How ORNL isotopes enhance our nation's security

(As published in The Oak Ridger's Historically Speaking column the week of June 29, 2026)

Carolyn Krause and I recently heard a fascinating talk on important radioisotopes and stable isotopes produced at Oak Ridge National Laboratory. Jeremy T. Busby, associate laboratory director for the Isotope Science and Enrichment Directorate (ISED) at ORNL, spoke to Friends of ORNL on "Isotopes: Vital to U.S. Success." His talk mentioned some history of the lab's isotope production and research, as well as current achievements.

At my request Carolyn conducted some additional research by delving into websites to learn more about the fascinating history and significance of certain ORNL-produced isotopes. ISED has fact-checked her series of three articles for this column to ensure its accuracy and clarity. ORNL has provided photos as well.

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Airport security in the United States and Western countries has improved immensely because of nickel-63, a radioisotope produced in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory. Nickel-63 enables the detection of traces of explosives on skin and in baggage.

"We're the only producer of nickel-63 for the Western world," said Jeremy T. Busby, associate laboratory director for the Isotope Science and Enrichment Directorate (ISED) at ORNL, in his recent talk to Friends of ORNL titled "Isotopes: Vital to U.S. Success."

Nickel-63 is produced by placing targets of stable nickel-62 into the HFIR. There they are bombarded with neutrons for several months to create the radioactive nickel-63 required for the explosive trace detectors (ETDs) used in airports all over the world, according to a 2011 ORNL news release.

Following the development and commercialization of ion mobility spectrometry devices based on a discovery in 1970 by two scientists at a company in West Palm Beach, Florida, airports began deploying ETDs that use nickel-63 for security screening in the late 1980s and early 1990s.

After the "shoe bomber" incident in 2001 and the "underwear bomber" incident in 2009, the deployment of nickel-63 trace detectors rose dramatically worldwide, deterring terrorist incidents that could lead to the destruction of planes, pilots and passengers while endangering national security.

A single successful attack can shut down global trade and travel for days, causing billions of dollars in damage to the economies of countries that depend on the safe, uninterrupted flow of air travel. Security agencies can use data on the presence of explosives at airports to trace the source of the explosive material. The information might enable security agents to find a larger terror cell or a clandestine manufacturing lab before they cause major damage.

After mass deployment of ETDs, no successful explosive-based hijacking has occurred in the United States, according to the U.S. Transportation Security Administration. ETDs are also used by U.S. Customs and Border Protection agents to detect persons carrying narcotics across international borders.

How do ETDs work? An airport security officer swabs a person's skin and surface of the individual's bag to collect microscopic chemical residue. The swab is inserted into the ETD, the collected residue is heated, and the resultant gas is passed through a chamber containing radioactive nickel-63.

This "beta emitter" releases low-energy electrons as it decays. The electrons initially ionize the gas, creating a constant current. If the residue comes from an explosive or narcotic, it eventually captures the constantly released nickel-63 electrons, causing a sharp drop in the measurable electric current. If the signature of the decreased current matches one of the chemical signatures for explosive or drug residues in the ETD's library, an alarm is triggered.

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Ytterbium-171 for quantum devices. ORNL is producing ytterbium-171, the "superstar" isotope for making quantum computers, quantum sensors and quantum networking devices. Ytterbium-171 is a stable isotope produced using electromagnetic separation at ORNL.

It is separated from another of the seven different isotopes in naturally occurring ytterbium. Using neutron irradiation, HFIR has converted one ytterbium isotope (ytterbium-176) into lutetium-177 for cancer treatment.

To obtain "pure" ytterbium-171 for quantum applications, lab staff separate it from ytterbium-172 using ORNL-improved electromagnetic isotope separators, which are smaller and more efficient than the calutrons used in Oak Ridge during World War II. Electrically charged atoms (ions) of the two isotopes are shot through a powerful magnetic field.

Because the atomic nuclei of the two isotopes have a slightly different mass, they take different curved paths in the magnetic field and end up in collectors spaced a small distance apart. That's how ORNL staff catch ytterbium-171 in useful amounts for use in research labs at ORNL and universities such as Harvard and Princeton.

Because of its unique nuclear spin, the neutral ytterbium-171 atomic nucleus has only two energy levels when cooled to its lowest energy state; these quantum levels correspond to the 0 or 1 representing the smallest piece of data that are each stored in "off" and "on" switches in classical computers like the Frontier supercomputer at ORNL. The qubit (quantum bit) is encoded in the nuclear spin rather than the electrons.

Ytterbium-171 nuclei can be either aligned against an external magnetic field (spin down, or the 0 state) or aligned with the magnetic field (spin up, or the 1 state). A pulse of laser light striking an ytterbium nucleus can make it spin in both directions at once, enabling quantum computers to perform massive calculations simultaneously.

In a quantum computer, ytterbium-171 atoms are one of the most stable candidates for making qubits because the nucleus is tiny and buried deep inside the atom. As a result, it is naturally shielded from external environmental threats to its stability, such as stray magnetic fields, noise and heat.

National security benefits of quantum applications using ytterbium-171 are believed to be cybersecurity (protecting classified intelligence and financial data from being hacked); battlefield operations (navigating in jammed areas without the benefit of GPS from satellites); military intelligence (finding hidden submarines and underground facilities by detecting tiny shifts in magnetic fields and gravity) and materials research that simulates molecules at a quantum level, potentially leading to the development of stronger armor and faster jet engines.

Improved enrichment technology for national defense. The U.S. Navy predicts that its supply of highly enriched uranium (HEU) –uranium fuel with a concentration of over 90% fissionable uranium-235 – will run out in the late 2040s. Its current supply is a finite stockpile of Cold War-era uranium including that stored at the Y-12 National Security Complex in Oak Ridge. The U.S. military is forbidden under international treaties to use uranium or enrichment technology imported from other countries for any use other than peaceful purposes.

Because the Navy will need domestic enriched uranium in two decades, ORNL is currently leading a high-stakes national security project in which its staff are building and testing a new generation of gas centrifuge machines they have developed. The smaller, modular centrifuges were designed using classified DUECE (Domestic Uranium Enrichment Centrifuge Experiment) technology.

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ORNL is partnering with BWXT Enrichment Operations in Oak Ridge to prove that DUECE technology can work at scale to make both low enriched uranium (LEU) and highly enriched uranium (HEU) for national defense. ORNL, which began development of the new centrifuge technology in 2016, is testing a cascade of DUECE centrifuges on its campus.
BWXT has constructed a building in the Horizon Center Industrial Park in Oak Ridge that will house the nation’s first advanced centrifuge manufacturing development facility. ORNL staff will work with employees at the BWXT pilot plant to demonstrate mass production of small centrifuges based on DUECE.

BWXT will later build a larger pilot plant in Erwin, Tennessee, for producing domestic LEU to fuel a reactor in a nearby nuclear power plant that will be used to generate tritium in neutron-bombarded rods containing lithium. Tritium is used to make highly explosive thermonuclear warheads for missiles.

Later, the BWXT centrifuge system will be “repurposed” to produce the domestic HEU required to fuel the small nuclear reactors BWXT makes to propel and provide power for the Navy’s missile-carrying submarines and aircraft carriers.

ORNL started out with a mission to support the national defense during World War II. Now, it still focuses mainly on research to solve difficult national problems during peacetime. But it will respond to any new challenges to maintaining our nation’s defense.

ORNL is now supporting the current goal to re-establish the United States’ ability to produce for the U.S. military “unobligated” enriched uranium – nuclear fuel produced using only 100% American technology and parts. ORNL is the largest source of isotopes made in America.

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Thanks, Carolyn. This has been an excellent series to bring insights into nuclear medicine and other uses of radioisotopes produced at ORNL over the years and even a look at today and the future of isotope production.

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Jeremy Busby, ORNL associate laboratory director for the Isotope Science and Enrichment Directorate (Courtesy of Carolyn Krause)

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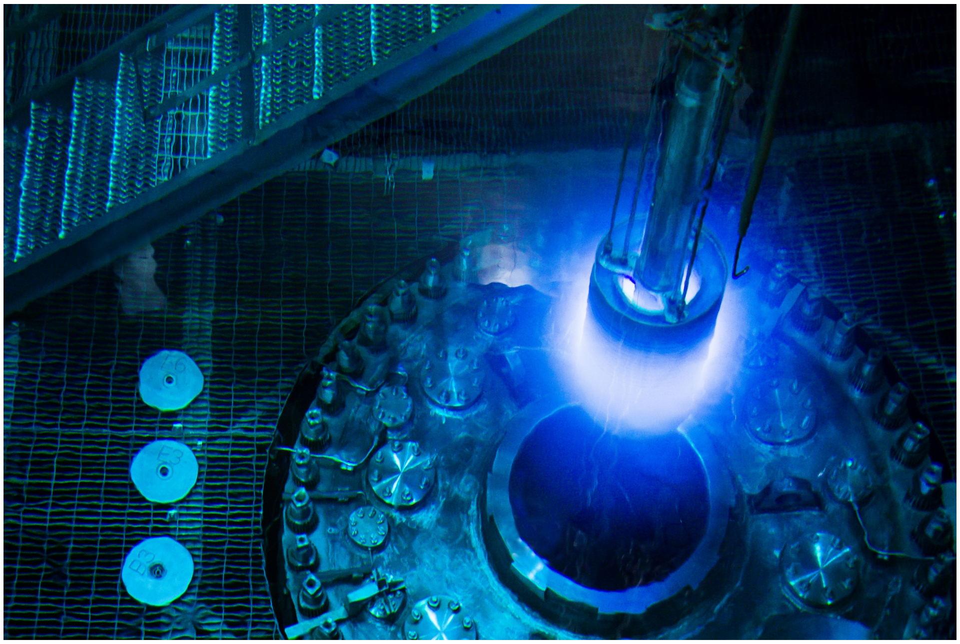

The High Flux Isotope Reactor at Oak Ridge National Laboratory is the highest flux reactor-based source of neutrons for research in the United States and produces a wide variety of isotopes for medical, industrial, and space related applications (Courtesy of ORNL)