# Niowave's Domestic Production of Mo-99 and other Fission Fragments from LEU without a Nuclear Reactor

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*Accelerating Your Particles*

# Outline

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- Niowave's System
- Licensing Strategy
- Lab Support
- Mo-99 Production
- Extraction & Uranium Recycling
- Summary

# Therapeutic α & β Emitters

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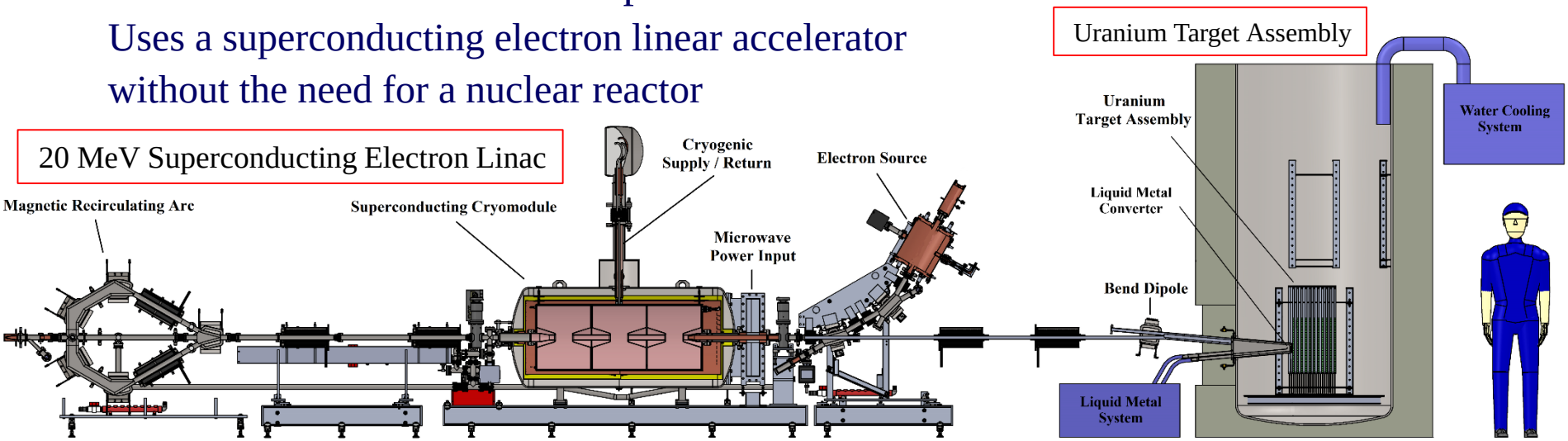
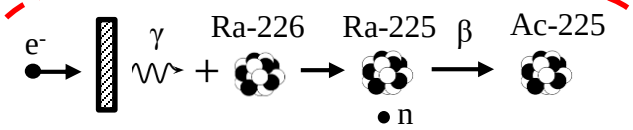
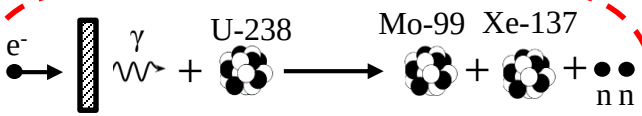
Niowave manufactures radioisotopes from radium and uranium

- Uses a superconducting electron linear accelerator
- without the need for a nuclear reactor

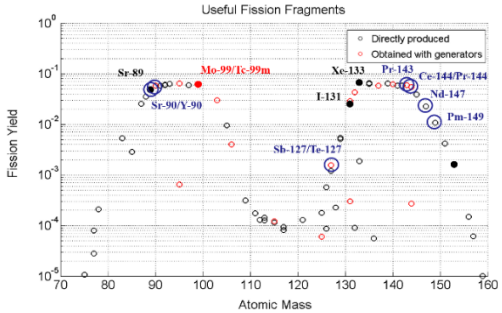



| | |
|---|---|
| Ac-225 | 10 d |
| Rn-222 | 3.8 d |
| Po-210 | 138 d |
| Bi-210 | 5.0 d |
| Bi-213 | 46 m |
| Bi-214 | 20 m |
| Pb-214 | 27 m |




| | |
|---|---|
| Mo-99→ Tc-99m | I-131 |
| Sb-127→Te-127 | Xe-133 |
| Ba-140→La-140 | Sr-89 |
| Ce-143→Pr-143 | Y-91 |
| Sr-90→Y-90 | Ce-141 |
| Ce-144→Pr-144 | Nd-147 |
| | Pm-149 |



# NRC Licensing Strategy

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| Category | | Phase 1 | Phase 2 | Phase 3 |
|---|---|---|---|---|
| Production Level | | Demo | Pilot | Commercial |
| $k_{eff}$ | | 0.43 | 0.75 | 0.95 |
| Fission Power | | 23 mW | 230 W | 230 kW |
| Activity Produced[1] | | 1 mCi batches | 10 Ci/week | 10 kCi/week |
| NRC | License Type | Materials | Materials | Materials |
| | Regulatory Process[2] | 10 CFR 30, 70 | 10 CFR 30, 70 | 10 CFR 30, 51, 70 (50 TBD) |
| Completion Date | | ~~Dec 2018~~ COMPLETE | Dec 2021 | Dec 2025 |

*[1]10 kCi/week Mo-99 EOB = 1,550 6 day Ci/week Mo-99*
*[2]Including 10 CFR 20, 3X, 40, 7X*

# National Laboratories

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- Argonne National Laboratory
  - Mo extraction (LMC & MoLLE)
  - UREX
- Los Alamos National Laboratory
  - Liquid metal neutron source
- Oak Ridge National Laboratory
  - Pellet pressing
- Pacific Northwest National Laboratory
  - Effluent monitoring and abatement
- Y-12 Security Complex
  - Uranium metal to oxide powder conversion

# Loading and Testing [1]

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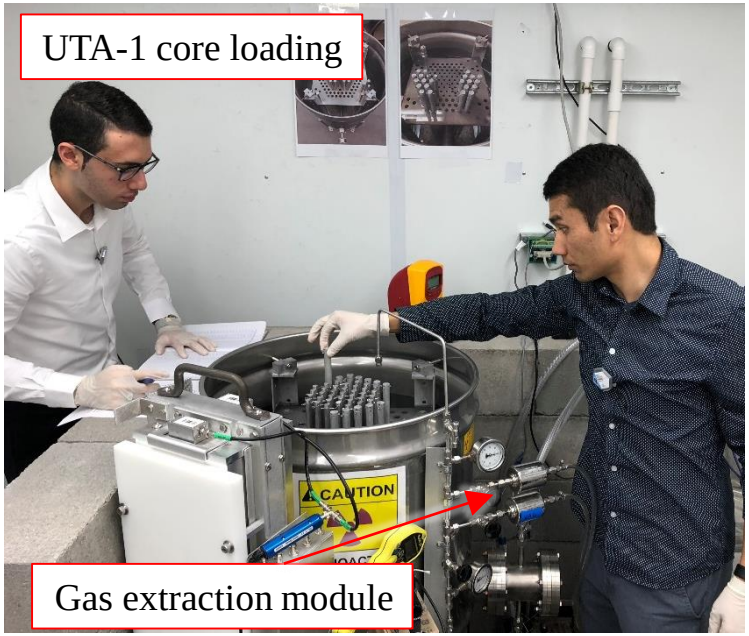


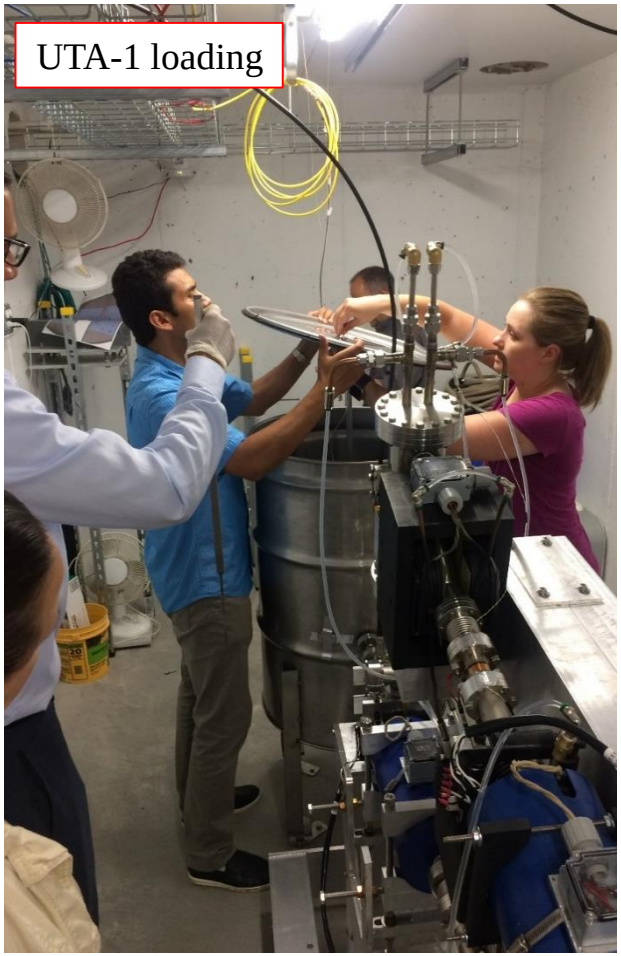


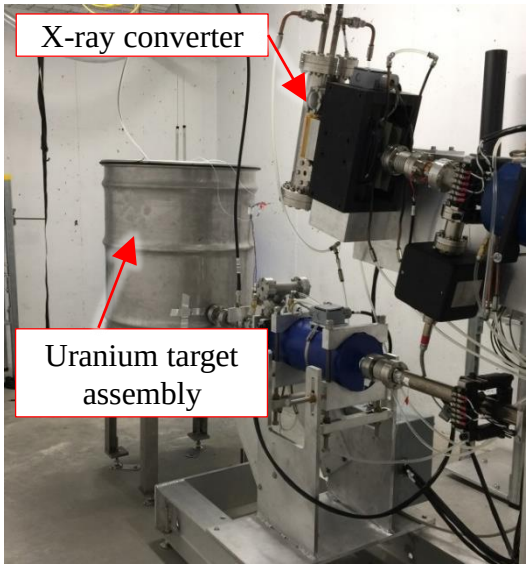


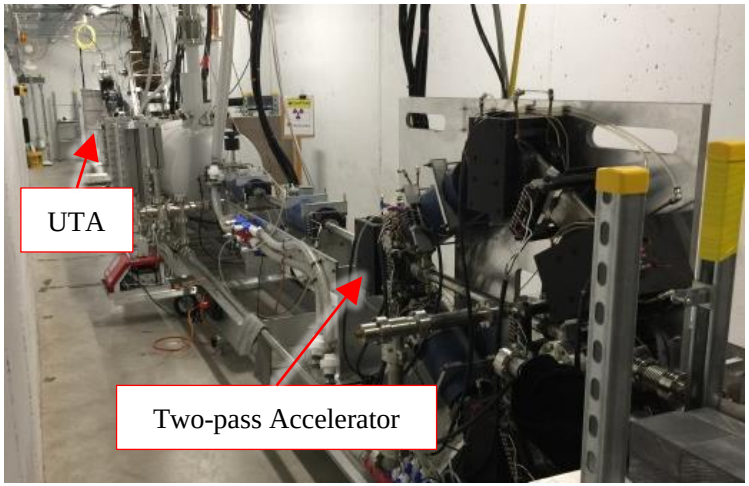


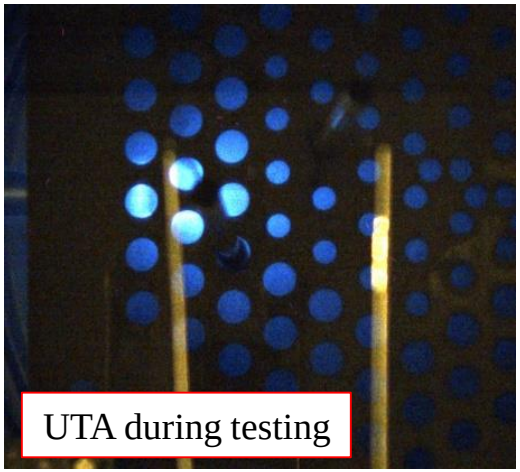

# LBE Neutron Converter

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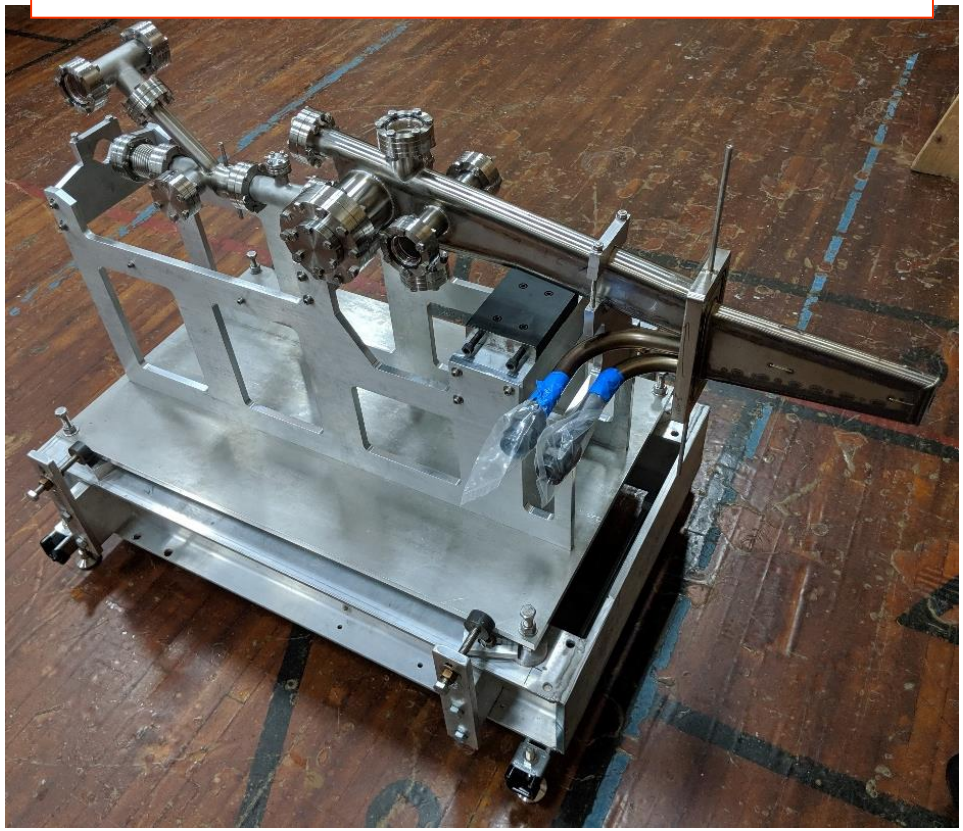
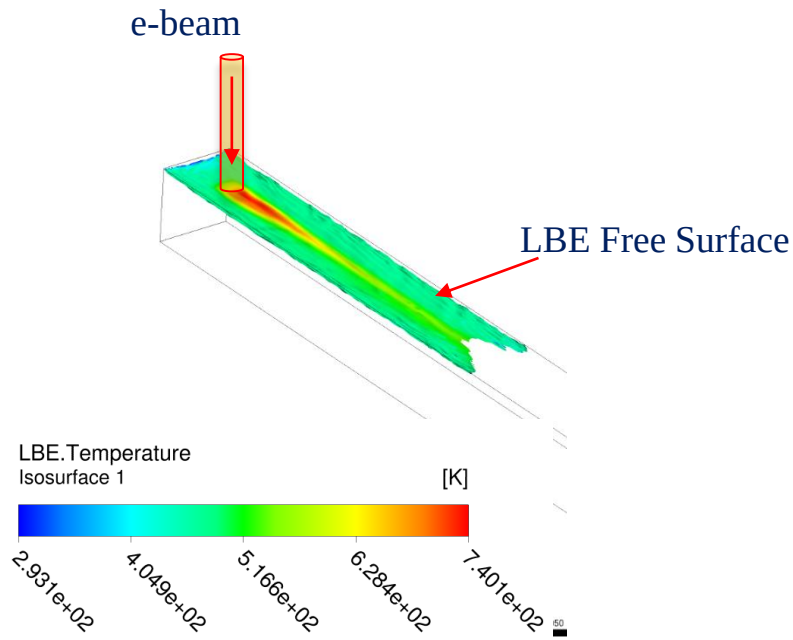
New high power LBE neutron converter



Thermal-hydraulics simulations of LBE converter



Los Alamos
NATIONAL LABORATORY
EST. 1943

# Mo-99 Extraction [1]

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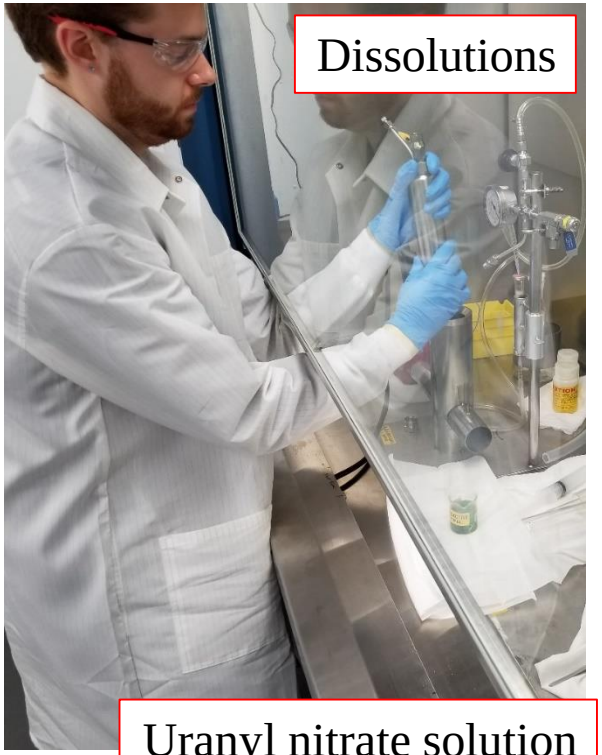
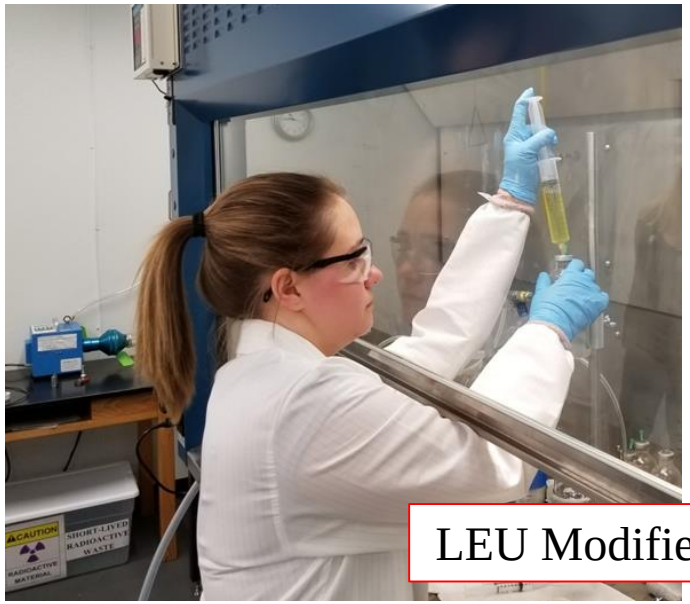
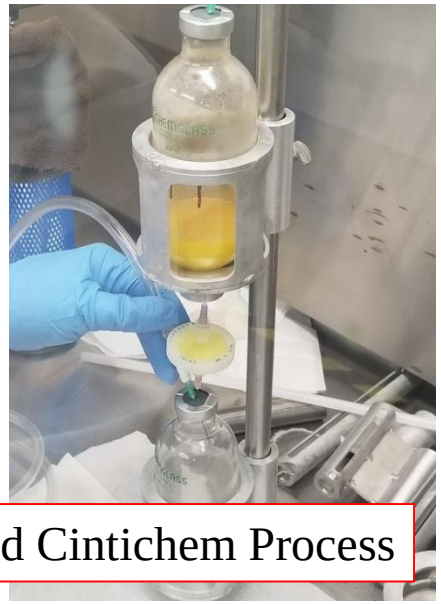
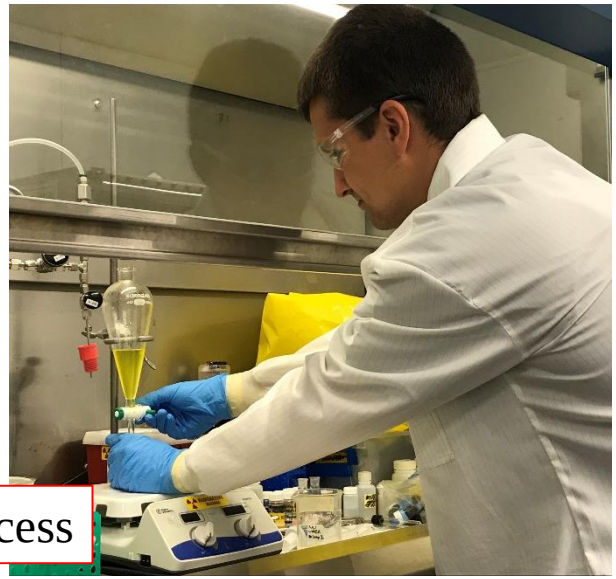




LEU Modified Cintichem Process

Uranyl nitrate solution



MoLLE Process

# Mo-99 Extraction [2]

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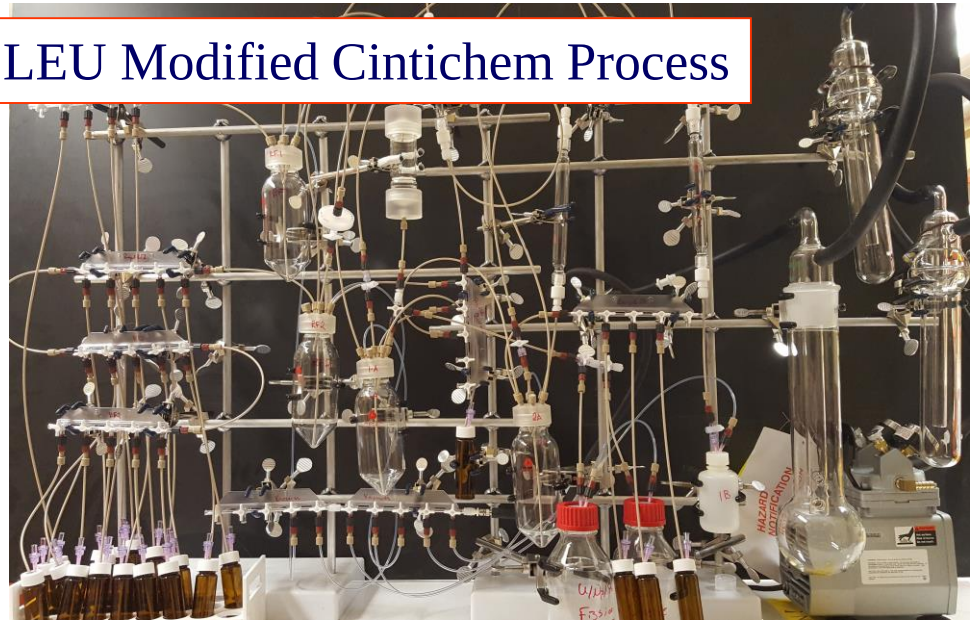
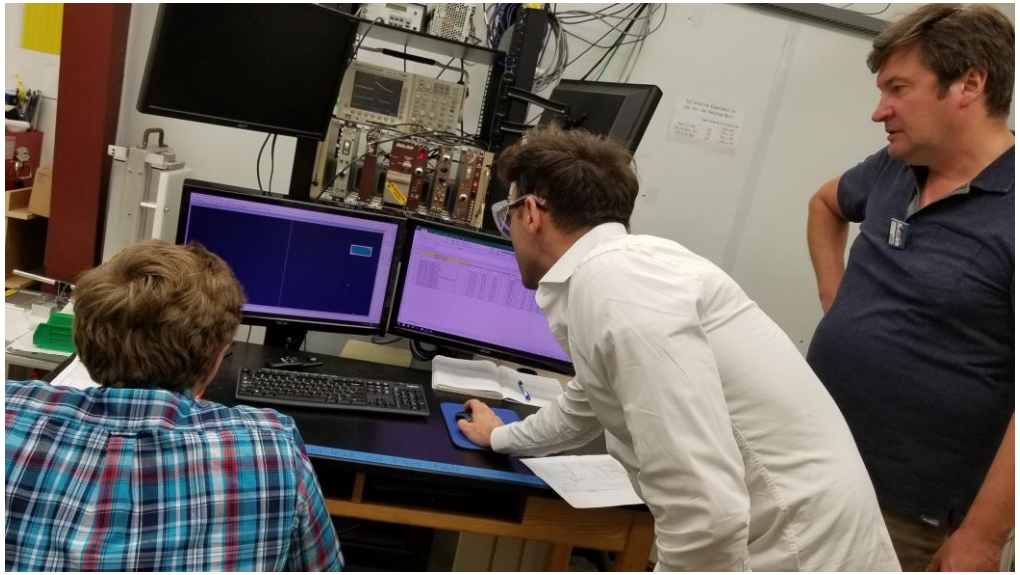
LEU Modified Cintichem Process



Mo-99 Liquid-Liquid Extraction



Argonne NATIONAL LABORATORY UNLV

# Uranium Recycling [1]

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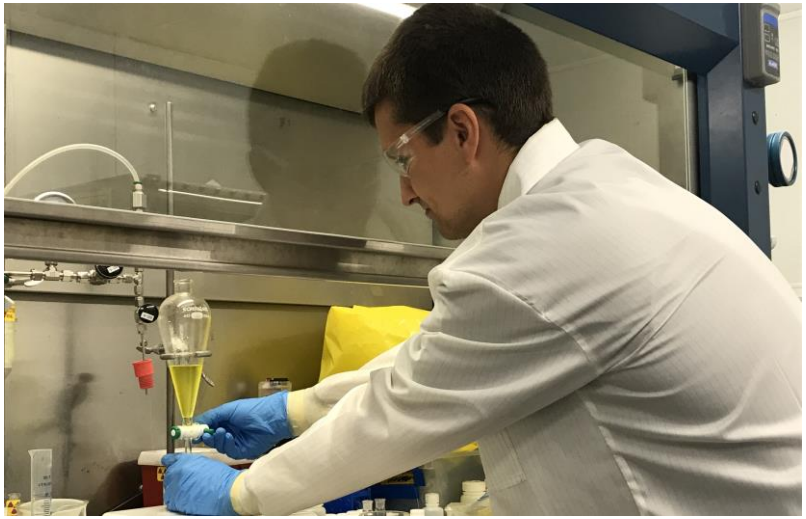
Training from world-class experts



Centrifugal Contactors

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# Uranium Recycling [2]

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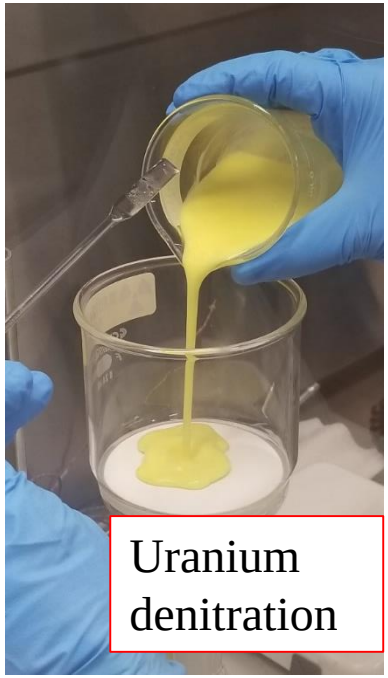


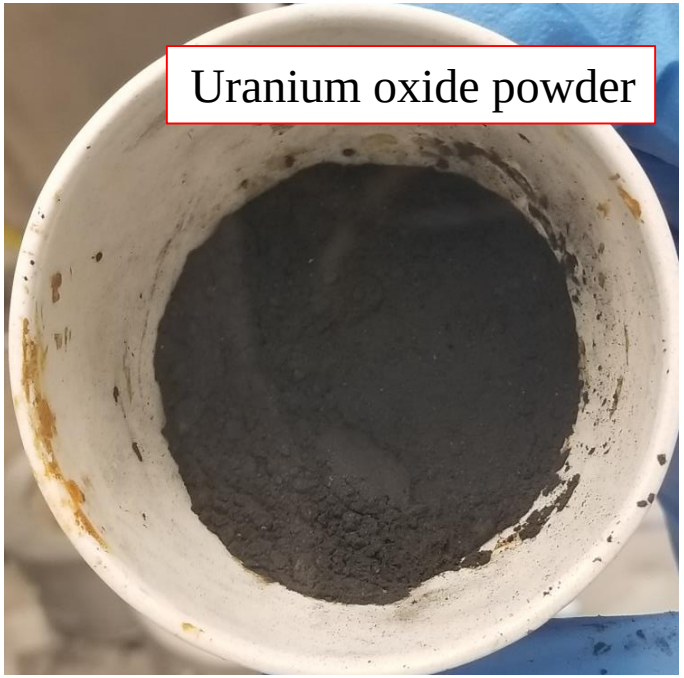


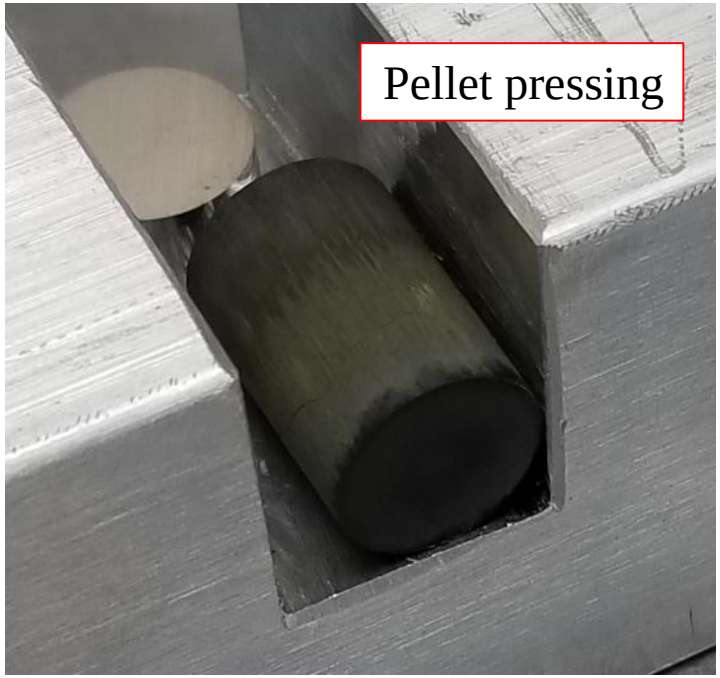

Pressed pellets are loaded for re-irradiation

OAK RIDGE National Laboratory

Y-12 National Security Complex

# Pellet Pressing

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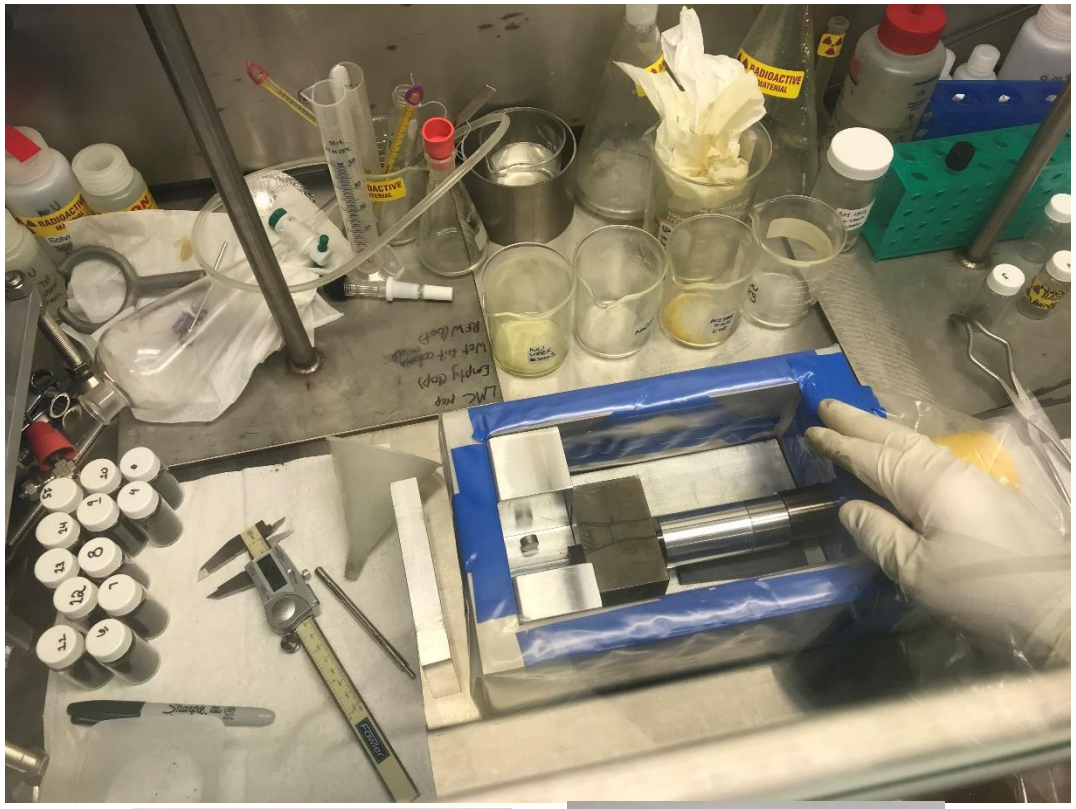

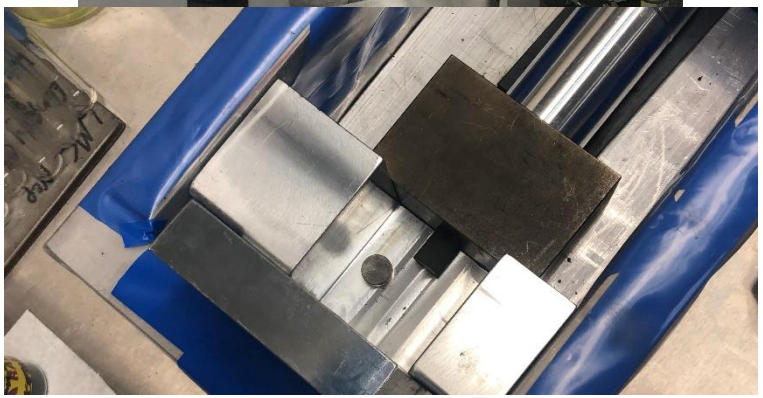

# Effluent Monitoring/ Abatement

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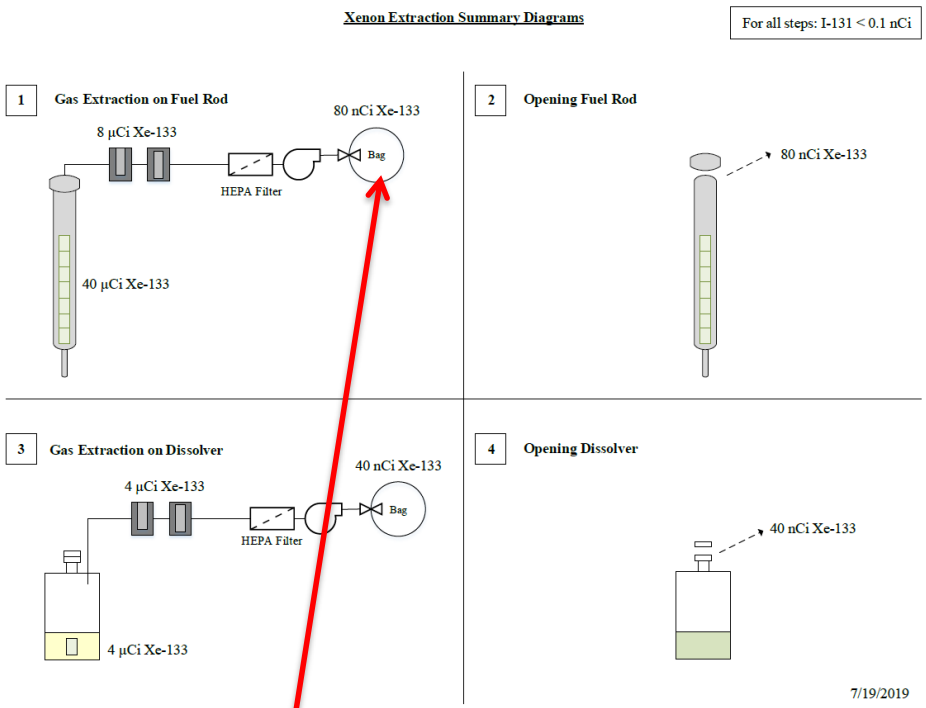
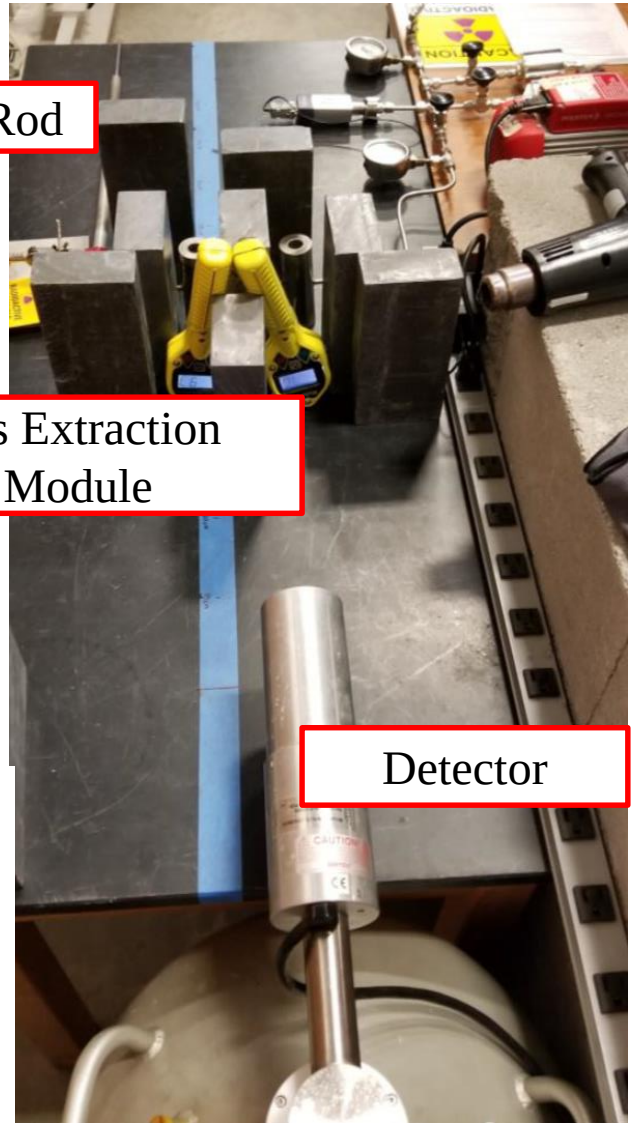


PNNL



# Summary

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## NRC, DOT, FDA regulated

R&D facility operational

- Sample quantities (mCi) of many isotopes available now (2019)

GMP production facility constructed

- Commissioning and FDA registration in 2020 with continuous, uninterrupted supply available in 2021
- **In 2021, β-emitters at 10 Ci/week**
- Isotopes delivered as an active pharmaceutical ingredient
- Larger quantities available in later years