNIIIEF, VNIITF.
  Purpose is to develop a database to store all pertinent Russian nuclear safety information in a computerized system in order to provide ready access to safety information, assist system analysis, capture historic information, and facilitate indexed retrieval. Database is developed and several hundred documents have been entered. Project is on-going.
- Development of a Common US/Russian Aircraft Crash Accident Database, VNIIIEF.
  Provides an exchange of crash data for large cargo type aircraft so that the combined results will improve the statistical data on aircraft accident characteristics. Database is defined and some initial data has been transmitted to and from Russia.
- Russian Railroad Operations and Accident Databank for the Transportation of Hazardous Materials, VNIITF.
  Purpose is to provide; a description of operations and rules for hazardous materials transportation, accident statistics, and the accident database. Received first task describing operations. Project terminated because restrictions on access to accident data precluded completion. Dialog is continuing on potential follow-on work.
- Hazardous Materials Data Bank, VNIITF.
  Purpose is to develop a data bank for risk calculations associated with the operational safety of complex technical systems and transportation operations. Project is completed. Provided an ACCESS developed database with a representative sample of types of data implemented into the database. Can be used with follow-on projects.

Table 2-III. Description and Status of Accident Environment Characterization Projects

- Experiments on the Contamination Resulting from Accidental Dispersal of Surrogate Radioactive Material, (three contracts to date) VNIITF.
  The first contract developed the experimental concept and process. The subsequent contracts will characterize the test materials, set up the experimental facilities, perform the tests and analyze the test results. The tests will quantify macro climatic variability effects on dispersal of respirable particulate using three materials sequentially released in an explosive puff. This project has progressed to the test preparation stage.
• Railway Car Accident Simulation tests or Ground Transportation Test Data, VNIIEF.
  Project to identify and provide documentation on existing full scale and sub-scale fire and crash tests performed on rail cars used to transport hazardous materials. Project completed. Provided all test data including a video of test highlights. No follow-on projects planned.

• Development of an Actively Cooled Calorimeter Test Device, VNIIEF
  Project to design and provide complete design drawings and details for calorimeter test device for shipping container validation, to develop one prototype panel of the calorimeter, and to test it under extreme fire input conditions. Project completed. Seeking funding for follow-on work.

• Environmental Tests of Wood Impact Limiters (Dampers), VNIIEF, VNIITF.
  Project to provide mechanical and physical characteristics of redwood and three selected Russian woods for container safety impact mitigation applications. Data provided is crush strength under varying load rates, temperature, moisture content and grain angle. Project completed. Seeking additional funding for follow-on work. Expect publication on project results.

• Container O-ring Seals Environmental Tests, VNIIEF.
  Purpose is to test several types of elastomer o-rings to determine critical material properties and leak resistance under accident conditions. Project completed. Seeking additional funding for follow-on work. Expect publication on project results.

• Abnormal Environment Penetration Tests on Shipping Containers, VNIITF.
  Purpose is to record experimental data and develop empirical models of the penetration of representative container cross sections by small arms projectiles and limited penetration probes representing flying debris from accidents. Project completed. Potential follow-on project being negotiated.

• Aircraft Crash and Fire Test Evaluations, VNIIEF, VNIITF.
  The purpose is to obtain experimental data on full and sub-scale cargo aircraft crashes including structural damage, fuel dispersal, and fire. This contract provided a feasibility study. Project completed. Follow-on of acquiring hardware and conducting tests is contingent on funding.

• Fuel Fire Characterization and Object Response, VNIITF.
  This project will characterize the thermal environment of the VNIITF fire test facility which provides a unique class of fire environments. Follow-on projects are envisioned to perform a suite of fire experiments for simulated accident environments. Project is ongoing.

• Development of a Numerical Model to Predict Decomposition and Burn Processes of Organic Materials, VNIIEF.
  This project will develop a transient, physically based engineering model that can predict decomposition and burning processes of organic materials as well as associated heat transfer through the material. Project is in process.

• Development of an International Vibration Standard for Radioactive Material Packaging,
VNIIEF.

This project will provide an international standard that defines the surface transportation vibration environment and describes test methods for demonstrating compliance with the requirements. Project nearing completion.

- Container Materials Aging Tests (three contracts; birch, pine and foam), VNIIEF.
  These projects will provide essential data for defining the useful life of birch, pine and polyurethane foam in the kind of environment it would experience when used in a radioactive material container. Projects are in process.

Table 2-IV. Description and Status of Assessment Projects

- Environmentally Clean Materials Recycling, VNIITF.
  This project will provide a feasibility and options assessment of the materials that are anticipated to be processed. This project is finished. The focus was on demonstrating water jet technology for disposal and recycling of explosives. Follow-on projects are contingent on obtaining funding.

- Safety of Technical Systems Exposed to Lightning, VNIIEF, VNIITF.
  The purpose of this project is to develop and compare experimental results and computation, and analytical models for lightning interaction with technical systems. Project is in process.

Table 2-II. Description and Status of Product Development Project

- Design and Analysis of Prototype Explosive Resistant Containers, VNIIEF.
  The initial project is to develop designs for explosive-resistant containers for safe handling and transportation of generic conventional explosive devices. The goal of these designs is complete containment of both the explosive force and any hazardous byproducts of the accidentally initiated explosion. Project completed. ISTC follow-on project is funded. Sandia follow-on project is under negotiation.

Two additional papers have been prepared for presentation to the 14th International System Safety Conference on these projects. The first gives some insights drawn from some of the contracts associated with risk assessment methodology and the second discusses the status of the product development project on the “Design and Analysis of Prototype Explosive Resistant Containers”. Follow-on initiatives for this project are being pursued by both Sandia and by the International Science and Technology Center, (ISTC).

Potential Future Projects

Potential future safety projects have been discussed with the institutes. Those that are at a development stage beyond preliminary discussion are given in Table 3. While the Sandia safety program has a great interest in pursuing all of these projects and several additional ones that are not listed, the practical limitations of current budget constraints makes this
impossible. Our current best estimate is that a few of these projects will be funded in fiscal year 1997. Development or collaboration with other organizations in order to fund projects of mutual interest is being actively pursued.

Table 3. Potential Future Safety Projects

- Risk Assessment of Hazardous Transportation System, VNIIEF, VNIITF
- Explosive Container Follow-on Project, VNIIEF.
- Actively Cooled Calorimeter Follow-on, VNIIEF.
- Seals Testing Follow-on, VNIIEF.
- Aircraft Crash Tests, VNIIEF, VNIITF.
- 2D/3D Modeling Follow-on, VNIIEF, VNIITF.
- Deformation of HE at High Strain Rates, VNIIEF.
- Compressive Deformation of Foam at High Strain Rates, VNIIEF.
- Dispersal Experiment Final Test and Evaluation, VNIITF.
- HE Defects and Decomposition Study, VNIITF.
- Penetration Follow-on Tests, VNIITF.
- Lightning Follow-on Tests and Theoretical Modeling, VNIIEF, VNIITF.

Program Conclusions

Much has been accomplished in the last two years. The Sandia safety program, as well as other Sandia programs, have developed an excellent working relationship with several of the Russian nuclear institutes. Sandia has jointly participated in several safety symposia and workshops which have not been discussed in this paper, and has also funded several safety projects, many of which are now completed, with VNIIEF and VNIITF. It is expected that a highly productive collaboration with VNIIEF, VNIITF and VNIIA will continue. Sandia is prepared to participate with other organizations in future collaborative efforts with the Russian institutes, both in safety and in other areas of mutual interest.

References


4. Russian Federal Nuclear Center, All-Russian Research Institute of Technical Physics, Information Brochure, 1996 (est.).

5. Dr. Olga S. Vorontsova, Head of foreign Scientific Department, VNIIIEF safety contact, 607200, Arzamas-16, Mira Avenue 37, Nizhni Novgorod region, Russia, Phone: (83130) 1-41-05, Fax: (83130) 5-45-65, e-mail: dc_3001@spd.rfnc.nnov.su.

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