

**“We Crash, Burn, and Crush”:  
A History of Packaging at  
Sandia National Laboratories, 1978 – 1997**

*C. J. Mora and P. McConnell*

Sandia National Laboratories  
Albuquerque New Mexico 87185 USA

## **BACKGROUND**

Even prior to the beginning of the nuclear age, the packaging and transportation of nuclear materials was a prime national concern. Nuclear materials such as uranium and plutonium had to be transported safely (and secretly) to the Manhattan Engineer District Laboratory in Los Alamos, New Mexico.

The subsequent post-war use of nuclear power for the generation of electricity and accelerated weapons development programs resulted in radioactive waste byproducts, such as spent fuel and plutonium, that were stored on-site at utilities and federal weapons sites. While projected repositories for long-term storage of radioactive waste are being planned, both low- and high-level radioactive materials on occasion must be moved safely. Movement to interim-storage and, for low-level waste, repository sites, is accomplished by a combination of truck, rail, ship, and air. The U.S. Department of Energy (DOE) directs transportation activities including cask development technology for use in single or multimodal (a combination of land, water, and air) transport. In 1978, Sandia National Laboratories was selected as the lead contractor for basic transportation technology.

## **EARLY RESEARCH AND REGULATORY DEVELOPMENT (1936 – 1978)**

The U.S. Postal Service first established regulations governing shipment of radioactive materials when it was discovered that exposure of photographic film to ionizing radiation from materials being shipped through the U.S. mail was clouding the film. The basic regulation governing domestic shipment of radioactive substances was adopted on

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-ACO4-94AL8500.

July 13, 1936. This was followed by Railway Express regulations requiring the "segregation" of radioactive parcels shipped by rail. (Pellettieri, et al., 1985)

World War II and the development of nuclear weapons by 1945 resulted in greatly increased and varied shipments of radioactive materials relating to national defense. These shipments were under the jurisdiction of the U.S. Army Manhattan Engineer District, which developed the first atomic bombs.

The Atomic Energy Act of 1954 regulated the shipment of radioactive materials to protect the health and safety of the public. The Act placed responsibility for the enforcement of transportation regulations equally with the Atomic Energy Commission (AEC) and the Interstate Commerce Commission (ICC).

In the 1960s, the AEC sponsored theoretical and practical work on criticality, early "operations research" studies, and tests using scale models of heavy casks. Sandia Corporation, one of the facilities involved in these studies, conducted fire tests. An offshoot of Los Alamos Laboratory, Sandia Laboratories was originally the parent laboratory's Z Division, the engineering and field testing group. Z Division was established in 1945 at Albuquerque's Sandia Base, an Army installation. In 1948 Z Division was reorganized as the Sandia Branch of Los Alamos, and in 1949 it was separated from Los Alamos when it came under AT&T management. (Furman, 1990)

In 1963, the International Atomic Energy Agency (IAEA), a United Nations agency, published regulations governing worldwide transport of radioactive materials. These regulations were based, in part, but not identical to, on AEC/ICC orders and regulations. Later, both the AEC and ICC published revisions to the Radioactive Materials Regulations which made the U.S. standards for transport consistent with those of the IAEA.

### **RADIOACTIVE MATERIAL PACKAGE TESTS AT SANDIA NATIONAL LABORATORIES, 1975-1977**

In the early 1970s, the AEC wanted to validate the safety of existing radioactive material (RAM) package design regulations. To this end, Sandia National Laboratories (SNL) conducted a series of full-scale tests on truck, rail, and air transportation packages to obtain empirical and accurate quantitative data on the response of packages to severe transportation accidents. The resultant tests were spectacular and attracted a great deal of media attention. Most significantly, these tests validated the safety of existing



*In one of the most spectacular full-scale crash tests conducted at Sandia, a locomotive impacts a transport vehicle carrying a spent-fuel cask. This test was performed in 1976.*

regulations. SNL engineers also demonstrated that they had the capability to perform such tests, and that they possessed the instrumentation and engineering support to obtain and analyze the test data. Between 1975 and 1977, SNL carried out a series of unique, original full-scale tests of spent-fuel casks carried on trucks and railroad cars for the AEC and the U.S. Department of Transportation. The tests conducted included truck impact tests at 98 and 138 km/h (60 and 84 mph) in which truck trailers carrying a spent-fuel cask were impacted onto three-meter (10-foot) thick concrete barriers. In the rail tests, a 12-tonne (10 ton) diesel locomotive crashed into a spent-fuel cask at 131 km/h (80 mph) at a simulated rail crossing. A rail car impacted a spent-fuel cask system at 131 km/h. A rail car propelled by rocket motors was crashed into a concrete barrier. And finally, a rail car and cask system were subjected to an intense fire test for over 1.5 hours.

### **THE SNL TRANSPORTATION TECHNOLOGY CENTER**

In 1978, DOE officials surveyed the various DOE laboratories with the intention of selecting a lead laboratory for conducting basic transportation technology development. The Transportation Technology Center (TTC) was established that same year with SNL as the lead contractor, largely on the basis of the demonstrated effectiveness of the full-scale crash tests and the design, analysis, and testing technology that supported the effort.

The SNL TTC was given the mission of coordinating packaging and transportation research and development efforts among the DOE national laboratories and contractors. The SNL programs anticipate future RAM system needs, identify potential problems, and develop innovative technology to solve transportation and packaging problems and needs for DOE and other federal agencies. Constructive interactions are essential with both federal and international regulators and domestic codes and standards organizations. SNL's core technology and experience provide the necessary basis for a systematic approach to RAM management and packaging, and issues of storage, transportation, and disposal.

Since these landmark tests were conducted, SNL has performed, designed, or supervised numerous other tests. SNL also has hosted international contingents at many tests of RAM packages. Results from these tests have led to the certification of RAM packages and of the application of technologies essential to the safe transport of radioactive material.

### **TRUPACT-II**

Studies on a transport system for defense transuranic (TRU) waste were initiated at SNL in 1978. A cask, designated TRUPACT-II, was designed for the shipment of low-level radioactive materials from DOE sites to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. The waste is in diverse forms such as rags, paper, tools, and clothing. Preliminary design of a shipping container was completed in 1981 by General Atomics (now GA Technologies) under contract to SNL. Six 1/4-scale models of the

containers were built for testing, and full-scale tests were conducted on the panels of the containers and the transport drums. An early model, called TRUPACT I, was also designed and tested at SNL. TRUPACT II (to be used for WIPP transport) was tested at SNL.

### **BENEFICIAL USES SHIPPING SYSTEM CASK**

Design of the Beneficial Uses Shipping System (BUSS) for the shipment of cesium chloride and strontium fluoride irradiation capsules began at SNL in 1980. Prototype containers were tested under simulated severe accident conditions to ensure their integrity and to obtain DOE and NRC certification. The BUSS cask was put into service in 1993 at the DOE Hanford Site.



*The TRUPACT-II package undergoing drop tests at Sandia's Coyote Canyon test area. The package had to survive a 30-foot drop onto an unyielding surface and a drop from 40 inches onto a steel spike.*



*View of the BUSS cask mounted on truck trailer.*

### **C-141B DROP TESTS**

In 1994, the Defense Nuclear Agency (DNA) asked SNL to carry out a safety evaluation on Minuteman III weapons when subjected to an accident during transport on a C-141B aircraft. Two aircraft sections with mock weapons containers were subjected to drop tests at varying altitudes and velocities. The test results are being used by DNA to validate numerical predictions of aircraft response during postulated accident conditions.

### **MIDAS**

MIDAS is the acronym for Mobile Instrumentation Data Acquisition System, a self-contained, fully automated data collection and processing facility housed in a 13.4-meter (44-foot) trailer with multichannel structural and thermal data acquisition systems. MIDAS was designed and built between 1989 and 1993 by SNL to provide on-site data acquisition and analysis capabilities for testing of radioactive materials packages. It has been used to collect data in Germany and various U.S. locations in addition to numerous tests at SNL.

## MOSAIK

Sandia carried out the MOSAIK drop test program to confirm the applicability of a fracture mechanics methodology for the brittle fracture fail-safe design of Type B transportation casks. This program demonstrated the viability of ferritic materials, specifically ductile iron, for Type B transportation cask containment under extraregulatory conditions. Ductile iron is widely used in Europe as a structural material for radioactive material casks. Sandia obtained the MOSAIK cask from a German manufacturer for a series of five drop tests conducted in 1993 and 1994 which varied from a height of 9 to 18 meters (30 to 60 feet).

## SEARAM

*SeaRAM* is a DOE program to evaluate the severity of maritime accidents and the response of radioactive material shipping containers to such accidents. Significant quantities of nuclear fuel previously shipped to foreign countries for use in their experimental research reactors are being returned to the United States. Accordingly, DOE made a commitment to Congress to conduct a study to assess the safety of RAM transport by sea. DOE is cooperating with the IAEA by sharing results of the *SeaRAM* program. One component of

*SeaRAM* is to evaluate the effects of a shipboard fire on a simulated spent fuel cask. The results will be used in risk analyses that will be valuable in the preparation of Environmental Assessments and Environmental Impact Statements for sea transport of radioactive material. SNL conducted a series of fire tests in 1995 to gather information on potential shipboard accident conditions. In collaboration with the U.S. Coast Guard, the fire tests were conducted at the Coast Guard Fire and Safety Test Detachment. A series of fires were set in one of the holds of the test ship *Mayo Lykes*, a cargo freighter located at Little Sand Island in Mobile Bay, Alabama. The responses of simulated cargoes and the ship holds were monitored. The results will be useful in assessing thermal response of radioactive material packages for a wide range of shipboard fires.



*A simulated cargo fire test using a wood crib. This test was conducted in 1995 on the Mayo Lykes, a cargo freighter located at the U.S. Coast Guard test site in Mobile Bay, Alabama.*

## PATRAM

An important outgrowth of RAM transportation technology development activities at SNL has been the series of International Symposia on Packaging and Transportation of Radioactive Materials (PATRAM). The purpose of these symposia has been to

offer guidance to and interactions within the nuclear transportation industry on technical advances in RAM package development. The first symposium, sponsored by the AEC and SNL, was held in Albuquerque in 1965. Since that time, eleven highly successful PATRAM symposiums have been held both in the U.S. and in foreign countries — among the cities that have hosted PATRAM meetings have been Washington, Berlin, New Orleans, Miami Beach, Yokohama, Las Vegas, and, in 1998, Paris.

## **CHRONOLOGY OF TRANSPORTATION ACTIVITIES**

*(Transportation Technology at Sandia, 1995)*

- 1936 First federal regulation governing shipment of radioactive materials. It was necessitated because photographic film was being clouded by ionizing radiation from materials being shipped by US mail.
- 1945 Z Division moved from Los Alamos to Sandia Base in Albuquerque, New Mexico.
- 1948 Sandia Branch of Los Alamos established.
- 1949 AT&T signed contract to manage Sandia Laboratories for Atomic Energy Commission (AEC).
- 1956 Sandia Laboratories branch established at Livermore, California to provide engineering support for Lawrence Livermore Laboratory.
- 1958 AEC published packaging and transportation regulations in Title 10, Code of Federal Regulations, Part 71 (10 CFR 71).
- 1961 Publication of international "Regulations for Safe Transport of Radioactive Material." Safety Series No. 6 by International Atomic Energy Agency (IAEA).
- 1965 First Symposium on Packaging and Transportation of Radioactive Materials (PATRAM) held in Albuquerque, New Mexico.
- 1967 Interstate Commerce Commission safety responsibilities transferred to newly created Department of Transportation (DOT). IAEA published revised Safety Series No. 6.
- 1968 Second PATRAM Symposium held in Gatlinburg, Tennessee. DOT issued revised regulations to conform with international standards.
- 1971 Third PATRAM Symposium held in Richland, Washington.

- 1972 Flight recorder tests compared Type B package survival to flight recorder.
- 1973 Development initiated on Plutonium Air Transport (PAT-1 and PAT-2) and continued through 1977. IAEA published revised Safety Series No. 6.
- 1974 Fourth PATRAM Symposium held in Miami Beach, Florida. Energy Reorganization Act of 1974 divided AEC into Nuclear Regulatory Commission (NRC) and Energy Research and Development Administration (ERDA).
- 1975 Full-scale cask tests on trucks and railroad cars; continued through 1977. TRANSNET, an interactive computer network that provides online access and user support was implemented. RADTRAN I, a transportation risk analysis code designed for TRANSNET, was developed.
- 1977 Department of Energy (DOE) established; replaced ERDA. NRC published "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes" (NUREG-0170) - the first national risk assessment of radioactive material transportation. Sandia published final report by L.L. Bonzon (SAND76-0437) on special impact tests of plutonium shipping containers.
- 1978 Sandia designated as lead laboratory for transportation research and development; Transportation Technology Center (TTC) established. Studies initiated on transport system for contact-handled TRU waste (TRUPACT-1) which includes rags, paper, tools, large equipment, floor sweepings, etc. Fifth PATRAM Symposium held in Las Vegas, Nevada.
- 1980 Sixth PATRAM Symposium held in Berlin, Germany; the acronym "PATRAM," coined by German hosts, was adopted. Preliminary TRUPACT-1 design completed. The first comprehensive study of transportation risks in urban areas, "Transportation of Radionuclides in Urban Environs," published by Sandia. Defense High-Level Waste (DHLW) cask development started and prototype built.
- 1981 RADTRAN II, an updated code, issued.
- 1982 Design initiated on Beneficial Uses Shipping System (BUSS).
- 1983 Seventh PATRAM Symposium, New Orleans, Louisiana.
- 1986 Eighth PATRAM Symposium, Davos, Switzerland.
- 1987 RADTRAN III issued.
- 1988 PATRAM Symposium held in Washington, DC.

- 1990 RADTRAN IV issued.
- 1991 Mobile Instrumentation Data Acquisition System (MIDAS) transported to Germany to support joint DOE/German test program. MOSAIK cask drop test program at SNL completed.
- 1992 Tenth PATRAM Symposium held in Yokohama, Japan. AT&T notified DOE that it would not renew contract to operate Sandia. BUSS cask certified by NRC and DOE.
- 1993 In October, Martin Marietta Corporation (later Lockheed Martin Corporation in 1995) assumed operation of Sandia. BUSS cask shipped to Hanford, Washington to be used in their site cleanup effort.
- 1994 MIDAS completed, documented, and fully operational. "SeaRAM," a program for the evaluation of the safety of radioactive material transport by sea, was initiated.
- 1995 Drop test of Rocky Flats pipe components (January). Drop test of Bettis honeycomb impact limiter (March). SeaRAM fire tests carried out in the hold of test ship at US Coast Guard Fire Test Facility in Mobile Bay, Alabama (September). Drop test of Bettis 235R package (September). SeaRAM pool-fire tests carried out on deck of test ship in Mobile Bay, Alabama. (November). Eleventh PATRAM Symposium held in Las Vegas, Nevada.
- 1996 IAEA Standard Safety Series Numbers, ST-1 and ST-2, published superceding Safety Series No. 6, 7, and 37.
- 1997 SeaRAM bulkhead fire tests carried out in test ship at Mobile Bay, Alabama with US Coast Guard collaboration.
- 1998 Twelfth PATRAM Symposium held in Paris, France.

## REFERENCES

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