SCIENTIFIC BREAKTHROUGHS

Year: yyyy

Laboratories Involved: xxxx

<Scientific breakthrough description here>

Link: Link here

DISCOVERED 22 NEW ELEMENTS

Years: 1937, 1944, 1940, 1940, 1941, 1944, 1944, 1949, 1950, 1952, 1952, 1955, 1957, 1961, 1964, 1967, 1974, 1998, 2003, 2000, 2010, 2006[1]

Laboratories Involved: Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge[2]

Federal support of heavy element chemistry began with the Manhattan Project as the elements beyond uranium were unknown before then. Since then, this activity has been continuously supported in some manifestation throughout the Atomic Energy Commission years up to the present-day Department of Energy due to its importance to energy and defense. The long-term support of this activity to researchers investigating the fundamental properties of the actinides has been crucial to maintain U.S.-based leadership in this critical field.[3]

To date the National Labs have discovered 22 new elements: technetium, promethium, astatine, neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, lawrencium, rutherfordium, dubnium, seaborgium, flerovium, moscovium, livermorium, tennessine and oganesson.[4]

Link: https://education.jlab.org/itselemental/

[1] From *It's Elemental: The Periodic Table of Elements*, Thomas Jefferson National Accelerator Facility, https://education.jlab.org/itselemental/

[2] From *It's Elemental: The Periodic Table of Elements*, Thomas Jefferson National Accelerator Facility, https://education.jlab.org/itselemental/

[3] From *Office of Science, Basic Energy Sciences: Core Research Activities*, 2014, Department of Energy, https://www.osti.gov/servlets/purl/1297037/

[4] From *75 Breakthroughs by America's National Laboratories*, Department of Energy, 2018, https://www.energy.gov/articles/75-breakthroughs-americas-national-laboratories-0/

IDENTIFIED GOOD AND BAD CHOLESTEROL

Year: 1950 (First Paper in Science)[5]

Laboratories Involved: Lawrence Berkeley[6]

Lipoproteins are fat molecules that carry cholesterol in the blood. Cholesterol is divided into high-density lipoprotein, the so-called good cholesterol, and low-density lipoprotein, the bad cholesterol. That's common knowledge today, but it was a groundbreaking and controversial notion in the 1950s, when Berkeley Lab's John Gofman used an analytic ultracentrifuge at Berkeley Lab to separate and measure the different lipoproteins. He was also the first to propose that high-density and low-density lipoprotein particles play a role in heart disease.

His research was met with skepticism, however, so Gofman began a prospective study of lipoproteins in a group of 1,905 employees at the Lawrence Radiation Laboratory at Livermore between 1954 and 1956. In 1966, he reported that men who developed heart disease had lower levels of the HDL2 (the larger high-density lipoprotein particles) and HDL3 (the smaller high-density lipoprotein particles). It would take several more years for Gofman's work to gain currency in the scientific community.[7]

Link: https://newscenter.lbl.gov/2011/01/04/cholesterol-heart-disease/

[5] From *Communicating Science: Building on a Legacy of Achievements*, Human Genome Project, Lawrence Berkeley National Laboratory, https://doe-humangenomeproject.ornl.gov/communicating-science-building-on-a-legacy-of-achievements/
[6] From *From Dusty Punch Cards, New Insights Into Link Between Cholesterol and Heart Disease*, Lawrence Berkeley National Laboratory, 2011, https://newscenter.lbl.gov/2011/01/04/cholesterol-heart-disease/
[7] From *From Dusty Punch Cards, New Insights Into Link Between Cholesterol and Heart Disease*, Lawrence Berkeley National Laboratory, 2011, https://newscenter.lbl.gov/2011/01/04/cholesterol-heart-disease/

PIONEERED FUSION POWER DEVICES

Year: 1953[8]

Laboratories Involved: Princeton Plasma Physics[9]

U.S. government support for fusion energy research and development began in the 1950's,[10] when Princeton Plasma Physics Laboratory was founded as a secret government project dubbed "Project Matterhorn." The project began constructing the Model A stellarator, based on the invention of Lyman Spitzer Jr., and experiments began in 1953.[11]

A stellarator is a machine that uses magnetic fields to confine plasma in the shape of a donut, called a torus. These magnetic fields allow scientists to control the plasma particles and create the right conditions for fusion. Stellarators use extremely strong electromagnets to generate twisting magnetic fields that wrap the long way around the donut shape. Relative to tokamaks (another main technology being explored for fusion power), stellarators require less injected power to sustain the plasma, have greater design flexibility, and allow for simplification of some aspects of plasma control, at the expense of increased complexity (especially for the magnetic field coils).[12]

Link: https://www.energy.gov/science/doe-explainsstellarators

[8] From *PPPL's Theory Department: Building on the Work of Giants*, Princeton Plasma Physics Laboratory, 2024, https://www.pppl.gov/news/2024/pppl%E2%80%99s-theory-department-building-work-giants
[9] From *PPPL's Theory Department: Building on the Work of Giants*, Princeton Plasma Physics Laboratory, 2024, https://www.pppl.gov/news/2024/pppl%E2%80%99s-theory-department-building-work-giants
[10] From *DOE Explains... Fusion Energy Science*, Department of Energy, https://www.energy.gov/science/doe-explainsfusion-energy-science
[11] From *PPPL's Theory Department: Building on the Work of Giants*, Princeton Plasma Physics Laboratory, 2024, https://www.pppl.gov/news/2024/pppl%E2%80%99s-theory-department-building-work-giants
[12] From *DOE Explains... Stellarators*, Department of Energy, https://www.energy.gov/science/doe-explainsstellarators

UNCOVERED MESSENGER RNA

Year: 1956[13]

Laboratories Involved: Oak Ridge[14]

In 1956, research by Oak Ridge biologists Elliot Volkin and Lazarus Astrachan enabled them to observe the role that RNA plays when a virus infects a bacterium. They discovered that, when a bacteriophage virus infects a bacterium, the virus takes over the cell's protein-making machinery and instructs it to make viral proteins. The coding sequences of the virus's genes are copied from its DNA into short-lived RNAs that are transported out of the nucleus into the cytoplasm, where the proteins are assembled. Because these RNAs transport information from genes in the nucleus to the cytoplasm, they are called messenger RNAs.

French scientists François Jacob and Jacques Monod later published a paper that further illuminated the function of mRNA, an accomplishment for which they received a Nobel Prize in 1965. Many years later, highly effective mRNA vaccines developed by Pfizer and Moderna were successfully used to slow the COVID-19 pandemic, bringing the topic to daily conversation.[15]

Link: https://www.ornl.gov/blog/covid-19-mrna-vaccines-have-oak-ridge-roots

[13] From *COVID-19 mRNA Vaccines have Oak Ridge Roots*, ORNL Review, Oak Ridge National Laboratory, 2022, https://www.ornl.gov/blog/covid-19-mrna-vaccines-have-oak-ridge-roots
[14] From *COVID-19 mRNA Vaccines have Oak Ridge Roots*, ORNL Review, Oak Ridge National Laboratory, 2022, https://www.ornl.gov/blog/covid-19-mrna-vaccines-have-oak-ridge-roots
[15] From *COVID-19 mRNA Vaccines have Oak Ridge Roots*, ORNL Review, Oak Ridge National Laboratory, 2022, https://www.ornl.gov/blog/covid-19-mrna-vaccines-have-oak-ridge-roots

DETERMINED ROLE OF Y CHROMOSOME

Year: 1959[16]

Laboratories Involved: Oak Ridge[17]

Some of Oak Ridge's earliest research involved exploring the genetic effects of radiation on mammals. To accomplish this work, Liane and Bill Russell designed and oversaw one of the largest mouse research facilities in the world: the Oak Ridge National Laboratory Mouse House. The laboratory housed more than a quarter-million mice at its peak, enabling research on genetic mutations that set occupational dose limits for humans.[18]

At this facility, Liane Russell and her colleagues discovered in that maleness in mice and humans depends on the presence of the Y chromosome and is unrelated to the number of X chromosomes.[19] She revealed the next year that only one of the two X chromosomes of a mammalian female is active.[20] Her work also led to the standard precautions observed today for the exposure of pregnant women to diagnostic X-rays.[21]

Link: https://www.ornl.gov/blog/ornl-review/house-russells-built

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[16] From *Timeline of ORNL Science: Y Chromosome Discovery*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-y-chromosome-discovery
[17] From *Timeline of ORNL Science: Y Chromosome Discovery*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-y-chromosome-discovery
[18] From *The House the Russells Built*, Oak Ridge National Laboratory, 2018, https://www.ornl.gov/blog/ornl-review/house-russells-built
[19] From *The House the Russells Built*, Oak Ridge National Laboratory, 2018, https://www.ornl.gov/blog/ornl-review/house-russells-built
[20] From *Timeline of ORNL Science: Y Chromosome Discovery*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-y-chromosome-discovery
[21] From *The House the Russells Built*, Oak Ridge National Laboratory, 2018, https://www.ornl.gov/blog/ornl-review/house-russells-built

PURIFIED VACCINES

Year: 1961[22]

Laboratories Involved: Oak Ridge[23]

In 1961 a biology team headed by Norman Anderson, with advice from Jonas Salk of polio vaccine fame, adapted centrifuge technology (previously developed to produce enriched uranium for nuclear reactor fuel[24]) to separating viruses from human leukemic plasma. This striking use of nuclear separations technology to advance science and medical research led in several directions. Anderson and his team experimented with centrifuges whirling up to 141 ,000 revolutions per minute and learned the machines could separate impurities from the viruses causing polio and Hong Kong flu. By cleansing vaccines of foreign proteins, the zonal centrifuge could produce a vaccine pure enough to minimize the fever reactions that often accompanied immunizations.

By the late 1960s, commercial zonal centrifuges based on the ORNL invention produced vaccine for millions of people and purified rabies vaccines for their pets.[25]

Link: https://www.ornl.gov/timeline#event-centrifuges-for-safer-vaccines

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[22] From *Big Biology*, Oak Ridge Review, Oak Ridge National Laboratory, 1992, https://www.ornl.gov/sites/default/files/ORNL%20Review%20v25n3-4%201992.pdf
[23] From *Big Biology*, Oak Ridge Review, Oak Ridge National Laboratory, 1992, https://www.ornl.gov/sites/default/files/ORNL%20Review%20v25n3-4%201992.pdf
[24] Parenthetical comment from *Timeline of ORNL Science: Centrifuges for Safer Vaccines*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-centrifuges-for-safer-vaccines
[25] From *Big Biology*, Oak Ridge Review, Oak Ridge National Laboratory, 1992, https://www.ornl.gov/sites/default/files/ORNL%20Review%20v25n3-4%201992.pdf

HOUSED THE WORLD'S FASTEST SUPERCOMPUTERS

Year: 1964 (and many years thereafter)[26]

Laboratories Involved: Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Sandia[27]

For over half a century, America has led the world in high-performance computing (HPC), thanks to sustained federal government investments in research and the development and regular deployment of new systems, as well as strong partnerships with U.S. computing vendors and researchers. Within the federal government, the Department of Energy (DOE) leads the effort of pushing the boundary of what is possible with the nation's fastest and most capable supercomputers housed at the DOE National Laboratories.[28]

Supercomputers are used to model and simulate complex, dynamic systems that would be too expensive, impractical or impossible to physically demonstrate. Supercomputers are changing the way scientists explore the evolution of our universe, biological systems, weather forecasting and even renewable energy. The National Labs make their high performance computing facilities available to researchers from industry and academia so that these public investments in state-of-the-art technology are able to generate the greatest possible intellectual and economic benefit.[29]

Link: https://www.energy.gov/supercomputing-and-exascale

[26] From *Computing on the Mesa*, National Security Science, Los Alamos National Laboratory, 2020, https://discover.lanl.gov/publications/national-security-science/2020-winter/computing-on-the-mesa/
[27] From *Exascale Computing Project: About ECP*, Oak Ridge National Laboratory, https://www.ornl.gov/content/about-ecp
[28] From *High Performance Computing*, Department of Energy, https://www.energy.gov/science/high-performance-computing
[29] From *Supercomputing and Exascale*, Department of Energy, https://www.energy.gov/supercomputing-and-exascale

DISCOVERED GAMMA RAY BURSTS

Year: 1967[30]

Laboratories Involved: Los Alamos[31]

In 1967, Los Alamos scientist Ray Klebesadel saw, in data from two Vela satellites, evidence that something extraordinary had happened in outer space. He had discovered the most powerful explosions in the universe—gamma-ray bursts (GRBs). GRBs are essentially massive space explosions that produce gamma rays, which are a form of radiation.

In order to monitor space for nuclear explosions, the detection instruments on the Vela satellites measure x-rays, neutrons, and gamma rays, all byproducts of nuclear explosions. Scientists expected that there would be some naturally occurring gamma rays in outer space; what they didn't expect were enormous bursts of them that are about a trillion times brighter than the sun. We now know that a GRB is produced by the collapse of matter at the formation of a new black hole, but scientists at the time could only speculate about what was causing them.[32]

Link: https://discover.lanl.gov/publications/national-security-science/2020-summer/the-mystery-flash-that-changed-astrophysics/

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[30] From *The Mystery Flash that Changed Astrophysics*, National Security Science, Los Alamos National Laboratory, 2020, https://discover.lanl.gov/publications/national-security-science/2020-summer/the-mystery-flash-that-changed-astrophysics/

[31] From *The Mystery Flash that Changed Astrophysics*, National Security Science, Los Alamos National Laboratory, 2020, https://discover.lanl.gov/publications/national-security-science/2020-summer/the-mystery-flash-that-changed-astrophysics/

[32] From *The Mystery Flash that Changed Astrophysics*, National Security Science, Los Alamos National Laboratory, 2020, https://discover.lanl.gov/publications/national-security-science/2020-summer/the-mystery-flash-that-changed-astrophysics/

SCOOPED AND STUDIED MOON ROCKS

Year:1969[33]

Laboratories Involved: Oak Ridge[34]

Oak Ridge National Laboratory expertise supported man's first walk on the Moon in a few different ways.[35] Researchers helped design a lunar rock scoop for Apollo 11 astronauts, which was made of 12 individual parts and resembled a space-age butterfly net. The soil sampler played an important role on Apollo 11 and subsequent lunar landing missions 12, 14 and 15. [36] In addition, Oak Ridge (and Y-12) supplied a vacuum-sealed “moon box” for housing rock samples collected on the Moon. Six Apollo missions, flown between 1969 and 1972, used these boxes to bring back a total of 842 pounds of lunar material, including 2,200 separate samples of lunar rocks, core samples, pebbles, sand and dust.[37]

Following the lunar landing, an ORNL team analyzed the rocks and published the results in the "Moon Issue" of *Science* in 1970. As part of their study, the team members assayed lunar samples for uranium, thorium, and other indicators of the rock's age.[38]

Link: https://www.ornl.gov/news/fifty-years-apollo-11-ornl-moon-scoop-remains-source-family-pride

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[33] From *Timeline of ORNL Science: Moon Exploration Support*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-moon-exploration-support
[34] From *Timeline of ORNL Science: Moon Exploration Support*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-moon-exploration-support
[35] From *Timeline of ORNL Science: Moon Exploration Support*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-moon-exploration-support
[36] From *Fifty Years Since Apollo 11, ORNL ‘Moon Scoop’ Remains a Source of Family Pride*, Oak Ridge National Laboratory, 2019, https://www.ornl.gov/news/fifty-years-apollo-11-ornl-moon-scoop-remains-source-family-pride
[37] From *Apollo ‘Moon Boxes’ Made at Y-12*, Y-12 National Security Complex, 2017, https://www.y12.doe.gov/sites/default/files/assets/document/09-07-17.pdf
[38] From *Timeline of ORNL Science: Moon Exploration Support*, Oak Ridge National Laboratory, https://www.ornl.gov/timeline#event-moon-exploration-support

DETERMINED BUILDING BLOCKS OF MATTER

Years: 1956, 1962, 1964, 1968, 1974, 1976, 1977, 1995, 2000[39]

Laboratories Involved: Brookhaven, Fermi, Los Alamos, Savannah River, SLAC, Thomas Jefferson[40]

The Standard Model of Particle Physics is scientists' current best theory to describe the most basic building blocks of the universe. It explains how particles called quarks (which make up protons and neutrons) and leptons (which include electrons) make up all known matter. It also explains how force carrying particles, which belong to a broader group of bosons, influence the quarks and leptons.[41]

DOE has a long history of supporting research into fundamental particles. Five of the six types of quarks (down, strange, charm, bottom, and top[42]), one type of lepton (tau[43]), and all three neutrinos were discovered at what are now DOE national laboratories. Researchers supported by DOE, often in collaboration with scientists from around the world, have contributed to Nobel Prize-winning discoveries and measurements that refined the Standard Model. These efforts continue today, with experiments that make precision tests of the Standard Model and further improve measurements of particle properties and their interactions.[44]

Link: https://www.energy.gov/science/doe-explainsthe-standard-model-particle-physics

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[39] From *Science: Worldwide Particle Physics Discoveries*, Fermi National Accelerator Laboratory, https://fnal.gov/pub/science/particle-physics-101/worldwide-discoveries.html
[40] From *Science: Worldwide Particle Physics Discoveries*, Fermi National Accelerator Laboratory, https://fnal.gov/pub/science/particle-physics-101/worldwide-discoveries.html
[41] From *DOE Explains... the Standard Model of Particle Physics*, Department of Energy, https://www.energy.gov/science/doe-explainsthe-standard-model-particle-physics
[42] From *Science: Worldwide Particle Physics Discoveries*, Fermi National Accelerator Laboratory, https://fnal.gov/pub/science/particle-physics-101/worldwide-discoveries.html
[43] From *Science: Worldwide Particle Physics Discoveries*, Fermi National Accelerator Laboratory, https://fnal.gov/pub/science/particle-physics-101/worldwide-discoveries.html
[44] From *DOE Explains... the Standard Model of Particle Physics*, Department of Energy, https://www.energy.gov/science/doe-explainsthe-standard-model-particle-physics

UNMASKED CAUSE OF DINOSAUR EXTINCTION

Year: 1979[45]

Laboratories Involved: Lawrence Berkeley[46]

A Berkeley team was the first to propose that the mass extinctions that took place 65 million years ago were caused by Earth's collision with an asteroid. The impact threw a cloud of dust into the atmosphere so thick that it obscured the sun, suppressed photosynthesis, and caused a massive die-off, including the demise of the dinosaurs. The team analyzed rock samples collected Italy and other locations from the Cretaceous-Paleogene boundary layer of the Earth's crust. The samples contained a clay layer enriched in the element iridium by 600 times the normal concentration found on Earth.

They concluded that this iridium had extraterrestrial origins and was deposited when the mixture of dust and ash from the impact of an iridium-enriched asteroid settled. Their paper caused a sensation in the scientific community, but over time, much more evidence has come to light to support the theory, including direct evidence for the asteroid's impact in a crater in Mexico.[47]

Link: https://newscenter.lbl.gov/2010/03/09/alvarez-theory-on-dinosaur/

[45] From *Berkeley Scientists Report First Evidence that Dinosaur Extinction Caused by Meteorite Impact*, Science Beat, Lawrence Berkeley National Laboratory, 1979, https://www2.lbl.gov/Science-Articles/Archive/dinosaur-extinction.html
[46] From *Berkeley Scientists Report First Evidence that Dinosaur Extinction Caused by Meteorite Impact*, Science Beat, Lawrence Berkeley National Laboratory, 1979, https://www2.lbl.gov/Science-Articles/Archive/dinosaur-extinction.html
[47] From *Frank Asaro, Nuclear Chemist who Contributed to Dinosaur Extinction Theory and Archaeological Studies, Passes Away*, Lawrence Berkeley National Laboratory, 2014, https://eta.lbl.gov/news/57850/frank-asaro-nuclear-chemist-who

SET QUANTUM COMPUTING FRAMEWORK

Year: 1980[48]

Laboratories Involved: Argonne[49]

Quantum computers are computers that consist of quantum bits, or "qubits," that play a similar role to the bits in today's digital computers. The laws of quantum mechanics allow qubits to encode exponentially more information than bits. By manipulating information stored in these qubits, scientists can quickly produce high-quality solutions to difficult problems.[50]

Argonne scientist Paul Benioff made seminal contributions to the foundations of quantum computing with four papers published in the early 1980s. He demonstrated for the first time that a quantum computer was theoretically possible, helping to catalyze an entire field that is now focused on building quantum systems to relay information and perform dauntingly complex calculations. These papers are regarded as the first recognizable theoretical framework for a quantum computer. The field is now a fast-growing area of research that could have applications in cybersecurity, cryptography, medicine and more.[51]

Link: https://www.anl.gov/article/remembering-paul-benioff-renowned-scientist-and-quantum-computing-pioneer

[48] From *Quantum Computing, the Early Days and Effect of Scalar Scaling Field on Physics, Geometry*, Argonne National Laboratory, https://www.phy.anl.gov/theory/workshops/qc2016/talks/qc2016_benioff.pdf
[49] From *Remembering Paul Benioff, Renowned Scientist and Quantum Computing Pioneer*, Argonne National Laboratory, 2022, https://www.anl.gov/article/remembering-paul-benioff-renowned-scientist-and-quantum-computing-pioneer
[50] From *DOE Explains... Quantum Computing*, Department of Energy, https://www.energy.gov/science/doe-explainsquantum-computing
[51] From *Remembering Paul Benioff, Renowned Scientist and Quantum Computing Pioneer*, Argonne National Laboratory, 2022, https://www.anl.gov/article/remembering-paul-benioff-renowned-scientist-and-quantum-computing-pioneer

QUANTIFIED RISK OF RADON GAS

Year: 1983[52]

Laboratories Involved: Lawrence Berkeley[53]

Scientists at Berkeley became aware of reported measurements of radioactive radon gas in houses and realized that exposures to indoor radon (more specifically to alpha-particle emitting radon decay products) could be an important source of radiation exposures to the general population. An early focus of their work was understanding the source(s) of radon in houses - especially houses with elevated concentrations.

An important outcome of that research was the understanding that buildings can draw radon-laden gas from the surrounding soils via the same mechanism driving air infiltration. Ultimately their work evaluated the combination of factors - radium concentrations in local soils, soil characteristics, residential building types and typical weather conditions - for large regions of the country and created a predictive tool for estimating the likelihood of finding houses with elevated radon concentrations at a regional scale.[54]

Link: https://eta.lbl.gov/news/remembering-tony-nero

[52] From *Energy Technologies Area: the 1980s*, Lawrence Berkeley National Laboratory, https://eta.lbl.gov/1980s
[53] From *Energy Technologies Area: the 1980s*, Lawrence Berkeley National Laboratory, https://eta.lbl.gov/1980s
[54] From *Energy Technologies Area: Remembering Tony Nero, 1942-2023,* Lawrence Berkeley National Laboratory, 2024, https://eta.lbl.gov/news/remembering-tony-nero

REPLICATED PROTEINS FOR VACCINES

Year:1984 (Patented)[55]

Laboratories Involved: Brookhaven[56]

With colleagues in the Biology Department, F. William Studier developed Brookhaven Lab's most successful technology: the T7 protein expression system.[57] T7 is a virus that infects *E. coli* bacteria. Studier found a way to direct T7's prolific copying capability toward making things other than more T7s. They cloned the T7 RNA polymerase (the enzyme that transcribes DNA genes into messenger RNA), then used this along with a powerful T7 promoter (a genetic element serving as a "start" signal for gene transcription) to produce large amounts of RNA from almost any gene. These RNAs could be delivered to ribosomes to be translated into proteins, or used directly. [58]

This science was fundamental to enabling the mRNA-based Pfizer/BioNTech and Moderna COVID vaccines nearly 40 years later. At manufacturing plants, T7-derived promoters and enzymes crank out kilograms of spike-protein mRNA at a time—leaving our own cells to do the protein-making after a dose of instructions is injected into our arms.[59]

Link: https://www.bnl.gov/newsroom/news.php?a=218806

[55] From *F. William Studier: Basic Research Leads to Most Successful BNL Technology*, Brookhaven National Laboratory, 2011, https://www.bnl.gov/newsroom/news.php?a=22241
[56] From *F. William Studier: Basic Research Leads to Most Successful BNL Technology*, Brookhaven National Laboratory, 2011, https://www.bnl.gov/newsroom/news.php?a=22241
[57] From *F. William Studier: Basic Research Leads to Most Successful BNL Technology*, Brookhaven National Laboratory, 2011, https://www.bnl.gov/newsroom/news.php?a=22241
[58] From *The Science Behind the Shot: Biotech Tools Developed at Brookhaven Lab Fundamental to Making COVID-19 Vaccines*, Brookhaven National Laboratory, 2021, https://www.bnl.gov/newsroom/news.php?a=218806
[59] From *The Science Behind the Shot: Biotech Tools Developed at Brookhaven Lab Fundamental to Making COVID-19 Vaccines*, Brookhaven National Laboratory, 2021, https://www.bnl.gov/newsroom/news.php?a=218806

REVOLUTIONIZED ACCELERATORS

Year: 1988 (Feasibility Demonstrated)[60]

Laboratories Involved: Thomas Jefferson[61]

Particle accelerators are devices that speed up the particles that make up all matter in the universe and collide them, allowing scientists to study those particles and the forces that shape them.[62] The Continuous Electron Beam Accelerator Facility (CEBAF) project began in the mid-1980s at Jefferson Lab as the first large-scale application of superconducting radio frequency technology (SRF) to accelerators. To apply SRF at that scale, the challenges were technological, industrial, and in some cases scientific. SRF was a newly developed technology, and reliable SRF components needed to be manufactured, processed, assembled, tested, and installed on a production basis.[63]

Today, CEBAF can be thought of as the world's most powerful microscope for studying the nucleus of the atom. Without SRF technology, it would require three times as much power to operate and performance would be greatly reduced.[64] SRF itself is a complex multidisciplinary field that is still advancing, and its limits are not yet known.[65]

Link: https://www.jlab.org/accelerator/srf/overview

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[60] From *Jefferson Lab Timeline*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/about/visitors/history
[61] From *Jefferson Lab Timeline*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/about/visitors/history
[62] From *DOE Explains… Particle Accelerators*, Department of Energy, https://www.energy.gov/science/doe-explainsparticle-accelerators
[63] From *What Has JLab Done with SRF?*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/accelerator/srf/CEBAF
[64] From *Why is JLab Unique?*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/about/visitors/science/unique
[65] From *SRF Overview*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/accelerator/srf/overview

CREATED THE FIRST US WEBSITE

Year: 1991[66]

Laboratories Involved: SLAC[67]

As the World Wide Web was poised to begin its transformation of modern communications – and, well, life as we know it – a group of SLAC staff saw an opportunity to vastly improve the exchange of information within large, international physics collaborations. That inspiration led to the first website ever created in North America on a server at the DOE's SLAC National Accelerator Lab.

The idea was to collect information about software in high energy physics and publicize it, so people would be able to reuse the work of others without starting from scratch. The existing tools did not provide a good way to share up-to-date information about experiments, while the web offered an intuitive, collaborative tool to develop, share and rapidly update such information – which is why SLAC scientists saw it as such a game changer.[68]

Link: https://www6.slac.stanford.edu/news/2021-12-13-slac-tony-johnson-remembers-www-wizards-and-birth-north-americas-first-website

[66] From *Early Web Chronology and Documents (1991-1994),* SLAC National Accelerator Laboratory, https://ahro.slac.stanford.edu/wwwslac-exhibit/early-web-chronology-and-documents-1991-1994
[67] From *Early Web Chronology and Documents (1991-1994),* SLAC National Accelerator Laboratory, https://ahro.slac.stanford.edu/wwwslac-exhibit/early-web-chronology-and-documents-1991-1994
[68] From *SLAC's Tony Johnson Remembers the WWW Wizards and the Birth of North America's First Website*, SLAC National Accelerator Laboratory, 2021, https://www6.slac.stanford.edu/news/2021-12-13-slac-tony-johnson-remembers-www-wizards-and-birth-north-americas-first-website

SET FUSION WORLD RECORDS

Year: 1993[69]

Laboratories Involved: Princeton Plasma Physics[70]

A world-record burst of more than 3 million watts of fusion energy — enough to momentarily light some 3,000 homes — was produced at the Tokamak Fusion Test Reactor in 1993. It did so again the very next day when TFTR shattered the mark by creating more than six million watts of fusion energy. The excitement reached even the normally staid control-room log, where an operator noted the historic event with the exclamation, “EEYAH”!

The breakthroughs proved the practicality of combining equal amounts of the hydrogen isotopes deuterium and its radioactive cousin tritium — the same combination that will be used in ITER and future fusion power plants — to form the superhot, charged plasma gas that fuels fusion reactions. The achievements generated headlines around the world and laid the foundation for the development of fusion energy in facilities such as ITER, the vast international experiment being built in France to demonstrate the feasibility of fusion power.[71]

Link: https://web.ornl.gov/info/news/pulse/no408/feature.shtml

[69] From *Celebrating the 20th Anniversary of the Tritium Shot Heard Around the World*, DOE Pulse, Department of Energy, 2014, https://web.ornl.gov/info/news/pulse/no408/feature.shtml
[70] From *Celebrating the 20th Anniversary of the Tritium Shot Heard Around the World*, DOE Pulse, Department of Energy, 2014, https://web.ornl.gov/info/news/pulse/no408/feature.shtml
[71] From *Celebrating the 20th Anniversary of the Tritium Shot Heard Around the World*, DOE Pulse, Department of Energy, 2014, https://web.ornl.gov/info/news/pulse/no408/feature.shtml

LOWERED THE COST OF BIOFUELS

Year: 1995 (Award)[72]

Laboratories Involved: NREL [73]

One of our greatest challenges is to reduce our nation's dependence on imported petroleum. To accomplish this, we need a variety of alternative fuels, including ethanol.[74] In the 1990s, NREL demonstrated how enzymes can be used to help free carbohydrates from corn fibers, allowing them to be fermented into ethanol.[75] Two years later, NREL developed a new, genetically engineered organism known as Zymomonas mobilis, which enhances the fermentation of biomass sugars, leading to greater yields of ethanol and lower costs. The advantages that Zymomonas mobilis holds over traditional yeast processes lead to more economical and environmentally friendly methods of producing ethanol.[76]

In 2004, NREL's work to improve the enzymatic process with enzyme companies Novozymes Biotech, Inc. and Genencor International (now part of DuPont) won another R&D 100 Award. Today, a nascent cellulosic ethanol industry is being built, with several companies using the enzymatic approach.[77]

Link: https://www.nrel.gov/docs/fy07osti/40742.pdf

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[72] From *R&D 100 Awards Demonstrate Clean Energy Legacy*, Continuum, National Renewable Energy Laboratory, 2014, https://www.nrel.gov/docs/fy15osti/62831.pdf
[73] From *R&D 100 Awards Demonstrate Clean Energy Legacy*, Continuum, National Renewable Energy Laboratory, 2014, https://www.nrel.gov/docs/fy15osti/62831.pdf
[74] From *Research Advances: Cellulosic Ethanol*, National Renewable Energy Laboratory, 2007, https://www.nrel.gov/docs/fy07osti/40742.pdf
[75] From *R&D 100 Awards Demonstrate Clean Energy Legacy*, Continuum, National Renewable Energy Laboratory, 2014, https://www.nrel.gov/docs/fy15osti/62831.pdf
[76] From *Zymomonas Mobilis: Lowering the Cost of Converting Biomass to Ethanol*, Department of Energy, 2001, https://www1.eere.energy.gov/vehiclesandfuels/pdfs/success/zmobilis_mar_2001.pdf
[77] From *R&D 100 Awards Demonstrate Clean Energy Legacy*, Continuum, National Renewable Energy Laboratory, 2014, https://www.nrel.gov/docs/fy15osti/62831.pdf

LOCKED NUCLEAR WASTE IN GLASS

Year: 1996[78]

Laboratories Involved: Savannah River[79]

The Department of Energy (DOE) Office of Environmental Management is responsible for roughly 90 million gallons of radioactive liquid waste. The production of plutonium for nuclear weapons to defend our nation that began 70+ years ago resulted in high level radioactive waste, which is a mix of liquid, sediment, salts and sludge.[80]

Savannah River National Lab (SRNL) develops glass and ceramic materials to stabilize this waste.[81] These materials chemically bind the radioactive and hazardous components into a solid, durable material that will withstand degradation for thousands of years. The goal is not elimination of the radioactive materials (because it isn't possible), rather, safely remove liquid waste from tanks and convert the liquid waste into a safer form for long-term storage. This conversion removes the threat to the environment from leaks, spills or leaching and allows for closure of aging waste tanks.[82]

Link: https://www.srnl.gov/fact-sheets/applied-materials-science-for-waste-immobilization/

[78] From *Tank Waste Disposal*, Matter Magazine, Savannah River National Laboratory, 2023, https://www.srnl.gov/matter_magazine/tank-waste-disposal/
[79] From *Tank Waste Disposal*, Matter Magazine, Savannah River National Laboratory, 2023, https://www.srnl.gov/matter_magazine/tank-waste-disposal/
[80] From *Tank Waste Disposal*, Matter Magazine, Savannah River National Laboratory, 2023, https://www.srnl.gov/matter_magazine/tank-waste-disposal/
[81] From *Factsheets: Applied Materials Science for Waste Immobilization*, Savannah River National Laboratory, https://www.srnl.gov/fact-sheets/applied-materials-science-for-waste-immobilization/
[82] From *Tank Waste Disposal*, Matter Magazine, Savannah River National Laboratory, 2023, https://www.srnl.gov/matter_magazine/tank-waste-disposal/

UNCOVERED COSMIC ACCELERATION

Year: 1998[83]

Laboratories Involved: Lawrence Berkeley[84]

The universe is expanding, and it expands a little faster all the time. Scientists call the speeding up of this expansion cosmic acceleration. The universe has experienced two distinct periods of cosmic acceleration. The first, called inflation, occurred a fraction of a second after the Big Bang. The second is the extended period of cosmic acceleration that began about 9 billion years after the Big Bang and continues today. Scientists discovered the increasing expansion of the universe in 1998 through observations of distant supernovae (exploding stars). The scientists who discovered cosmic acceleration, including Lawrence Berkeley National Laboratory's Saul Perlmutter, received the 2011 Nobel Prize in Physics.

This discovery posed a new question that scientists continue to explore today: what is the “dark energy” that is overcoming the effect of gravity and pulling our universe apart? The Department of Energy supports researchers who seek to understand dark energy, looking for clues about the early inflation of the universe.[85]

Link: https://www.energy.gov/science/doe-explainscosmic-acceleration-and-dark-energy

[83] From *DOE Explains... Cosmic Acceleration and Dark Energy*, Department of Energy, https://www.energy.gov/science/doe-explainscosmic-acceleration-and-dark-energy
[84] From *DOE Explains... Cosmic Acceleration and Dark Energy*, Department of Energy, https://www.energy.gov/science/doe-explainscosmic-acceleration-and-dark-energy
[85] From *DOE Explains... Cosmic Acceleration and Dark Energy*, Department of Energy, https://www.energy.gov/science/doe-explainscosmic-acceleration-and-dark-energy

SEQUENCED THE HUMAN GENOME

Year: 2000[86]

Laboratories Involved: Lawrence Berkeley, Lawrence Livermore, Los Alamos[87]

One of the most important developments in the field of biology over the past century was the Human Genome Project (HGP). The HGP was a 10-year effort led by the U.S. government that culminated in the first complete sequencing of a human genome in 2000. The HGP launched the field of genomics, transformed medicine, and largely gave birth to the modern biotechnology industry.

The original idea and impetus for the HGP came from DOE's Office of Science (then called the Office of Energy Research). Many researchers viewed the sequencing of an entire human genome as nearly impossible. But based on DOE's long experience with "Big Science" endeavors dating back to the Manhattan Project, HGP pioneers had confidence in the federal government's ability to deploy sufficient resources to accomplish this task. DOE's initial reason for leading the HGP was its interest in better understanding the genetic effects of radiation exposure. But DOE and the scientific community knew that success in the project would have much broader consequences for both science and society.[88]

Link: https://www.energy.gov/science/doe-explainsgenomics

[86] From *DOE Explains... Genomics,* Department of Energy, https://www.energy.gov/science/doe-explainsgenomics
[87] From *About Us: History*, Joint Genome Institute, Lawrence Berkeley National Laboratory, https://jgi.doe.gov/about-us/history/
[88] From *DOE Explains... Genomics,* Department of Energy, https://www.energy.gov/science/doe-explainsgenomics

GENERATED THE BRIGHTEST LASER LIGHT

Year: 2003 (Upgrade Complete)[89]

Laboratories Involved: Thomas Jefferson[90]

Jefferson Lab's Free-Electron Laser (FEL) is the world's highest-power tunable infrared laser and was developed using the lab's expertise in superconducting radiofrequency (SRF) accelerators. The FEL also provides ultraviolet laser light, including vacuum ultraviolet light, and is also a source of Terahertz light.[91] The Free-Electron Laser (FEL) achieved a record 10 kilowatts of infrared laser light in 2004[92], later surpassed in 2006 by achieving 14.2 kilowatts.[93]

The FEL uses electrons to produce laser light. These electrons are energized using the lab's superconducting accelerator technology and steered into a wiggler, which uses magnetic fields to shake the electrons, forcing them to release energy as photons (light). As in a conventional laser, the photons are bounced between two mirrors and emitted as a coherent beam of light, which can be tuned to precise colors or wavelengths. Compared to conventional lasers, the FEL can produce intensely powerful light in brief bursts with extreme precision.

Link: https://www.jlab.org/free-electron-laser

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[89] From *Jefferson Lab: Accelerators: Free Electron Laser*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/FEL/felscience.html

[90] From *Jefferson Lab: Accelerators: Free Electron Laser*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/FEL/felscience.html

[91] From *Jefferson Lab: Free Electron Laser*, Thomas Jefferson National Accelerator Facility, https://www.jlab.org/free-electron-laser

[92] From *FEL Achieves 10 Kilowatts*, On Target, Thomas Jefferson National Accelerator Facility, 2004, https://www.jlab.org/sites/default/files/documents/news/ontarget/2004/August2004.pdf

[93] From *Researchers' Hottest New Laser Beams 14.2 KW,* Thomas Jefferson National Accelerator Facility, 2006, https://www.jlab.org/news/releases/researchers-hottest-new-laser-beams-142-kw

RECREATED AFTERMATH OF THE BIG BANG

Years: 2005[94]

Laboratories Involved: Brookhaven[95]

Quarks and gluons are the building blocks of protons and neutrons, which in turn are the building blocks of atomic nuclei. The only way to separate these particles is to create a state of matter known as quark-gluon plasma. In this plasma, the density and temperature are so high that protons and neutrons melt. This soup of quarks and gluons permeated the entire universe until a few fractions of a second after the Big Bang, when the universe cooled enough that quarks and gluons froze into protons and neutrons.[96]

The Relativistic Heavy Iron Collider (RHIC) at Brookhaven was the first machine to demonstrate the formation of quark-gluon plasma, and determine its unexpected properties. Instead of an ideal gas of weakly interacting quarks and gluons, the plasma discovered at RHIC behaves like a nearly frictionless liquid. The temperatures achieved in such RHIC collisions are more than 4 trillion degrees Celsius, the hottest ever created in a laboratory. [97]

Link: https://www.energy.gov/science/doe-explainsquarks-and-gluons

[94] From *RHIC Scientists Serve up 'Perfect' Liquid*, Brookhaven National Laboratory, 2005, https://www.bnl.gov/newsroom/news.php?a=110303
[95] From *RHIC Scientists Serve up 'Perfect' Liquid*, Brookhaven National Laboratory, 2005, https://www.bnl.gov/newsroom/news.php?a=110303
[96] From *DOE Explains...Quarks and Gluons*, Department of Energy, https://www.energy.gov/science/doe-explainsquarks-and-gluons
[97] From *Hot Nuclear Matter Featured in* Science*,* Brookhaven National Laboratory, 2012, https://www.bnl.gov/newsroom/news.php?a=111436

HARVESTED ENERGY FROM AIR

Year: 2009[98]

Laboratories Involved: Pacific Northwest[99]

Electricity can be created by processing heat associated with naturally occurring temperature differences in the environment. This essentially inexhaustible source of heat can be converted into electrical power sufficient to run compact, low-power devices like wireless sensors for decades. Researchers at Pacific Northwest National Laboratory developed the science behind the Perpetua Power Puck, which harvests energy from its surrounding environment with the capability for replacing outright conventional batteries.

The Power Puck is a renewable energy source that has no moving parts. The technology can save time and money in situations where information needs to be collected and power sources need to be maintained at remote sites, such as dams, bridges and pipelines. These energy harvesters are expected to last as long as the sensors and transmitters they power. The Perpetua Power Puck is being marketed for industrial automation, military, energy efficient buildings and other applications. [100]

Link: https://www.pnnl.gov/about/rd100awards.asp

[98] From *About PNNL: R&D 100 Awards*: 2009, https://www.pnnl.gov/about/rd100awards.asp
[99] From *About PNNL: R&D 100 Awards*: 2009, https://www.pnnl.gov/about/rd100awards.asp
[100] From *About PNNL: R&D 100 Awards*: 2009, https://www.pnnl.gov/about/rd100awards.asp

PREVENTED HEART ATTACKS

Year: 2010[101]

Laboratories Involved: NETL[102]

A coronary stent is a small, self-expanding metal mesh tube that saves thousands of lives every year by opening blocked arteries and allowing blood to flow freely again. NETL and Boston Scientific Corporation, Inc. (BCSI) jointly developed a novel platinum/chromium alloy stent, with high visibility in x-ray scanning. Better visibility means greater ease and precision in placement of the stent inside the patient's blood vessel. In addition, the greater yield strength of the alloy allowed the stent's designers to make a thinner, more flexible stent that is more easily threaded through the winding path of the artery without doing damage along the way.

Since introduction in 2010, the platinum/chromium coronary stent series has become the leading stent platform in the world. Total sales since introduction have exceeded $4 billion. BSCI now has a 45 percent share of the market in the U.S. and a 33 percent global share of the coronary stent market using the alloy.[103]

Link: https://www.netl.doe.gov/sites/default/files/2019-03/BDO12-004_Coronary%20Stent.pdf

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[101] From *Success Story: Novel Platinum/Chromium Alloy for the Manufacture of Improved Coronary Stents*, National Renewable Energy Laboratory, 2014, https://www.netl.doe.gov/sites/default/files/2019-03/BDO12-004_Coronary%20Stent.pdf

[102] From *Success Story: Novel Platinum/Chromium Alloy for the Manufacture of Improved Coronary Stents*, National Renewable Energy Laboratory, 2014, https://www.netl.doe.gov/sites/default/files/2019-03/BDO12-004_Coronary%20Stent.pdf

[103] From *Success Story: Novel Platinum/Chromium Alloy for the Manufacture of Improved Coronary Stents*, National Renewable Energy Laboratory, 2014, https://www.netl.doe.gov/sites/default/files/2019-03/BDO12-004_Coronary%20Stent.pdf

BUILT WORLD'S MOST POWERFUL MAGNET

Year: 2012[104]

Laboratories Involved: Los Alamos[105]

In March 2012, scientists at Los Alamos National Laboratory set a world record by achieving a 100.75 tesla magnetic pulse, about 2,000,000 times more powerful than the Earth's magnetic field. This 100 tesla multi-shot magnet, called such because it can be used over and over again without being destroyed by the force of the magnetic field it creates, is pulsed -- meaning the field it generates can only be sustained for a short period of time.[106]

The magnet itself is located inside a liquid nitrogen container that keeps it at a chilly -198.15 degrees Celsius (-324.67 degrees Fahrenheit), which prevents the magnet from overheating due to the powerful pulse of electricity.[107] By studying materials under extreme magnetic field conditions, scientists make essential contributions to fundamental materials science, energy research, and stewardship of the nation's nuclear stockpile.[108]

Link: https://www.energy.gov/articles/teslas-lab-los-alamos-powerful-magnets-come-full-circle

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[104] From *From Tesla's Lab to Los Alamos: Powerful Magnets Come Full Circle*, Department of Energy, 2013, https://www.energy.gov/articles/teslas-lab-los-alamos-powerful-magnets-come-full-circle
[105] From *From Tesla's Lab to Los Alamos: Powerful Magnets Come Full Circle*, Department of Energy, 2013, https://www.energy.gov/articles/teslas-lab-los-alamos-powerful-magnets-come-full-circle
[106] From *From Tesla's Lab to Los Alamos: Powerful Magnets Come Full Circle*, Department of Energy, 2013, https://www.energy.gov/articles/teslas-lab-los-alamos-powerful-magnets-come-full-circle
[107] From *From Tesla's Lab to Los Alamos: Powerful Magnets Come Full Circle*, Department of Energy, 2013, https://www.energy.gov/articles/teslas-lab-los-alamos-powerful-magnets-come-full-circle
[108] From *National High Magnetic Field Laboratory – Pulsed Field Facility*, Los Alamos National Laboratory, https://organizations.lanl.gov/physical-sciences/materials-physics-applications/nhmfl/

MADE THE FIRST MOLECULAR MOVIE

Year: 2015[109]

Laboratories Involved: SLAC[110]

One of modern science's most important quests is to understand how the world works at the tiniest and fastest scales – the realm of atoms and molecules. Up to the mid-2010s, all scientists had were static pictures of this world[111], until researchers at SLAC produced the first 'molecular movie' tracking ultrafast structural changes as ring-shaped gas molecules burst open and unraveled.[112]

Molecular movies capture images of a molecule, at extremely high resolution, within just a few quadrillionths of a second of each other, and then string them together like frames from a film into a movie that shows how the molecule moves and changes over time. Doing so requires a very specialized camera, and SLAC has two such resources: the Linac Coherent Light Source, which shoots movies with brilliant pulses of X-ray laser light, and an "electron camera" known as MeV-UED that shoots them with intense pulses of electrons, a technique called ultrafast electron diffraction.[113]

Link: https://www6.slac.stanford.edu/news/2019-10-07-what-molecular-movie

[109] From *New 'Molecular Movie' Reveals Ultrafast Chemistry in Motion*, SLAC National Accelerator Laboratory, 2015, https://www6.slac.stanford.edu/news/2015-06-22-new-molecular-movie-reveals-ultrafast-chemistry-motion
[110] From *New 'Molecular Movie' Reveals Ultrafast Chemistry in Motion*, SLAC National Accelerator Laboratory, 2015, https://www6.slac.stanford.edu/news/2015-06-22-new-molecular-movie-reveals-ultrafast-chemistry-motion
[111] From *What is a Molecular Movie?*, SLAC National Accelerator Laboratory, 2019, https://www6.slac.stanford.edu/news/2019-10-07-what-molecular-movie
[112] From *New 'Molecular Movie' Reveals Ultrafast Chemistry in Motion*, SLAC National Accelerator Laboratory, 2015, https://www6.slac.stanford.edu/news/2015-06-22-new-molecular-movie-reveals-ultrafast-chemistry-motion
[113] From *What is a Molecular Movie?*, SLAC National Accelerator Laboratory, 2019, https://www6.slac.stanford.edu/news/2019-10-07-what-molecular-movie

SUPER SIZED 3D PRINTING

Year: 2016 (World Record)[114]

Laboratories Involved: Oak Ridge[115]

3D printing (also called additive manufacturing) is the process of making an object by depositing material, one tiny layer at a time.[116] Additive manufacturing processes have been widely limited by slow printing rates, a narrow range of source materials, and small-volume product output capabilities. In 2014, Oak Ridge National Laboratory (ORNL) and Cincinnati Incorporated (CI) helped transcend these limits by developing the Big-Area Additive Manufacturing (BAAM) technology, which enabled processing rates 500 times faster and build volumes 100 times larger than those of state-of-the-art commercial printing systems—with less material and energy waste.[117]

In 2014 Oak Ridge National Laboratory designed and produced the world's first 3D-printed car (a full-scale Shelby Cobra), with partners Local Motors and Cincinnati Incorporated. In 2016, it earned a Guinness World Record for the world's largest solid 3D-printed item, a trim-and-drill tool for evaluation by The Boeing Company. Oak Ridge has also printed vehicles, buildings, heavy machinery, and even a submersible.[118]

Link: https://www.ornl.gov/blog/moving-future-3d-printing

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[114] From *3D Printed Tool for Building Aircraft Achieves Guinness World Records Title*, Oak Ridge National Laboratory, 2016, https://www.ornl.gov/news/3d-printed-tool-building-aircraft-achieves-guinness-world-records-title

[115] From *Moving Into the Future with 3D Printing*, Oak Ridge National Laboratory, 2018, https://www.ornl.gov/blog/moving-future-3d-printing

[116] From *How 3D Printers Work*, Department of Energy, 2014, https://www.energy.gov/articles/how-3d-printers-work

[117] From *Success Stories: Development of BAAM System Spurs Birth of an Industry*, Department of Energy, 2019, https://www.energy.gov/technologytransitions/articles/development-baam-system-spurs-birth-industry

[118] From *Moving Into the Future with 3D Printing*, Oak Ridge National Laboratory, 2018, https://www.ornl.gov/blog/moving-future-3d-printing

MEASURED EVOLUTION OF THE UNIVERSE

Year: 2019 (survey completed)[119]

Laboratories Involved: Argonne, Fermi, Lawrence Berkeley[120]

Ordinary matter makes up just 5 percent of the universe; the remaining 95 percent is made of dark matter and dark energy. The Dark Energy Survey (DES), led by Fermilab, analyzes data obtained with one of the world's largest digital cameras to investigate the nature of dark energy. With their 570-megapixel Dark Energy Camera, which is mounted on the 4-meter Blanco telescope in Chile, DES scientists surveyed about 300 million galaxies in the southern sky, completing data-taking in 2019.[121]

The Dark Energy Camera is one of the most powerful astronomical survey instruments of its kind: In each snapshot, it is able to capture the light from more than 100,000 galaxies up to 8 billion light-years away,[122] to produce the most precise measurements of the universe's composition and growth to date.[123] DES scientists also spotted the first visible counterpart of gravitational waves ever detected, a collision of two neutron stars that occurred 130 million years ago.[124]

Link: https://news.fnal.gov/2021/05/dark-energy-survey-releases-most-precise-look-at-the-universes-evolution/

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[119] From *Dark Matter and Dark Energy*, Fermi National Accelerator Laboratory, https://www.fnal.gov/pub/science/particle-physics/experiments/dark-matter-and-dark-energy.html
[120] From *Dark Energy Survey: Collaboration and Sponsors*, Fermi National Accelerator Laboratory, https://www.darkenergysurvey.org/collaboration-and-sponsors/
[121] From *Dark Matter and Dark Energy*, Fermi National Accelerator Laboratory, https://www.fnal.gov/pub/science/particle-physics/experiments/dark-matter-and-dark-energy.html
[122] From *Dark Matter and Dark Energy*, Fermi National Accelerator Laboratory, https://www.fnal.gov/pub/science/particle-physics/experiments/dark-matter-and-dark-energy.html
[123] From *Dark Energy Survey Releases the Most Precise Look at the Universe's Evolution*, Fermi National Accelerator Laboratory, 2021, https://news.fnal.gov/2021/05/dark-energy-survey-releases-most-precise-look-at-the-universes-evolution/
[124] From *Dark Matter and Dark Energy*, Fermi National Accelerator Laboratory, https://www.fnal.gov/pub/science/particle-physics/experiments/dark-matter-and-dark-energy.html

ACHIEVED FUSION IGNITION

Year: 2022[125]

Laboratories Involved: Lawrence Livermore[126]

A team at Lawrence Livermore National Laboratory (LLNL)'s National Ignition Facility (NIF) conducted the first controlled fusion experiment in history to reach the ignition milestone, also known as scientific energy breakeven, meaning it produced more energy from fusion than the laser energy used to drive it. LLNL's experiment surpassed the fusion threshold by delivering 2.05 megajoules (MJ) of energy to the target, resulting in 3.15 MJ of fusion energy output, demonstrating for the first time a most fundamental science basis for inertial fusion energy (IFE).

Many advanced science and technology developments are still needed to achieve simple, affordable IFE to power homes and businesses, and DOE is currently restarting a broad-based, coordinated IFE program in the United States. Combined with private-sector investment, there is a lot of momentum to drive rapid progress toward fusion commercialization.[127]

Link: https://www.energy.gov/articles/doe-national-laboratory-makes-history-achieving-fusion-ignition

[125] From *DOE National Laboratory Makes History by Achieving Fusion Ignition,* Department of Energy, 2022, https://www.energy.gov/articles/doe-national-laboratory-makes-history-achieving-fusion-ignition
[126] From *DOE National Laboratory Makes History by Achieving Fusion Ignition,* Department of Energy, 2022, https://www.energy.gov/articles/doe-national-laboratory-makes-history-achieving-fusion-ignition
[127] From *DOE National Laboratory Makes History by Achieving Fusion Ignition,* Department of Energy, 2022, https://www.energy.gov/articles/doe-national-laboratory-makes-history-achieving-fusion-ignition