Department of Energy Isotope Program

Artificial Intelligence for Isotopes

Report on the 2022 Workshop on Artificial Intelligence for Isotope R&D and Production

U.S. DEPARTMENT OF ENERGY | Office of Science

Isotope Program
U.S. Department of Energy

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Report on the Department of Energy Isotope Program's
2022 Workshop on Artificial Intelligence for Isotope R&D and Production

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EXECUTIVE SUMMARY

The Department of Energy Isotope Program (DOE IP) hosted a virtual workshop on Artificial Intelligence (AI) for Isotope R&D and Production on March 17 and April 14, 2022. The purpose of the workshop was for DOE IP to further its understanding of the potential roles for and subsequent opportunities to incorporate AI into its activities. The workshop brought over 80 participants together from both the AI and isotope science communities. Participants contributed ideas through plenary talks, lightning talks, and breakout discussion sessions. The primary focus of all discussions was related to isotope production and processing. However, isotope enrichment, workforce development, and supply chain management were also discussed. This report documents the information presented and discussed at the workshop.

The DOE IP is in the early stages of applying AI tools, including machine learning (ML) and robotics, to solve challenges in both its research and isotope production activities. The DOE IP is maintaining a progressive R&D posture and AI tools are likely to play an integral role in future activities. The 2022 Workshop on AI for Isotope R&D and Production discussed at length research and development efforts planned and already underway. Enthusiasm for the growth of AI in the DOE IP mission space was palpable among participants. The presentations and roundtable discussions emphasized the benefits AI could have if fostered and incorporated to its full potential. They also highlighted areas where AI could be utilized within isotope production and isotope production science.

Today, DOE IP-funded researchers are exploring the use of scientific ML to build predictive models through the combination of expert knowledge with efficient optimization algorithms. These state-of-the-art predictive models promise to enable efficient design of experimental campaigns, real-time monitoring of isotope processing operations, optimization of nuclear target designs for isotope production with nuclear reactors and particle accelerators, as well as enhanced operation of irradiation and isotope enrichment systems – all contributing to a more robust supply of isotopes critical to the Nation. Robotic systems are being explored for remote handling of radioactive materials and automation of repetitive tasks, thereby increasing personnel safety and reliability of operations. Yet, these examples represent a minor amount of the abundant areas that exist for bringing AI tools to bear fully against challenges in the isotope space.

Two major themes emerged during the workshop for where DOE IP should focus its activities in AI to realize the largest impact: Intelligent Knowledge Bases (theme one) and Autonomous Physical Systems (theme two). These areas represent the two pillars necessary for an AI-enabled ecosystem that dramatically accelerates scientific and technological breakthroughs in isotope manufacturing and facilitates their rapid translation to routine implementation. At maturity, Intelligent Knowledge Bases are capable of interaction with humans through natural language. They can make inferences through consideration of heterogenous and sparse data. They can robustly answer questions on a variety of topics (e.g., optimal isotope production and processing paths). Fully actualized Autonomous Physical Systems are self-driving entities capable of accomplishing tasks in the real world. They can receive instructions from humans through natural language to reach a destination and can determine the necessary routing. In the case of isotope manufacturing, the destination could be the synthesis of new separation material that meets manufacturability, scalability, and composition criteria. Together, both areas enable through AI a new paradigm in which isotope science and technology development is dramatically accelerated and robustly implemented for routine production, thereby positioning the Nation to better meet emergent isotope needs.

The two themes of Intelligent Knowledge Bases and Autonomous Physical Systems are broad and encompass large areas of opportunity for incorporating AI into DOE IP mission areas. The initial building blocks of each can be constructed through existing DOE IP programmatic approaches, including the existing research and development program regular funding opportunities. As each matures, there will be an increased necessity for coordination of the projects in areas including data format and availability, benchmark datasets, shared multi-physics models, and coordinate data creation campaigns. One suggested approach inspired by related efforts is the establishment of one or more larger umbrella projects. This approach would ensure a high level of coordination and ensure resulting data, techniques, and tools are as available and usable as possible.

CHAPTER 1
INTRODUCTION

1.1 Scope

This report summarizes the outcomes of the DOE IP sponsored *Artificial Intelligence for Isotope R&D and Production* workshop held on March 17 and April 14, 2022. The purpose of the workshop was for DOE IP to further its understanding of the potential roles for and subsequent opportunities to incorporate AI into isotope R&D and production activities. The workshop brought experts together from the AI and isotope communities to learn from each other and have discussions. The workshop was attended by 83 participants from academia, federal research facilities, and federal agencies. The goals of the workshop were to:

- Goal One. Foster and accelerate the integration of AI into the DOE IP's R&D and isotope production activities.
- Goal Two. Identify compelling opportunities for AI to address challenges in the isotope R&D and production space.
- Goal Three. Increase mutual awareness of the Isotope and AI communities with each other's state-of-the-art and facilitate building of diverse and interdisciplinary teams.

This workshop did not explore the use of AI for isotope applications, such as in the power systems or medical spaces, but instead focused on AI for isotope production and R&D directly related to isotope manufacturing.

1.2 Motivation and Impact

The demand for radioactive and stable isotopes has dramatically increased in recent years. The DOE IP produces and distributes critical isotopes in short supply to the Nation, is the steward of world-leading isotope production capabilities, maintains a cutting-edge research and development program, and supports development of the isotope workforce. DOE IP isotope manufacturing activities and the associated R&D towards novel and improved isotope manufacturing approaches could greatly benefit from adoption and application of AI. Although AI tools are already being leveraged within the DOE IP, there is significant room for increased utilization of AI tools.

AI encompasses a broad topical area focused on the theory and development of artificial systems capable of performing tasks that involve sensing, reasoning, interacting, and learning. Recent years have seen dramatic innovations in both AI fundamentals and applications. AI has become ubiquitous due to the rapidly growing number of successes already realized and the even greater potential of AI to positively impact society. State-of-the-art AI tools are increasingly capable of handling complex tasks and being broadly applied to a range of problems.

1.3 Attendance

The workshop was open to undergraduate and graduate students, post-doctoral researchers, university faculty, national laboratory staff, and federal employees. There were 104 registrants for the workshop. Eighty-three (83) of those 104 registrants participated in at least one day of the workshop with 38 registrants participating both days of the workshop. Registrants were asked to provide their level of experience with isotope R&D and production as well as with artificial intelligence. Table 1 provides the results of those surveys. Registrants were also asked to provide their employment type. Table 2 provides the results. Note that a response of "Other" was found to be given by 3 employees of ORISE and 2 employees of universities that were not faculty. Overall, the participation was well-aligned with expectations for the workshop. The participation of a significant portion of attendees with little to no prior experience with either isotope R&D and production or artificial intelligence was desired. This indicates that the workshop successfully brought together the two communities.

Table 1: Registration Survey Results

Question: **Do you have prior experience with isotope research & development and/or production?**	
Yes, and currently engaged in isotope research & development and/or production.	64 registrants (61%)
Yes, but not currently engaged in isotope research & development and/or production.	10 registrants (10%)
Little to no prior experience.	30 registrants (29%)
Question: **Do you have prior experience with developing or applying artificial intelligence tools?**	
Yes, the development of artificial intelligence tools.	4 registrants (4%)
Yes, the application of artificial intelligence tools.	15 registrants (14%)
Yes, both the development and application of artificial intelligence.	22 registrants (21%)
Little to no prior experience.	63 registrants (61%)

Table 2: Number of Registrations and Participants by Employment Type

Employment Type	Registrants	Unique Participants	Participated Day 2	Participated Day 1	Participated Days 1 & 2
Federal Employee	10	8	7	8	7
National Laboratory	62	50	40	32	22
University Faculty	18	13	6	11	4
Post-doctoral Researcher	4	4	4	2	2
Graduate Student	3	2	2	2	2
Undergraduate Student	2	1	1	0	0
Other	5	5	1	5	1
Total	104	83	61	60	38

1.4 Lightning Talks

Lightning talks were provided as one of multiple avenues for workshop attendees to participate in the discussions and contribute. Each lightning talk discussed an area within the DOE IP mission space that currently involves or could involve artificial intelligence (machine learning, neural networks, computer vision, robotics, natural language processing, etc.). Several lightning talks also discussed how lessons-learned from the application of artificial intelligence to other areas of science and technology could be translated to the DOE IP mission space. Each lighting talk was limited to five-minutes and allowed a single slide. A total of 16 lightning talks were submitted by 14 individuals. All were presented at the workshop. Table 3 provides a list of the lighting talk presenters, their institutions, and titles.

Table 3: Lightning Talk Presenters, Institutions, and Titles

Name	Institution	Title
Rob Emery	University of Washington	AI/Machine Learning to Assist Facility Operations and Maintenance
Jerry Nolan	Argonne National Laboratory	Robotic Retrieval
Yawen Li	University of Washington	AR/VR Assisted Hot Cell Operation Through Glove Controlled Robotic Hands
Ron Moore	Oak Ridge National Laboratory	ORNL Stable Isotope Production: Electromagnetic Isotope Separation (EMIS)
Jasmine Hatcher-Lamarre	Brookhaven National Laboratory	Natural Language Processing for Isotope Production Literature Review

Ken Brooks	DOE Isotope Program	How can AI use data from the Drug Development process to forecast future isotope needs?
Rob Emery	University of Washington	AI/Predictive Analytics to Identify Needs and Allocate DOE IP Resources
John Gahl	University of Missouri	AI Unsupervised Learning - Clustering Algorithm for Isotope Selection
Etienne Vermeulen	Los Alamos National Laboratory	AI/ML for Boiling in Isotope Production Cooling
Karl Mueller	Pacific Northwest National Laboratory	Approaching autonomy: High throughput testing, prediction, and validation for redox electrolytes
Ping Yang	Los Alamos National Laboratory	SeparationML Autonomous Discovery Loop
Hunter Andrews	Oak Ridge National Laboratory	Machine Learning for Autonomous Spectroscopy Calibration Models
Matt O'Hara	Pacific Northwest National Laboratory	Improving Separation Method Development Efficiency: Combining Sensor-laden Fluidics with AI/ML
Sherry Yennello	Texas A&M University	Physics-inspired Machine Learning for Isotope Identification
Lee Bernstein	UCB-LBNL	Machine Learning for Charged Particle Evaluated Nuclear Data
Jerry Nolan	Argonne National Laboratory	Medical Isotope Research with Gammasphere

1.5 Breakout Sessions

Three concurrent breakout sessions were held on the second day of the workshop. The breakout session participants are listed below. Each breakout session started with the same prompts.

- Breakout Session A
  - Kristian Myhre (moderator), DOE Isotope Program
  - Tracey Vieser (technical support), ORISE
  - Ken Brooks, DOE Isotope Program
  - Ethan Balkin, DOE Isotope Program
  - Dave Bivans, DOE Isotope Program
  - Justin Griswold, Oak Ridge National Laboratory
  - Jasmine Hatcher-Lamarre, Brookhaven National Laboratory
  - Etienne Vermeulen, Los Alamos National Laboratory
  - Karl Mueller, Pacific Northwest National Laboratory
  - Ping Yang, Los Alamos National Laboratory
  - Andrew Voyles, University of California Berkeley/Lawrence Berkeley National Laboratory
- Breakout Session B

- Draguna Vrabie (moderator), Pacific Northwest National Laboratory
    - Laura Hammons (technical support), ORISE
    - Yawen Li, University of Washington
    - Ellen O'Brien, Los Alamos National Laboratory
    - Hunter Andrews, Oak Ridge National Laboratory
    - Jeongseog Song, Argonne National Laboratory
    - Ron Moore, Oak Ridge National Laboratory
    - Dohyun Kim, Brookhaven National Laboratory
    - Stephen Eilertson, University of Tennessee
- Breakout Session C
    - Arne Freyberger (moderator), DOE Isotope Program
    - Nathan Murray (technical support), ORISE
    - Lee Bernstein, University of California Berkeley/Lawrence Berkeley National Laboratory
    - Alan Tatum, Oak Ridge National Laboratory
    - Rob Emery, University of Washington
    - Jerry Nolen, Argonne National Laboratory
    - Matt O'Hara, Pacific Northwest National Laboratory
    - Lauren McIntosh, Texas A&M University
    - Danda Rawat, Howard University
    - Jon Neuhoff, DOE Isotope Program

CHAPTER 2
RADIOISOTOPE PRODUCTION

The production of a radioisotope occurs through transmutation of one nucleus into another that is unstable. This transmutation may be the result of radioactive decay or particle irradiation of a target, which itself may be radioactive. The isotope production targets may be bombarded by neutral particles (*e.g.*, neutron, photon) or charged particles (*e.g.*, proton, deuteron, alpha) having a wide range of energies. Breakthroughs in the science and technology of targets for isotope production can enable increased isotope production yields and minimize target failures during routine production. Improvements in target manufacturability, timeline for safety qualification, ease of physical and chemical processing post-irradiation, as well as other benefits are also possible.

2.1 Nuclear Reactions

An in-depth knowledge and understanding of nuclear reactions, including the cross sections for primary and secondary reactions, is key to radioisotope production. The data analysis involved with cross section studies is an especially challenging area that AI techniques – particularly neural networks and scientific ML – are well suited to address. Large radiation detection systems, such as the Gammasphere installed at Argonne National Laboratory's ATLAS (Argonne Tandem Linac Accelerator System) facility, can be utilized to collect large volumes of data during irradiations studies. This data may include over a thousand gamma lines and many times more spectra. A single day of data collection can produce enough data for several months of processing by traditional non-AI approaches. AI, however, could drastically reduce the time it takes to process data such that real-time or near real-time analysis is possible. This opens the door to exciting opportunities for guiding experimental measurements. ML may also be used to augment nuclear data evaluation such that knowledge gaps are filled predictive models enhanced by AI. Physics-inspired, or domain-aware ML models, are expected to bolster the accuracy of AI models for attribution of radiation signatures in, for example, gamma spectra. Texas A&M University is exploring this concept to aide in the identification of isotopes produced in irradiated samples. The physics-inspired ML approaches are expected to decrease the limits of detection and enable accurate attribution of noisy radiation signatures. A team of researchers at the University of California – Berkeley, Lawrence Berkeley National Laboratory, Brookhaven National Laboratory, and Los Alamos National Laboratory are applying ML techniques – such as K-nearest neighbors, support vector machine, and random forest – to nuclear data evaluation. The standard process for nuclear data evaluation is exposed to human bias and large uncertainties. There is no clear way to combine nuclear data from the various libraries that exist. AI tools, however, can combine these sparse and disparate datasets in models constructed through iterative ML-enabled processes that are able to simultaneously consider and reconcile multitudes of data. The team has explored this approach with neutron cross sections and obtained promising results.

2.2 Target Design and Manufacturing

The process for designing isotope production targets must consider numerous factors. An especially important factor is thermal loading. Improper cooling during irradiation can lead to target warping and degradation or even complete failure of the target system. The latter must be avoided as it can pose safety risks to personnel as well as damage facilities and equipment. The production of many high-priority isotopes is limited by the maximum power that a target can withstand before failing. Target cooling systems are key. LANL is leveraging ML to rapidly process video datasets to feed the construction of computational fluidic dynamics models that accurately describe the water-cooling of targets during irradiation. The end goal is to enable predictive modeling of how targets will behave under intense irradiation conditions that lead to high thermal loadings. This in turn will allow for improved target designs that can withstand maximal beam currents and therefore be used to produce larger quantities of radioisotopes. AI tools may also be used in other target design and manufacturing areas. Multi-physics models may be driven towards co-optimization of isotope production yields and thermal performance through variation of parameters including isotopic content, material types, and geometry.

2.3 Irradiation Control

The tuning of numerous parameters throughout an irradiation campaign is necessary. In some cases, this tuning must occur continuously and at a high feedback rate between the system and the parameter optimizer, which is historically a human or simple feedback-based controller. AI tools hold strong promise for accomplishing this much more effectively. As this area matures, the utilization of digital twins and AI at the edge will become increasingly impactful and important. Digital twins, which are a virtual representation of a physical system, will be fed with live data from an array of sensors that enable extraordinary control of the system to optimize for enhanced isotope production yields. Practically, this would be realized through optimal and precise placement of particle beams on targets during irradiation. Additionally, these same AI-driven pairing of digital and physical twins could allow for increased operational times through predictive maintenance.

2.4 Post-Irradiation Handling

Robotic systems are of high interest for the remote handling of highly radioactive material, such as freshly irradiated targets. In many cases, the transportation of a highly radioactive irradiated target is necessary between the accelerator or reactor area and the final processing area. This transportation can occur either within or between buildings. Routine implementation of robotic systems for such tasks can be accomplished through programming. The benefit of AI manifests when non-routine scenarios and non-ideal conditions must be addressed. In this case, AI can be used to train the robotic systems to make independent decisions on, for instance, the appropriate responses to a stuck target or unexpectedly high radiation fields. ANL is exploring the use of a commercially available robotic platform based on the Robot Operating System to integrate two robotic arms with a remote-controlled cart. The team at Argonne National Laboratory is utilizing an augmented reality operator interface to control the robot currently but is moving towards an automated system. Digital twin simulations are planned for use in training the robotic system with realistic synthetic data. An exciting possibility with this approach is its broad applicability to enable operation of these systems with reduce training times and in facilities that were not originally designed with robotic operations in mind.

CHAPTER 3
RADIOISOTOPE PROCESSING

Physical and chemical processing of radioactive materials is a key aspect of radioisotope manufacturing. Radioisotopes produced through irradiation of a target or decay of a parent radioisotope often result in a mixture of two or more chemical elements. These radioactive materials frequently require some level of physical processing, such as cutting or grinding, prior to chemical processing. Separation, purification, and radiochemical synthesis is then necessary to yield the chemically pure isotope in the required final form. The discovery and maturation of these processing techniques and the materials that underpin them is time and resource intensive. Further, the common timescale for emergent radioisotope needs necessitates rapid translation of processing techniques to routine and reliable implementation at scale. In addition to achieving end-product specifications, processing techniques must also be efficient and safe to be implemented. AI tools offer unique promise to dramatically improve radioisotope processing from the discovery stage through the routine implementation stage.

3.1 Separations and Purification

Molecular constructs for separation materials can take decades of detailed studies to discover and develop practical synthetic pathways for. A promising approach to addressing this issue is high throughput experimentation (HTE). HTE is increasingly commonplace due to wider availability of off-the-shelf automated experimental systems that enable orders of magnitude more experiments to be run per unit time. Augmentation of HTE with AI can take the systems towards an autonomous, self-driving capability that truly capitalizes on HTE and other automated experimental capabilities. Further, AI can incorporate modeling and simulation into the decision-making process alongside physical experimental activities. The Energy Storage Materials Initiative at Pacific Northwest National Laboratory is one example of a project wherein HTE has been coupled with AI to approach autonomous discovery. Although ESMI is focused on electrolytes and other materials for energy storage, the concepts are translatable to DOE IP mission space. The discovery of separation materials, such as chromatography resins, is one example of an area that would greatly benefit from AI-enabled autonomous HTE platforms. Los Alamos National Laboratory has begun to apply this concept towards the development of ligands for solvent extraction-based separations of lanthanides and actinides. This is an important topic area for isotope processing and the technical approach may be extended to other separations (e.g., transition metals) and/or techniques (e.g., ion exchange, extraction chromatography, precipitation).

3.2 Processing at Scale

Once developed, separation and purification approaches must be scaled and routinely operable. The scaling up of a process can be lengthy and resource intensive. AI tools again offer unique promise in enabling more rapid scale up of processing with reduced resource needs. For instance, AI models can be built from heterogeneous data such as from bench and production scale tests. AI techniques can then be utilized to draw connections between the two and enable improved design and selection of bench scale tests that will most appropriately translate during scale up. AI tools can also be utilized for real-time monitoring of radioisotope processing activities to realize improved process reliability. Calibration of the sensor systems can even be performed in an autonomous fashion utilizing AI, as is being considered by Oak Ridge National laboratory. This would significantly reduce the time and resources required to bring a new radioisotope into routine production.

CHAPTER 4
OTHER AREAS

4.1 Workforce Development

There is a significant need for an isotope workforce that is well-versed in the utilization of AI to solve science and technology challenges. This will require the training of students as well as early, middle, and late career staff. This is a similar opportunity faced by other domains that continue to integrate and leverage state-of-the-art AI tools and techniques.

4.2 Enrichment

The research investments that DOE IP makes in the isotope enrichment science and technology arena nurtures a core competency that is vital to ensuring Nation's security and prosperity. The isotopic composition of a material can be critical for determining the usefulness of a material for an application. Isotopically enriched material is, for instance, required for many isotope production targets to reduce the production of undesired side products that could hinder end-use applications. Isotopic enrichment involves the separation of two or more isotopes of the same element from each other. One or more of these isotopes may be radioactive. DOE IP has invested significant resources into re-establishing domestic electromagnetic isotope separation (EMIS) and gaseous centrifuge isotope separation (GCIS) capabilities to produce a variety of critical stable isotopes and has also invested in modest radioactive EMIS capabilities. Enrichment technologies other than EMIS or GCIS are also of interest to DOE IP. Intense and focused research campaigns are required before a new enriched isotope can be routinely produced. Challenge areas that are being addressed include energy and feedstock efficiency of enrichment technologies as well as final recovery of the enriched isotope.

AI has the potential to significantly improve operational efficiencies of isotope enrichment devices. EMIS, GCIS, and other types of enrichment devices have a multitude of parameters that must be tuned for optimal performance. Example parameters include ion beam optics as well as power supply voltages and currents, though many others exist. The process for tuning these parameters to optimal values is intensive due to their quantity and frequent co-dependency. At the same time, numerous sensors and instrument readouts provide an opportunity for real-time autonomous optimization using AI tools. This could ultimately lead to reduced operator hours for the same isotope production rate, which ORNL has begun to consider. Further, improved consistency could be realized due to the precise autonomous control of enrichment devices to optimize production yield, purity, and/or other key targets. This would be especially helpful in addressing the impact that device component degradation has on which parameter levels are optimal. The useful lifetime of components may even be extended through enhanced ability to compensate for degradation effects. An opportunity exists to realize short-term gains in this area as significant amounts of EMIS operational data exists that could be used to train AI systems.

The selection of appropriate material forms is a frequent challenge for EMIS devices on both the front and back ends of production cycles. The properties of EMIS feedstock materials are paramount to achieving efficient feedstock utilization. On the back end of the enrichment cycle, the isotope collectors must be designed for facile recovery of enriched isotopes through chemical processing. AI solutions to rapidly solving R&D challenges in this area share common ground with those described for isotope production and isotope processing.

4.3 Institutional Knowledge

The maintenance of institutional knowledge is one of the most important activities of a program. Institutional knowledge must be readily accessible, whether through human experts or documents, and carefully curated to be effectively applied in the future. AI tools can be leveraged to capture and summarize institutional knowledge. Natural language processing models can extract critical knowledge from documents including procedures and protocols such that the contained knowledge is maintained. Detailed summaries of all information can then be automatically produced by AI with little to no redundancy.

4.4 Supply Chain Management

Isotope demand forecasts are key to planning production schedules and guiding efforts to expand existing or establish new isotope manufacturing capabilities. But accurate levels for isotopes are difficult to estimate even just a handful of years into the future. AI techniques may offer a solution to this challenge for certain isotopes. In the case of radioisotopes for radiopharmaceuticals, there is a wealth of information that could be investigated with AI tools to make predictions of future isotope demand levels. Potential public data sources for AI-guided data harvesting include scholarly publications, conference proceedings and abstracts, press releases, Nuclear Regulatory Commission license applications and amendments, Food and Drug Administration applications and announcements, as well as Securities and Exchange Commission filings. Other isotope application spaces may have similar data that could be used to forecast isotope demands with AI tools, though the medical application space is expected to be a richer data source compared to others.

Isotopes are manufactured at multiple facilities, each with unique capabilities and operational characteristics. A deeper understanding and integration of them would enable a more robust ability to respond to emergent isotope needs. AI-driven manufacturing digital twins, which are virtual replicas of real-world manufacturing capabilities, offer unique promise. The fidelity and level of detail that a manufacturing digital twin has can be altered based on specific needs and available resources. Heterogenous models can even be used if necessary or desired, thereby balancing performance with resources. AI tools then drive the digital twin model to predict optimal system operations and can be used to accurately predict the impact different scenarios would have.

APPENDIX A: AGENDA

Agenda for Day 1 – March 17, 2022			
Time	**Topic**	**Speaker(s)**	**Organization**
11:00 am	Welcome to the 1st Day! Introduction and Workshop Objectives	Kristian Myhre	DOE Isotope Program
11:20 am	Overview of the Department of Energy Isotope Program	Jehanne Gillo	DOE Isotope Program
11:40 am	Session 1: Building Blocks of Isotope R&D and Production		
	Isotope Production and Processing	Cathy Cutler	Brookhaven National Laboratory
	Translation of Novel Radiopharmaceuticals: From Bench to Bedside and Beyond	Anna Wu	City of Hope
	The Horizon-broadening Isotope Production Pipeline Opportunities (HIPPO) Program	Sherry Yenello	Texas A&M University
12:40 pm	Session 1 Q&A		
1:00 pm	*Break*		
1:30 pm	Session 2: Building Blocks of Applied Artificial Intelligence		
	Foundations in AI for Scientific Discovery	Courtney Corley	Pacific Northwest National Laboratory
	Building Blocks of Applied AI	Kristin Persson	Lawrence Berkeley National Laboratory
	Applied AI: Transforming Theory to Practice	Vijayan Asari	University of Dayton
2:30 pm	Session 2 Q&A		
3:00 pm	Closing Remarks and Day 2 Overview	Kristian Myhre Jehanne Gillo	DOE Isotope Program DOE Isotope Program
3:20 pm	*Adjourn 1st Day*		

Agenda for Day 2 – April 14, 2022			
Time	**Topic**	**Speakers**	**Organization**
11:00 am	Welcome to the 2nd Day!	Kristian Myhre	DOE Isotope Program
11:10 am	Round One of Lightning Talks	Rob Emery Jerry Nolan Yawen Li Ron Moore Jasmine Hatcher-Lamarre Ken Brooks Rob Emery John Gahl	Univ. of Washington Argonne National Lab Univ. of Washington Oak Ridge National Lab Brookhaven National Lab DOE Isotope Program Univ. of Washington Univ. of Missouri
12:00 pm	*Break*		
12:10 pm	Round Two of Lightning Talks	Etienne Vermeulen Karl Mueller Ping Yang Hunter Andrews Matt O'Hara Sherry Yennello Lee Bernstein Jerry Nolan	Los Alamos National Lab Pacific Northwest National Lab Los Alamos National Lab Oak Ridge National Lab Pacific Northwest National Lab Texas A&M University Univ. of California Berkely, Lawrence Berkely National Lab Argonne National Lab
1:00 pm	*Break*		
1:30 pm	Breakout Sessions (*with breaks*)	All Workshop Participants	
4:10 pm	*Break*		
4:30 pm	Summary of Breakout Sessions	Kristian Myhre Draguna Vrabie Arne Freyberger	DOE Isotope Program Pacific Northwest National Lab DOE Isotope Program
5:00 pm	Closing Remarks	Kristian Myhre Jehanne Gillo	DOE Isotope Program DOE Isotope Program