75 BREAKTHROUGHS

BY THE U.S. DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES

2017

MADE IN USA

75 BREAKTHROUGHS

By America's National Laboratories

U.S. DEPARTMENT OF ENERGY

AMES LABORATORY
Creating Materials & Energy Solutions

Argonne NATIONAL LABORATORY

BROOKHAVEN NATIONAL LABORATORY

Fermilab

INL Idaho National Laboratory

Jefferson Lab
Thomas Jefferson National Accelerator Facility

BERKELEY LAB
Lawrence Berkeley National Laboratory

Lawrence Livermore National Laboratory

Los Alamos NATIONAL LABORATORY

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

PPPL PRINCETON PLASMA PHYSICS LABORATORY

Sandia National Laboratories

SLAC NATIONAL ACCELERATOR LABORATORY

SRNL

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AMERICA'S NATIONAL LABORATORIES . . .

have been changing and improving the lives of millions of people for more than 75 years. Born at a time when the world faced a dire threat, the laboratories came together to advance science, safeguard the nation and protect our freedoms for generations to come. This network of Department of Energy Laboratories has grown into 17 facilities, working together as engines of prosperity and invention. As this list of breakthroughs attests, Laboratory discoveries have spawned industries, saved lives, generated new products, fired the imagination and helped to reveal the secrets of the universe. Rooted in the need to serve the public good and support the global community, the National Laboratories have put an American stamp on the last century of science. With equal ingenuity and tenacity, they are now engaged in innovating the future.

At America's National Laboratories, we've. . .

Advanced supercomputing

The National Labs operate some of the most significant high performance computing resources available, including 32 of the 500 fastest supercomputers in the world. These systems, working at quadrillions of operations per second, model and simulate complex, dynamic systems – such as the nuclear deterrent – that would be too expensive, impractical or impossible to physically demonstrate. Supercomputers are changing the way scientists explore the evolution of our universe, climate change, biological systems, weather forecasting and even renewable energy.

Decoded DNA

In 1990, the National Labs joined with the National Institutes of Health and other laboratories to kick off the Human Genome Project, an international collaboration to identify and map all of the genes of the human genome.

Brought the web to the United States

National Lab scientists, seeking to share particle physics information, were first to install a web server in North America, kick-starting the development of the worldwide web as we know it.

Put eyes in the sky

Vela satellites, first launched in 1963 to detect potential nuclear detonations, transformed the nascent U.S. space program. The satellites featured optical sensors and data processing, logic and power subsystems designed and created by National Labs.

Revolutionized medical diagnostics and treatment

Researchers at the National Labs helped to develop the field

of nuclear medicine, producing radioisotopes to diagnose and treat disease, designing imaging technology to detect cancer and developing software to target tumors while sparing healthy tissue.

Powered NASA spacecraft

The National Labs built the enclosure for the radioisotope thermoelectric generators that fuel crafts such as Cassini and have begun producing plutonium- 238 for future NASA missions.

Harnessed the power of the atom

National Lab scientists and engineers have led the world in developing safe, efficient and emissions-free nuclear power. Starting with the first nuclear reactor to generate electricity, National Labs have been the innovation engine behind the peaceful use of nuclear energy. Today's labs are supporting the next generation of nuclear power that will be available for the nation and world.

Brought safe water to millions

Removing arsenic from drinking water is a global priority. A long-lasting particle engineered at a National Lab can now do exactly that, making contaminated water safe to drink. Another technology developed at a National Lab uses ultraviolet light to kill water-borne bacteria that cause dysentery, thus reducing child mortality in the developing world.

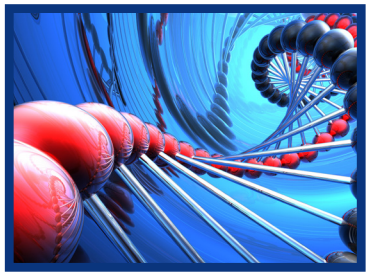
Filled the Protein Data Bank

National Lab X-ray facilities have contributed a large portion of more than 100,000 protein structures in the Protein Data Bank. A protein's structure reveals how it functions, helping scientists understand how living things work and develop treatments for disease. Almost all new medications that hit the market start with these data bank structures.

Invented new materials

National Labs provide the theory, tools and techniques that offer industry revolutionary materials such as strong, lighter-weight metals and alloys that save fuel and maintenance costs and enable cleaner, more efficient engines.

Found life's mystery messenger

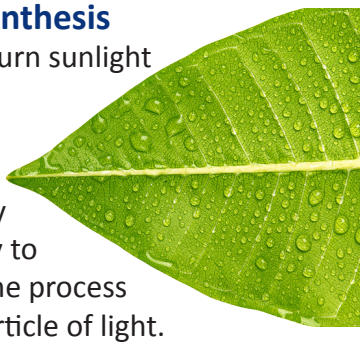


National Lab scientists discovered how genetic instructions are carried to the cell's protein manufacturing center, where all of life's processes begin. Subsequent light source research on the genetic courier, called messenger RNA, has revealed how the information is transcribed and how mistakes can cause cancer and birth defects.

Mapped the universe — and the dark side of the moon

Credit for producing 3D maps of the sky — and 400 million celestial objects — goes to National Lab scientists, who also developed a camera that mapped the entire surface of the moon.

Shed light on photosynthesis



Ever wonder how plants turn sunlight into energy? National Lab scientists determined the path of carbon through photosynthesis, and today use X-ray laser technology to reveal how each step in the process is triggered by a single particle of light. This work helps scientists explore new ways to get sustainable energy from the sun.

Solved cultural mysteries

The works of ancient mathematician Archimedes — written over by medieval monks and lost for millennia — were revealed to modern eyes thanks to the X-ray vision and light-source technology at National

Labs. These studies also have revealed secrets of masterpiece paintings, ancient Greek vases and other priceless cultural artifacts.

Revolutionized accelerators

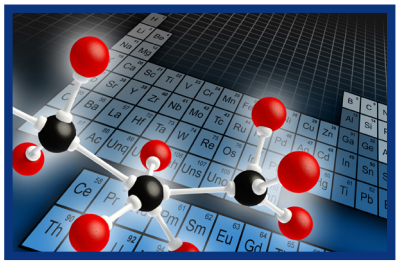
A National Lab built and operated the first large-scale accelerator based on superconducting radio frequency technology. This more efficient technology now powers research machines for exploring the heart of matter, examining the properties of materials and providing unique information about the building blocks of life.

Revealed the secrets of matter

Protons and neutrons were once thought to be indivisible. National Lab scientists discovered that protons and neutrons were made of even smaller parts, called quarks. Over time, experimenters identified six kinds of quarks, three types of neutrinos and the Higgs particle, changing our view of how the material world works.

Confirmed the Big Bang and discovered dark energy

National Lab detectors aboard a NASA satellite revealed the birth of galaxies in the echoes of the Big Bang. Dark energy — the mysterious something that makes up three-quarters of the universe and causes it to expand at an accelerating rate — also was discovered by National Lab cosmologists.



Discovered 22 elements

The periodic table would be smaller without the National Labs. To date the National Labs have discovered: technetium, promethium, astatine, neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, lawrencium, rutherfordium, dubnium, seaborgium, flerovium, moscovium, livermorium, tennessine and oganesson.

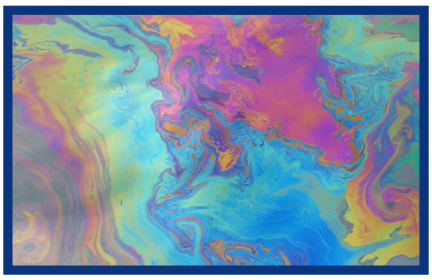
Made refrigerators cool

Next-generation refrigerators will likely put the freeze on harmful chemical coolants in favor of an environmentally friendly alloy, thanks to National Lab scientists.

Got the lead out

Removing hazardous lead-based solders from the environment is a reality thanks to a lead-free alloy of tin-silver-copper developed at a National Lab. The lead-free solder has been licensed by more than 60 companies worldwide.

Invented a magic sponge to clean up oil spills



National Lab scientists used a nano technique to invent a new sponge that can absorb 90 times its own weight in oil from water. It can be wrung out to collect the oil and reused hundreds of times — and it can collect oil that has sunk below the surface, something previous technology couldn't do.

Added the punch to additive manufacturing

High-pressure gas atomization processing pioneered at a National Lab made possible the production of titanium and other metal-alloy powders used in additive manufacturing and powder metallurgy.

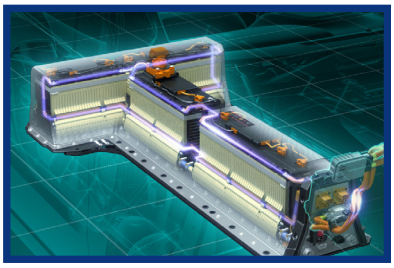
Created inexpensive catalysts

Low-cost catalysts are key to efficient biomass

refining. National Lab scientists created catalysts that are inexpensive and stable for biomass conversion.

Created high-tech coatings to reduce friction

National Lab scientists created ways to reduce wear and tear in machines from table fans to car engines all the way up to giant wind turbines, such as a diamond-like film that rebuilds itself as soon as it begins to break down — so that engines last longer and need fewer oil additives.



Put the jolt in the Volt

Chevy's Volt would not be able to cruise on battery power were it not for the advanced cathode technology that emerged from a National Lab. The same technology is sparking a revival of America's battery manufacturing industry.

Cemented a new material

National Lab scientists have developed a novel and versatile material that blends properties of ceramic and concrete to form a non-porous product that can do everything from seal oil wells to insulate walls with extra fire protection. It even sets in cold weather.

Pioneered efficient power lines

New kinds of power lines made from superconductors can carry electric current with no energy loss. Now deployed by National Lab scientists, these prototypes could usher in a new era of ultra-efficient power transmission.

Made early universe quark soup

National Lab scientists used a particle collider to recreate the primordial soup of subatomic building blocks that last existed shortly after the Big Bang. The research is expanding scientists' understanding of matter at extreme temperatures and densities.

Levitated trains with magnets

Say goodbye to traffic jams. National Lab scientists developed a technology that uses the attractive and repulsive forces of magnets to levitate and propel trains. Maglev trains now ferry commuters in Japan and China and will be operational in other countries soon.

Developed efficient burners

National Lab researchers developed cleaner-combusting oil burners, saving consumers more than $25 billion in fuel costs and keeping more than 160 megatons of carbon dioxide out of Earth's atmosphere.

Improved automotive steel

A company with National Lab roots is pioneering a metal that weighs significantly less than regular steel, retains steel's strength and malleability and can be fabricated without major modifications to the automotive manufacturing infrastructure.

Looked inside weapons

National Lab researchers created a device that could identify the contents of suspicious chemical and explosive munitions and containers, while minimizing risk to the people involved. The technology, which quickly identifies the chemical makeup of weapons, has been used to verify treaties around the world.

Pioneered nuclear safety modeling

National Lab scientists began developing the Reactor Excursion and Leak Analysis Program

(RELAP) to model nuclear reactor coolant and core behavior. Today, RELAP is used throughout the world and has been licensed for both nuclear and non-nuclear applications, including modeling of jet aircraft engines and fossil-fuel power plant components.

Identified good and bad cholesterol

The battle against heart disease received a boost in the 1960s when National Lab research unveiled the good and bad sides of cholesterol. Today, diagnostic tests that detect both types of cholesterol save lives.

Unmasked a dinosaur killer

Natural history's greatest whodunit was solved in 1980 when a team of National Lab scientists pinned the dinosaurs' abrupt extinction on an asteroid collision with Earth. Case closed.

Pitted cool roofs against carbon dioxide

National Lab researchers and policy experts led the way in analyzing and implementing cool roofing materials, which reflect sunlight, lower surface temperature and slash cooling costs.

Squeezed fuel from microbes

In a milestone that brings advanced biofuels one step closer to America's gas tanks, National Lab scientists helped develop a microbe that can produce fuel directly from biomass.

Tamed hydrogen with nanoparticles

To replace gasoline, hydrogen must be safely stored and easy to use, which has proven elusive. National Lab researchers have now designed a new pliable material using nanoparticles that can rapidly absorb and release hydrogen without ill effects, a major step in making fuel-cell powered cars a commercial reality.

Exposed the risk

You can sleep easier thanks to National Lab research that quantified the health risk posed by radon gas in parts of the country. Subsequent EPA standards, coupled with radon detection and mitigation measures pioneered by a National Lab research team, prevent the naturally occurring gas from seeping into basements, saving thousands of lives every year.

Created a pocket-sized DNA sampler

A tool that identifies the microbes in air, water and soil samples is fast becoming a workhorse in public health, medical and environmental cleanup projects. Developed by National Lab scientists, the credit-card-sized device pinpoints diseases that kill coral reefs and catalogs airborne bacteria over U.S. cities. It also was used to quickly categorize the oil-eating bacteria in the plumes of the Deepwater Horizon spill.

Fabricated the smallest machines

The world's smallest synthetic motors — as well as radios, scales and switches that are 100,000 times finer than a human hair — were engineered at a National Lab. These and other forays into nanotechnology could lead to life-saving pharmaceuticals and more powerful computers.

Preserved the sounds of yesteryear

National Lab scientists engineered a high-tech way to digitally reconstruct aging sound recordings that are too fragile to play, such as Edison wax cylinders from the late 1800s. Archivists estimate that many of the millions of recordings in the world's sound archives, including the U.S. Library of Congress, could benefit from the technology.

Exposed explosives

A credit-card sized detector developed by National Lab scientists can screen for more than 30 kinds of explosives in just minutes. The detector, called ELITE, requires no power and is widely used by the military, law enforcement and security personnel.

Toughened airplanes

A National Lab and industry technique for strengthening metal by bombarding it with laser pulses has saved the aircraft industry hundreds of millions of dollars in engine and aircraft maintenance expenses.

Simulated reality

Trains, planes and automobiles — and thousands of other objects — are safer, stronger and better-designed thanks to computer simulation software, DYNA 3D, developed by National Lab researchers.

Detected the neutrino

Starting with the Nobel-Prize winning discovery of the neutrino in 1956 by Fred Reines and Clyde Cowan Jr., National Lab researchers have made numerous contributions to neutrino physics and astrophysics.

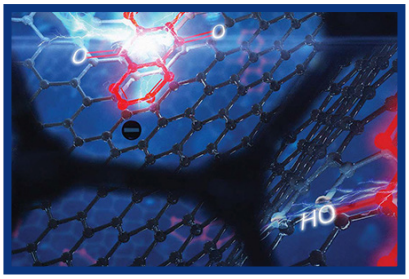
Discovered gamma ray bursts

Sensors developed at the National Labs and placed aboard Vela satellites were used in the discovery of gamma-ray bursts (GRBs) in 1973. GRBs are extremely energetic explosions from distant galaxies. Scientists believe that most of these bursts consist of a narrow beam of intense radiation released when a rapidly rotating, high-mass star collapses to form a neutron star, a quark star or a black hole.

Created the first 100-Tesla magnetic field

National Lab scientists achieved a 100.75-Tesla magnetic pulse in March 2012, setting a world record. The pulse was nearly 2 million times more powerful than Earth's magnetic field. The 100-Tesla multi-shot magnet can be used over and over again without being destroyed by the force of the field it creates, and produces the most powerful non-destructive magnetic field in the world.

Froze smoke for hot uses



National Labs researchers perfected aerogels, known as frozen smoke. They are one of the lightest solids ever made and have the highest heat resistance of any material tested. They also are fireproof and extraordinarily strong — able to support more than a thousand times their own weight. As a result of their heat resistance, aerogels are outstanding candidates for insulation in buildings, vehicles, filters and appliances.

Invented the cell sorter

During the 1960s, a National Lab physicist invented a "cell sorter" — a novel device that works much like an ink jet printer, guiding a tiny flow of cell-containing droplets so cells of interest can be deflected for counting and study. Cell sorters are a vital tool for studying the biochemistry behind many diseases, including cancer and AIDS.

Ushered a domestic energy renaissance

National Lab research jump-started the shale gas revolution by pointing the way to key technologies and methodologies for cost efficient extraction. An estimated $220 million in research and development expenditures on unconventional gas R&D from 1976 to 1992 have resulted in an estimated $100 billion in annual economic activity from shale gas production alone.

Enabled space exploration

National Labs invented Laser-Induced Breakdown Spectroscopy (LIBS), the backbone of the device that allowed the Curiosity Rover to analyze material from Mars. Lab researchers also found the right combination of materials to make high-efficiency solar cells for spacecraft.

Sharply curtailed power plant air emissions

National Lab scientists introduced some 20 innovative technologies — such as low nitrogen oxide (NOx) burners, flue gas desulfurization (scrubbers) and fluidized bed combustion — through the Clean Coal Technology Development Program that have deeply penetrated the marketplace, substantially controlled harmful power plant emissions and benefited energy production and air quality.

Made wind power mainstream

Increasing wind turbine efficiency with high efficiency airfoils has reduced the cost of wind power by more than 80 percent over the last 30 years. Now deployed in wind farms nationwide, these turbines owe their existence to National Lab research.

Engineered smart windows

National Lab scientists have created highly insulated windows that change color to modulate interior temperatures and lighting. If broadly installed, they could save about 5 percent of the nation's total energy budget.

Delivered troops safely

National Lab researchers have developed computer models that effectively manage the complex logistical tasks of deploying troops and equipment to distant destinations.

Channeled chips and hips

Integrated circuits and artificial hips owe their success to a National Lab discovery that revealed how to change a material by injecting it with charged atoms, called ions. Ion channeling is now standard practice in industry and science.

Made 3D printing bigger and better

A large-scale additive manufacturing platform developed by a National Lab and an industry partner printed 3D components 10 times larger and 200 times faster than previous processes. So far, the system has produced a 3D-printed sports car, SUV, house, excavator and aviation components.

Purified vaccines

National Lab researchers adapted nuclear separations technology to develop a zonal centrifuge used to purify vaccines, which reduces or eliminates unwanted side effects. Commercial centrifuges based on the invention produce vaccines for millions of people.

Built a better building

A National Lab has built one of the world's most energy efficient office buildings. The facility, operating as a living laboratory at a lab site, uses 50

percent less energy than required by commercial codes and only consumes energy produced by renewable power on or near the building.

Improved airport security

Weapons, explosives, plastic devices and other concealed tools of terrorists are easier to detect thanks to technology developed at a National Lab and now installed in airports worldwide.

Improved grid resiliency

A National Lab created an advanced battery that can store large amounts of energy from intermittent renewable sources — such as wind and solar — onto the power grid, while also smoothing over temporary disruptions to the grid. Several companies have licensed the technology and offer it as a commercial product.

Solved a diesel dilemma

A National Lab insight into how catalysts behave paved the way for a new, "lean-burn" diesel engine that met emissions standards and improved fuel efficiency by 25 percent over conventional engines.

Harvested energy from air

A miniature device — commercialized by private industry after a National Lab breakthrough — generates enough power from small temperature changes to power wireless sensors or radio frequency transmitters at remote sites, such as dams, bridges and pipelines.

Gone grid friendly

Regulating the energy use of household appliances — especially at peak times — could slash energy demand and avoid blackouts. A National Lab appliance-control device senses grid stress and responds instantly to turn off machines and reduce end-use demand, balancing the system so that the power stays on.

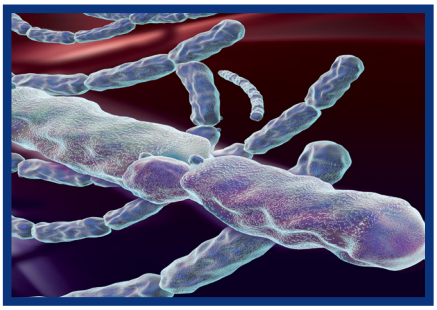
Put the digital in DVDs

The optical digital recording technology behind music, video and data storage originated at a National Lab nearly 40 years ago.

Locked nuclear waste in glass

Disposal of U.S. Cold War waste is safer thanks to National Lab scientists who developed and deployed a process to lock it into glass to keep it from leaching into the environment.

Cleaned up anthrax



Scientists at a National Lab developed a non-toxic foam that neutralizes chemical and biological agents. This foam was used to clean up congressional office buildings and mail rooms exposed to anthrax in 2001.

Removed radiation from Fukushima seawater

After a tsunami damaged the Fukushima Daiichi nuclear power plant in 2011, massive amounts of seawater cooled the reactor. A molecular sieve engineered by National Lab scientists was used to extract radioactive cesium from tens of millions of gallons of seawater.

Sped up Ebola detection

In 2014, researchers from a National Lab modeled the Liberian blood sample transport system and made recommendations to diagnose patients quicker. This minimized the amount of time people were waiting together, reducing the spread of Ebola.

Prevented unauthorized use of a nuclear weapon

In 1960, National Lab scientists invented coded electromechanical locks for all U.S. nuclear weapons. The switch blocks the arming signal until it receives the proper presidential authorization code.

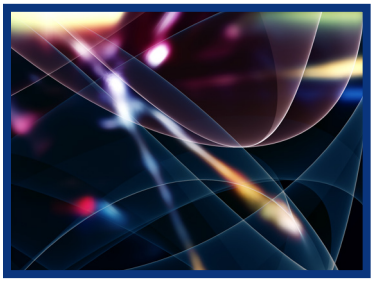
Launched the LED lighting revolution

In the 1990s, scientists at a National Lab saw the need for energy-efficient solid-state lighting and worked with industry to develop white LEDs. Today, white LEDs are about 30 percent efficient, with the potential to reach 70 percent to 80 percent efficiency. Fluorescent lighting is about 20 percent efficient and incandescent bulbs are 5 percent.

Mastered the art of artificial photosynthesis

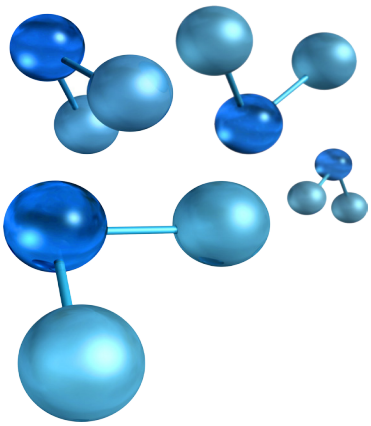
National Lab scientists engineered and synthesized multi-layer semiconductor structures in devices that directly convert sunlight to chemical energy in hydrogen by splitting water at efficiencies greater than 15 percent. This direct conversion of sunlight to fuels paves the way for use of solar energy in applications beyond the electrical grid.

Advanced fusion technology



From the first fusion test reactor to briefly produce power at the megawatt scale, and the world's largest and most energetic laser creating extreme conditions mimicking the Big Bang, the interiors of planets and stars and thermonuclear weapons, to the international experiment to generate industrial levels of fusion energy from burning plasmas, fusion science and applications are advancing because of the National Labs.

Made the first molecular movie



National Lab scientists have used ultrafast X-rays to capture the first molecular movies in quadrillionths-of-a-second frames. These movies detail the intricate structural dances of molecules as they undergo chemical reactions.

The National Laboratory System

Protecing America Through Science and Technology

U.S. DEPARTMENT OF ENERGY

For more than 75 years, the Department of Energy's national laboratories have solved important problems in science, energy and national security. This expertise keeps our nation at the forefront of science and technology in a rapidly changing world. Partnering with industry and academia, the laboratories also drive innovation to advance economic competitiveness and ensure our nation's future prosperity.

Ames Laboratory
Ames, Iowa

Argonne National Laboratory
Argonne, Illinois

Brookhaven National Laboratory
Upton, New York

Fermi National Accelerator Laboratory
Batavia, Illinois

Idaho National Laboratory
Arco, Idaho

Lawrence Berkeley National Laboratory
Berkeley, California

Lawrence Livermore National Laboratory
Livermore, California

Los Alamos National Laboratory
Los Alamos, New Mexico

National Energy Technology Laboratory
Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania

National Renewable Energy Laboratory
Golden, Colorado

Oak Ridge National Laboratory
Oak Ridge, Tennessee

Pacific Northwest National Laboratory
Richland, Washington

Princeton Plasma Physics Laboratory
Princeton, New Jersey

Sandia National Laboratory
Albuquerque, New Mexico

Savannah National Laboratory
Aiken, South Carolina

SLAC National Accelerator Laboratory
Menlo Park, California

Thomas Jefferson National Accelerator Facility
Newport News, Virginia