## Isotope R&D and Production

### Overview

The mission of the DOE Isotope Program (DOE IP) is to:

- Produce and/or distribute stable isotopes and radioisotopes that are in short supply or unavailable in the U.S., including related isotope services.
- Maintain mission readiness of critical national infrastructure and core competencies needed to manufacture isotopes and ensure national preparedness to respond to gaps in supply chains during times of national emergency.
- Conduct research and development (R&D) to develop transformative isotope production, separation, and enrichment technologies to enable federal, academic, and industrial innovation, research, and emerging technologies. Nurture a diverse and inclusive domestic workforce with unique and world-leading core competencies.
- Mitigate U.S. dependence on foreign supplies of isotopes and promote robust domestic supply chains for U.S. economic resilience.

The DOE IP produces high priority radioactive and stable isotopes in short supply for the Nation that no domestic entity has the infrastructure or core competency to meet market demand. The Program is typically the only, or one of few, global or domestic producers for these novel isotopes. Isotopes are high-priority and often rare commodities of strategic importance for the Nation and are essential in medical diagnosis and treatment, discovery science, national security, advanced manufacturing, space exploration and communications, biology, quantum information science, clean energy, climate and environmental science, archaeology, and other fields. Isotopes can directly enable emerging technology, and contribute to the economic, technical, and scientific strength of the United States.

The DOE IP utilizes particle accelerators, research nuclear reactors, modern isotope enrichment capabilities, and radiochemical processing infrastructure throughout the DOE National Laboratory complex and at universities to employ and nurture domestic capabilities to meet national isotope demand. Throughout the COVID-19 pandemic, the DOE IP continued operating as a Department "Mission Essential Function" to ensure isotope availability for a broad suite of applications and intervened multiple times to prevent disruptions in supply chains of critical medical isotopes. The DOE IP works closely with U.S. industry to ensure availability of needed isotopes for their continued stability and planned growth and facilitates commercialization of isotope production to the domestic private sector. The DOE IP supports a world-leading R&D program in innovative isotope production, enrichment, and separations. Isotope manufacturing and R&D activities provide collateral benefits for training and workforce development, and promotion of a future U.S.-based expertise relevant to clean energy, accelerator science, nuclear engineering, nuclear physics, isotope enrichment, and radiochemistry. These disciplines are foundational, not only to isotope production and processing, but underpin many essential aspects of basic and applied nuclear and radiochemical science. Research and production activities develop and employ techniques and platform technologies in artificial intelligence (AI), machine learning (ML), robotics, and advanced manufacturing.

The DOE IP manages federal inventories of isotopes, such as helium-3 for cryogenics, quantum information science (QIS), and national security; Russia is the other major producer of helium-3. The DOE IP is also responsible for the national repository of all stable isotopes that were created by the calutrons (electromagnetic ion separation) developed as part of the Manhattan Project. The calutrons ceased operations in 1998, leaving the U.S. with no broad isotope enrichment capability. Russia has the largest stable isotope enrichment capability world-wide, followed by Urenco in the Netherlands, and then China, which is expanding their capabilities. The U.S. inventory of stable isotopes is limited, or has even been depleted in some cases, causing the U.S. to be dependent on foreign supply chains. The DOE IP has developed and is implementing modern stable isotope enrichment capabilities to rebuild domestic manufacturing capabilities, replenish inventories, protect American security, and promote U.S. economic resilience. The DOE IP also considers DOE-owned legacy waste or inventories and extracts isotopes of interest to re-purpose unwanted or excess materials and reduce waste disposal.

All funding for DOE IP is executed through the Isotope Production and Distribution Program revolving fund. The revolving fund maintains its financial viability by utilizing the appropriation for the Isotope R&D and Production Office, along with

collections from customers through the sale of isotopes and services. The funds in this Budget Request are used to support mission readiness of the DOE IP infrastructure, staff, and facilities; conduct innovative R&D related to the production, enrichment, and processing of isotopes; and strengthen and develop the highest priority new capabilities to meet the Nation's growing demand of isotopes. The customer collections from sales pay for the activities associated with the actual production, distribution, and related services of the isotope. Isotopes sold to commercial customers and foreign entities are priced to recover the full cost of production, or if a market exists, the market price (whichever is higher). Isotopes for domestic research are sold at a reduced price to promote innovation and scientific advances.

The National Isotope Development Center (NIDC) is located at the Oak Ridge National Laboratory (ORNL) and is responsible for the day-to-day business operations for the DOE IP, including sales, contract negotiation, marketing assessment, public outreach, quality control, packaging, and transportation. The NIDC arranges for regular and frequent interfaces between DOE IP and industrial, academic, and medical communities to ensure that strategies are evidence-based and informed by stakeholder interactions. Furthermore, the DOE IP formally canvasses the broad federal community for isotope demands every other year to align priorities with evidence-based program evaluations.

**Highlights of the FY 2023 Request**

In FY 2023, the DOE IP anticipates increased domestic demand for novel isotopes, especially for medicine, nuclear batteries, space applications, commercial applications, clean energy, national security, biology, discovery research, and quantum computing. The Program enables high priority production and chemical processing capabilities and supports mission readiness to meet high priority demands, and to reduce U.S. dependence on foreign supply chains, particularly Russia and China. The DOE IP continues to promote disaster resilience, operating as a DOE Mission Essential Function in a pandemic environment to ensure availability of isotopes for treatment and diagnosis of cancer and infectious disease, and mitigating disruptions in isotope supply chains as a result of Russian sanctions. A diverse and inclusive workforce is nurtured and trained in advanced manufacturing practices, current Good Manufacturing Practices (cGMP), AI/ML), robotics and transformative isotope enrichment, isotope production, and chemical separations. Attention is paid to promoting career opportunities for engagement in federal science and technology programs, creating jobs in underserved communities.

In FY 2023, mission readiness levels of both radio- and stable isotope production facilities are at an average 80 percent, approximately maintained relative to the FY 2022 Request. This enables the Program to produce high priority isotopes in short supply and mitigate the most critical disruptions in supply chains. On the radioisotope front, there is an effort to develop domestic supply chains of isotopes needed for nuclear batteries and space applications and to mitigate disruptions in Russian supply chains. In stable isotopes, there are global shortfalls for several stable isotope feedstocks that are needed to produce critical medical isotopes to treat and diagnose U.S. patients. These stable isotopes are currently oversubscribed from Russia and the DOE IP strives to ramp up newly established production within available funds. Efforts continue to develop new enrichment technology to promote clean energy and reduce fuel cycle costs and waste.

The FY 2023 Request includes $12.0 million in Total Estimated Cost (TEC) funding, at the same level as the FY 2022 Request, to continue the U.S. Stable Isotope Production and Research Center (SIPRC) at ORNL, which will provide large scale stable isotope production capacity for the Nation. SIPRC will build upon the expertise in gas centrifuge (GC) and electromagnetic isotope separation (EMIS) technology nurtured by the Stable Isotope Production Facility (SIPF) and the Enriched Stable Isotope Prototype Plant (ESIPP); SIPRC relieves U.S. dependence on foreign countries and supports national security and economic resilience. Support continues for the conceptual design of the proposed ORNL Radioisotope Processing Facility (RPF), to address a lack of available radiochemical processing infrastructure within the DOE IP complex to make available isotopes in short supply. Current radiochemical separations infrastructure is oversubscribed and in need of refurbishment, and while the DOE IP has the core competency to fill additional gaps in critical isotope supply chains, there is no available processing infrastructure in which to complete the production of some critical isotopes.

Funding in core research is approximately maintained to support a diverse and inclusive workforce and participation in several Office of Science initiatives increases. The DOE IP increases efforts in the SC Fundamental Science to Transform Advanced Manufacturing Initiative, pursuing innovative approaches to target manufacturing, such as ink jet printing of thin film targets for isotope production, modular automated systems for radioisotope purification and processing, and modern enrichment technology. As part of the Biopreparedness Research Virtual Environment (BRaVE) Initiative, the DOE IP increases support to tackle chemical processing of irradiated reactor targets, which has become a significant obstacle and

single point failure in the program. This is actively limiting the ability of the Program to make available certain new isotopes and provide assurance of the Nation's readiness to respond to disruptions in global isotope supply chains. This funding will develop short-term reactor target processing capabilities at the University of Missouri Research Reactor (MURR) Radioisotope Science Center (RSC). The contributions to the MURR RSC will also create jobs in an underserved community in Missouri, enabling new opportunities to become involved in federal science and technology. Critical efforts are modestly increased relative to FY 2021 Enacted in the ongoing SC Quantum Information Science (QIS) Initiative to advance the domestic production of isotopes of interest for QIS. Funding increases participation in the Reaching a New Energy Sciences Workforce (RENEW) initiative, supporting the Isotope Program Traineeship to promote innovative and transformative approaches to isotope production and processing, including advanced manufacturing, artificial intelligence and machine learning, and robotics. The Traineeship provides direct funding and emphasizes participation of minority serving institutions, increasing the diversity and equity of workforce development opportunities in the program. The DOE IP participates in two new initiatives: the Accelerate Innovations in Emerging Technologies by supporting transitional research to advance readiness of novel isotopes to preclinical and clinical medical trials; and the Funding for Accelerated, Inclusive Research (FAIR) initiative which will provide focused research investments at minority serving institutions, including attention to underserved and environmental justice regions.

The FY 2023 Request continues the Facility for Rare Isotope Beams (FRIB) Isotope Harvesting at Michigan State University effort, which adds the capabilities to extract and process significant quantities of isotopes from the beam dump of the FRIB, cost effectively repurposing unwanted product. FRIB is a Nuclear Physics DOE Scientific User Facility dedicated to the study of nuclear structure and astrophysics research. The FY 2023 Request also supports preparations of ORNL facilities for the receipt, storage, and processing of the heavy curium product stream (for use in californium-252 and actinide production) coming from 65 Mark 18-A targets being processed by the National Nuclear Security Administration (NNSA) recovery project at the Savannah River Site (SRS) over the next decade.

Research

The DOE IP supports core research groups at Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Idaho National Laboratory (INL), Los Alamos National Laboratory (LANL), ORNL, and Pacific Northwest National Laboratory (PNNL) to conduct transformative research for novel or advanced production and separation techniques for high priority isotopes in short supply.

Critical medical isotope production activities in the FY 2023 Request are maintained. In medicine, there is quickly escalating interest in alpha and beta emitters for revolutionary cancer and infectious disease therapy and diagnostics. A high priority of the DOE IP remains the dedicated research effort to develop large scale production capabilities of the alpha-emitter actinium-225 (Ac-225), a high-priority isotope that has shown stunning success in the treatment of diffuse cancers and infections. The DOE IP has established itself as the world leader in this arena, typically being the sole global source for many of these isotopes of interest or leading the way in transformative research and manufacturing to make them available. In addition to Ac-225 derived from thorium-229 processing, DOE IP now routinely produces accelerator-produced Ac-225 and is continuing research to develop efficient full-scale production and processing capabilities to enable sufficient supply of the isotope for cancer treatment. In partnership with the National Institutes of Health (NIH), the DOE IP continues research facilitating the transition of novel radioisotopes and targeted delivery agents from the laboratory to use in clinical trials for both diagnosis and treatment of disease, supporting a known "valley of death" that lies at the intersection of these two federal programs.

As part of the SC BRaVE Initiative, National Preparedness of the DOE IP and its ability to perform effectively in times of national crisis is enhanced by the RSC at MURR. The RSC is planned to be located in the Discovery Ridge Research Park near the University of Missouri and will provide the surrounding underserved rural area with job opportunities in isotope science. Funding also supports scientists and engineers to pursue design of the Radioisotope Processing Facility (RPF) for new long-term capabilities at ORNL.

Competitive research funds to universities and national laboratories support targeted high priority activities, including research to alleviate the current U.S. dependence on foreign sources of deuterium, which was last produced in the U.S. in 1981. Deuterium is used in the development, production, and sale of compounds used in chemistry, biomedical and diagnostic research, environmental analysis, physics, and the semi-conductor industry. Research topics include production

of highly enriched lithium-7 and chlorine-37 for molten salt reactors, new sources of helium-3 for cryogenics, advanced manufacturing approaches to isotope production, critical nuclear data measurements, novel radioisotope enrichment technology, next generation targetry, modular automated systems, robotics, the application of machine learning and artificial intelligence to isotope production, and production of neptunium-236 for nuclear forensics.

Scientists perform simulations and conduct cutting-edge research to develop stable isotope enrichment capabilities. Every stable isotope enriched requires an intense and independent research campaign. Dedicated machines are designed and optimized for isotopes of interest for quantum computing. As this technology is dual-use, nurturing a core competency in this technology is vital to the Nation. R&D associated with purification and processing of the existing isotope inventory continues and other enrichment technologies are investigated. Research to promote clean energy considers isotopically tailored low activation materials for fusion and fast fission nuclear reactors, and transformative technology development to enrich isotopes that can yield fuel cycle cost savings and reduced nuclear waste.

The DOE IP supports universities with unique capabilities, such as the multi-particle cyclotron at the University of Washington, where full-scale production of the alpha-emitter astatine-211 was developed to support research into the use of the isotope in cancer therapy; and MURR which the DOE IP uses for the production of lutetium-177 for cancer therapy research, selenium-75 for biochemical and environmental research, and gold-199 for cancer imaging/therapy and detection of environmental compounds. The newest addition to the University Isotope Network is the University of Alabama-Birmingham cyclotron, which will provide niche medical isotopes through the DOE IP. This partnership also provides job opportunities to expand their workforce and enhance their isotope science activities. Funding also supports implementation of isotope production capabilities at additional facilities at Texas A&M University, the University of Pennsylvania, Duke University, and the University of Wisconsin. The coordinated university network is designed to leverage the unique and often underutilized facilities available at academic institutions which are generally more suited to low-energy production reactions and can support nationwide availability of short-lived radioisotopes.

Emphasis is placed on providing training opportunities to students and post-docs to help assure a vibrant diverse and inclusive workforce essential to the technologies associated with isotope production. In addition to the recently initiated DOE IP Traineeship Program, which continues as the RENEW initiative in the FY 2023 Request, and supports undergraduate and graduate students. DOE IP also sponsors workshops at professional society meetings to promote communication of advances in isotope availability and invests in the Nation's future nuclear chemistry and biomedical researchers through support for the Nuclear Chemistry Summer School (NCSS) program. The NCSS, jointly supported with SC's Basic Energy Sciences (BES) and Nuclear Physics (NP) programs, consists of an intensive six-week program of formal accredited lectures on the fundamentals of nuclear science, radiochemistry, and their applications in related fields, as well as laboratory practicums focusing on state-of-the-art instrumentation and technology used routinely in basic and applied nuclear science.

Facility Operations

The DOE IP is the steward of several facilities for isotope production and chemical processing, and in addition, leverages facilities and capabilities across the United States government complex that are owned by other Federal entities. The DOE IP stewards the Isotope Production Facility (IPF) at LANL, the Brookhaven Linac Isotope Producer (BLIP) facility at BNL, the Enriched Stable Isotope Prototype Plant (ESIPP) at ORNL, and hot cell facilities for processing and handling irradiated materials and purified products at ORNL, BNL, and LANL. In addition, the DOE IP utilizes the capabilities of the Low Energy Accelerator Facility (LEAF) at ANL, the High Flux Isotope Reactor (HFIR) at ORNL, the Advanced Test Reactor (ATR) at INL, processing and packaging infrastructure for strontium-90 at PNNL, processing and packaging infrastructure for lithium-6 and lithium-7 at the Y-12 National Security Complex, americium-241 recovery from NNSA plutonium processes at the LANL Plutonium Facility, the extraction and distribution of helium-3 at the Savannah River Site (SRS), and the radioisotope separator at INL for nuclear forensics isotopes.

Funding maintains National Preparedness and mission readiness for the production and radio-chemical separations of isotopes at a growing portfolio of production sites to provide domestic supply chains of critical isotopes not available commercially or domestically; the isotope production and processing costs are paid by the customer. Infrastructure and capital investments enable critical and compelling enhancements to production or processing capability, including recovery of valuable isotopes from legacy reactor targets (Mark 18-A); development of enrichment capabilities for heavier stable isotopes; and the fabrication and assembly of enrichment technology. Scientists and engineers support the implementation

of Food and Drug Administration (FDA) regulatory requirements for production of isotopes such as actinium-225 to enable their use in approved or future radiopharmaceuticals.

DOE IP supports readiness of ESIPP at ORNL to produce research quantities of enriched stable isotopes using electromagnetic separation and centrifuge technologies. The first campaign at ESIPP produced ruthenium-96 to provide the unique target material to the Relativistic Heavy Ion Collider (RHIC) for its planned physics program. A follow-on campaign at ESIPP focuses on production of ytterbium-176, previously only produced in Russia, and needed to produce high priority medical isotopes to treat prostate cancer. Funding also supports the commissioning of gas centrifuges for SIPF.

Some examples of produced isotopes across the DOE IP are:

- actinium-225, actinium-227, cerium-134, scandium-47, scandium-44, holmium-166m, tungsten-188, lutetium-177, strontium-89, strontium-90, tin-117m, vanadium-48, manganese-52, gold-199, cobalt-55, and cobalt-60 for cancer therapy and imaging diagnostics
- bismuth-213, lead-212, astatine-211, copper-67, thorium-227, thorium-228, radium-223, and radium-224 for cancer and infectious disease therapy and research
- americium-241 and californium-252 for oil and gas exploration and production well logging
- cadmium-109 for X-ray fluorescence imaging and environmental research
- barium-133 for quantum computing research, medical standards, and industrial sources
- berkelium-249, americium-243, uranium-238, plutonium-242, plutonium-244, californium-249, californium-251einsteinium-254, and curium-248 for use as targets for discovery of new super heavy elements
- fermium-257 for heavy element chemistry research
- selenium-75 for industrial radiography
- silicon-32 for oceanography and climate modeling
- ytterbium-171 for quantum memory
- ytterbium-176 as feedstock for isotopes that treat prostate cancer
- nickel-63 for explosives detection
- lithium-6 and helium-3 for neutron detectors for homeland security applications
- strontium-90, promethium-147, and thulium-170 for nuclear batteries
- arsenic-73, iron-52, and zinc-65 as tracers in metabolic studies

It can take decades for an economically and technically viable commercial market to be formed for any novel isotope. The DOE IP works closely with industry to commercialize technology and promote domestic independent producers in a smooth transition that does not disrupt supply and or prohibit research. At that point, the DOE IP stops production so as to not compete with the domestic industry. Recent examples in which domestic commercial production now exists include strontium-82 for cardiac heart imaging and germanium-68 for medical diagnostics.

Projects

The prototype capabilities of the ESIPP, developed through DOE IP-supported research, demonstrated the feasibility of new EMIS and GC technologies and re-established a small general enriched stable isotope production capability in the U.S. The subsequent SIPF Major Item of Equipment (MIE) at ORNL modestly increases GC production capability. The implementation of SIPF continues to support the commissioning of GCs to produce enriched Xenon-129. Xenon-129 has demonstrated effectiveness in polarized lung imaging and there is currently no U.S. production capability. This isotope has also garnered the interest of the medical community in monitoring lung function and damage from infectious disease such as COVID-19.

The U.S. SIPRC line-item construction project further expands GC production capability and significantly increases EMIS production capability to meet the Nation's growing demand for stable isotopes. SIPRC will mitigate the Nation's dependence on foreign countries for stable isotope supply. CD-1, Approve Alternative Selection and Cost Range, and Subproject-1 CD-3A, Approve Long Lead Procurement, was received on November 4, 2021. The current Total Project Cost (TPC) point estimate is $250,000,000 with an updated preliminary TPC range of $187,000,000 to $338,000,000. Demand drivers include enriched stables isotopes for medical, national security and fundamental research projects to mitigate dependence on foreign countries. With support from the DOE IP, ORNL is advancing production capabilities for these stable isotopes, primarily through EMIS and GC technologies.

## Isotope R&D and Production
## FY 2023 Research Initiatives

Isotope R&D and Production supports the following FY 2023 Research Initiatives.

(dollars in thousands)

| | FY 2021 Enacted | FY 2022 Annualized CR | FY 2023 Request | FY 2023 Request vs FY 2021 Enacted |
|---|---|---|---|---|
| Accelerate Innovations in Emerging Technologies | – | – | 1,051 | +1,051 |
| Biopreparedness Research Virtual Environment (BRaVE) | – | – | 5,073 | +5,073 |
| Fundamental Science to Transform Advanced Manufacturing | – | – | 1,000 | +1,000 |
| Funding for Accelerated, Inclusive Research (FAIR) | – | – | 2,000 | +2,000 |
| Quantum Information Science | – | 4,300 | 4,300 | +4,300 |
| Reaching a New Energy Sciences Workforce (RENEW) | – | – | 4,000 | +4,000 |
| **Total, Research Initiatives** | **–** | **4,300** | **17,424** | **+17,424** |

*Note:*

- *The DOE Isotope Program was included in the Office of Nuclear Physics Appropriation in FY 2021 and thus did not independently participate in SC research initiatives in FY 2021.*

## Isotope R&D and Production
## Funding

(dollars in thousands)

| | FY 2021 Enacted | FY 2022 Annualized CR | FY 2023 Request | FY 2023 Request vs FY 2021 Enacted |
|---|---|---|---|---|
| **Isotope R&D and Production** | | | | |
| Isotopes, Research | – | 30,903 | 38,827 | +38,827 |
| Isotopes, Operations | – | 41,097 | 46,624 | +46,624 |
| **Subtotal, Isotope R&D and Production** | **–** | **72,000** | **85,451** | **+85,451** |
| **Construction** | | | | |
| 20-SC-51, U.S. Stable Isotope Production and Research Center (SIPRC), ORNL | – | 12,000 | 12,000 | +12,000 |
| **Subtotal, Construction** | **–** | **12,000** | **12,000** | **+12,000** |
| **Total, Isotope R&D and Production** | **–** | **84,000** | **97,451** | **+97,451** |

**Basic and Applied R&D Coordination**
R&D coordination and integration are deeply rooted in all activities of the DOE IP as a goal of the Program is to ensure that critical isotopes needed to achieve federal missions are available. Stable and radioactive isotopes are vital to the missions of many federal agencies, including the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), Department of Defense (DoD), Office of the Director of National Intelligence (ODNI), National Institute of Standards and Technology (NIST), Federal Bureau of Investigations (FBI), Department of Agriculture, Department of Homeland Security (DHS), NNSA, National Science Foundation (NSF), and other SC programs. The DOE IP conducts the biennial Workshop on Federal isotope Supply and Demand to collect 5-year projections from all federal agencies across the USG complex to ensure adequate supply and evidence-based Program priorities. The DOE IP participates in Federal Working Groups and Interagency groups to promote communication, including the White House Office of Science and Technology Policy National Science and Technology Council Subcommittee on Critical and Strategic Mineral Supply Chains, and the Interagency Group on He-3, which it leads and that reports to the White House National Security Council staff. The DOE IP participates in the Certified Reference Material Working Group which ensures material availability for nuclear forensics applications that support national security missions. As a service, the DOE IP collects demand and usage information on helium-4 from the federal complex and provides it to the Bureau of Land Management (BLM) so that BLM can optimize their plans for the helium-4 Federal Reserve.

While the DOE IP is not responsible for the production of molybdenum-99, the most widely used isotope in diagnostic medical imaging in the Nation, it works closely with NNSA, the lead entity responsible for domestic molybdenum-99 production, offering technical and management support. SIPRC will produce molybdenum-98 and molybdenum-100, precursors to certain molybdenum-99 production routes to ensure domestic supply chain resilience.

**Program Accomplishments**
*Production of Promethium-147 for Industrial and Medical Applications*
ORNL has demonstrated the recovery of promethium-147, an important radioisotope for U.S. industrial applications, from the radiological waste generated during production of plutonium-238, a radioisotope used in space power systems. Promethium-147 is a radioisotope used to measure the thickness of thin plastic films (as in cell phones), as a power source for nuclear batteries, and in medical imaging applications. The isotope was only produced in Russia and the latest information indicates that they are leaving the market causing a supply disruption. By mining plutonium-238 radiological waste, ORNL minimizes its radiological legacy while providing a domestic source for a critically needed radioisotope, promoting U.S. economic resilience. Additional R&D is being advanced on promethium-147 production from the neodymium-146 irradiation route.

*ORNL Constructs and Commissions Next-Generation Electromagnetic Isotope Separator*
ORNL and DOE IP recently completed construction and commissioning of a second-generation EMIS device which is optimized to separate isotopes of high-mass elements that require very high assay, or purity. The newest EMIS is designed to nominally have five times the resolution over the previous modern EMIS devices, which are actively producing high demand enriched stable isotopes at ORNL. The latest design is being utilized to highly enrich ytterbium-176, which will be used to produce the radiopharmaceutical lutetium-177. Lutetium-177 has been FDA approved to treat certain digestive tract cancers, including pancreatic cancer. This new EMIS is also able to simultaneously produce ytterbium-171, which is being collected for quantum memory. SIPRC will include the second-generation design of EMISs. The enriched ytterbium isotopes are otherwise only available from U.S. constrained calutron inventory or new production in Russia.

*Novel Imaging Analog for the Targeted Alpha Therapy Isotope Actinium-225 Facilitates Development of New Treatments*
Ac-225 is a tremendously promising radioisotope for treating cancer and is being produced by DOE IP to support medical trials. To facilitate research and promote understanding of the impact and travel of Ac-225 in the body, imaging isotopes are needed that mimic the transport behavior of this therapy isotope. LANL researchers developed and demonstrated the production and purification of cerium-134, which is very well-suited for this task as it attaches efficiently to the same tumor targeting agents as the Ac-225. The novel cerium-134 isotope was sent to collaborators at Lawrence Berkeley National Laboratory where the first positron emission tomography (PET) images were collected, showing how this isotope behaved in a mouse model. This work provides a powerful tool for helping to develop additional Ac-225 based treatments for cancer and other diseases and is generating significant interest from the medical and imaging communities.

**Activities and Explanation of Changes**

(dollars in thousands)

| FY 2021 Enacted | FY 2023 Request | Explanation of Changes FY 2023 Request vs FY 2021 Enacted |
|---|---|---|
| **Isotope R&D and Production** **$ —** | **$97,451** | **+$97,451** |
| Isotopes, Research $ — | $38,827 | +$38,827 |
| Isotopes Research was under the Nuclear Physics program in the FY 2021 Enacted Appropriation with a funding level of $29,660,000. As part of the SC reorganization in FY 2020, a separate Office of Isotope R&D and Production was established. | The Request will support high impact R&D activities at universities and national laboratories leading to advanced, innovative, and novel isotope production and processing technologies, to increase the availability of isotopes in short supply and promote U.S. economic resilience. The priority R&D will remain on the development of full-scale processing and technology capabilities for the production of alpha-and beta-emitters for cancer therapy, of which the DOE IP is a global leader, and to promote their transition to medical applications. The Request will maintain the University Isotope Network to perform the R&D necessary to enable routine production. Research to develop enrichment capability for new stable isotopes of importance, including isotopes for clean energy and quantum computing is maintained. Participation in the Advanced Manufacturing initiative will continue with innovative isotope production technology that can facilitate commercial engagement and the promotion of domestic supply chains, such as “desktop” inkjet printing of production targets. Support for the DOE IP Traineeship Program with a goal to increase the diversity of the workforce as part of RENEW will increase in FY 2023. | Evidence-based research activities will improve or develop innovative isotope production, enrichment, and processing technology with the goal of increasing domestic supplies of critical isotopes for medicine, energy, national security, and other fields. Funding will support high priority efforts in QIS, Advanced Manufacturing, and National Preparedness (BRaVE), while promoting diversity and inclusion in the isotope scientific workforce and providing equitable inclusion opportunities in federal science and technology programs. Participation in the FAIR and Accelerate initiatives will be supported. Funding for competitive research will decrease to support participation in SC initiatives and core research at production facilities. Modest funding will support the continuation of the conceptual design of the RPF at ORNL. |

(dollars in thousands)

| FY 2021 Enacted | FY 2023 Request | Explanation of Changes<br>FY 2023 Request vs FY 2021 Enacted |
|---|---|---|
| | Research will increase for the BRaVE initiative in partnership with the University of Missouri to address a single point failure in reactor isotope processing and create tech-savvy jobs in an underserved rural area of Missouri with the implementation of the Radioisotope Science Center at MURR. Design for the ORNL RPF project will continue to advance needed chemical processing infrastructure at ORNL. Research to advance isotope harvesting capabilities and expertise at FRIB are roughly maintained.<br><br>The Request will support participation in the Accelerate initiative which will support scientific research to accelerate the transition of isotope science advances to clinical trials. Also, the Request will support the FAIR initiative which will provide focused investment on enhancing isotope research on clean energy, climate, and related topics at minority serving institutions, including attention to underserved and environmental justice regions. | |
| Isotopes, Operations $ — | $46,624 | +$46,624 |
| Isotopes Operations was under the Nuclear Physics program in the FY 2021 Enacted Appropriation with a funding level of $36,340,000. | The Request will support mission readiness (~80 percent optimum) of the growing portfolio of isotope production and processing sites and nurtures critical core competencies in isotope production and development, promoting robust domestic supply chains for cancer therapy and other applications. Support will maintain NIDC activities to interface with the growing stakeholder community and rapidly expanding isotope portfolio. Funding will continue to support electromagnetic separation technology optimized to heavy elements, enriched radioisotope separation technology, extraction of valuable isotopes from legacy Mark 18-A targets. | Evidence-based activities support readiness to produce stable isotopes, commission new centrifuges, support NIDC, and produce radioisotopes at national lab and university reactors and accelerators. |

(dollars in thousands)

| FY 2021 Enacted | FY 2023 Request | Explanation of Changes FY 2023 Request vs FY 2021 Enacted |
|---|---|---|
| Construction $ — | $12,000 | +$12,000 |
| The U.S. Stable Isotope Production and Research Center (SIPRC) was under the Nuclear Physics program in the FY 2021 Enacted Appropriation with a funding level of $12,000,000. | The Request will support the continuation of engineering design and approved long lead procurements of the U.S. SIPRC. | Progress will continue in design and approved long lead procurements of the U.S. SIPRC to mitigate dependence on foreign supply of isotopes. |

## Isotope R&D and Production
## Construction Projects Summary

(dollars in thousands)

| | Total | Prior Years | FY 2021 Enacted | FY 2022 Annualized CR | FY 2023 Request | FY 2023 Request vs FY 2021 Enacted |
|---|---|---|---|---|---|---|
| **20-SC-51, U.S. Stable Isotope Production and Research Center, ORNL** | | | | | | |
| Total Estimated Cost (TEC) | 213,800 | – | – | 12,000 | 12,000 | +12,000 |
| Other Project Cost (OPC) | 6,600 | – | – | 3,200 | – | – |
| **Total Project Cost (TPC)** | **220,400** | **–** | **–** | **15,200** | **12,000** | **+12,000** |
| **Total, Construction** | | | | | | |
| **Total Estimated Cost (TEC)** | **N/A** | **N/A** | **–** | **12,000** | **12,000** | **+12,000** |
| **Other Project Cost (OPC)** | **N/A** | **N/A** | **–** | **3,200** | **–** | **–** |
| **Total Project Cost (TPC)** | **N/A** | **N/A** | **–** | **15,200** | **12,000** | **+12,000** |

*Notes:*

- *The total for the U.S. Stable Isotope Production and Research Center (SIPRC) of $220,400,000 does not include $29,600,000 included in the Nuclear Physics program for prior years.*
- *The full preliminary total for SIPRC, combining the Nuclear Physics and Isotope R&D and Production funding, is $250,000,000.*
- *This project is not baselined.*

## Isotope R&D and Production
## Funding Summary

(dollars in thousands)

| | FY 2021 Enacted | FY 2022 Annualized CR | FY 2023 Request | FY 2023 Request vs FY 2021 Enacted |
|---|---|---|---|---|
| Research | – | 24,703 | 37,827 | +37,827 |
| Facility Operations | – | 41,097 | 46,624 | +46,624 |
| Projects | | | | |
| Line Item Construction (LIC) | – | 18,200 | 13,000 | +13,000 |
| **Total, Projects** | **–** | **18,200** | **13,000** | **+13,000** |
| **Total, Isotope R&D and Production** | **–** | **84,000** | **97,451** | **+97,451** |

*Note:*

- *Isotope R&D and Production funding was included in the Nuclear Physics program in the FY 2021 Enacted appropriation.*

**Isotope R&D and Production**
**Scientific Employment**

| | FY 2021 Enacted | FY 2022 Annualized CR | FY 2023 Request | FY 2023 Request vs FY 2021 Enacted |
|---|---|---|---|---|
| Number of Permanent Ph.Ds (FTEs) | – | 34 | 41 | +41 |
| Number of Postdoctoral Associates (FTEs) | – | 27 | 30 | +30 |
| Number of Graduate Students (FTEs) | – | 23 | 33 | +33 |
| Number of Other Scientific Employment (FTEs) | – | 84 | 103 | +103 |
| **Total Scientific Employment (FTEs)** | **–** | **168** | **207** | **+207** |

*Notes:*

- *Other Scientific Employment (FTEs) includes technicians, engineers, computer professionals and other support staff.*
- *Isotope R&D and Production funding was included in the Nuclear Physics program in the FY 2021 Enacted appropriation.*

**20-SC-51, U.S. Stable Isotope Production and Research Center (SIPRC)**
**Oak Ridge National Laboratory, Oak Ridge, Tennessee**
**Project is for Design and Construction**

**1. Summary, Significant Changes, and Schedule and Cost History**

**Summary**

The FY 2023 Request for the U.S. Stable Isotope Production and Research Center (SIPRC) is $12,000,000 of Total Estimated Cost (TEC) funding. The current Total Project Cost (TPC) point estimate is $250,000,000 with a preliminary TPC range of $187,000,000 to $338,000,000.

**Significant Changes**

This project data sheet (PDS) is an update of the FY 2022 PDS; the project is not a new start in FY 2023. The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-1, Approve Alternative Selection and Cost Range and Subproject 1 CD-3A, Approve Long Lead Procurement, which was approved on November 4, 2021. The TPC point estimate and range are a result of advancing project maturity with the completion of conceptual design. FY 2023 funding will continue support for Project Engineering and Design (PED) activities and approved long-lead procurements (CD-3A scope), such as materials for known designs of technologies developed under previous projects. As a result of evidence-based peer review, a second round of long lead procurements (CD-3B), originally planned for 1Q FY 2023, was combined with CD-3A. The prior projects referenced include the completed Enriched Stable Isotope Production Prototype (ESIPP) and the ongoing Stable Isotope Production Facility (SIPF) Major Item of Equipment.

A Federal Project Director (FPD) with certification Level III has been assigned to the U.S. SIPRC.

**Critical Milestone History**

| Fiscal Year | CD-0 | Conceptual Design Complete | CD-1 | CD-2 | Final Design Complete | CD-3 | CD-4 |
|---|---|---|---|---|---|---|---|
| FY 2020 | 1/4/19 | 4Q FY 2020 | 4Q FY 2020 | 3Q FY 2022 | 2Q FY 2022 | 3Q FY 2022 | 4Q FY 2027 |
| FY 2021 | 1/4/19 | 4Q FY 2020 | 4Q FY 2020 | 3Q FY 2022 | 2Q FY 2022 | 3Q FY 2022 | 4Q FY 2027 |
| FY 2022 | 1/4/19 | 4Q FY 2021 | 4Q FY 2021 | 4Q FY 2025 | 4Q FY 2025 | 4Q FY 2025 | 1Q FY 2031 |
| FY 2023 | 1/4/19 | 2/26/21 | 11/4/21 | 4Q FY 2025 | 4Q FY 2025 | 4Q FY 2025 | 1Q FY 2032 |

*Note:*

- *CD-2, CD-3, and CD-4 dates are for the overall project and correspond to the latest subproject date for a given CD.*

Critical Decision dates for SP-1, SP-2 and SP-3 are broken out below:

| FY 2023 | | | | | | |
|---|---|---|---|---|---|---|
| Subproject (SP) | CD-0 | Conceptual Design Complete | CD-1 | CD-3A | CD-2/3 | CD-4 |
| SP-1 | 1/4/19 | 2/26/21 | 11/4/21 | 11/4/21 | 2Q FY 2024 | 4Q FY 2030 |
| SP-2 | 1/4/19 | 2/26/21 | 11/4/21 | 3Q FY 2025 | 1Q FY 2026 | 1Q FY 2032 |
| SP-3 | 1/4/19 | 2/26/21 | 11/4/21 | 1Q FY 2025 | 1Q FY 2026 | 2Q FY 2031 |

*Note:*

- *The estimated cost and schedule shown are preliminary.*

**CD-0** – Approve Mission Need for a construction project with a conceptual scope and cost range

**Conceptual Design Complete** – Actual date the conceptual design was completed (if applicable)

**CD-1** – Approve Alternative Selection and Cost Range

**CD-2** – Approve Performance Baseline

**Final Design Complete** – Estimated/Actual date the project design will be/was complete(d)

**CD-3** – Approve Start of Construction

**D&D Complete** – Completion of D&D work

**CD-4** – Approve Start of Operations or Project Closeout

| Fiscal Year | Performance Baseline Validation | CD-3A | CD-3B |
|---|---|---|---|
| FY 2020 | 3Q FY 2022 | 4Q FY 2020 | – |
| FY 2021 | 3Q FY 2022 | 4Q FY 2020 | – |
| FY 2022 | 4Q FY 2023 | 4Q FY 2021 | 1Q FY 2023 |
| FY 2023 | 2Q FY 2024 | 11/4/21 | – |

**CD-3A for Sub-Project 1** – Approve Long-Lead Procurements, (EMIS components and Facility Site Preparation)
**CD-3B for Sub-Project 1 –** Approve Long-Lead Procurements for Facility (Site preparations). In FY 2022, CD-3B was combined with CD-3A.

**Project Cost History**

This project is at CD-1/3A with a preliminary point estimate of $250,000,000 and Total Project Cost (TPC) range of $187,000,000 to $338,000,000. No construction, excluding for approved long lead procurement, will be performed until the project performance baseline has been validated and CD-3 has been approved.

(dollars in thousands)

| Fiscal Year | TEC, Design | TEC, Construction | TEC, Total | OPC, Except D&D | OPC, Total | TPC |
|---|---|---|---|---|---|---|
| FY 2020 | 5,000 | — | 5,000 | 500 | 500 | 5,500 |
| FY 2021 | 14,000 | 274,000 | 288,000 | 10,000 | 10,000 | 298,000 |
| FY 2022 | 36,000 | 203,200 | 239,200 | 10,800 | 10,800 | 250,000 |
| FY 2023 | 36,000 | 201,800 | 237,800 | 12,200 | 12,200 | 250,000 |

*Note:*

- *FY 2020 funding does not provide a full estimate for total TEC and OPC, it only reflects actual TEC and OPC requested as of the FY 2020 Congressional Budget Request. Previous versions of this table reflected TBD for FY 2020 TPC.*

**2. Project Scope and Justification**

**Scope**

The scope of this project includes design and construction of a building and associated instrumentation and equipment for enriching isotopes. Electromagnetic isotope separator systems and gas centrifuge cascades will be designed and implemented in this new single facility to promote operational, cost and security effectiveness, with space for future growth. The planned facility will include adequate space for test stands and prototype systems development and will be a purely technical facility (i.e., minimal office and staff amenities), and located on the Oak Ridge National Laboratory (ORNL) main campus. Gas centrifuges and electromagnetic separators are leveraged by existing designs developed from prior projects and R&D supported by the DOE Isotope Program (DOE IP). The laboratory considered the optimal number of production systems for each type of technology as part of the alternatives analysis for CD-1.

**Justification**

SIPRC is critical to the Nation and to the DOE IP within SC's Office of Isotope R&D and Production. The facility will expand the only broad U.S. stable isotope production capability to enable multiple production campaigns of enriched stable isotopes. SIPRC utilizes innovative technology to establish domestic supply chains of critical stable isotopes and nurtures domestic core competencies in enrichment technologies using centrifuges and electromagnetic ion separators. This will provide domestic supply chains of critical isotopes for industry, medicine, and national security and mitigate U.S. dependencies on foreign suppliers. The current capacity within the United States is insufficient to meet the Nation's growing demands and the current inventory of stable isotopes is being depleted. The SIPRC project will provide an adequately sized building and transformative technology to address our Nation's stable isotope needs in a more economical and operationally efficient manner.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, and all appropriate project management requirements will be met.

Key Performance Parameters (KPPs)

Preliminary Key Performance Parameters (KPPs) are defined at CD-1 and may change as each subproject continues towards CD-2, Approve Performance Baseline. CD-1 approval was received November 4, 2021. At CD-2 approval, the KPPs will be baselined. The Threshold KPPs represent the minimum acceptable performance that the project must achieve. The Objective KPPs represent the desired project performance. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion.

Summary of preliminary KPPs is indicated below.

| Performance Measure | Threshold | Objective |
|---|---|---|
| Design/construct building | SP-1: Beneficial occupancy of the facility obtained. | SP-1: Beneficial occupancy of the facility obtained. |
| Instrumentation design/development | SP-1: Ninety percent (90 percent) of the EMIS machines complete the operability demonstration by running simultaneously with gas for 4 hours. | SP-1: One hundred percent (100 percent) of the EMIS machines complete the operability demonstration by running simultaneously with gas for 4 hours. |
| | SP-2:<br>a. The SIPRC project will complete the validation and verification (V&V) of the controls system with the completed documentation of the process.<br>b. The SIPRC project will complete documented system leak tests with results meeting the requirements laid out in the systems requirements documents.<br>c. The SIPRC project will complete a mechanical operability test of the completed production GCIS cascade. | SP-2:<br>The SIPRC project will complete a 100Mo gas test of the constructed cascade using molybdenum hexafluoride gas. Evidence of completion will be the report on the results of the gas test. |

| Performance Measure | Threshold | Objective |
|---|---|---|
| | SP-3:<br>a. The SIPRC project will complete the validation and verification (V&V) of the controls system with the completed documentation of the process.<br>b. The SIPRC project will complete documented system leak tests with results meeting the requirements laid out in the systems requirements documents. | SP-3:<br>The SIPRC project will successfully complete an operability test of the TCI's feed and withdrawal system using a defined gas, either surrogate or actual planned SiF4 gas. The system must be able to flow gas at the planned flow rate range per the systems requirements document and withdraw the gas from the system piping into cold traps. Evidence of completion will be a report on the results of this test. |

**3. Financial Schedule**

(dollars in thousands)

| | Budget Authority (Appropriations) | Obligations | Costs |
|---|---|---|---|
| **Total Estimated Cost (TEC)** | | | |
| Design (TEC) | | | |
| FY 2020 | 12,000 | 12,000 | – |
| FY 2022 | 9,000 | 9,000 | 11,500 |
| FY 2023 | 6,000 | 6,000 | 11,500 |
| Outyears | 9,000 | 9,000 | 13,000 |
| **Total, Design (TEC)** | **36,000** | **36,000** | **36,000** |
| Construction (TEC) | | | |
| FY 2021 | 12,000 | 12,000 | – |
| FY 2022 | 3,000 | 3,000 | 13,600 |
| FY 2023 | 6,000 | 6,000 | 7,000 |
| Outyears | 180,800 | 180,800 | 181,200 |
| **Total, Construction (TEC)** | **201,800** | **201,800** | **201,800** |
| Total Estimated Cost (TEC) | | | |
| FY 2020 | 12,000 | 12,000 | – |
| FY 2021 | 12,000 | 12,000 | – |
| FY 2022 | 12,000 | 12,000 | 25,100 |
| FY 2023 | 12,000 | 12,000 | 18,500 |
| Outyears | 189,800 | 189,800 | 194,200 |
| **Total, TEC** | **237,800** | **237,800** | **237,800** |

(dollars in thousands)

| | Budget Authority (Appropriations) | Obligations | Costs |
|---|---|---|---|
| **Other Project Cost (OPC)** | | | |
| FY 2019 | 500 | 500 | 171 |
| FY 2020 | 2,100 | 2,100 | 2,429 |
| FY 2021 | 3,000 | 3,000 | 3,000 |
| FY 2022 | 3,200 | 3,200 | 3,200 |
| Outyears | 3,400 | 3,400 | 3,400 |
| **Total, OPC** | **12,200** | **12,200** | **12,200** |

(dollars in thousands)

| | Budget Authority (Appropriations) | Obligations | Costs |
|---|---|---|---|
| **Total Project Cost (TPC)** | | | |
| FY 2019 | 500 | 500 | 171 |
| FY 2020 | 14,100 | 14,100 | 2,429 |
| FY 2021 | 15,000 | 15,000 | 3,000 |
| FY 2022 | 15,200 | 15,200 | 28,300 |
| FY 2023 | 12,000 | 12,000 | 18,500 |
| Outyears | 193,200 | 193,200 | 197,600 |
| **Total, TPC** | **250,000** | **250,000** | **250,000** |

**4. Details of Project Cost Estimate**

(dollars in thousands)

| | Current Total Estimate | Previous Total Estimate | Original Validated Baseline |
|---|---|---|---|
| **Total Estimated Cost (TEC)** | | | |
| Design | 27,000 | 27,000 | **N/A** |
| Design - Contingency | 9,000 | 9,000 | **N/A** |
| **Total, Design (TEC)** | **36,000** | **36,000** | **N/A** |
| Construction | 150,000 | 150,000 | **N/A** |
| Construction - Contingency | 51,800 | 53,200 | **N/A** |
| **Total, Construction (TEC)** | **201,800** | **203,200** | **N/A** |
| **Total, TEC** | **237,800** | **239,200** | **N/A** |
| *Contingency, TEC* | *60,800* | *62,200* | ***N/A*** |
| **Other Project Cost (OPC)** | | | |
| R&D | 2,600 | 2,600 | **N/A** |
| Conceptual Design | 4,100 | 4,000 | **N/A** |
| Start-up | 2,100 | 1,500 | **N/A** |
| OPC - Contingency | 3,400 | 2,700 | **N/A** |
| **Total, Except D&D (OPC)** | **12,200** | **10,800** | **N/A** |
| **Total, OPC** | **12,200** | **10,800** | **N/A** |
| *Contingency, OPC* | *3,400* | *2,700* | ***N/A*** |
| **Total, TPC** | **250,000** | **250,000** | **N/A** |
| ***Total, Contingency (TEC+OPC)*** | ***64,200*** | ***64,900*** | ***N/A*** |

**5. Schedule of Appropriations Requests[ddd]**

(dollars in thousands)

| Fiscal Year | Type | Prior Years | FY 2021 | FY 2022 | FY 2023 | Outyears | Total |
|---|---|---|---|---|---|---|---|
| FY 2020 | TEC | 5,000 | — | — | — | — | 5,000 |
| | OPC | 500 | — | — | — | — | 500 |
| | TPC | 5,500 | — | — | — | — | 5,500 |
| FY 2021 | TEC | 12,000 | 12,000 | — | — | 264,000 | 288,000 |
| | OPC | 2,600 | 3,000 | — | — | 4,400 | 10,000 |
| | TPC | 14,600 | 15,000 | — | — | 268,400 | 298,000 |
| FY 2022 | TEC | 12,000 | 12,000 | 12,000 | — | 203,200 | 239,200 |
| | OPC | 2,600 | 3,000 | 3,200 | — | 2,000 | 10,800 |
| | TPC | 14,600 | 15,000 | 15,200 | — | 205,200 | 250,000 |
| FY 2023 | TEC | 12,000 | 12,000 | 12,000 | 12,000 | 189,800 | 237,800 |
| | OPC | 2,600 | 3,000 | 3,200 | — | 3,400 | 12,200 |
| | TPC | 14,600 | 15,000 | 15,200 | 12,000 | 193,200 | 250,000 |

*Note:*

- *FY 2020 funding does not provide a full estimate for total TEC and OPC, it only reflects actual TEC and OPC requested as of the FY 2020 Congressional Budget Request. Previous versions of this table reflected TBD for FY 2020 TPC.*

**6. Related Operations and Maintenance Funding Requirements**

| | |
|---|---|
| Start of Operation or Beneficial Occupancy | 4Q FY 2030 |
| Expected Useful Life | 30 years |
| Expected Future Start of D&D of this capital asset | 2060 |

Related Funding Requirements
(dollars in thousands)

| | Annual Costs | | Life Cycle Costs | |
|---|---|---|---|---|
| | Previous Total Estimate | Current Total Estimate | Previous Total Estimate | Current Total Estimate |
| Operations | N/A | 33,295 | N/A | 1,106,807 |
| Utilities | N/A | 4,053 | N/A | 133,735 |
| Maintenance and Repair | N/A | 2,992 | N/A | 90,458 |
| Total, Operations and Maintenance | N/A | $40.340 | N/A | $1,331,000 |

[ddd] The project does not have CD-2 approval; FY 2023 schedules and costs are estimates consistent with the updated preliminary point estimate.

**7. D&D Information**

| | Square Feet |
|---|---|
| New area being constructed by this project at ORNL | 54,000 |
| Area of existing facility(ies) being replaced | N/A |
| Area of any additional D&D space to meet the "one-for-one" requirement | N/A |

The new area being constructed in this project is not replacing existing facilities. Any existing space that is freed up from consolidating activities into SIPRC will likely be repurposed.

**8. Acquisition Approach**

The ORNL Management and Operating (M&O) contractor, UT Battelle, will perform the acquisition for this project, overseen by the DOE Oak Ridge National Laboratory Site Office. The M&O contractor will be responsible for awarding and administering all subcontracts related to this project. Its annual performance evaluation and measurement plan will include project performance metrics on which it will be evaluated.

## Isotope Production and Distribution Program Fund

### Overview

The Department of Energy's (DOE) Isotope Production and Distribution Program Fund, more commonly called the DOE Isotope Program (DOE IP), provides critical isotopes in short supply to the Nation and develops robust domestic supply chains to meet federal missions, facilitate emerging technology, reduce U.S. dependence on foreign supply, and promote the Nation's economic prosperity and technical strength. The DOE IP produces and sells radioactive and stable isotopes, byproducts, surplus materials, and related isotope services worldwide, and is often the single source for these critical assets. Isotopes are used for hundreds of essential applications that benefit society every day, such as revolutionary cancer therapy, diagnostic medical imaging, clean energy, explosives detection, quantum computing, advanced manufacturing, nuclear batteries, space exploration, national security, and biological tracers. For example, radioisotopes are used in the diagnosis or treatment of about one-third of all patients admitted to hospitals.[eee] Substantial national and international research, medicine, industry, and national security relies upon the use of isotopes and is strongly dependent on the DOE IP's products and services.

A priority of the DOE IP is to mitigate the Nation's dependency on foreign supply chains of isotopes, particularly those from sensitive countries or essential for facilitating innovative technology. DOE IP continuously assesses isotope needs to inform program direction, including frequent industry stakeholder meetings and biennial federal workshops to evaluate U.S. federal demand for the advancement of federal missions and emerging technology.

The Department supplies isotopes and related services to the Nation under the authority of the Atomic Energy Act of 1954, which specifies the role of the U.S. Government in isotope distribution. Isotopes sold to commercial customers are priced to recover the full cost of production or the market price (whichever is higher). Research isotopes are sold at a reduced price to ensure that the high priority research requiring them does not become cost prohibitive. The DOE IP operates under a revolving fund, the Isotope Production and Distribution Program Fund, established by the 1990 Energy and Water Development Appropriations Act (Public Law 101-101), as amended by the 1995 Energy and Water Development Appropriations Act (Public Law 103-316). Funding for this revolving fund is provided by the combination of annual appropriations from the Science appropriation account (from the Office of Isotope R&D and Production Program [IRP] beginning in FY 2022; prior to FY 2022, appropriations were included in the Nuclear Physics program), and collections from isotope sales; both are needed to maintain the Isotope Program's viability. The revolving fund allows continuous and smooth operations of isotope production, sales, and distribution independent of the federal budget cycle and fluctuating sales revenue. An independent cost review of the fund's revenues and expenses is conducted annually by an external contractor.

Annual appropriations in IRP fund a payment into the revolving fund to maintain mission-readiness of facilities, including the support of core scientists and engineers needed to produce and process isotopes, and the maintenance and enhancement of isotope facilities and capabilities to assure reliable production and provide novel isotopes in high demand and short supply. In addition, appropriated funds provide support for R&D activities associated with development of new production and processing techniques for isotopes and workforce development in isotope production and chemical processing. Each site's production expenses, including processing and distributing isotopes, are offset by revenue generated from sales. About 80 percent of the resources in the revolving fund are used for operations, maintenance, isotope production, and R&D for new isotope production techniques, with approximately 20 percent available for process improvements, unanticipated changes in revenue, manufacturing equipment, capability and infrastructure upgrades, and capital equipment such as assay equipment, glove boxes, and shipping containers needed to ensure on-time deliveries.

The DOE IP produces radioisotopes by irradiating targets in accelerators and reactors at national laboratories and universities, and from extraction of materials and legacy waste. Accelerator facilities include the Brookhaven Linac Isotope Producer at Brookhaven National Laboratory, the Isotope Production Facility at Los Alamos National Laboratory, the Low Energy Accelerator Facility at Argonne National Laboratory, the University of Washington cyclotron, and the new addition of the University of Alabama-Birmingham cyclotron. Reactor facilities include the High Flux Isotope Reactor at Oak Ridge

[eee] https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/med-use-radioactive-materials.html

National Laboratory (ORNL), the University of Missouri Research Reactor, and the Advanced Test Reactor at Idaho National Laboratory. Irradiated targets are processed in associated hot cells and gloveboxes at these facilities. Isotopes are also extracted and purified at the Y-12 National Security Complex near ORNL, the Pacific Northwest National Laboratory, and the Savannah River Site. Enriched stable isotopes are distributed from inventory and produced at ORNL.

In FY 2022, a total of $123.0 million is estimated to be deposited into the revolving fund. This consists of the FY 2022 appropriation of $82.0 million paid into the revolving fund from the Isotope R&D and Production program, plus anticipated collections of $41.0 million to recover costs related to isotope production and isotope services. In FY 2022, the DOE IP expects to sell about 120 different radioactive and stable isotopes to a broad range of research and commercial customers, including major pharmaceutical companies, industrial stakeholders, and researchers at hospitals, national laboratories, other federal agencies, universities, and private companies. Among the isotopes produced, about seven are high-volume isotopes often with commercial applications and the remaining are lower-volume, mostly research isotopes, which are more expensive to produce and thus not readily available otherwise. Collections in FY 2021 included, for example, sales of actinium-225, actinium-227, strontium-89, californium-252, helium-3, nickel-63, and selenium-75.

The DOE IP is the global leader in the development and provision of alpha-emitters for novel cancer-fighting therapies, enabling and accelerating the conduct of clinical trials. Actinium-225 is used in pharmaceuticals under development to treat cancer and other diseases that have metastasized. Actinium-227 provides radium-223 for Xofigo®, which is the first alpha particle-emitting radioisotopic drug approved by the Federal Drug Administration; Xofigo® extends patient survival as well as alleviates the excruciating pain associated with cancer that has metastasized to bone. Californium-252 has a variety of industrial applications, including oil and gas well-logging and fission start-up sources in nuclear reactors. Helium-3 is used in neutron detectors for national security and cryogenics and pediatric lung imaging. Nickel-63 supports national security through its use in detectors for explosives and illicit material, and performance of nuclear batteries. Selenium-75 is used as a radiography source.

As a Mission Essential Function in the DOE, the DOE IP continued isotope production operations throughout the COVID-19 pandemic to mitigate supply chain disruptions in critical isotopes. The production sites across the national laboratory complex quickly and successfully established safe protocols for continued operations to ensure critical isotope supply and overcame extraordinary global transportation hurdles. Not only did the DOE IP meet commitments to its stakeholders during the pandemic, but the DOE IP monitored international supply chains and stepped in to fill shortages when international suppliers could either not produce or transport their product during the pandemic. In FY 2022, DOE IP expects to make approximately 1,000 shipments of isotopes, which is a 25 percent increase from FY 2021.

**Highlights of the FY 2023 Request**

For FY 2023, the Department foresees continued strong growth in isotope demand, including alpha and beta emitters for novel cancer therapy and medical diagnostics; stable isotopes to enable high-discovery science, emerging technologies in medicine and national security; isotopes for quantum information science; isotopes to promote clean energy; and isotopes for nuclear batteries and power supplies. The FY 2023 Request of the IRP Budget is $97.5 million. Revolving fund resources will be used to address the following priorities in the program:

- Promote world-leading core competencies for isotope production to address gaps in supply chains and the provision of innovative, rare isotopes for high priority applications.
- Through cutting-edge research and advanced manufacturing, introduce novel and critical isotopes to the Nation to facilitate emerging technology and applications (medicine, quantum computing, clean energy, nuclear batteries…), promoting U.S. economic prosperity and technical strengths.
- Mitigate U.S. dependence on foreign supply chains and promote domestic production capabilities with technology transfer.
- Advance and expand transformative, domestic stable isotope enrichment capabilities.
- Enhance isotope processing capabilities to address a lack of infrastructure limiting the availability of new isotopes, mitigating single point failures to increase the Nation’s preparedness for reacting to global supply chain disruptions. Address targeted, high priority critical infrastructure needs.

The FY 2023 Request in the IRP Budget includes $3.0 million to continue the Isotope Harvesting research effort at the Facility for Rare Isotope Beams (FRIB) to extract and process significant quantities of high-value isotopes from the FRIB beam dump. FRIB, funded in the Nuclear Physics program, is a DOE Scientific User Facility dedicated to the study of nuclear structure and astrophysics research. The FY 2023 Request in the IRP includes $12.0 million to continue the U.S. Stable Isotope Production and Research Center (SIPRC) at ORNL, to advance stable isotope production capacity for the Nation to commercial scale production of multiple isotopes simultaneously. The U.S. must continue to implement modern technology if it is to become independent of other sensitive countries with greater production capabilities for enriched stable isotopes . This construction project will build upon the developed expertise in centrifuge and electromagnetic ion separation technology nurtured by the Stable Isotope Production Facility (SIPF) Major Item of Equipment, funded through NP and IRP. The IRP Request supports and participates in high priority initiatives for the Department and Administration, including Quantum Information Science, Advanced Manufacturing, National Preparedness in the Biopreparedness Research Virtual Environment (BRaVE), Artificial Intelligence and Machine Learning, Climate/Clean Energy, Reaching a New Energy Sciences Workforce (RENEW), Accelerate Innovations in Emerging Technologies, and Funding for Accelerated, Inclusive Research (FAIR).

**Program Accomplishments**

*Enabling the Development of Innovative Radiopharmaceuticals*
The U.S. Food and Drug Administration (FDA) has accepted its Type II Drug Master File (DMF) submission for Actinium-225 Nitrate (thorium-229 derived) developed by the DOE Isotope Program. The alpha-emitting radionuclide and its decay product bismuth-213 have gained considerable interest within the medical community for targeted radiotherapy of cancer and other diseases. A DMF is a confidential, detailed document that is submitted to the FDA with information about facilities, processes, or articles used in the manufacturing, processing, packaging, and storing of human drug products. An active DMF enables clinical investigators or pharmaceutical companies to reference the filing in their regulatory submissions.

*Domestic Centrifuge Manufacturing Capability*
The DOE IP completed the establishment of a domestic centrifuge manufacturing capability (CMC) at Oak Ridge National Laboratory. The CMC utilizes state-of-the art machinery and advanced manufacturing techniques to support centrifuge fabrication for the Stable Isotope Production Facility (SIPF) MIE, which has modest centrifuge capability, and the Stable Isotope Production and Research Center (SIPRC) which has large electromagnetic separation and centrifuge capability.

*UAB joins the DOE IP University Isotope Network*
The University of Alabama at Birmingham has officially joined the DOE IP University Isotope Network (UIN). UAB will offer Valladium-48, Manganese-52, and Cobalt-55 medical isotopes to the isotope user community through DOE IP. UAB is the third academic site to join the UIN. This partnership sets the stage for more technical jobs and workforce development at UAB, as well as enhanced isotope production technologies.