OAK RIDGE National Laboratory

Isotope Program
US Department of Energy

NIDC | NATIONAL ISOTOPE DEVELOPMENT CENTER
MANAGED BY THE U.S. DEPARTMENT OF ENERGY ISOTOPE PROGRAM

Progress on Reducing the Nation's Dependency on Foreign Isotope Supplies and Impacts of COVID on Supply Chains

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U.S. DEPARTMENT OF ENERGY

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Presentation Outline

- Early U.S. investment in isotope production
- Transition to foreign dependency & consequences
- Reemergence of U.S. capabilities
- Impacts of COVID on isotope supply chains

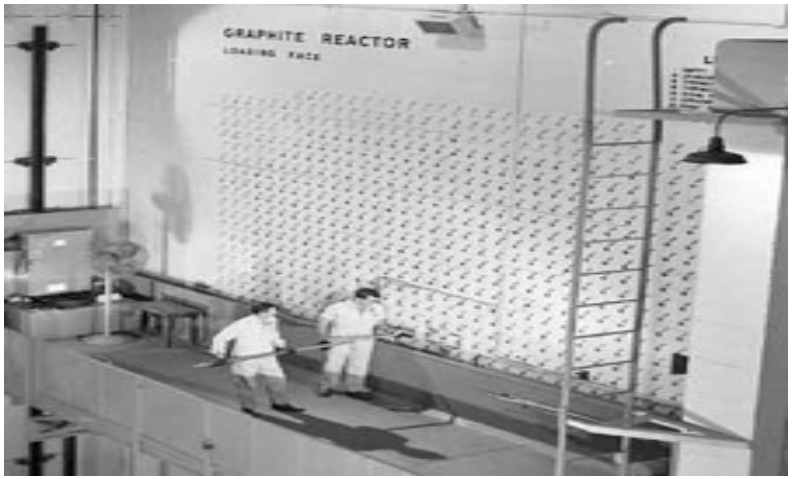
Early Investment in Isotope Production (Started in 1940s)

- Hot cell facilities were built to process a variety of isotopes.
- Developed a workforce of chemists and engineers to manage production and processing.
- Developed business operations, packaging and transportation, and logistics.

LIFE Magazine, May 1950: Isotope Circle at Oak Ridge National Laboratory

In August 1946, the Laboratory's research director, Eugene Wigner, handed the first shipment of a reactor-produced radioisotope, a container of carbon-14, to the director of the Barnard Free Skin and Cancer Hospital of St. Louis, Missouri.

First medical isotope shipment in1946



ORNL Graphite Reactor used for isotope production.

U.S. Transitioned from a Primary Producer to an Importer

1946-1985

U.S. production fueled isotope research and commercialization

- Cinticem reactor in New York produced isotopes until 1989
- National Labs producing isotopes for research and industry
- Calutrons converted from uranium to stable isotope enrichment

1986-2000

Foreign producers take advantage of losses in U.S. production capabilities

- U.S. production reactors extended outage (HFIR) and shutdown (ORR) in late 1980s
- U.S. radioisotope processing facilities shutdown in late 1980s
- DOE calutrons used for stable isotope enrichment close in 1999
- Fall of the Soviet Union in 1991; **Russia enters global market**

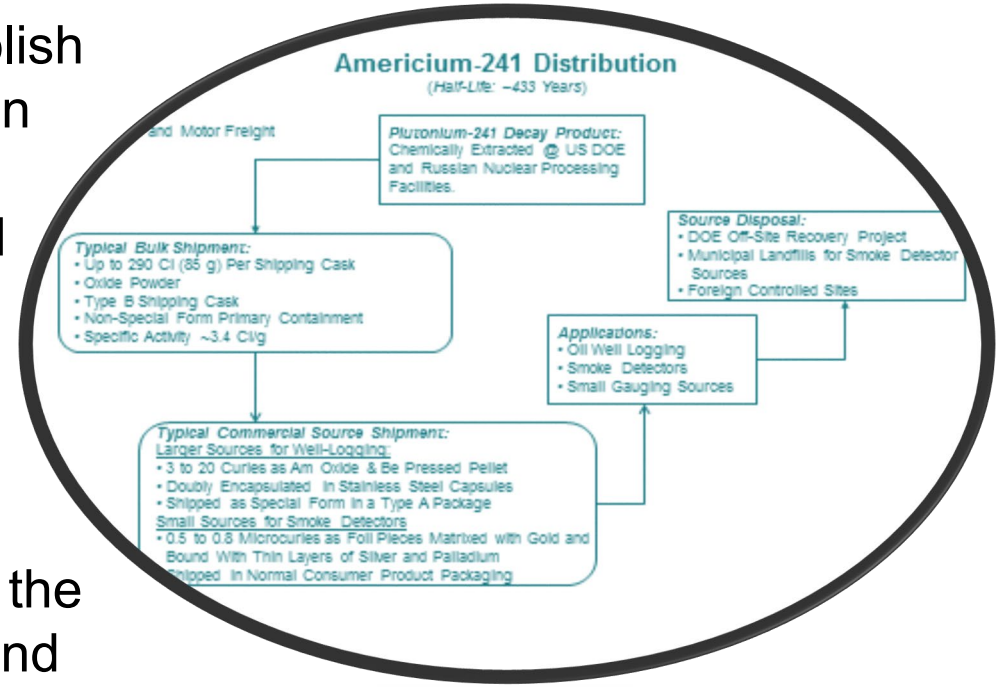
2001 - Present

U.S. production is limited, and bulk isotopes used in industry, research, and medicine are imported.

- U.S. currently relies on foreign sources for bulk quantity isotopes
- U.S. industry refines foreign-supplied bulk isotopes into high value end-use products
- Russia, Belgium, Canada and the Netherlands are now primary suppliers of bulk quantity isotopes

Consequences of Foreign Dependency

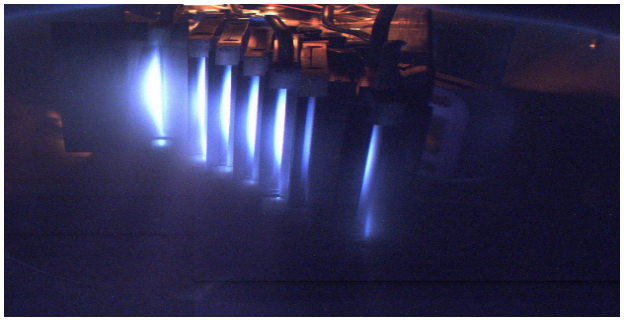
- Geopolitical issues can result in supply disruptions
- Foreign producers can establish single-supplier monopolies on certain isotope products, resulting in higher prices and unreliable service
- Potential erosion of U.S. production capabilities and expertise
- From a security perspective, the U.S. has minimal influence and control over global distribution of bulk isotope quantities



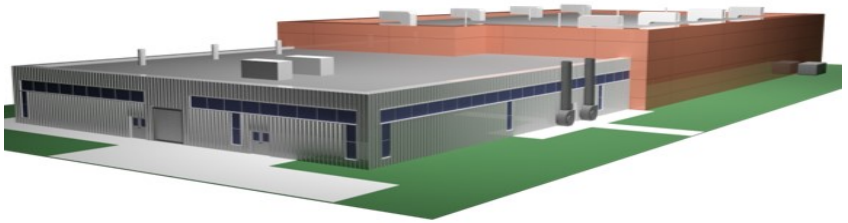
The Isotope Program is Taking Steps to Mitigate Potential Disruptions from Foreign Suppliers

- Continually assessing various isotope markets
- Monitoring isotopes that are foreign-supplied
- Estimating the time it will take to establish U.S. production
- Proactively addressing foreign supply chain vulnerabilities

Reemergence of U.S. Isotope Production



Investing in isotope enrichment technology



Planning for new isotope processing facilities

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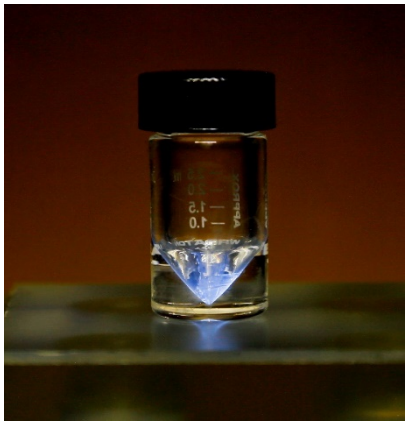
Supporting discovery



Developing medical isotopes

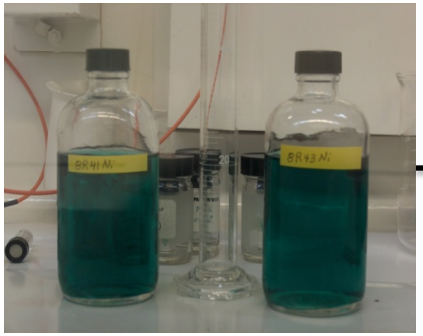
Providing needed infrastructure

U.S. Government's Role in the Supply Chain

U.S. Government Sector

Bulk Supplier Market (DOE)

Bulk/Feedstock Products from:
- High Flux Reactors
- High Energy Accelerators
- Stable/Radio Inventories



Pure radiochemical or irradiated stable precursor is the starting ingredient.

U.S. Commercial/Private Sector

Commercial Source Market

Commercial Products
- Industrial source manufacturers
- Radiopharmaceutical companies
- Specialty chemical companies

Certified Commercial Sources

Medical Generator Systems

End-Use Device Market

- Oil/gas exploration
- QA (non-destructive testing)
- Explosives detection
- Gauges / Alarms
- Biomedical imaging
- Medical therapy
- Nuclear research & safety
- Geological dating
- Environmental tracers

Scanning Devices Containing Sources

Medical Imaging Devices

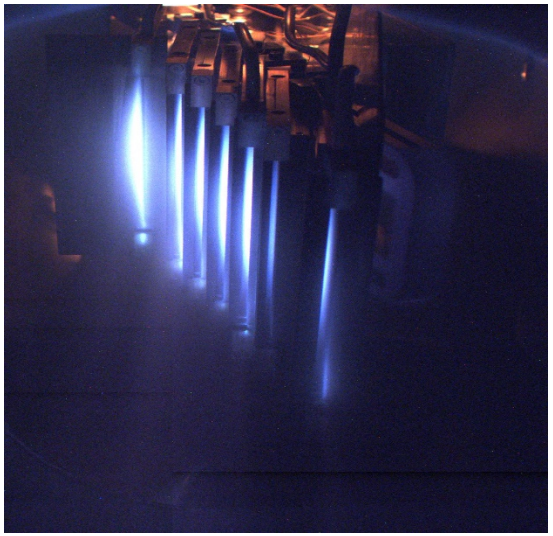
Stable Isotopes: Diverse Medical, Research, and Industrial Applications

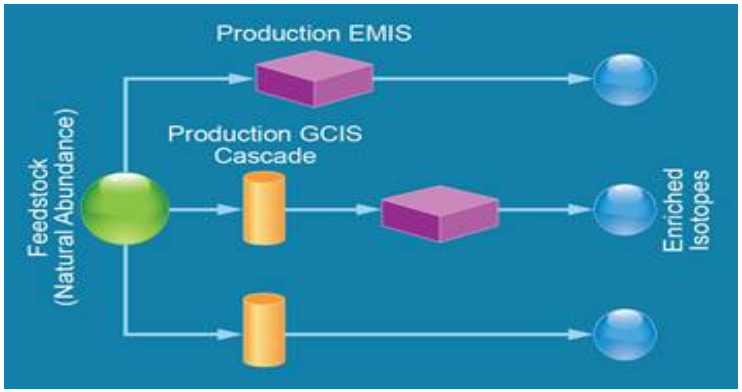
Russia and Netherlands produce kilograms of enriched stable isotopes for U.S. market

Isotope	Application	Amount
Ytterbium-176	Reactor production of Lu-177 for cancer treatment	>200 grams per year
Germanium-76	Nuclear physics (Majorana Collaboration)	~100 kilograms for initial experiment
Zinc, depleted in Zn-64	Zn coolant additive is a corrosion inhibitor in nuclear power plants. Depleting in Zn-64 reduces activation products and lowers personnel exposure during maintenance.	Hundreds of kilograms per year used by U.S. nuclear power industry
Molybdenum-98 and -100	Reactor & accelerator production of Mo-99 for medical imaging	Potentially tens of kilograms needed per year to support new production capabilities in U.S.
Strontium-88	Production of Sr-89 for palliative treatment of pain for bone cancer patients	Hundreds of grams per year
Thallium-203	Production of Tl-201 for heart imaging	~600 grams per year

Isotope Program Stable Isotope Production & R&D Investments can Reduce U.S. Dependence

- Reestablished U.S. stable isotope enrichment capabilities in 2018 at Oak Ridge National Laboratory
- Produced ~100 milligrams of enriched **Ru-96** for DOE nuclear physics research project
- Development and testing underway for enriching **Yb-176, Xe-129, Mo-98**, and **Mo-100** for medical applications
- Planning underway to expand production capacity to kilogram quantities





Lithium-7: Power Reactor Corrosion Inhibitor

- U.S. fleet of commercial Pressurized Water Reactors (PWRs) is 100% reliant on enriched Li-7 from Russia and China
- The U.S. has ~65 operating PWRs generating ~13% of the U.S. electric power needs
- Used to buffer reactor coolant and prevent corrosion
- ~500 kilograms are imported into the U.S. annually

Working to Reduce U.S. Foreign Dependency on Lithium-7

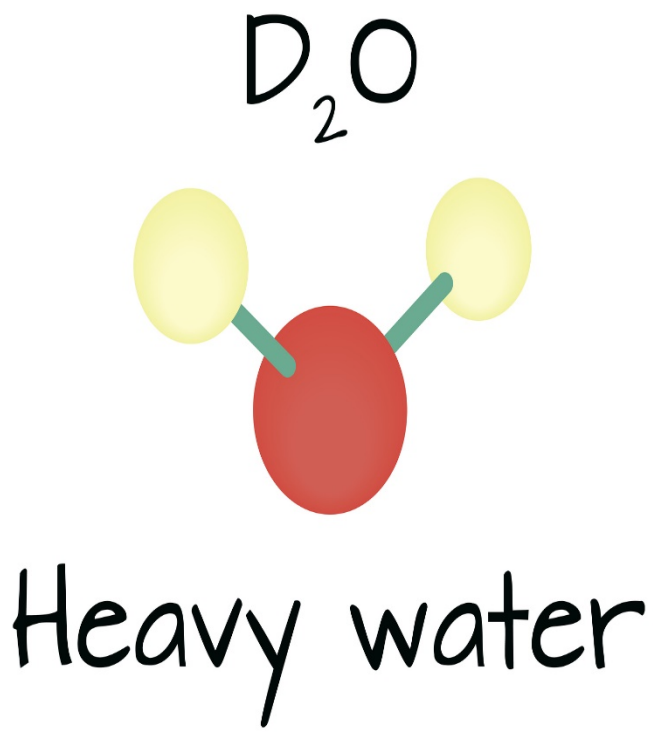
- Investing in the development of alternative technologies for enriching Li-7
- Working with the Nuclear Energy Institute (NEI) and the Electric Power Research Institute (EPRI) to investigate recycling
- NEI and EPRI are also investigating the possible use of other materials instead of Li-7 for PWR chemistry.
- Working with private industry on alternative supply opportunities for advanced power reactor technology to address near and long-term needs

Heavy Water (D_2O): Deuterated Compounds for Research and Medicine

- Primarily used as moderator for heavy water nuclear power reactors in foreign countries
- Excess production from Canada, India, and Argentina is available to U.S. commercial markets
- The U.S. imports ~75 metric tons per year
- U.S. applications include:
  - Nuclear magnetic resonance (NMR) and mass spectroscopy (MS) instrumentation, both powerful analytical tools at major research and medical institutes.
  - Protein labeling for research and in solvent preparation
  - Drug discovery and development programs using deuterated compounds
  - Fiber optics technology applications

Working to Reduce U.S. Foreign Dependency on Heavy Water (D_2O) / Deuterium

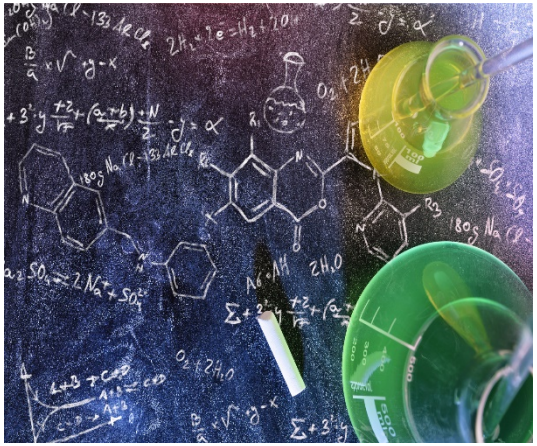
- Investing in the development of alternative technologies for enriching deuterium
- Working with scientists at the National Energy Technology Laboratory (NETL) on potential enrichment techniques
- Monitoring supply and demand for the U.S. market



Carbon-14: Carbon Labeling for Research and Medicine

- U.S. market is ~60 to 80 curies per year
- Global market is ~1,000 to 2,000 curies per year
- Russia is currently the sole supplier of C-14
- C-14 labeled pharmaceuticals are key to new drug development
- C-14 labeled drug candidates offer unsurpassed sensitivity and specificity for FDA required administration, distribution, metabolism, and excretion (ADME) studies

C-14 production and process development is underway with the goal of reestablishing U.S. production of this important biomedical isotope within 2 to 3 years



Americium-241: Oil and Gas Exploration

- U.S. demand is ~200 grams (~680 curies) per year
- Global demand is ~650 grams (~2,200 curies) per year
- Primary application is for AmBe neutron sources used in oil and gas exploration
- Small quantities used for smoke detectors
- Russia has been the sole supplier

Production and distribution of **Am-241** has been reestablished at LANL sufficient to meet U.S. demand.

Cobalt-60: Gamma Surgery and Sterilization

High Specific Activity (HSA) Co-60

- ~500 kilocuries of HSA Co-60 is deployed throughout the U.S. in medical therapy devices
- Used for gamma surgery in treatment of brain tumors
- Currently all HSA Co-60 is imported from Russia and Canada

First shipment of **HSA Co-60** in over five years from the Advanced Test Reactor at INL is planned for spring 2021

Iridium-192: Gamma Radiography Applications

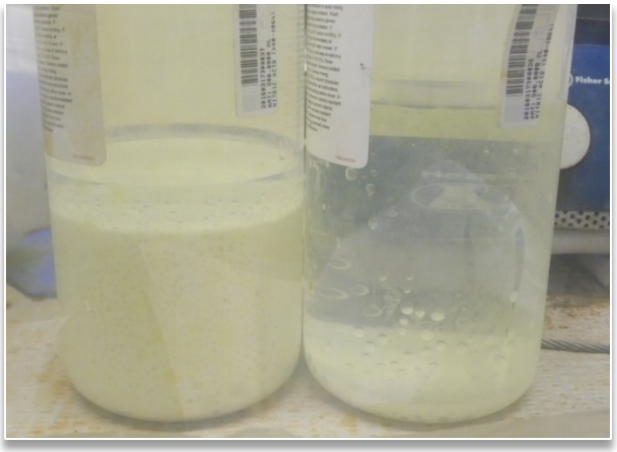
Nondestructive Testing for U.S. Infrastructure

- ~800,000 curies of Ir-192 are imported into U.S. annually
- Enough bulk radioisotope to build ~8,000 individual sources
- Industrial applications include shipbuilding, boiler manufacturing, and oil/gas pipeline inspections
- U.S. dominated production in this market up until 1986
- Currently imported primarily from Russia, Belgium, and Netherlands

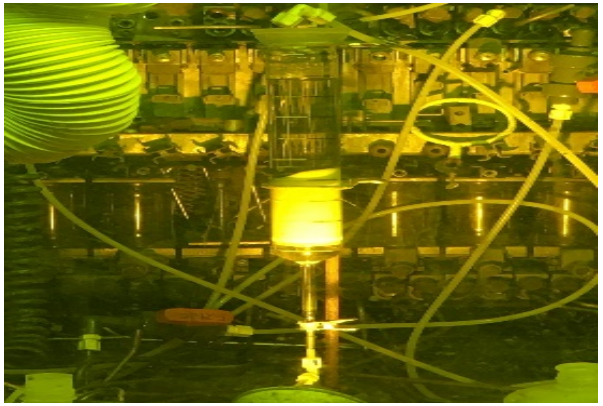
The DOE Isotope Program continues to assess production and processing capabilities within the DOE Complex for **Ir-192**

Isotopes Formerly Only Available from Foreign Producers; Now U.S. Produced

- **U-234** extracted from legacy PuBe sources used to reestablish U.S. inventory. U-234 is used in power monitoring devices in nuclear power plants. Shipments to industry are ongoing
- **Ba-133** production is ongoing for sources used in the oil and gas industry.
- **Pm-147** production development for thickness gauging sources and nuclear batteries is underway with test samples being evaluated by industry.



Uranium-234 solution undergoing precipitation process in preparation for conversion to uranium oxide (U_3O_8).



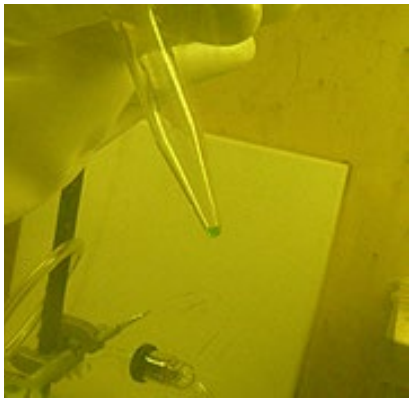
Promethium-147 purification process

Summary of Mitigations to Reduce Dependency

Isotope	Mitigation
Cf-252	Increase supply if demand increases
He-3	Evaluating new sources, recycle, & invest in alternative technologies
Fe-55	Investigating restart of production
Cs-137	Recommend alternative technology
Co-57	Investigating production method
Sr-90	Increased available inventory at PNNL
Cd-109	Maintaining production at LANL
Pd-103	Evaluating reactor and accelerator production
W-188	Reestablished production at ORNL
Ce-134	Initiating production at LANL

Isotope Program Continues to Maintain Production Capacity for Unique Commercial and Research Isotope Activities

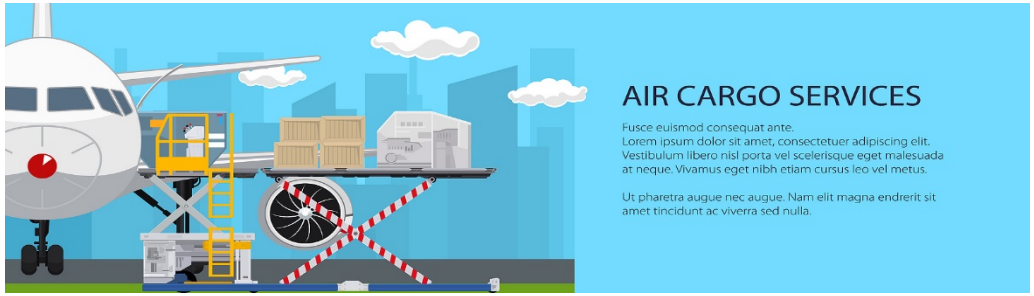
- **Californium-252** sources for reactor startups, nuclear fuel quality control, and coal/mineral analyzers
- **Nickel-63** for explosives detection instruments
- **Actinium-225** for cancer treatment research
- **Heavy Element** production for nuclear physics research
- Continued distribution of research quantities from legacy inventory of ~245 **enriched stable isotopes** by the U.S.
- Transitioned medical imaging isotopes **Sr-82** and **Ge-68** from government to the U.S. private sector production.



Supply Chain Impacts of COVID-19

COVID Consequences started in March 2020

- Passenger aircraft flight cancellations resulting in lost capacity for shipping short-lived medical isotopes, especially for international shipments.
- Lost capacity from passenger flights shifted to cargo flights. This temporarily overwhelmed the air cargo system.
- Universities halted research activities reducing demand for research isotopes.
- Commercial isotope supply chains encountered disruptions in manufacturing, end-use applications, and transportation.
- Commercial isotope product manufacturers attempted to balance supply and demand with weekly disruptions in one or more market sectors associated with the broader supply chain.



COVID Mitigation

- **DOE isotope production was designated as a mission critical function within the DOE Office of Science**
- Initiated transportation discussions early in the process to plan shipment routing. Discussions included shipping personnel, the customer, and the freight-forwarder, when applicable.
- Performed daily updates on shipments to the DOE Isotope Program management. This allowed real-time situational awareness.
- Freight-forwarders anticipated problems and were able to reroute shipments as necessary

Questions?