NIOWAVE
Accelerating the Fight Against Cancer

Niowave NRC Preapplication Meeting

Uranium Cycle Processes

Public Session

August 16, 2023

Outline

- Review/Intro
- Licensing
  - Part 70 (SNM) vs. Production Facility
  - Cat III SNM
- Process Overview
  - Facility overview
  - Equipment layout
  - Ventilation system
- Preliminary Hazard Analysis summary
  - Process Flow Diagrams
  - Specific Hazards
- Next steps

NIOWAVE

Accelerating the Fight Against Cancer

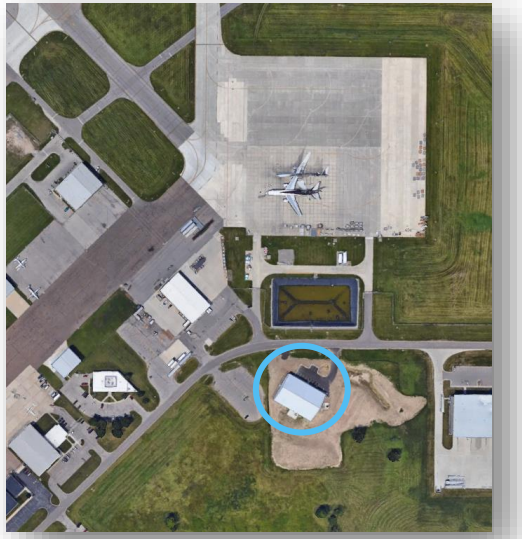
Review

Niowave Facilities

6000 m^2

1300 m^2

Headquarters: Management, Administration, Shop, Research and Development

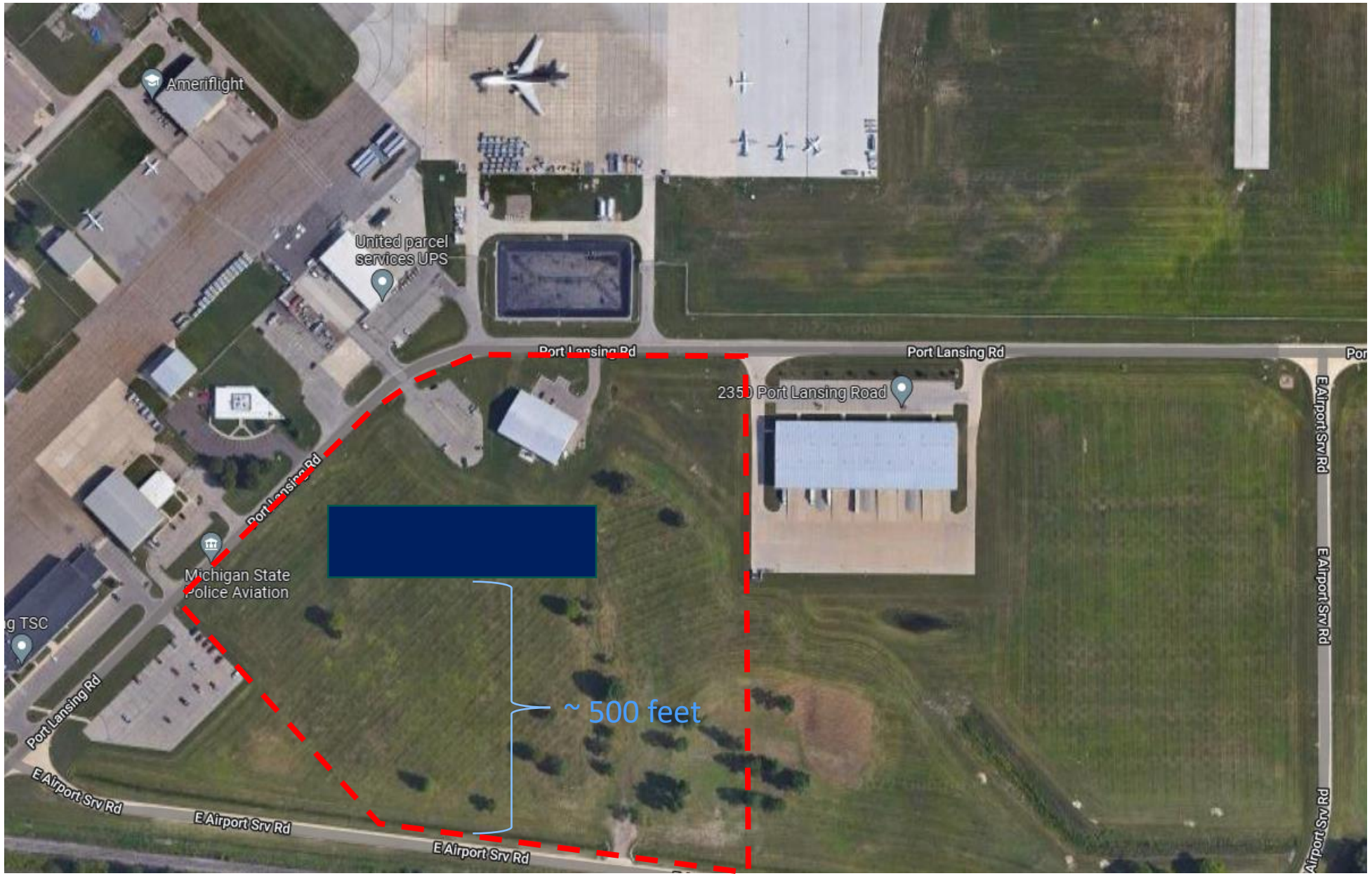


1300 m^2

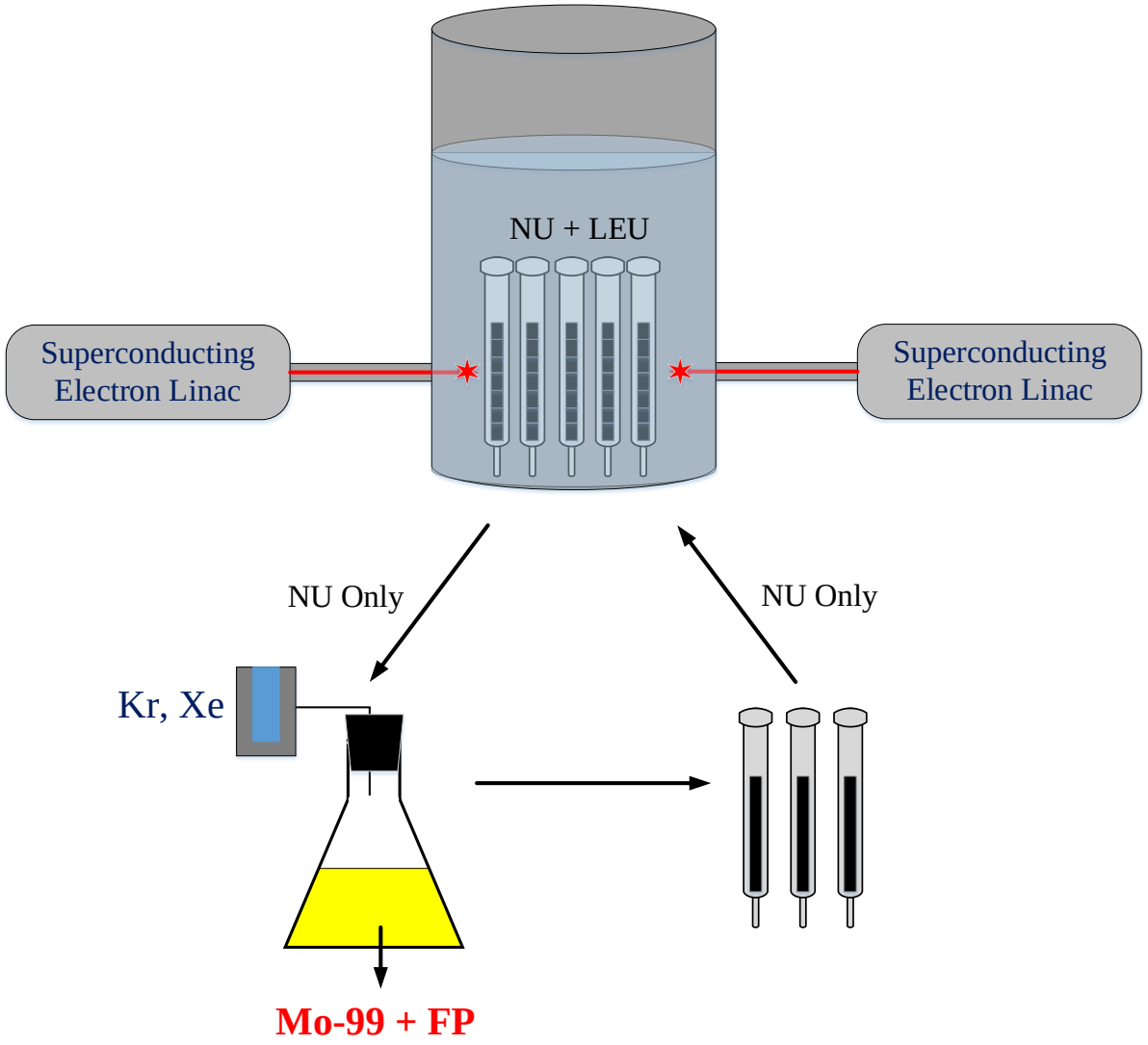
Production Facility: Receiving, Inspection, Processing, Shipping, Storage

Mo-99 Commercial Facility Overview

NIOWAVE
Accelerating the Fight Against Cancer



Mo-99 Commercial System Overview



Accelerator Driven Neutron Source (x2)	
Electron Beam Power	200 kW = 40 MeV x 5 mA
Neutron Source Intensity	~ 2.0 x 10^{14} n/s

Uranium Target Assembly	
$k_{effective}$	≤ 0.95
LEU Target Mass	XX kgU
NU Target Mass	60 kgU
LEU Fission Power	XX kW
NU Fission Power	21 kW
Mo-99 Activity Produced	6 kCi/week EOB

Uranium Cycle & Isotope Pipeline	
NU processed	60 kgU/week
LEU processed	None
Mo-99 Activity Extracted & Shipped	0.8 kCi/week EOB (2% US Demand)
Other Isotopes	Xe, I, Sr, Lanthanides

NIOWAVE
Accelerating the Fight Against Cancer

Licensing Considerations

Production Facility

Production facility means:
(1) Any nuclear reactor designed or used primarily for the formation of plutonium or uranium-233; or
(2) Any facility designed or used for the separation of the isotopes of plutonium, except laboratory scale facilities designed or used for experimental or analytical purposes only; or
(3) Any facility designed or used for the processing of irradiated materials containing special nuclear material, except (i) laboratory scale facilities designed or used for experimental or analytical purposes, (ii) facilities in which the only special nuclear materials contained in the irradiated material to be processed are uranium enriched in the isotope U-235 and plutonium produced by the irradiation, if the material processed contains not more than 10^{-6} grams of plutonium per gram of U-235 and has fission product activity not in excess of 0.25 millicuries of fission products per gram of U-235, and (iii) facilities in which processing is conducted pursuant to a license issued under parts 30 and 70 of this chapter, or equivalent regulations of an Agreement State, for the receipt, possession, use, and transfer of irradiated special nuclear material, which authorizes the processing of the irradiated material on a batch basis for the separation of selected fission products and limits the process batch to not more than 100 grams of uranium enriched in the isotope 235 and not more than 15 grams of any other special nuclear material.

Special nuclear material means (1) plutonium, uranium-233, uranium enriched in the isotope-233 or in the isotope-235, and any other material which the Commission, pursuant to the provisions of section 51 of the act, determines to be special nuclear material, but does not include source material; or (2) any material artificially enriched by any of the foregoing, but does not include source material.

Source Material means: (1) Uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores … . Source material does not include special nuclear material.

SNM Categories

Category III, Special nuclear material of low strategic significance means

•Less than an amount of special nuclear material of moderate strategic significance (see category II above) but more than 15 grams of uranium-235 (contained in uranium enriched to 20 percent or more in U-235 isotope) or 15 grams of uranium-233 or 15 grams of plutonium or the combination of 15 grams when computed by the equation grams = (grams contained U-235) + (grams plutonium) + (grams U-233); or

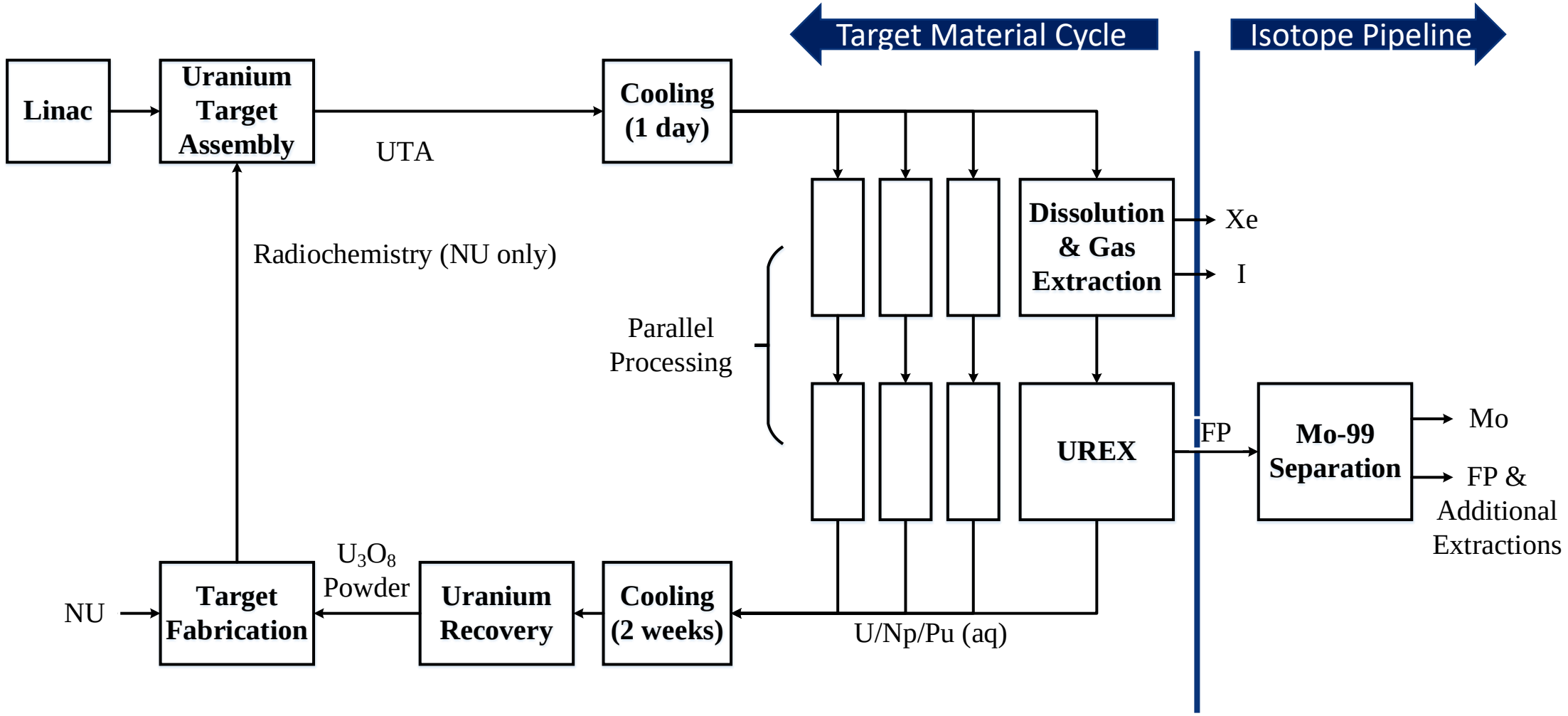
•Less than 10,000 grams but more than 1,000 grams of uranium-235 (contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope); or

•10,000 grams or more of uranium-235 (contained in uranium enriched above natural but less than 10 percent in the U-235 isotope).

NIOWAVE
Accelerating the Fight Against Cancer

Preliminary Hazard Analysis (Uranium Cycle)

Closed Loop Uranium Cycle



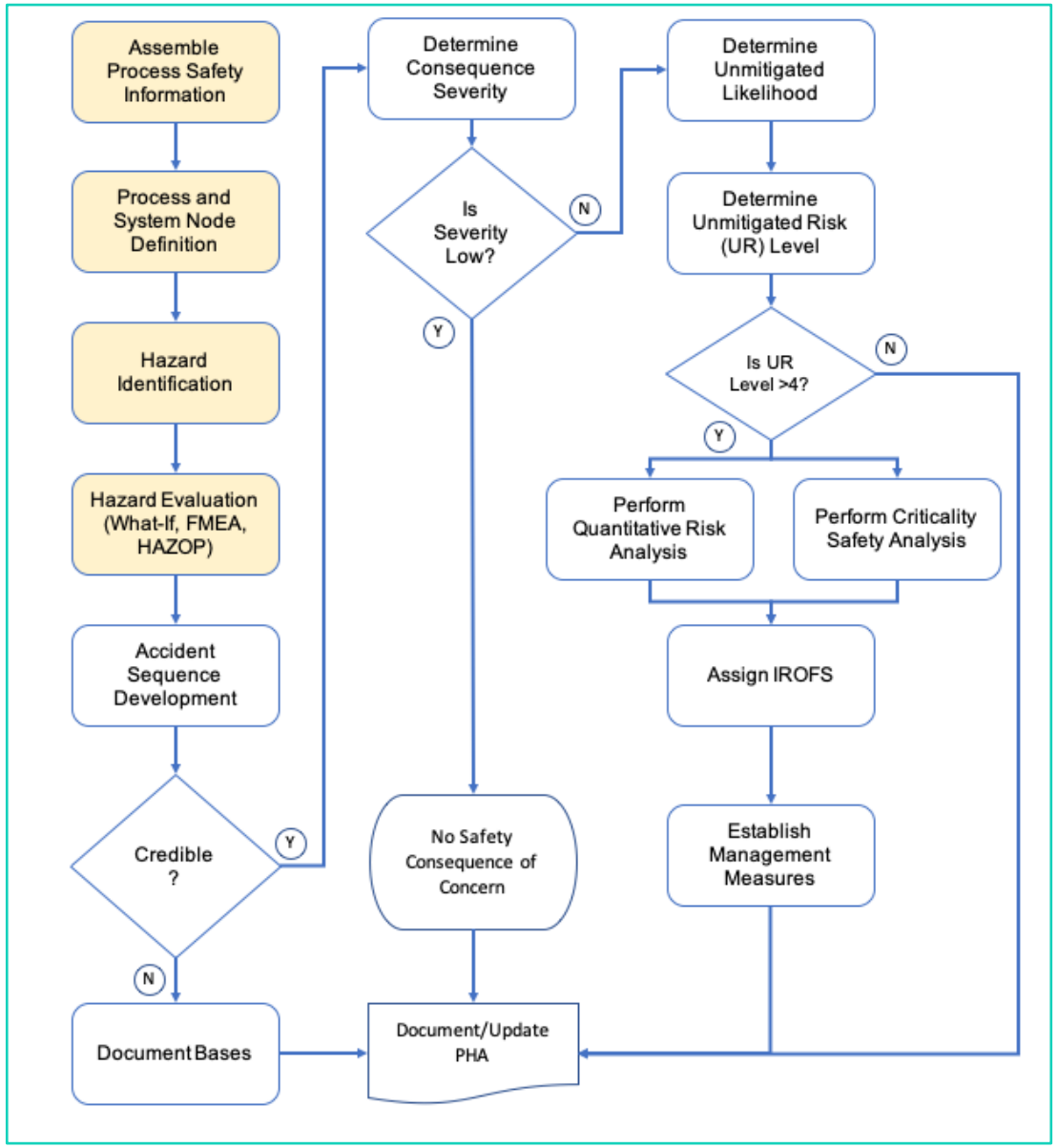
Preliminary Hazard Analysis #2

- Niowave Commercial Mo-99 Facility – Uranium Cycle (UC) Processes
- Conducted on July 10-13, 2023, at the Niowave offices
  - Attended by Niowave and SRNL
- PreHA review based on conceptual design level of process safety information
  - Augmented by Niowave experience with lab scale process execution
- What-If hazard evaluation method applied
- PHA will be performed when detailed design is matured
- The hazard evaluation team also reviewed the Mo-99 separation process

Preliminary Hazards Analysis Flow Diagram

GUIDANCE

- NUREG – 1513 Integrated Safety Analysis Guidance Document
- NUREG-1520, Standard Review Plan for Fuel Cycle Facilities License Applications, Final Report
- Center for Chemical Process Safety, Guidelines for Hazard Evaluation Procedures



Scope of Analysis

Uranium Cycle (UC)

- **Node UC-1 – Uranium Oxide Dissolution**
- **Node UC-2 – Gas Extraction**
- **Node UC-3 – Modified UREX**
- **Node UC-4 - Uranium Recovery**
- **Node UC-5 – Target Fabrication**

Isotope Pipeline (IP)

- **Node IP-1 – Mo-99 Separation (initial review)**

Typical Hazard Categories

Hazard Category
Radiological
Nuclear Criticality
Chemical • Toxic • Explosive • Flammable • Reactive • Soluble uranium uptake
Standard Industrial Hazards • Fire • Kinetic or potential energy • High voltage or current • High or low temperature • High or low pressure • Asphyxiants • Internal flooding

Next Steps

- The Preliminary Hazard Analysis produces tables with postulated process and system upsets, initiating events, consequences, and potential controls to prevent and/or mitigate the events.
  - Based on the PreHA results, credible accident sequences are developed.
  - Consequence and likelihood evaluations are developed to determine risk level.
  - IROFS are determined for accident sequences with unacceptable risk level to prevent and/or mitigate accident sequences to ensure compliance with the §70.61 performance requirements.
- License Completion
  - Fire hazards analysis
  - More PHA's (Fire, Natural, Aircraft, etc)
  - ISA
  - Finish License Application
  - Others

NIOWAVE

Accelerating the Fight Against Cancer

Thank you