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From Nuclear Weapons to Global Security: 75 Years of Research and Development at Sandia National Laboratories

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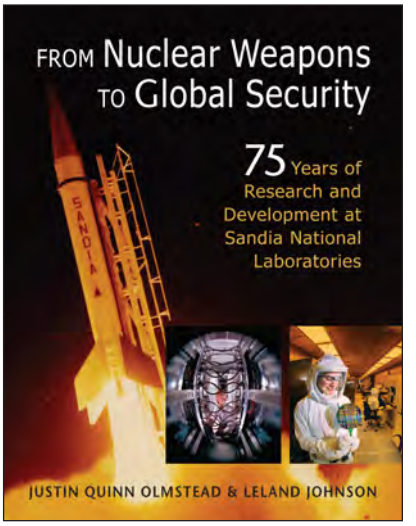

ISBNs: 978-1-962551-33-5 pb
978-1-962551-34-2 ebook

LYNNE RIENNER PUBLISHERS

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Introduction

On 22 January 1966, a US Air Force B-52 collided with a KC-135 refueling tanker above Palomares, Spain. The B-52 was carrying four B28 thermonuclear bombs. The entire crew of the KC-135 and three crew members of the B-52 were killed, while the remaining four crew members of the bomber parachuted to safety. As the B-52 broke up, its nuclear bombs were torn from their racks. One bomb struck the ground with minimal damage after its parachute opened. A second bomb struck the ground at an estimated 325 feet per second, causing its explosive to detonate and scattering its plutonium. The third bomb hit the ground at an estimated 225 feet per second, also exploding and scattering plutonium over several hundred acres. The fourth bomb could not be located. Scientists from Sandia National Laboratories were called on to analyze the fourth bomb's trajectory and related factors and provide the Navy with its location, which led to a successful recovery. Soon tasked with developing a novel nuclear detonation safety concept, Sandians landed on a strong link concept that created a barrier isolating the weapon's detonators and firing sets from electrical signals. Sandians also incorporated a weak link, where components vital to arming a weapon were designed to fail during accidents before strong links were destroyed.

In the second half of the twentieth century, the United States has repeatedly looked to and relied on its scientific community and national laboratories to solve problems in the national interest. The Palomares incident, one of several accidents in the 1960s, is just one example of Sandia National Laboratories' ability to respond to the needs of the US government. It illustrates a relatively early episode in Sandia's history that helped establish the Labs as a go-to organization that the nation turns to in an emergency, be it security, environmental, or energy related.

An integrated complex of contractor-operated nuclear materials production facilities, component production plants, and weapon assembly plants has

produced the nation's nuclear weapons stockpile. These facilities are gathered together under the National Nuclear Security Administration (NNSA), a semi-autonomous agency under the Department of Energy. The three laboratories involved in nuclear weapons design are Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories. Los Alamos and Lawrence Livermore design the high-explosive/nuclear system package, and Sandia designs the rest of the nuclear bomb or warhead. This includes the arming, fuzing, and firing systems along with the other components. In essence, Sandia weaponizes the nuclear systems designed at its partner laboratories. It is the system integrator for nuclear weapon design. Sandia also serves as the liaison with the integrated contractor complex to see the production phase of the work through to completion. Sandia is the principal point of contact with the Department of Defense and the military services. The focus of this book is on Sandia, so the narrative will naturally cover what the Labs have done and be limited in its coverage of the other laboratories. This should in no way be seen as a slight, as each laboratory has a critically important role to play in the nation's security and its own history to tell.

Aerial photo of Sandia National Laboratories, Albuquerque, New Mexico in 2016.

Aerial photo of Sandia National Laboratories, Lawrence Livermore, California, site in 2018.

Sandia is a product of the World War II Manhattan Project. During the war, the design, development, testing, and assembly of Little Boy and Fat Man (the two atomic bombs used during the war) were all done at Los Alamos. In late 1945, the Los Alamos Laboratory began transferring its field testing and engineering organization, known as Z Division, to Sandia Base near Albuquerque. Some staff from the Army Air Corps 509th Composite Group at Wendover Air Base in Utah joined the original group to do weapon assembly, forming the nucleus of what became Sandia Laboratory in 1948. The following year, American Telephone and Telegraph, (AT&T) agreed to take over management of Sandia. It formed Sandia Corporation, a wholly owned subsidiary of Western Electric to be the managing and operating contractor of the Sandia facilities in New Mexico. Sandia became a separate operation from Los Alamos on 1 November 1949.

Sandia's history is not something that can be neatly packaged. This is because its mission has expanded over time, adding cyber, biological, space, and counterterrorism to its original nuclear weapons mission. Today Sandia's portfolio encompasses nuclear deterrence, global security, national security programs, energy and homeland security, and advanced science and technology.

The innovative technologies developed in these areas and the ideas and people behind them are covered in this book. Although there is some variation, each chapter covers a time period of roughly five or ten years. Due to the pace of technology and world events, some chapters overlap in time period but with different focuses. For example, Chapters 5 and 6 both cover the 1970s, but because Sandia's work in energy and weapons was so large and diverse, it was necessary to break the chapters up along those lines. Even so, each chapter provides an understanding of Sandia's evolution, the various technical challenges it has met, its innovations, and discoveries while responding to the ever-changing geopolitical context.

Sandia's success is a result of the people who work at the Labs. How individual and group decisions have affected the direction of Sandia and its role in national security are covered in varying degrees. The early chapters focus on Sandia's growth from Z Division to its transition into Sandia Corporation. These chapters walk the reader through the reasons for forming an engineering wing separate from Los Alamos and examine the reasons behind the University of California's decision to end its management of production engineering. The details of the search for industrial management that settled on AT&T and Truman's personal request for them to take over Sandia lay the foundation for how Sandia would operate over the next seventy-five years. These chapters also cover the inevitable issues that follow such a sweeping change in leadership while demonstrating how quickly Sandia started growing.

As the book progresses, the impact of decisions from Sandia leadership, engineers, scientists, and the nation's policymakers can be found in how the Labs reacted to the nation's needs. These reactions culminate in varied ways, such as Sandia's ability to apply novel application to engineering issues concerning weapons development, and the early use of computers to aid in the development of weapon specification, coupled with attempts at creating a safer environment for those handling nuclear weapons. Sandia's establishment of fundamental research as an essential aspect of its work is covered in the first few chapters, and its impact can be seen as the book progresses. The importance of this cognizant move to include this type of research in its toolkit is seen in achievements such as hot-air solder leveling, fusion research, and the Z machine. In addition, Sandia researchers developed a method to remove radioactive contaminants from wastewater and used it to help clean up water contaminated after Japan's Fukushima Daiichi nuclear power plant disaster.

Over its history, the Labs has played a fundamental role in designing, testing, and overseeing production of all of the nonnuclear components in the nuclear stockpile; systems integration; nuclear weapons safety and use control; monitoring (nuclear detection); treaty verification; treaty negotiation support;

and stockpile surveillance. Sandia's continued role in support of the nation's nuclear deterrent has branched into a number of areas. Much of what Sandia does involves weapons themselves—evaluation of components, subsystems, performance, and extending the life of weapons in the stockpile. But the technological breakthroughs have also led to Sandia's work with satellite programs since the 1960s.

Initially designing sensors to detect nuclear bursts in support of treaty verification of international arms control agreements, Sandia ultimately fielded payloads and support systems for twenty-three defense satellites and fifty-one global positioning satellites. In this same vein, the Labs developed radiation-hardened components that allow warheads and satellites to survive the harsh conditions of space. With nuclear weapons comes nuclear weapons security and nonproliferation. In these areas Sandia developed the permissive action link, a coded electromagnetic lock that prevents unauthorized use of a US nuclear weapon. Sandia technologies such as microscopic sensors and large intelligence-gathering systems help monitor compliance with international treaties, the theft or diversion of nuclear materials, and biological and chemical weapons. Preventing the global spread of weapons of mass destruction (WMDs) is one of Sandia's major efforts. Sandia's work to ensure the safety and security of the nuclear stockpile led to its early foray into what is now known as counterterrorism. Because of the growing concern about the availability of WMDs to nonstate actors, this area of work continued to grow as the Labs developed chemical monitoring systems to provide early warning of airborne chemical agents that might be used in a terrorist attack.

Sandia's work with supercomputers began as a means of testing nuclear weapon components without detonating one and advanced into use in petroleum exploration and atmospheric climate modeling. Sandia's supercomputing innovations, beginning with ASCI Red, the first computer capable of more than a trillion operations per second, continued with the development of Red Storm, a supercomputer that has been used by US government agencies, universities, and customers worldwide. In 2018, Sandia added Astra, the world's fastest Arm technology–based supercomputer. Astra is the first advanced prototype platform to evaluate emerging high-performance computing technologies for stockpile stewardship.

Just as Sandia has been able to do more for the nation than just act as an engineering wing for Los Alamos, it has been able to leverage its technical and scientific knowhow to benefit society as a whole. The need for improved semiconductors and microelectronics for weapons and satellites led to Sandia developing technology such as strained-layer superlattice (SLS) that had both military and commercial applications. Used in advanced radar fuzes, fiber optics, DVD

players, and cell phones, SLS has been and remains a contribution that has had a major impact on human activity. In addition, sensor technology developed at Sandia for use in warheads was an early component of the vehicle airbags many people rely on.

Sandia's growing field of non–nuclear weapons research has provided as many major scientific and technical achievements as the weapons side of the Labs. Its contributions are in the areas of clean rooms, self-soldering circuit boards, shale oil exploitation, drill bits, physical security (early counterterrorism), decontamination foam, biosecurity, studies of climate change, medical diagnostic technology, quantum computing, and hypersonic glide vehicles. In many of these areas, it is possible to dig a little deeper to gain a true understanding of these accomplishments. For instance, in climate change, which is incontrovertibly connected to energy research, Sandia made advancements in photovoltaics and grew from managing the Systems Definition portion of the National Photovoltaic Conversion program in 1975 to operating the National Solar Thermal Test Facility. Sandia developed an innovative wind turbine blade that produces up to 10 percent more energy than traditional linear blade designs. The Labs established its Combustion Research Facility where researchers have developed ways reduce air pollution from engines and coal-powered utility plants.

Additionally, Sandia used the expertise it developed from establishing the clean room to sterilize space vehicles from microbiological contamination. This early foray into biological applications led to further contributions in medicine with the creation of a bionic pancreas, as well as technologies that neutralized chemical and biological agents. Like much of what Sandia does, the clean room was originally intended to support nuclear weapons, providing a dust-free environment for manufacturing close-tolerance weapons parts. It quickly became a basic enabling technology for the electronics industry and improved hospital operating room safety. In the following pages, these achievements—along with others such as hydrogen monitoring, cybersecurity, anthrax detection and decontamination, combustion science, solar power, advanced radar, computation-based product design, international cooperation, airbag sensors, and pulsed power—will provide readers with a clear understanding of the various scientific and technical achievements Sandia has contributed to national security, world security, and society.

Any focus on what Sandia does must begin with extolling the virtues of the mission support staff. The engineers and scientists at Sandia would not be able to provide exceptional service were it not for those doing the important if often unheralded work of mission support. It is due to the dedication of the doctors, nurses, and janitorial staff that the Labs was able to remain open during the Covid-19 pandemic in 2020. It is because of the Corporate Computing Help

Desk and the massive, secure, and efficient information technology infrastructure that Sandians are able to work on site or remotely to continue delivering innovation and engineering. On an everyday basis, the men and women of the Security Services ensure that there are no breaches—cyber, insider, or otherwise. The administrative assistants, the key to all effective and efficient workplaces, ensure things run smoothly and on time. The men and women of human resources ensure Sandia has a world-leading workforce that embodies Sandia's core values. Facilities makes sure there is a well-maintained place to work. Business personnel, archivists, attorneys, information managers, technical writers, artists, mail carriers, emergency personnel, and environment, safety, and health teams all play important roles in the Labs' ability to meet its mission and exceed the world's expectations. The work mission support does often go unseen, but make no mistake, it is essential to Sandia's success.

It is important to note that Sandia's impact goes beyond science and technology. The Labs' work also has an effect on the people, cities, and regions where it is active. Sandia works with diverse and qualified small business suppliers to promote innovation and deliver cutting-edge technology. The Small Business Act (1953) mandated that federal contractors use small businesses, including those that are small, disadvantaged businesses; small businesses owned by women, veterans, and service-disabled veterans; and small businesses in impoverished areas called Historically Underutilized Business Zones (HUBZone). To meet this mandate, Sandia created its Small Business Utilization Department, which negotiates annually with NNSA to set small business subcontracting goals.

The Labs' commitment to partnering with small businesses to achieve its national security missions strengthens local and national economies. In 2022, Sandia's subcontract-related payments to small, disadvantaged, woman-owned, veteran-owned, service-disabled-veteran-owned, and HUBZone businesses amounted to over $1.5 billion nationwide. Almost $500 million of that total was spent in New Mexico and another $246 million in California. Sandia's commitment to small business has led to 67 percent of all Labs suppliers being small businesses, amounting to five hundred new small businesses supporting its mission.

Sandia also contributes to the state economy through participation in the New Mexico Small Business Assistance (NMSBA) Program. The Sandia NMSBA program was a response to the Laboratory Partnership with Small Business Tax Credit Act, passed by the New Mexico legislature in 2000. By 2010, Sandia's NMSBA program had created and retained 1,549 jobs, decreased operating costs by $45.7 million, increased revenues by more than $82.4 million, and invested more than $17.4 million in expansion efforts and

purchases of local goods and services.[1] In 2022, Sandia provided $2.4 million of technical assistance to NMSBA and assisted 130 small business in the state. In addition, the Sandia Science & Technology Park, a 250-acre master-planned research park adjacent to the Laboratories, employed more than 2,000 people at an average salary of $71,612, compared with the median household income in New Mexico of $56,206.[2]

Aside from the financial impact on its communities, the Labs' workforce has had an impact on its communities. Since Sandia vice president and first general manager Tim Shea became chairman of Albuquerque's Community Chest (precursor to the United Way) in 1951, Sandians have contributed through annual charity drives. In 1957, the first payroll deduction plan was introduced, an action declared key by Ted Sherwin, then manager of the Public Relations Department. That year, Sandia employee contributions amounted to about 20 percent of the total pledged to the United Way of Albuquerque. In a campaign currently called Sandia Gives, employee donations have continued to account for about 20 percent of the total raised annually by the United Way of North Central New Mexico, with total employee contributions in 2022 coming to $4.6 million.

In 1956, two Sandians noticed many Albuquerque children without shoes. Instead of exchanging holiday gifts, the scientists decided to buy shoes for children. Sandia continued this tradition of donating shoes during the holidays. In 2019 it was rebranded as Hearts and Soles and moved to Valentine's Day. Sandians donate approximately $10,000 annually to the program. Sandia California began its own community campaign in 1969 called LEAP (the Livermore Employees Assistance Plan). Agencies that shared the $175,000 donated per year were located in the Tri-Valley area. In addition, Sandia California has hosted an annual Sandia Women's Connection Math and Science Awards for more than thirty years. Sandia is a contributor to the Tri-Valley Business Council's alternative energy workforce incubator initiative that enables career pathways in high school and college to be mapped to the alternative energy workforce. Sandia has also been an active partner with Las Positas College, a community college in Livermore.

Not surprisingly, because it is a science and technology–based organization, Sandia's contributions to its communities have always included an education focus. Recognizing that children must have their basic needs met before they can learn, Sandia strives to improve family stability. Using money from the fee awarded for performance from the prime contract, Sandia, in 1997, began by investing $180,000 in the community. In 2002, this commitment increased to $1.4 million annually—a commitment the National Technology and Engineering Solutions of Sandia elected to keep and one that continues today.

For more than thirty-five years, Sandia Employee Resource Groups and the Community Involvement team have offered a wide variety of outreach programs to introduce careers in science, technology, engineering, and mathematics (STEM) fields. The Black Leadership Committee (through HM Tech), Hispanic Outreach for Leadership and Awareness (through Manos), and the American Indian Outreach Committee (through Dream Catchers) offer outreach programs that introduce students to STEM careers. From 2001 to 2019, Sandia's Family Science Night was seen as a crucial means of enhancing fun science activities in New Mexico and California. It provided an evening for parents and students to engage in fun, hands-on science at their elementary school. In 2014, Sandia started holding Family Math Nights, during which Labs personnel provide an evening for parents and students to engage in fun, hands-on math games at their elementary school. The Department of Energy Regional Science Bowls are legacy programs that are hosted by the Sandia New Mexico and California sites. Sandia has also sponsored the New Mexico Car Challenge since 2007. Originally named the Alternative Fuels Challenge (hydrogen-fueled cars and electric cars), this middle school competition engages students in building and racing a car, incorporating design and oral presentation competitions. Sandians continue to serve their communities by volunteering and donating goods, blood, and money.

This book lays out the work of Sandia National Laboratories in its first seventy-five years, situating it in the context of the events and decisions that drove the work. International events and shifting national priorities provide context for the turning points where the Labs shifted its emphasis and explored new areas. The result has been an ongoing evolution in the nature and focus of the projects Sandia has undertaken. Four essential themes run throughout this book. First, Sandia is an engineering laboratory with deep and broad research capability and a culture of technical excellence. As such, it has developed a culture of getting the work done and the product out—something Labs' employees have always prided themselves on. Reflecting the technological enthusiasm identifiable in American science and engineering more broadly, this attitude thrived on the technological challenges inherent in the arms race of the Cold War. Technological challenges have continued to drive Sandians as they addressed new issues brought about by the energy crisis, the security needs of the post-9/11 world, and more recently, climate change.

Second, as noted earlier, the tremendous destructive potential of nuclear weapons has required an extremely small allowable risk of failure in their safety, security, and use control. Insistence that weapons will work reliably has been joined by an equally adamant demand that they not work when they are not supposed to (i.e., an accident or in unauthorized hands). The tension in

these competing ideas led Sandians to offer and promote technological solutions to problems of safety, security, and use control, often leading the way on these issues in the weapons community.

A third theme is Sandia's flexibility, which has allowed for extensive and quick mobilization of its research and development capabilities. Sandia has had both the breadth and depth of expertise to support its mission programs. Due to its essentially independent internal technical capabilities and management style, it also has the flexibility to allow a project to draw on relevant capabilities from across its facilities and among its personnel.

A fourth and final theme is a direct result of the previous three. Sandia is a national laboratory. Along with its partner laboratories and the national laboratory system overall, it was designed to serve the national interest in an innovative and independent way. Sandia is not expected to do only what it is told. It has not only been responsive to the requests of its national security customer base, but also is counted on to look forward to identify and offer creative solutions to problems no one else recognized. It brings those solutions forward based on its extensive technical and human capabilities.

Notes

1. Heather Clark, "Sandia's Effect on New Mexico's Economy, Community Highlighted in 2010 Economic Impact Report," *Lab News*, 14 January 2011. https://www.sandia.gov/Lab News/2011/01/14/110114-3/.

2. "Real Median Household Income in New Mexico," Economic Research, US Census Bureau, St. Louis Federal Reserve. https://fred.stlouisfed.org/series/MEHOINUSNMA672N.