NATIONAL ECONOMIC IMPACTS

from the National Nuclear Security Administration

and Lawrence Livermore National Laboratory

CRADAs and License Agreements

Conducted by TechLink
National Partnership Intermediary
U.S. Department of Defense

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National Nuclear Security Administration

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NNSA ensures the United States maintains a safe, secure, and reliable nuclear stockpile through the application of unparalleled science, technology, engineering, and manufacturing.

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CRADAs and license agreements supported by the Lawrence Livermore National Laboratory have benefits across a broad range of applications, including health and medical.

EXECUTIVE SUMMARY

This study evaluates the economic outcomes and impacts of 205 Cooperative Research and Development Agreements (CRADAs) and 218 technology license agreements between Lawrence Livermore National Laboratory (LLNL) and a total of 307 outside partners. The primary purpose of the study was to quantify the extent to which these technology transfer (T2) agreements have contributed to economic activity and job creation in the United States. The secondary purpose was to identify the extent to which CRADAs and technology license agreements contribute to the National Nuclear Security Administration's (NNSA) core missions of maintaining the nuclear stockpile, monitoring and promoting nonproliferation, and responding to nuclear and radiological emergencies.

The relevant agreements were executed between 2000 and 2020 by LLNL, one of the three national laboratories managed by NNSA, a semi-autonomous agency within the U.S. Department of Energy (DOE). The research team successfully surveyed 294 T2 partners out of 307 total, with some having multiple T2 agreements, for a 96

percent total response rate. Each was asked a series of questions regarding sales of new products and services and other outcomes resulting from the technologies associated with these T2 partnerships. In addition, two qualitative questions were asked to determine other benefits from these T2 agreements. Lastly, several additional qualitative questions were posed to all partners, which specifically focused on nuclear weapons, stockpile, and non-proliferation.

The results of six exceptional T2 agreements were highlighted in a series of success stories published by TechLink. These narratives demonstrate how the projects were used to advance scientific understanding and to support NNSA in achieving its nuclear weapons mission. The research team was able to obtain full or partial information on the economic outcomes of 408 out of the 423 license agreements and CRADAs, or 96 percent of all T2 agreements, same as the total response rate.

The IMPLAN economic impact assessment model was used to estimate the economic impacts in the U.S. related to the sales of products and services enabled by these license agreements and CRADAs. The results of this study are believed to significantly understate the actual economic impacts because of multiple agreements with confidential outcomes, non-responding partners, the effects of inflation, and other factors discussed in the report.

Major findings from the study included the following:

Total sales resulting from LLNL's license agreements and CRADAs:
$3.5 billion

Sales to the government:
$224 million

Total economic impact nationwide:
$8.1 billion

New tax revenue (federal, state, and local):
$832 million

Jobs per year, with average compensation of approximately $88,000:
1,321

Estimated cost savings for the U.S. government:
Over $696 million

DOE, NNSA, and LLNL

The Department of Energy (DOE) is a major engine of innovation in the United States. DOE's seventeen national laboratories typically surpass all other federal agencies in total numbers of invention disclosures, patent applications, and issued patents. These inventions cover a wide spectrum of technology areas—from electronics, advanced materials, sensors, semiconductors, and various computer-related technologies (including cybersecurity and artificial intelligence) to environmental technology, biotechnology, diverse energy-related technologies, and nuclear weapons development.

The National Nuclear Security Administration (NNSA), a semi-autonomous agency within DOE, manages three of DOE's national laboratories: Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (Sandia). All three of these NNSA labs are government-owned, contractor-operated facilities. They are responsible for maintaining the safety, security, and reliability of the nation's nuclear weapons stockpile, and reducing the global threats

of nuclear proliferation and nuclear terrorism. In addition, they develop nuclear propulsion capabilities for the U.S. Navy.

In 1952 at the height of the Cold War, LLNL was established to meet urgent national security needs by advancing nuclear weapons science and technology. Throughout its history, LLNL has maintained a dedicated workforce and world-class research capabilities, strengthening national security through science and technological innovations. LLNL has been anticipating, developing, and delivering solutions for the nation's most challenging national security problems for nearly 70 years.[1]

NNSA also operates the Kansas City National Security Campus, Nevada National Security Site, Pantex Plant, Savannah River Site, and the Y-12 National Security Complex. These plants and sites have a variety of tasks and objectives that have impacts across the globe, which include but are not limited to manufacturing and obtaining components for nuclear weapons, recognizing and assisting with nuclear deterrents, ensuring the safety and security of the U.S. nuclear weapons stockpile, supplying tritium, and enriching uranium for nuclear weapons. These five NNSA sites and plants closely collaborate with LLNL, LANL, and Sandia to ensure NNSA successfully completes its objectives and mission.

NNSA and Nuclear Weapons History

Nuclear security has been an area of critical importance in the United States since World War II. Following the success of the Manhattan Project in creating the world's first nuclear stockpile, preservation and enhancement of these weapons has been a crucial U.S. national imperative. As its name suggests, NNSA is tasked with the safety and security of these weapons, using an evolving strategy to combat dynamic threats.

As noted in President Biden's Interim National Security Strategy Guidance (March 2021), the Administration is exploring options to reduce the role of nuclear weapons in our national security strategy, while still ensuring our strategic deterrent remains safe, secure, and effective, and that our extended deterrence commitments to our allies remain strong and credible. Of note, the 2022 Nuclear Posture Review (NPR) is currently underway. The Interim National Security Strategy Guidance will be updated, and the results of the 2022 NPR will inform future requirements. NNSA maintains a skilled team of scientists and engineers, pursuing discovery and innovation in the field of nuclear technologies. These professionals work in world class laboratories and facilities, across government agencies, and with trusted industry partners to employ all available knowledge and techniques to further NNSA's mission. These initiatives consistently result in successful and important innovations in the fields of nuclear technology, non-proliferation, and nuclear propulsion. NNSA's versatility and capabilities have also allowed it to successfully explore improvements in areas such as national security infrastructure, cybersecurity, and information technology, providing benefits to the U.S. beyond its core mission.

As nuclear technology continues to rapidly progress, the successful achievement of NNSA's mission becomes increasingly important. Rival powers, rogue nations, and terror groups all threaten the security of the United States as they, too, pursue nuclear development. The U.S. today faces a more diverse and advanced group of nuclear threats than at any other time in the nation's history. With this understanding, the invaluable nature of NNSA's mission to pursue nuclear deterrence and de-escalation cannot be overstated. The ability of NNSA to provide a robust, flexible, and functional nuclear deterrence plan is crucial to the overall safety of the nation. However, today's nuclear environment demands that when deterrence fails, the

1 See *https://www.llnl.gov/about/history*

United States be prepared with an advanced, mobile, and effective nuclear stockpile. To accomplish this, NNSA constantly improves and enhances the nuclear stockpile while concurrently ensuring its security. Finally, the continuous improvement of Navy craft challenges NNSA to provide contemporary and advanced methods of nuclear propulsion to give the U.S. Navy every possible advantage. The essential nature of these three tasks compounds to establish the importance of NNSA operations. Successful completion of its mission allows NNSA to help provide the bedrock for the safety and security of the U.S. military, the federal government, and the American people.

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The NNSA was established by Congress in 2000. A semi-autonomous agency within the U.S. Department of Energy, the NNSA is responsible for enhancing national security through the military application of nuclear science.

PURPOSE OF STUDY

This study quantifies the national economic impacts and other important outcomes of technology transfer (T2) agreements established by LLNL. The agreements covered in the study include Cooperative Research and Development Agreements (CRADAs) and various technology licenses, including patent licenses, bailment licenses, copyright licenses, and hybrid licenses. This study also evaluates the impact these CRADAs and licenses have had on non-proliferation, including reducing the threat of nuclear or radiological terrorism, nuclear material management, and security.

DOE and other U.S. government agencies have a legal mandate to transfer their inventions to the private sector to benefit the nation's economy and help ensure national technological competitiveness.[2] Licensing is the primary means by which DOE labs transfer inventions to the private sector for conversion into new commercial and mission-related products. These are legally binding contracts that give licensees—usually for-profit corporations—the right to make, use, and sell federal government-owned inventions. CRADAs are unique contractual vehicles that enable federal labs and outside parties to

2 15 U.S.C. 3701 and 3710, and 35 U.S.C. 207-209, *inter alia.*

jointly develop new technologies, leveraging each other's expertise and resources.[3] Many DOE CRADAs result in nationally and internationally important products and services.

The **purpose of this study** was to evaluate the extent to which LLNL's licenses and CRADAs have resulted in new products and services that benefit the national economy, improve the nuclear weapons stockpile for the United States and our international allies, and support the NNSA mission. More specifically, its purpose was to determine the extent to which technology licenses and CRADAs established by LLNL have (1) contributed to new economic activity and job creation in the United States, and (2) resulted in the transition to actual use of new technologies that support the U.S. nuclear security enterprise. This study was sponsored by NNSA.

The research team surveyed all outside T2 partners having licenses and CRADAs active with LLNL during the 2000-2020 period.[4] This survey reached a total of 294 partners[5] with 408 different agreements—208 licenses and 200 CRADAs. Partners were asked about sales of new products and services and other significant outcomes directly related to their T2 agreements with LLNL. Several additional questions were posed to all partners, which focused on nuclear weapons, stockpile, and non-proliferation. The research team used the IMPLAN model to estimate the total economic impacts in the U.S. related to the reported sales. IMPLAN analysis yielded estimates of economic output, value added, employment, labor income, and tax revenue.

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CRADAs and license agreements represent the ideal merging of commercial and governmental interests—various parties coming together for the benefit of America.

3 15 U.S.C. 3710a.

4 The time period for the study was defined by LLNL.

5 The term "partners" is used throughout this report to signify DOE's T2 partner. Most of these partners were for-profit but several were non-profits or universities. Use of the term "partners" is not only a convenient way to abbreviate the text; it also is appropriate because when the CRADA partners are universities, they typically transfer promising new CRADA-related inventions to the private sector for commercialization. The survey reached 294 out of 307 total T2 partners during the study period, or 96 percent.

RESEARCH TEAM

This economic impact study was conducted by TechLink in collaboration with the Business Research Division (BRD) of the Leeds School of Business at the University of Colorado Boulder. TechLink is a federally funded technology transfer center located at Montana State University. Since 1999, it has served as the primary national partnership intermediary of the Department of Defense (DoD), helping to develop license agreements, CRADAs, and other technology partnerships between DoD labs and U.S. industry nationwide.[6] Additionally, TechLink has conducted 20 national economic impact studies of T2 and Small Business Innovation Research (SBIR) programs on behalf of DoD, NNSA, and the National Cancer Institute. The BRD has been analyzing local, state, and national economies for more than 100 years and specializes in economic impact studies and customized research projects that help partners, associations, nonprofits, and government

6 For more information, see *http://techlinkcenter.org*

agencies make informed business and policy decisions.[7]

The principal authors of the study were Dr. Michael Wallner, Jeff Peterson, and Dr. Will Swearingen of TechLink, as well as Brian Lewandowski of the BRD. Other members of the team included Ray Friesenhahn, Joe Hutton, Cara Jorgensen, David Lynn, Nic Richardson, Chris Van Bockel, and Michelle Zook of TechLink.

METHODOLOGY

This study was undertaken in **three major phases** in mid-to–late 2021**:**

(1) Data Gathering. During the data gathering phase, the research team contacted LLNL's outside partners having CRADAs and license agreements that were active during the 2000-2020 time period. This phase began in June and lasted through August.

(2) Data Analysis. During this phase, the evaluation team analyzed the information gathered during the first phase. TechLink analysts developed descriptive statistics to interpret the quantities findings and open-coded the qualitative answers. Analysts at the BRD used the IMPLAN model to estimate the economic multipliers and total economic impacts resulting from the sales of new products and services derived from these agreements. This second phase was accomplished in September and October.

(3) Final Report. The authors prepared the final report in November and December, drawing on the results of the previous two phases.

Research processes conducted during the first two phases are described in the following sections.

Data Gathering

The study was initiated in June 2021, when LLNL staff provided TechLink with essential information on 205 CRADAs and 218 license agreements. TechLink economic research specialists successfully contacted 294 of the 307 partners for these agreements, collecting data on 200 CRADAs and 208 licenses. The partner response rate was 96 percent, although one firm did not provide data on all of its agreements. Only 13 partners did not participate in the study (two refused and the rest were unreachable). This left the outcomes of five CRADAs and 10 licenses unknown.

Respondents were asked a series of questions focusing on the outcomes of these agreements.[8] Respondents were also asked if they would be willing to be featured in a success story highlighting the T2 process and the outcomes of their projects. Six of the most noteworthy outcomes were highlighted in success stories published by TechLink.

For each agreement with sales results, researchers assigned an industry-specific 6-digit North American Industry Classification System (NAICS) code. This was an essential step for analysis of the overall economic

7 For more information, see *http://colorado.edu/leeds/centers/business-research-division*

8 Wording of the full survey is included in Appendix 3.

impact. NAICS codes are used to assign industry sectors employed by the IMPLAN model. As the federal government's standard industry classification system, NAICS codes allow partners to be aggregated according to the specific activities they undertake. For a list of NAICS codes used in this analysis, please refer to Appendix 4. Researchers drew on discussions with respondents to identify the industry most applicable to the product or service sales resulting from the agreement. During the review process, TechLink's Chief Data Analyst checked each code for accuracy.

TechLink subsequently submitted a final dataset of sales results from its survey to the BRD at the University of Colorado Boulder. The dataset included—for each agreement leading to sales—a code number to identify the agreement and conceal the partner's name, the 6-digit NAICS code for the corresponding product or service, the total sales figures, and the location of the research, manufacturing, or service.

Data Analysis

The survey outcomes were compiled into the data report below. Descriptive statistics provide an aggregate picture of the outcomes of the agreements, and economic impact modeling provides an estimate of how they have contributed to growth in the U.S. economy. Qualitative findings identify non-financial outcomes of these projects for both the private partners and for the lab. They also identify weapons, stockpile, and non-proliferation outcomes; provide estimated cost savings, and evaluated commercial-off-the shelf products available to the government.

The IMPLAN model employed by BRD generated estimates of the economic contributions resulting from the gathered sales figures. These are provided on the national level, using state-specific economic data to reflect local supply chains and economies.

IMPLAN draws on a mathematical input-output framework originally developed by Wassily Leontief, the 1973 Nobel laureate in economics, to study the flow of money through a regional economy. IMPLAN assumes fixed relationships between producers and their suppliers, based on demand, and that inter-industry relationships within a given region's economy largely determine how that economy responds to change. Increases in demand for a certain product or service causes a multiplier effect—a cascade of ripples through the economy. This increased demand affects the producer of the product, the producer's employees, the producer's suppliers, the suppliers' employees, and others, ultimately generating a total impact on the economy that significantly exceeds the initial change in demand.[9] For additional information regarding the economic impact survey and analysis methodologies employed, please see pages 14-16 below.

For example, under a CRADA with LLNL, a partner develops a device that detects radiation levels in the immediate vicinity of a nuclear fuel storage facility. It subsequently manufactures these detectors and sells them to NNSA and several civilian nuclear power plants. The manufacturer employs factory workers, who spend their earnings on groceries, housing, and other goods. The company must purchase machines, tools, components, and raw materials from other companies, which also employ workers who purchase goods. This ripple of activity extends through the economy.

In this example, *direct effects* are the sales of the radiation detector, the jobs and payroll required to produce it, and the value created during the production process. *Indirect effects* result from inter-industry purchases of components and raw materials needed to manufacture the device. *Induced effects* are driven by employees spending their wages across a wide spectrum of the economy. *Total economic impacts* are the sum of direct effects, indirect effects, and induced effects.

9 IMPLAN Group, LLC. IMPLAN [2021]. Huntersville, NC. IMPLAN.com.

Multipliers are ratios of the *total economic impacts* to the *direct effects* and are typically derived from the following equation: (direct effect + indirect effect + induced effect) / direct effect. Multipliers are specific to industry sectors and regions. The IMPLAN model distinguishes between 536 industry sectors, which are based on NAICS codes. Each sector has an output multiplier based on a unique pattern of purchases from other industries, both inside and outside of the regional economy. IMPLAN is updated annually using data collected by various federal agencies.

Upon receiving the sales data from TechLink, the BRD converted each NAICS code to its corresponding IMPLAN sector. With all the sales figures properly categorized, the model yielded an estimate of the direct, indirect, and induced effects resulting from the agreements. The overall purpose of this modeling exercise was to estimate the total economic contribution of these sales to the nation's economy, including total economic output, value added, employment, labor income, and tax revenue.

The sales data presented are aggregated, representing the total value of all domestic U.S. manufacturing and services reported in the survey. The survey did not ask when sales occurred; therefore, all dollars are assumed of equal value, despite occurring over the course of 22 years (2000-2021). For modeling, the analysis used 2019 as the base year, assuming 2019 dollars and basing impact estimates on the economy of 2019. While TechLink economic impact studies typically use the most recent year as a base of analysis, this study used 2019, to avoid skewing the estimate with the unusual economic landscape induced by the SARS-CoV-2 pandemic. Using 2019 as the reference year represents a conservative approach as it ignores the higher value of earlier sales figures due to inflation (for example, $100 in 2000 had the same purchasing power as $148 in 2019).

AdobeStock / Rawpixel.com

Sales of new products and services resulting from LLNL's license agreements and CRADAs total $3.5 billion.

SURVEY RESULTS

Basic Outcomes

Did your company[10] develop any new or improved products or services based on this CRADA or license?

As displayed in Table 1, 22 percent of agreements (18 percent of CRADAs and 27 percent of licenses) had resulted in new products or services at the time of the survey. Of the remainder, 16 percent (26 percent of CRADAs and 7 percent of licenses) were still in development. Most respondents, regardless of agreement type, reported developing no new products or services.

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10 Because the vast majority of T2 partners were companies, the survey was written using this term.

Table 1: New products or services resulting from T2 agreements with LLNL

Response	License	CRADA	Total
No	58%	51%	54%
Yes	**27%**	**18%**	**22%**
Tech Still in Development	7%	26%	16%
Unknown	6%	3%	4%
Tech Abandoned	3%	3%	3%

Note: Totals may not equal 100% due to rounding.

A "yes" answer to this question does not necessarily mean these technologies had been commercialized. Occasionally products resulting from these partnerships are simply turned over to LLNL as a developing technology or prototype. Alternately, a "no" answer does not necessarily mean that the T2 agreement didn't result in economic impacts.

As a result of this CRADA or license, how would you categorize the technology from an IP perspective?

Table 2 shows the technology categories reported by respondents. The most common (17 percent) category was Instruments and Sensors. Other commonly reported categories were Biological or Environmental (13 percent), Advanced Materials (11 percent), Advanced Manufacturing (10 percent), and Lasers and Optics (9 percent). Interestingly, responses of National Security (6 percent) and Nuclear Energy (0.2 percent) were comparatively rare.

Table 2: Technologies resulting from T2 agreements with LLNL

Category	Count	%
Instruments and Sensors	71	17%
Unknown	58	14%
Biological or Environmental	57	13%
Advanced Materials	46	11%
Advanced Manufacturing	44	10%

continued...

Table 2: Technologies resulting from T2 agreements with LLNL (continued)

Category	Count	%
Lasers and Optics	38	9%
Other Energy Related Technologies	37	9%
National Security (including weapons)	24	6%
Electronics	16	4%
Information Technology	12	3%
Other Non-energy Related Technologies	7	2%
Cybersecurity	5	1%
Photonics	5	1%
Communications	2	0%
Nuclear Energy	1	0%

Note: Totals may not equal 100% due to rounding.

Unknown responses (14 percent) included agreements not surveyed, situations where respondents were unable or unwilling to choose one of the offered categories, and non-responses.

Sales Outcomes

The following questions focus on the actual sales results. The survey recorded commercial activity attributable to these T2 agreements by asking about sales of new products or services that resulted from a CRADA or license. These numbers, which are used as the basis of the economic impact analysis, were identified as product or service sales dependent on the agreement, including sales on commercial markets, follow-on R&D funding, sales to government customers, sales by spin-off companies, and royalties paid or sales reported by a sublicensee of the technology. The sales are shown by category in Table 3. The sum of all five categories is referred to interchangeably as total combined sales or total direct impact.

Table 3: Total combined sales broken down by sales category

Sales Category	Aggregate Amount	Percent of Overall Sales
Commercial Sales	$2,518,765,432	71%
Follow-on R&D	$751,002,035	21%
Government Sales	$224,251,116	6%
Spinoff Sales	$33,500,000	1%
Licensee/Royalties	$2,416,973	0%
Total Combined Sales	$3,529,935,556	100%

Note: Totals may not equal 100% due to rounding.

The total combined sales of $3.5 billion represents the direct impact on the economy. As the starting point for economic impact analysis, these sales figures have been adjusted to reflect only products manufactured in the United States. In a small number of cases, manufacturing occurred elsewhere. In those cases, the sales figures were omitted from impact modeling.

Commercial Sales. The largest category of overall sales involved sales to non-government clients, a total of $2.5 billion. This represents 71 percent of all direct sales enabled by LLNL T2 agreements, which demonstrates the benefit of these partnerships to the U.S. economy.

Follow-on R&D. The partners in these agreements reported a collective total of $751 million in sales of subsequent R&D services related to their T2 agreements.

Government Sales. The survey found that sales to the U.S. government amounted to $224 million, representing 6 percent of the total combined sales. These sales involved products or services procured by the federal government, 46 percent of which ($102 million) were procured by entities within the Department of Energy.

Spinoff Sales. $33.5 million represents sales by companies created by the original T2 partner to commercialize a technology developed through a CRADA or license.

Licensee/Royalties. Nearly $2.5 million was reported as either royalties paid by, or sales attributed to a licensee or sub-licensee.

Commercialization

The survey indicated that about one-third of these T2 agreements led to sales. As Table 4 shows, 32

percent of all agreements led to the $3.53 billion in total combined sales. This includes 33 percent of the licenses (totaling $1.62 billion) and 31 percent of the CRADAs (totaling $1.91 billion).

Table 4: Percent of T2 agreements leading to sales, by agreement type

	Total Agreements	Percent with Sales	Percent without Sales	No Data Available	Total Direct Impact ($B)
License	218	33%	62%	5%	1.62
CRADA	205	31%	67%	2%	1.91
All	423	32%	64%	4%	3.53

Note: Totals may not equal 100% due to rounding.

Table 5 further breaks down the commercialization rate (portion with sales) by either product/service sales or follow-on R&D. The column labeled *Sales* is an aggregate of commercial sales, government sales, spinoff sales, and licensee sales/royalties.

Table 5: Commercialization rate by sales, follow-on R&D, or both

	Sales and/or Follow-on R&D	Sales	Follow-on R&D
License	33%	23%	19%
CRADA	31%	6%	27%
All Agreements	32%	15%	23%

Note: Totals may not equal 100% due to rounding.

The purpose of Table 5 is to illustrate the type of sales that result from each agreement type. Only 6 percent of CRADAs in the study have led to sales of products or services, to either public or government customers. Among licenses, 23 percent led to sales, and within the entire population of both licenses and CRADAs, only 15 percent led to sales. Follow-on research funding resulted from 27 percent of the CRADAs, 19 percent of the licenses, and a total of 23 percent of both types of T2 agreement.

Partner Size

The survey asked respondents for the size of the partner organization associated with the agreement, both at the time of the survey and at the time the agreement was signed. The purpose of this question was to determine if T2 agreements had contributed to company growth. Table 6 displays these results.

Table 6: Size of LLNL T2 partners

LLNL Partner Size Category	At Time of Agreement	At Time of Survey
Unknown	3%	8%
Very Small (1-9)	30%	23%
Small (10-99)	26%	26%
Medium (100-499)	10%	8%
Large (500+)	31%	34%

Note: Totals may not equal 100% due to rounding.

In a small percentage of cases, the partner size was not known. This includes 3 percent at the time the agreement was signed. Eight percent were marked unknown at the time of the survey, due to the partner being uncontacted, out of business, or acquired by a larger organization with no interest in the specified T2 technology.

In cases where the subject technology was acquired by a different entity, the size at the time of survey indicates the size of the current organization overseeing the technology portfolio. As Table 6 shows, approximately one-third of the LLNL T2 agreements involved large partners (500+ employees). This number increased from 31 percent to 34 percent between the signing of the agreements and the survey. The number of agreements associated with very small partners dropped from 30 percent to 23 percent, apparently driven by partners going out of business or being acquired by larger organizations.

Table 7 shows how sales results break down by partner size. A notable survey finding was that the commercialization rate (the percentage of agreements leading to sales) was similar despite the partner size. However, the volume of sales is heavily weighted toward large partners. The total combined sales of $2.2 billion by large partners represents nearly two thirds of all sales reported in the survey.

Table 7: Sales by partner size (if known) from the LLNL T2 Agreements

Partner Size	Agreements with Sales	Commercialization Rate by Partner Size	Total Combined Sales $ Millions	Government Sales $ Millions
Large (500+ employees)	38	29%	2,167	96
Medium (100-499 employees)	16	37%	294	99
Small (10-99 employees)	33	30%	844	26
Very Small (1-9 employees)	49	39%	224	4
Total	136	33%	3,530	224

Note: Total may not reflect sum of rows due to rounding.
Source: TechLink survey, July-August, 2021. Partner size at time of agreement.

Table 8 compares commercial outcomes among the partner size categories. For each measure (*Agreements in Study, Commercialized Agreements, Total Combined Sales,* and *Government Sales*) it indicates the proportion attributable to partners of a given size. In sum, Table 8 reveals how certain types of partners contribute to the overall impacts.

Table 8: Comparing commercial outcomes among partner sizes

Partner Size	Agreements in Study	Commercialized Agreements	Total Combined Sales	Government Sales
Large (500+ employees)	31%	28%	61%	43%
Medium (100-499 employees)	10%	12%	8%	44%
Small (10-99 employees)	26%	24%	24%	12%
Very Small (1-9 employees)	30%	36%	6%	2%
Total	97%	100%	100%	100%

Note: Totals may not equal 100% due to rounding.
"Agreements in Study" column does not add to 100% because for 3% of agreements, the partner size is unknown.

For example, 31 percent of the T2 agreements in the study (and 28 percent of commercialized agreements) involved large partners, and these large partners were responsible for 61 percent of all sales and 43 percent of sales to the government. In contrast, very small partners were involved in 36 percent of the commercialized agreements, yet only contributed 6 percent of total combined sales and 2 percent of sales to the government. These smallest partners also had the highest commercialization rates (39% - see Table 7), suggesting that

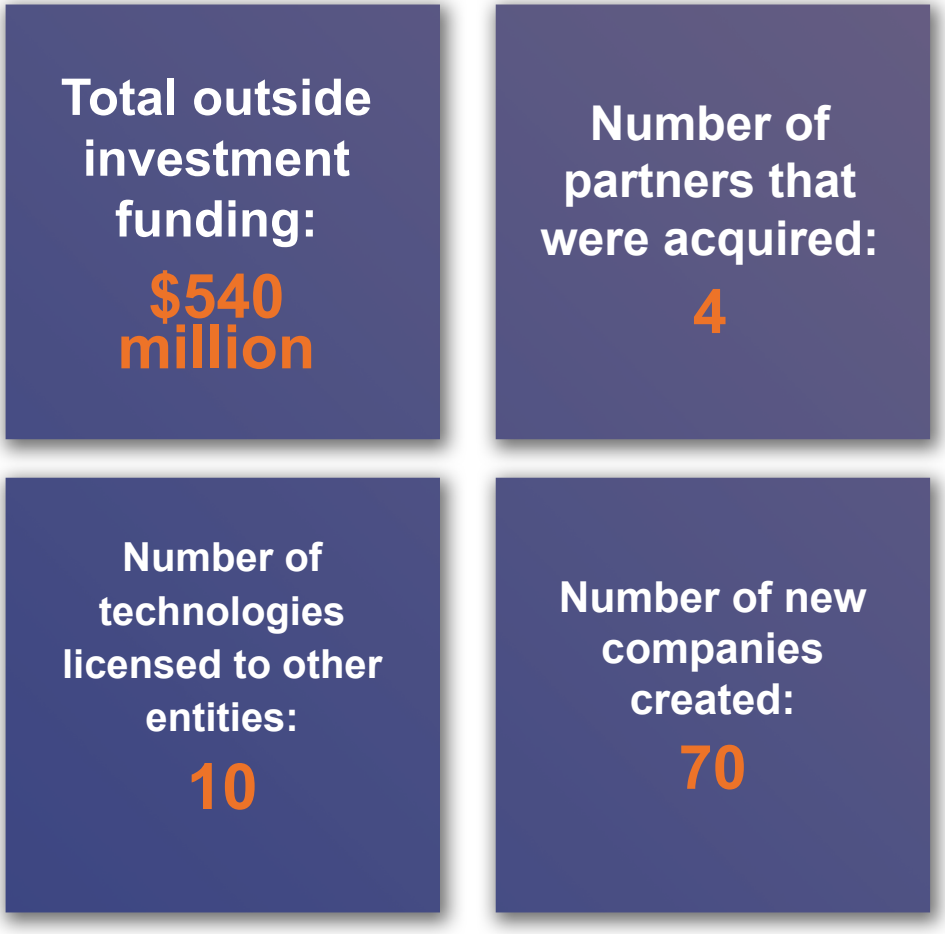
although they were more likely to find commercial success, the volume of sales is significantly smaller than among the larger partners. Furthermore, while medium sized partners only represented 10 percent of agreements in the study, they reported 44 percent of total government sales.

Other Economic Outcomes

In addition to sales, the respondents reported other significant economic outcomes, which are not included in the total economic impacts determined by IMPLAN modeling. The survey showed that 53 agreements led to $540 million in aggregated *outside investment funding* (including venture capital and angel funding). In addition, four companies reported that they were *acquired* primarily because of the technologies associated with the T2 agreements with LLNL. Partners also reported that they had *licensed* the technologies developed through ten agreements to third parties for commercialization.

The survey also found that these LLNL T2 agreements were responsible for the creation of 70 new companies. Respondents reported that 64 of these were startups created to pursue the T2 agreements with LLNL, and an additional six were created to commercialize the technological results of the agreements.

These other economic outcomes and impacts are summarized below:



ECONOMIC IMPACT ANALYSIS

The product and service sales described in the survey provided the foundation for an estimate of the total economic impact of these LLNL T2 partnerships on the U.S. economy. The study assumes that sales define the amount of a product (or service) produced, adjusted to only reflect production within the United States. The costs of producing these products translate into expenditures that support other industries and households, through the purchase of materials and labor. The value of those expenditures, and subsequent purchases along the many supply chains, result in the total economic impact.

Determining the impact to the U.S. economy requires that sales associated with international manufacturing be removed from the survey total. A small portion of the sales enabled by the T2 partnerships in this study were traced to offshore manufacturing. Through conversations with partner representatives and extensive

secondary research, TechLink researchers adjusted the sales figures collected by the survey to reflect only the sales that would have a domestic impact through manufacturing within the United States. The result of these adjustments is an estimated direct impact on the U. S. economy of approximately $3.53 billion.

The adjusted sales data was anonymized (by removing partner names) and delivered to the BRD at the University of Colorado Boulder. BRD staff employed the IMPLAN model to estimate the economic activity enabled by these partnerships. Results below are presented for *output, value added, employment, labor income*, and *tax revenue*. Table 9 displays the aggregated output from the IMPLAN model. The outcomes are discussed below.

Table 9: IMPLAN estimates of economic impacts from the LLNL T2 agreements

Total

Impact	Output	Value Added	Employment	Labor Income
1 - Direct	$3,529,935,515	$1,964,642,848	7,858	$1,086,198,581
2 - Indirect	$2,460,863,424	$1,220,219,095	9,486	$777,673,911
3 - Induced	$2,127,581,868	$1,250,649,011	11,728	$690,921,748
Total	$8,118,380,807	$4,435,510,954	29,072	$2,554,794,240

Total Economic Impact (Output): $8.1 Billion

Output represents the **total economic impact** and is the total value of purchases by intermediate and final consumers—the sum of direct, indirect, and induced sales. Output is one of the values most frequently cited by economic impact studies. According to the national IMPLAN model, the $3.5 billion in output, corresponding to the partner sales of domestically produced products or services, generated an additional $4.6 billion in sales economy-wide. Of this, $2.5 billion was the indirect effect, the result of inter-industry purchases, and $2.1 billion was the induced effect, or increased household spending economy-wide. The total economy-wide output was $8.1 billion. Dividing total economy-wide output by the direct sales of relevant products and services resulting from T2 partnership agreements with LLNL ($3.5 billion) yielded an output multiplier of 2.30. That is, for every dollar spent on U.S.-produced goods and services directly enabled by LLNL's CRADAs and licenses, an *additional* $1.30 in sales was generated economy-wide.

Value Added: $4.4 Billion

Value added is the difference between industry or partner output and the cost of intermediate inputs. Expressed differently, it is the difference between a product's sale price and its production cost (excluding labor). This measure recognizes that companies buy goods and services and create products of greater value than the sum of the component parts. This increase in value resulting from the production process is the "value added." As estimated by IMPLAN, value added is equal to the total sales (plus or minus inventory adjustments) minus the cost of the goods and services purchased to produce the products sold.

According to the IMPLAN model, the $3.5 billion in direct sales added $4.4 billion in value to the

national economy. Of this, $2.0 billion was the direct effect, $1.2 billion was the indirect effect, and $1.3 billion was the induced effect (*see* Table 9).

Employment: 29,072 Jobs (1,321 annual average)

According to the IMPLAN model, the sales resulting from the agreements and their ripple effects economy-wide supported an estimated 29,072 jobs. This includes 7,858 jobs through the direct effect (the sales of new products and services reported by the partner in the study), 9,486 from the indirect effect, and 11,728 from the induced effect (*see* Table 9). In these estimations, each job is defined as one job supported over one year. This means that, on average, an estimated 1,321 jobs were supported annually between 2000 and 2021.

Labor Income: $2.6 Billion

Labor income consists of employee compensation (wage and salary payments, including benefits), and proprietor income (income received by self-employed individuals). The national IMPLAN model estimated that direct labor income from the $3.5 billion in sales was $1.1 billion, or approximately $138,000 per job (*see* Table 9).

The indirect labor income was estimated at $778 million, or approximately $82,000 per job. The induced labor income was estimated to be $691 million—nearly $59,000 per job. Average compensation for indirect and induced jobs was substantially lower than for direct jobs because many are in lower-paid manufacturing and service sectors.

The total economy-wide labor income resulting from the agreements was nearly $2.6 billion. The **average compensation** for the 29,072 jobs supported through these agreements was approximately $88,000. This compares with third quarter 2020 median earnings in the United States of approximately $51,700. The labor income multiplier was 2.35, indicating that for every direct dollar of labor income attributable to LLNL T2 agreements, an *additional* $1.35 of employee compensation and proprietor income was generated nationally.

Tax Revenue: $832 Million

Tax revenue was estimated for the $3.5 billion in sales and its economy-wide indirect and induced effects. This tax revenue included social insurance taxes such as Social Security and Medicare (paid by employers, employees, and the self-employed), personal income taxes, motor vehicle licenses, property taxes, corporate profits taxes and dividends, and indirect business taxes, consisting mainly of excise and property taxes, fees, licenses, and sales taxes. Total taxes collected by federal, state, and local government entities were estimated at $832 million (*see* Table 10). This included $545 million in total federal taxes, and $287 million in total state and local tax revenues. In sum, for every dollar of direct sales generated through the agreements, $0.24 was collected in taxes by federal, state, and local governments.

Table 10: Estimates of the tax collections enabled by LLNL T2 agreements

Impact	State and Local Taxes ($M)	Federal Taxes ($M)	Total Taxes ($M)
1 - Direct	87	243	329
2 - Indirect	79	156	235
3 - Induced	121	146	268
Total	287	545	832

Source: IMPLAN model output based on TechLink Survey.
Numbers may not add due to rounding.

Cost Savings/Cost Avoidance

This study measured costs savings and cost avoidance for the government in two separate categories. The first is an assessment of the financial value of personnel, supplies, equipment, and other resources CRADA partners reported contributing to the project (in-kind contributions). This would be considered cost avoidance for the government, in that the CRADA partner spent their own funds for R&D on the project, rather than the government spending additional funds to achieve the desired results. The second is an estimate provided by the survey respondent of costs the government has saved or avoided to date due to results of these CRADAs or license agreements, such as through use of the resulting product, service, or technology. These cost savings are in addition to any in-kind contributions reported by the respondents, which result in total cost savings/cost avoidance for the government. These would be the sum of in-kind contributions and any cost savings or cost avoidance accrued from the T2 agreement results.

Any payments made to the government by the T2 partner, such as funds-in CRADAs for use of government facilities and personnel ($150 million total, as reported by LLNL), or patent licensing fees and royalties (not reported by LLNL), are not included in this report, but would represent additional significant value to the government resulting from these T2 agreements.

In-Kind Contributions

CRADA partner contributions, through both asset allocation and expenditures, are equivalent to cost savings under the assumption that the CRADA is in pursuit of NNSA's goals, and a private partner is removing that cost burden from the taxpayer. In all, 96 percent of CRADA responses (n=192) provided a dollar amount for the in-kind contributions. Responses are shown in Table 11.

Table 11: Estimated financial value of personnel, supplies, equipment, and other resources contributed to CRADAs

CRADA Partner Contributions (192 CRADAs)	
Total	$371,651,689
Average	$1,935,686
Median	$547,521
Maximum	$32,672,545
Minimum (excluding $0)	$25,000

The 192 CRADA partners reported in-kind contributions of over $371 million to their T2 projects with LLNL. The average amount reported was nearly $2 million, and the median amount was $547,521. The largest amount reported was $32.7 million, and the smallest amount reported was $25,000.

Cost Savings/Avoidance from T2 Agreement Results

All T2 partners were asked if the technology that resulted from the CRADA or license agreement had provided cost savings or cost avoidance to the U.S government to date. Few respondents provided estimates of government savings through cost avoidance, which could be due to the difficult nature of the question. Most T2 partners were unaware of how the results of these agreements progressed within NNSA or other government entities. However, Table 12 summarizes the answers provided by a total of just 18 respondents.

Table 12: Estimated cost savings or costs avoided to the U.S. government from LLNL T2 agreements

Estimated Cost Savings or Costs Avoided (18 responses)	
Total	$324,000,000
Average Given	$18,000,000
Median Given	$2,000,000
Maximum Given	$100,000,000
Minimum Given	$100,000

These respondents were as conclusive as possible with the amounts reported, while recognizing the amounts reported were based on their extensive understanding of the technology, their private finances,and

a limited understanding of public sector finances. Combined, these 18 responses total $324 million. Given that very few respondents had sufficient insight into government use of their technologies to be able to answer this question, these results are underreported and extremely conservative.

Qualitative Outcomes

The remainder of the survey collected qualitative data. The reporting on these answers varies from the numerical form used in the quantitative questions described above.

Security, Non-Proliferation, COTS

First, three survey questions sought outcomes related to security, non-proliferation, and commercial off-the-shelf products available to the military. These questions are listed below, with the qualitative answers provided subsequently.

Did this CRADA or license result in any products or services that are being used, or have been used by DOE/NNSA, the U.S. military, or any other national security agency?

Approximately 9 percent of responses to this question (n=39) were "yes", including 7 percent of CRADAs (n=15) and 11 percent of licenses (n=24).

The actual answers provided by respondents are listed below:

- Products enabled governments, businesses, and individuals to deploy wireless security systems to protect and monitor things, places, and people.
- We supplied the military and departments in the DoD who worked with satellite imaging over the desert and in the Middle East.
- This resulted in the development of devices and systems for the rapid detection and identification of biological agents.
- The agreement was employed by the United Nations inspectors in Iraq during their 2003 searches for biological weapons.
- The primary application areas in homeland security include the unattended monitoring of ambient air for aerosolized biological agents; the rapid assessment and diagnosis of potentially infected humans or animals in the field; and the on-site assessment of potentially contaminated locations and the effectiveness of decontamination procedures.
- The U.S. military uses this technology as suppressors for weapons.
- The product, purchased by SOCOM and the Navy, was a portable solution for decontaminating enclosures contaminated with biological and chemical agents.
- The Fission Meter has been successfully deployed to identify SNM via Neutron Multiplicity Counting.

- The technology assists with surveillance of incoming shipping, detectors mounted on our interrogation ships, and probes having position sensitive scintillator arrays for cargo searching.
- The technology was used for surveillance.
- The technology was used by researchers at DOE/NNSA facilities to develop next-generation methods for identification, imaging, characterization, and mass determination of fissile materials such as uranium oxide and plutonium.
- The patented design can be used with other aerosol analysis instruments to perform high-flow, atmosphere-pressure sampling.
- The device is considered important for laser based national-security, especially laser technology to shoot down drones.
- This technology involved uranium enrichment with fiber laser technology, which involved excitation of select atoms that can't be identified in this report.
- A framework for chemical treatment that the whole United States can use.
- This technology is useful for the detection of bacteria, viruses, and other bioaerosols.

Did your CRADA or license contribute to non-proliferation, including reducing the threat of nuclear or radiological terrorism, nuclear material management, security, removal, or disposal?

Approximately 4 percent of the responses (n=18) were "yes", including 5 percent of the CRADAs (n=10), and 4 percent of the licenses (n=8).

Few examples were given, but they included the following:

- This technology was supposed to be used to condense larger amounts of C-14 waste to become more manageable. The technology was partially developed and there was a benefit in developing the knowledge base, but no specific applications resulted from this CRADA.
- It was our partner's understanding that one of the goals of the CRADA was to keep foreign scientists and engineers from a certain country involved in a commercial high explosives project that kept them from leaving their institute and going to another country that might promote nuclear terrorism.
- The PSD scintillators enhance the specific sensitivity for low neutron fluxes in a relatively high gamma background.
- The project benefits the Department of Energy's non-proliferation objectives by creating non-weapons work for Russian scientists at the nuclear weapons institute in Snezhinsk. DOE benefits because it's enhancing the goals of an important non-proliferation program for NNSA.
- Additional benefits for the DOE because of our performing software evaluations, as well as helping to develop techniques for data analysis, time series analysis, and visualization

across the internet. These core capabilities can also be used in other non-proliferation programs at LLNL.

- This has applications in material accounting for nuclear safeguards. Stilbene has shown promise for use in applications, which employ active interrogation to detect fissile material, such as vehicle and cargo scanning and assay of uranium in nuclear fuel assemblies.
- This technology was developed for lasers to clean up radiological surfaces.

Did this CRADA or license technology or aspects of the technology result in any commercial off-the-shelf (COTS) products being purchased or used by DOE/NNSA, the U.S. military, or any other national security agency?

Only 9 percent of responses (n=37) to this question were "yes", including 6 percent of CRADAs (n=12) and 11 percent of licenses (n=25).

Answers included the following statements:

- Aspects of the technology involved COTS hardware, software, commercial lasers, and cooling.
- Chassis COTS.
- We expect DOE, NNSA, or other government entities to purchase or use this technology in the future.
- This resulted in a final reagent kit product that incorporated COTS.
- This technology was used for X-ray spectroscopy.
- This T2 agreement resulted in Gatan imaging filters for microscopy.
- Government satellite reconnaissance teams purchased the technology.
- The proprietary software uses commercial COTS hardware.
- The Detective family of products have been deployed by SOCOM, FBI, National Guard Bureau-Civil Support Teams, Defense Intelligence Agency, Pentagon Force Protection Agency, 20 CBRNE Nuclear Disablement Teams, DHS CWMD (formerly DNDO) and many other DoD, Intelligence agencies, and DHS organizations. These products have been deployed at all US DOE National Labs, DOE Radiological Assistance Programs, DOE Second Line of Defense now NSDD (Nuclear Smuggling Detection and Deterrence), and many other nuclear weapons related Programs. These products were used to interdict and identify specific threats.
- The objective of this project was to provide DoD and the intelligence agencies with highly portable, advanced, bio-detection instruments and to further the DOE objective of developing advanced instrumentation for the detection of biological terrorism agents into the hands of first responders.
- Police and fire departments would be the major users of these detection systems, as the first services on the scene when responding to chemical accidents or terrorist activities.

- What we are creating is a commercial off-the-shelf product. We imagine this research and market will be more academic focused.
- We are still in the concept stage for researchers and plan to market the technology in late 2021.

Other Uses and Benefits

Three open-ended qualitative questions concluded the survey. The researchers asked these questions to allow survey participants to respond subjectively. As a result, the answers varied from one word to multiple paragraphs in length.

The answers to these questions were combined into easily reportable data using NVivo, a software product that aids research scientists in organizing and analyzing unstructured qualitative information. This process involved reading each response, identifying key concepts, and conducting open coding to identify themes drawn from the answers that encompass similar ideas. Each answer was assigned at least one theme, depending on the nature of the response. Because the answers were open-ended, each response may have included ideas that fall within more than one theme. As the analysis progressed, new themes were identified, and similar themes were combined. The analysis ended with between 10 and 21 identified open codes or themes per question. The number of survey responses falling within each theme was calculated, as was the percent of overall answers that fell within each theme.

The themes were defined with each being unique and exclusive of the rest. Clearly, a respondent giving an answer falling within a specific theme does not mean that the partner does not recognize any of the other benefits. These answers were the first, unguided responses to the question. For ease of presentation, each theme was assigned a generalized title. Below, for each question, the titles are given, and the concepts covered by the open coding are described. The count and frequency of each theme is shown and displayed in tables and charts.

Have there been any other uses or benefits from this technology focused on non-stockpile-related national defense outcomes (such as medical benefits, cyber, transportation, etc.)?

The survey collected 75 responses to this question. A thorough analysis of these answers produced a list of themes in which the agreements benefitted national defense outcomes. Unlike the two questions that follow, these themes are not described further, because their titles are sufficient descriptions. Below, Table 13 lists the 20 areas (including several types of negative answer, as well as select themes only tangentially related to national defense), along with the count and frequency of each theme. For a visual representation of these findings, please reference Figure 1.

Table 13: Other non-stockpile-related national defense uses or benefits

Open Coded Themes	Count	Frequency
Medical	23	31%
NA	13	17%
Not Yet	6	8%
Scientific Research	5	7%
Transportation	5	7%
Would have but Terminal	4	5%
Cyber Security	3	4%
No	3	4%
Counter Terrorism	3	4%
Electrical Grid	2	4%
Commercial Use	2	3%
Energy	2	3%
Government Use	2	3%
Other	2	3%
Landmine Detection	1	1%
National Intelligence	1	1%
Navigation	1	1%
Nuclear Waste Cleanup	1	1%
Quality Inspection	1	1%
Training	1	1%

Note: Frequencies will not add to 100% because each answer may include multiple themes.

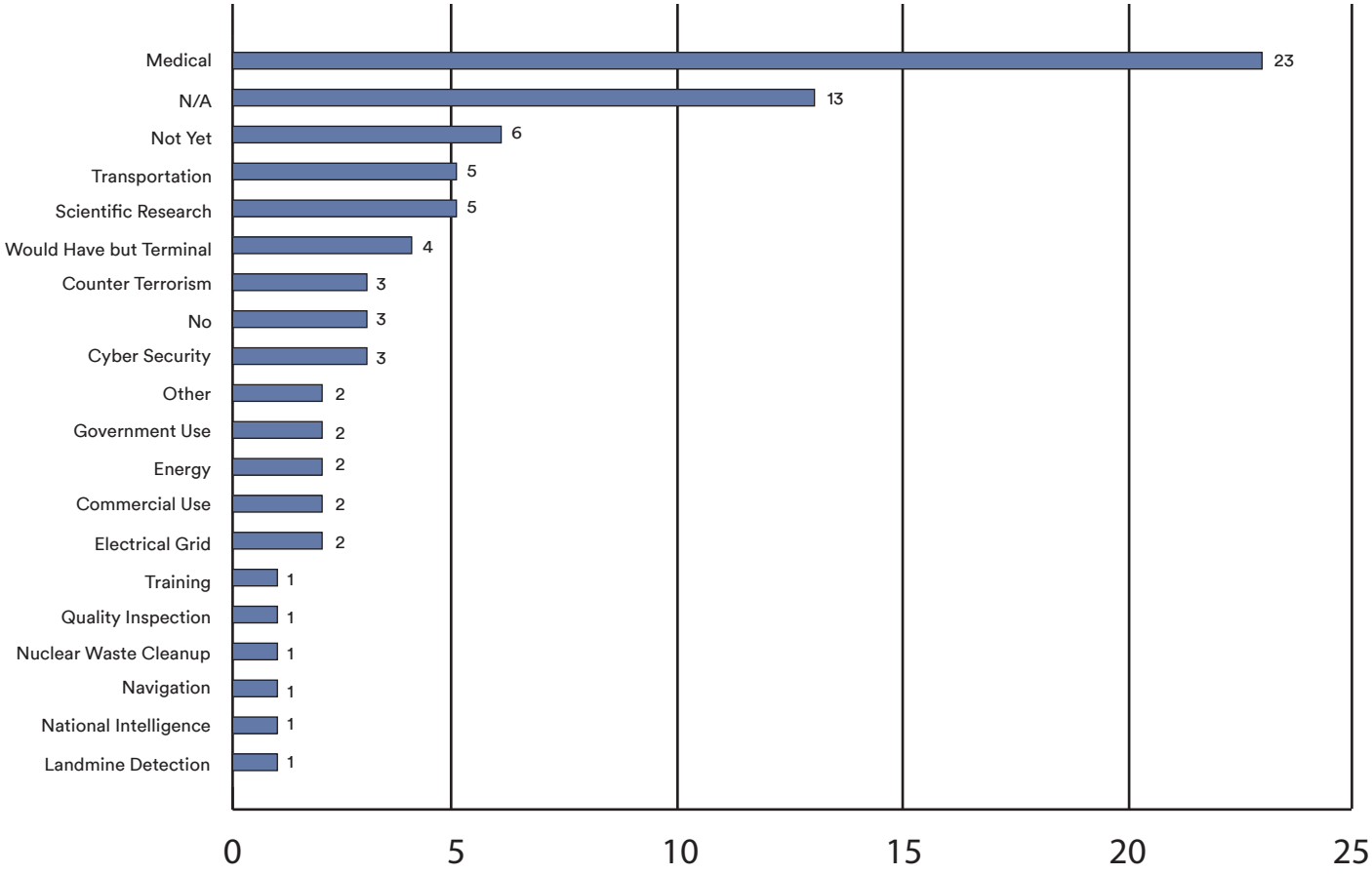


Figure 1: Other non-stockpile-related national defense uses or benefits

Have there been any benefits from this CRADA or license besides sales of new technology or other economic results?

The survey collected 159 responses to this question. After a thorough analysis, the answers were open coded into 13 unique themes. Below, the titles of each theme are listed, along with a general description of the responses included in each theme.

- **Knowledge** – New insight, knowledge, information, or research outcomes regarding technology, products, or processes. This answer was included in 32 percent of the responses (n=51).
- **Collaboration** – Collaborations, partnerships, exchanges of expertise, sharing knowledge, or partnership with NNSA, DOE, or the federal government. This answer was included in 17 percent of the responses (n=27).
- **Product** – New or improved products, services, or a marketable improvement on existing goods or services. This answer was included in 12 percent of the responses (n=19).
- **Access** – Access to the expertise, personnel, capabilities, knowledge, or advantages held by DOE or NNSA. This answer was included in 12 percent of the responses (n=19).

- **Funding** – Outside investment or funding resulting from the agreement or its outcomes. This answer was included in 9 percent of the responses (n=14).
- **Reputation** – Elevated credibility, partner profile, or reputation; media recognition; or industry award. This answer was included in 9 percent of the responses (n=14).
- **Future** – Future research projects or new service contracts between the public and private partners. This answer was included in 7 percent of the responses (n=11).
- **Relationships** – A specific research or business relationship with the lab or a specific individual. This answer was included in 6 percent of the responses (n=10).
- **NA** – Nothing happened, respondent didn't know, results classified, or answer was not applicable. This answer was included in 4 percent of the responses(n=7).
- **Savings** – Money saved, or the project was completed quickly. This answer was included in 4 percent of the responses (n=6).
- **Publications** – Articles published or patents filed. This answer was included in 3 percent of the responses (n=5).
- **Validation** – Prove, demonstrate, or validate the partner's abilities, products, or ideas. This answer was included in 3 percent of the responses (n=4).
- **Disappointment** – The experience or project was a disappointment to the partner. This answer was included in 2 percent of the responses (n=3).

The count and frequency of these themes among the 159 responses is shown in Table 14. Additionally, Figure 2 displays the data graphically.

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CRADAs and license agreements from Lawrence Livermore National Laboratory resonate across a variety of industries.

Table 14: Non-sales benefits, categories, counts, and frequencies

Open Coded Themes	Count	Frequency
Knowledge	51	32%
Collaboration	27	17%
Product	19	12%
Access	19	12%
Funding	14	9%
Reputation	14	9%
Future	11	7%
Relationships	10	6%
NA	7	4%
Savings	6	4%
Publications	5	3%
Validation	4	3%
Disappointment	3	2%

Note: Frequencies will not add to 100% because each answer may include multiple themes.

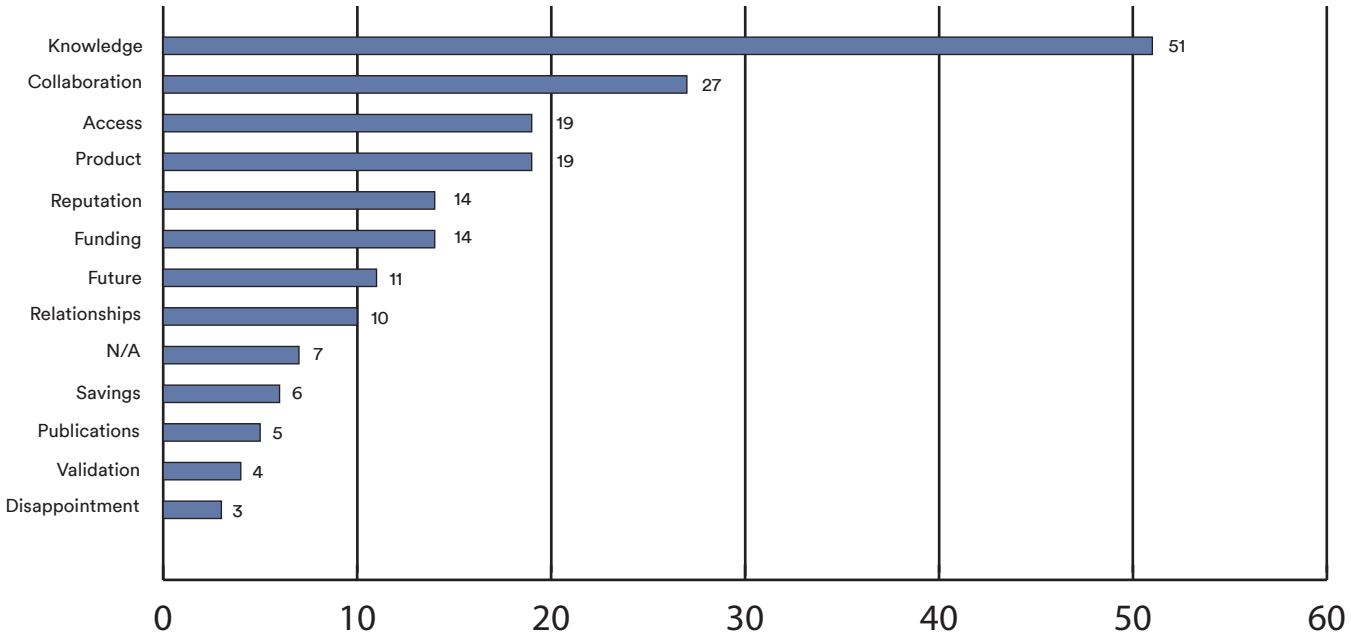

Figure 2: Non-sales benefits, categories, and response counts

Are you aware of any specific benefits to LLNL/NNSA/DOE from this CRADA or license?

The survey collected 134 responses to this question. After a thorough analysis, the answers were open coded into 10 unique themes. Below, the titles of each theme are listed, along with a general description of the responses.

- **Income** – Compensation, royalties, income, or funding received by the lab. This answer was included in 29 percent of responses (n=39).
- **Knowledge** – New knowledge, insight, or understanding related to the technology. This answer was included in 23 percent of responses (n=31).
- **Use** – A practical application of the technology. This answer was included in 19 percent of responses (n=26)
- **Access to Data** – Access to new data, feedback, and test results. This answer was included in 10 percent of responses (n=13).
- **Reputation** – Improved reputation, better profile, or recognition for the lab. This answer was included in 7 percent of responses (n=9).
- **Partner Resources** – Access to the partner's knowledge, expertise, facilities, products, or people. This answer was included in 7 percent of responses (n=9).
- **Collaboration** – Collaboration, engagement, or information exchange between the lab and the partner. This answer was included in 5 percent of responses (n=7).
- **N/A** – Any non-applicable answer, including "classified". This answer was included in 5 percent of responses (n=7).
- **Invention** – An invention, patent, or publication. This answer was included in 4 percent of responses (n=6).
- **Future** – Future work with the CRADA or license partner. This answer was included in 3 percent of responses (n=4).

The count and frequency of these themes among the 134 responses is shown in Table 15. Figure 3 displays the data graphically.

Table 15: Specific benefits to LLNL, NNSA, or DOE

Category	Count	Frequency
Income	39	29%
Knowledge	31	23%
Use	26	19%
Access to Data	13	10%
Reputation	9	7%
Partner Resources	9	7%
Collaboration	7	5%
N/A	7	5%
Invention	6	4%
Future	4	3%

Note: Frequencies will not add to 100% because each answer may include multiple themes.

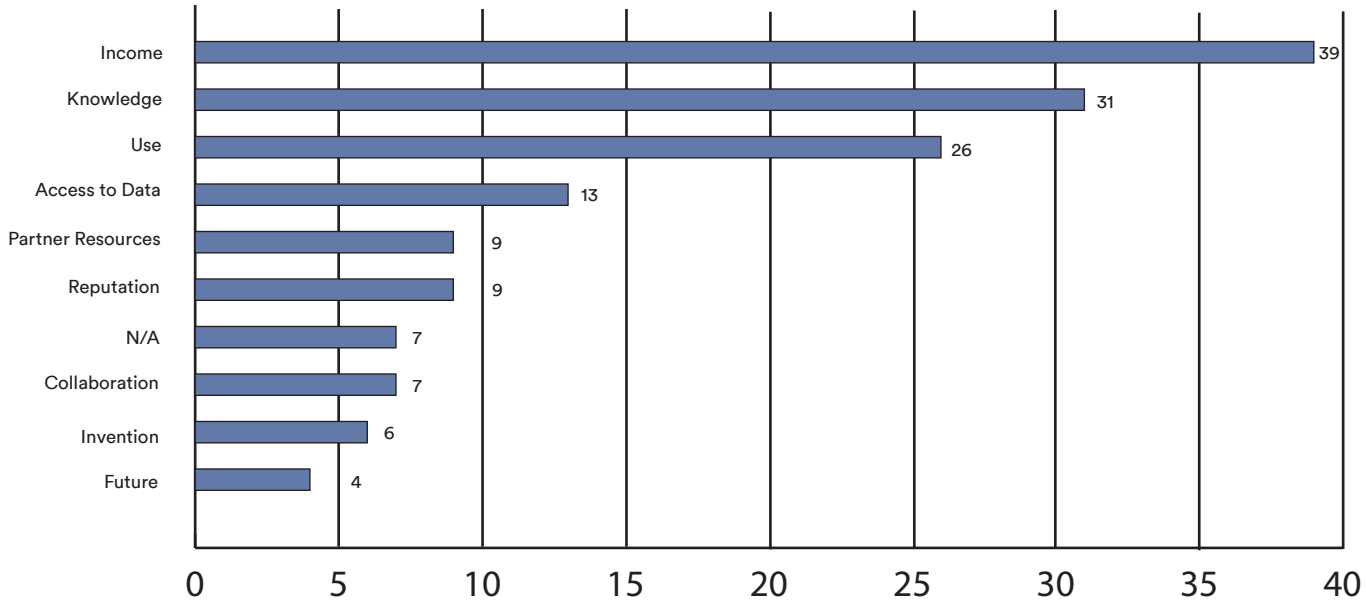

Figure 3: Specific benefits to LLNL, NNSA, or DOE

SUCCESS STORIES

After the survey, six T2 agreements with uniquely successful outcomes were highlighted in a series of success stories developed and published by TechLink. These projects cover a variety of scientific research and serve as case studies of how T2 enhances technological development and supports LLNL and NNSA in achieving their missions. The success stories also highlight the impacts these T2 agreements have had on the nation's international allies, nuclear weapons and nuclear energy security, nuclear nonproliferation, and the battle against SARS-CoV-2. The six technologies featured in the success stories include the following:

- Laser peening technology with major impacts on the F-22 and F-35 B and C model fighter jets.
- Satellite imaging technology used by DoD in the Middle East for intelligence and aerial desert visuals.
- Software modeling for simulating structural integrity testing at nuclear power plants and nuclear weapons facilities.
- Stilbene crystals to detect and monitor nuclear radiation, treaty compliance, and nonproliferation applications.
- Molecular testing technology development that has been used in the battle against SARS-CoV-2.
- A CRADA initiated at Sandia that ultimately was a collaboration between LLNL, Sandia, and Lawrence Berkeley resulting in the development and use of extreme ultraviolet lithography (EUV), which allows the semiconductor industry to reduce the cost of chips and speed up the time it takes to develop new chips.

SUMMARY

In summary, this study describes the outcomes of license agreements and CRADAs between LLNL and outside partners. The primary goal of the study was to estimate the economic contributions of these T2 agreements to the national economy. The secondary goal was to identify the extent to which these T2 agreements contribute to NNSA's core missions of maintaining the nuclear stockpile, monitoring, and promoting nonproliferation, as well as responding to nuclear and radiological emergencies. The study's findings are clear and succinct: through T2, NNSA and LLNL are important contributors to the United States economy, and these agreements have resulted in scientific and nuclear weapons advancements for the safety and security of the United States.

The study team conducted a rigorous survey of partners to determine the total sales of new products and services resulting from these CRADAs and licenses. Respondents to the survey collectively attributed $3.5 billion in sales to these agreements. The team estimated the economic ripple effects of these sales using the IMPLAN model. These estimates define the indirect and induced effects of these sales on the national

economy in terms of total economic output, value added, employment, labor income, and tax revenue.

The total economy-wide output over 22 years (2000-2021) was estimated at $8.1 billion. Value added, representing new wealth creation in the economy, was estimated at $4.4 billion. Employment impact estimates included 29,072 jobs with an average compensation of $88,000, and total labor income of $2.6 billion. The $3.5 billion in sales and its economy-wide effects generated approximately $832 million in total tax revenue, including $545 million in federal tax revenue and $287 million in state and local tax revenues.

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CRADAs and license agreements from Lawrence Livermore National Laboratory have contributed a total of $8.1 billion, nationwide.

APPENDIX 1

National Economic Impact Estimates by Year-Range Cohorts

This study is the second in a series of economic impact studies commissioned by NNSA. The preceding analysis, which focused on Sandia National Laboratories, only examined T2 agreements signed between 2000 and 2010. The current analysis for LLNL examined T2 agreements signed between 2000 and 2020. To facilitate comparison on a year-to-year basis, this appendix details the results by two year-range cohorts—agreements initiated between 2000 and 2010, and between 2011 and 2020.

Table 16 lists the survey-reported sales figures associated with agreements initiated between 2000 and 2010. Table 17 lists the estimated economic impacts of those agreements. Table 18 lists the survey-reported figures associated with agreements initiated between 2011 and 2020, while Table 19 lists the estimated total economic impacts of those agreements.

Table 16: Sales of products and services resulting from T2 agreements initiated between 2000 and 2010

Sales Category	Aggregate Amount	Percent of Overall Sales
Commercial Sales	1,941,248,656	71%
Follow-on R&D	572,611,893	21%
Government Sales	190,604,848	7%
Spinoff Sales	33,500,000	1%
Licensee/Royalties	500,000	0%
Total Combined Sales	2,738,465,397	100%

Note: Totals may not equal 100% due to rounding.
**Sales to the DOE are included in Sales to the Government*

Table 17: Estimates of the total economic impacts of T2 agreements initiated between 2000 and 2010

Impact	Output	Value Added	Employment	Labor Income
1 - Direct	$2,738,465,375	$1,541,706,941	5,415	$782,283,205
2 - Indirect	$1,898,710,736	$911,843,241	7,182	$576,237,976
3 - Induced	$1,576,210,311	$922,229,579	8,755	$510,722,573
Total	$6,213,386,422	$3,375,779,761	21,353	$1,869,243,755

Note: Totals may not equal 100% due to rounding.

Table 18: Sales of products and services resulting from T2 agreements initiated between 2011 and 2020

Sales Category	Aggregate Amount	Percent of Overall Sales
Commercial Sales	577,516,776	73%
Follow-on R&D	178,390,142	23%
Government Sales	33,646,268	4%
Spinoff Sales	-	0%
Licensee/Royalties	1,916,973	0%
Total Combined Sales	791,470,159	100%

Note: Totals may not equal 100% due to rounding.
**Sales to the DOE are included in Sales to the Government*

Table 19: Estimates of the total economic impacts of T2 agreements initiated between 2011 and 2020

Impact	Output	Value Added	Employment	Labor Income
1 - Direct	$791,470,140	$422,935,908	2,442	$303,915,376
2 - Indirect	$562,152,688	$308,375,854	2,304	$201,435,935
3 - Induced	$551,371,557	$328,419,432	2,973	$180,199,175
Total	$1,904,994,385	$1,059,731,194	7,719	$685,550,486

APPENDIX 2

Economic Impact Estimates by State

Tables 20 and 21 show economic impact estimates of the LLNL T2 agreements for each state and the District of Columbia. Some states had no direct impacts but were benefitted economically by demand from other states.

Table 20: State-specific economic impact estimates

State Impacts

	Output	Value Added	Employment	Labor Income
Alabama	$29,941,893	$14,195,182	120	$8,497,064
Alaska	$7,301,048	$3,530,942	30	$2,103,461
Arizona	$40,437,471	$19,319,609	162	$11,479,687
Arkansas	$23,004,176	$10,794,824	91	$6,434,365
California	$3,408,639,331	$2,204,390,300	12,401	$1,249,936,034
Colorado	$29,403,688	$13,835,648	118	$8,243,110
Connecticut	$16,878,934	$8,204,427	71	$4,996,003
Delaware	$15,517,025	$8,222,446	63	$5,537,386
District of Columbia	$5,358,521	$2,695,538	24	$1,615,064
Florida	$124,050,024	$57,615,427	516	$35,848,504
Georgia	$42,453,048	$20,135,298	171	$12,049,950
Hawaii	$15,188,524	$7,345,824	62	$4,362,261
Idaho	$12,614,405	$6,128,497	53	$3,665,234
Illinois	$1,650,583,429	$699,157,472	3,933	$364,326,623
Indiana	$148,596,553	$66,250,813	571	$39,489,319
Iowa	$61,229,410	$27,575,225	237	$16,421,955
Kansas	$21,680,110	$10,167,753	86	$6,048,021
Kentucky	$38,630,926	$18,098,361	154	$10,828,646
Louisiana	$28,880,191	$13,600,358	115	$8,097,345
Maine	$6,090,144	$2,913,915	25	$1,736,228
Maryland	$82,739,790	$45,691,604	386	$30,915,307
Massachusetts	$190,133,297	$108,506,281	815	$77,123,810
Michigan	$152,659,047	$72,003,894	652	$45,337,466

continued...

Table 20: State-specific economic impact estimates (continued)

State Impacts

	Output	Value Added	Employment	Labor Income
Minnesota	$41,304,071	$19,380,982	167	$11,670,417
Mississippi	$21,573,137	$10,191,916	86	$6,089,187
Missouri	$97,595,481	$44,888,076	364	$25,813,451
Montana	$6,810,631	$3,217,998	27	$1,918,555
Nebraska	$15,709,012	$7,284,359	62	$4,335,344
Nevada	$27,888,122	$13,246,638	111	$7,865,142
New Hampshire	$7,492,487	$3,601,647	32	$2,145,060
New Jersey	$38,182,753	$18,870,046	158	$11,692,286
New Mexico	$19,676,447	$9,379,785	88	$5,995,118
New York	$191,463,233	$95,834,501	697	$62,055,230
North Carolina	$44,071,912	$21,539,048	185	$12,914,993
North Dakota	$8,915,681	$4,185,261	36	$2,494,162
Ohio	$69,432,021	$32,641,912	287	$19,742,306
Oklahoma	$27,268,728	$12,765,992	108	$7,593,211
Oregon	$500,853,007	$287,623,108	2,399	$171,962,453
Pennsylvania	$75,825,079	$35,635,965	316	$22,634,172
Rhode Island	$5,913,853	$2,945,950	26	$1,800,153
South Carolina	$34,015,696	$16,587,154	159	$10,296,760
South Dakota	$8,188,069	$3,821,166	33	$2,275,184
Tennessee	$265,745,222	$134,634,722	1,020	$78,695,757
Texas	$177,795,221	$85,048,646	720	$50,749,354
Utah	$19,504,663	$9,218,376	78	$5,485,376
Vermont	$3,574,813	$1,696,276	15	$1,011,814
Virginia	$37,249,133	$18,234,533	158	$11,162,332
Washington	$69,719,558	$34,908,652	303	$20,995,055
West Virginia	$7,883,144	$3,772,380	32	$2,256,556
Wisconsin	$138,082,871	$61,812,366	530	$36,754,677
Wyoming	$4,635,777	$2,163,860	19	$1,297,291
Total	$8,118,380,807	$4,435,510,954	29,072	$2,554,794,240

APPENDIX 3

Survey Instrument

Demographic and Partner Information

Was your partner a start-up partner specifically created for this CRADA or license agreement?

How many employees did your company have at the time that this CRADA or license agreement was established?

- Unknown
- Large (500+ employees)
- Medium (100-499 employees)
- Small (10-99 employees)
- Very Small (1-9 employees)

How many employees does your company currently employ?

- Unknown
- Large (500+ employees)
- Medium (100-499 employees)
- Small (10-99 employees)
- Very Small (1-9 employees)

Product, Sales, and Funding

Did your company develop any new or improved products or services based on this CRADA or license agreement?

- Yes
- No
- Tech still in development
- Tech was abandoned
- Unknown

To date, what are your total cumulative commercial sales of products or services resulting from this CRADA or license agreement?

To date, what are your total cumulative sales to the U.S. Dept. of Energy/ NNSA (either directly or through a contractor) due to this CRADA or license agreement?

What are your total cumulative sales to the U.S. government, directly related to this CRADA or license agreement?

To date, what is the total cumulative amount of follow-on R&D funding (government or private sector) you've received that is directly related to this CRADA or license agreement?

Weapons, Stockpile, and Nonproliferation

Did this CRADA or PLA result in any products or services that are being used, or have been used, by DOE/NNSA, the U.S. military, or any other national security agency? Examples might include nuclear weapons testing, surveillance, maintenance, security, transportation, or other purposes related to nuclear weapons

- If yes, how has the CRADA or license agreement impacted the technological areas you just identified? Please provide specific examples (such as surveillance, maintenance, etc.).

Did your CRADA or PLA contribute to non-proliferation including reducing the threat of nuclear or radiological terrorism, nuclear material management, security, removal, or disposal?

- If yes, how has the CRADA or license impacted the technological areas you just identified? Please provide specific examples (such as nuclear or radiological terrorism, nuclear material management, security, removal, disposal, nuclear weapons testing, surveillance, maintenance, security, transportation, or other purposes pertaining to nuclear weapons)

Did this CRADA or PLA technology or aspects of the technology result in any commercial off the shelf (COTS) products being purchased or used by DOE/NNSA, the U.S. military, or any other national security agency? (Capture aspects or all of the technology, also capture which agency) What are your estimated cost savings to date for the life cycle of this technology?

- If yes, can you please provide examples/off the shelf notes?

Cost Savings

Can you please estimate the financial value of personnel, supplies, equipment, and other resources your company contributed to this individual CRADA?

In your opinion, throughout the life cycle of this technology to date, has the partnership provided additional cost savings or costs avoided to the U.S. government? (Other investments in the technology, product development, cheaper alternative products or services for the government, etc.).

- If yes, please estimate an amount.

Licensing, Spinoff, Investment, and Acquisition

Did your company license or sub-license any of the technology developed from this CRADA or license?

- To date, what are the total royalties received?
- To date, what are the total cumulative sales by the licensee related to this technology?

Did your company create a spin-off company to commercialize any technology developed under this

CRADA or PLA?

- To date, what are the total cumulative sales by the spin-off company?

Did your company receive any outside investment funding (angel, venture capital, or state funding) due to this CRADA or PLA?

- If yes, what was the investment amount?

Was the company acquired due to this CRADA or PLA?

- If yes, what was the acquisition amount?

Qualitative Information

Have there been any other uses or benefits from this technology focused on non-stockpile related national defense outcomes (such as medical benefits, cyber, transportation, etc.)?

Have there been any benefits to your company from this CRADA or PLA besides sales of new technology or other economic results?

Are you aware of any specific benefits to LLNL/NNSA/DOE from this CRADA or PLA?

Is your company interested in a possible success story focusing on this CRADA or PLA?

Technology Category

As a result of this CRADA or PLA, how would you categorize the technology from an IP perspective?

- Instruments + Sensors
- Unknown
- Biological or Environmental
- Advanced Materials
- Advanced Manufacturing
- Lasers and Optics
- Other Energy Related Technologies
- National Security (including weapons)
- Electronics
- Information Technology
- Other Non-energy Related Technologies
- Cybersecurity
- Photonics
- Communications
- Nuclear Energy

APPENDIX 4

NAICS Codes Assigned for Impacts in the Study

Code	Description
325120	Industrial gas manufacturing
325411	Medicinal and botanical manufacturing
325414	Biological product (except diagnostic) manufacturing
325920	Explosives Manufacturing
327110	Pottery, ceramics, and plumbing fixture manufacturing
332811	Metal heat treating
332994	Small arms, ordnance, and accessories manufacturing
333242	Semiconductor machinery manufacturing
333249	All other industrial machinery manufacturing
333314	Optical instrument and lens manufacturing
333318	Other commercial service industry machinery manufacturing
333413	Air purification and ventilation equipment manufacturing
333618	Other engine equipment manufacturing
333992	Welding and soldering equipment manufacturing
334220	Broadcast and wireless communications equipment manufacturing
334413	Semiconductor and related device manufacturing
334416	Capacitor, resistor, coil, transformer, and other inductor manufacturing
334418	Printed circuit assembly (electronic assembly) manufacturing
334510	Electromedical and electrotherapeutic apparatus manufacturing
334511	Search, detection, and navigation instruments manufacturing
334513	Industrial process variable instruments manufacturing
334515	Electricity and signal testing instruments manufacturing
334516	Analytical laboratory instrument manufacturing
334519	Watch, clock, and other measuring and controlling device manufacturing
335911	Storage battery manufacturing
335999	All other miscellaneous electrical equipment and component manufacturing
336111	Automobile manufacturing
336413	Other aircraft parts and auxiliary equipment manufacturing
339112	Surgical and medical instrument manufacturing
339113	Surgical appliance and supplies manufacturing
511210	Software publishers
541330	Architectural, engineering, and related services
541720	Scientific research and development services
621511	Medical and diagnostic laboratories

NATIONAL ECONOMIC IMPACTS

from the National Nuclear Security Administration
and Lawrence Livermore National Laboratory

CRADA and Patent License Agreements

MAJOR FINDINGS INCLUDE:

Total sales resulting from LLNL's license agreements and CRADAs **$3.5 billion**	Sales to the government: **$224 million**	Total economic impact nationwide: **$8.1 billion**
New tax revenue (federal, state, and local): **$832 million**	Jobs per year, with average compensation of approximately $88,000: **1,321**	Estimated cost savings for the U.S. government: **Over $696 million**