Hazard Analysis of Nuclear Criticality Safety at the MOX Fuel Fabrication Facility

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The Right Fit. The Right Time.

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Overview

- What is the MOX Project?
- French Reference Facilities
- Integrated Safety Analysis (ISA)
- Process Hazards Analysis (PrHA)
- Potential Critical Scenario Selection
- Nuclear Criticality Safety Evaluations (NCSE)
- Items Relied Upon for Safety (IROFS)
- Conclusion

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What is the MOX Project?

- **Primary Mission:**
  Nuclear Non-Proliferation
  - Convert 34 metric tons of surplus weapons-grade plutonium to mixed oxide (MOX) fuel for use in U.S. commercial power reactors
  - Once irradiated, plutonium will meet the spent fuel standard – making it inaccessible and unattractive for use in weapons
- **Regulated by the United States Nuclear Regulatory Commission (NRC), owned by the Department of Energy (DOE)**

What is the MOX Project?

- **Impact**
  - Total lifetime cost $4.8 billion plus $200-300 million/year to operate
  - Removes multiple warheads from the nuclear arsenal
  - Eliminates $500 million/year in security costs
  - Provides clean, carbon free energy that offsets over $21 billion in imported oil costs

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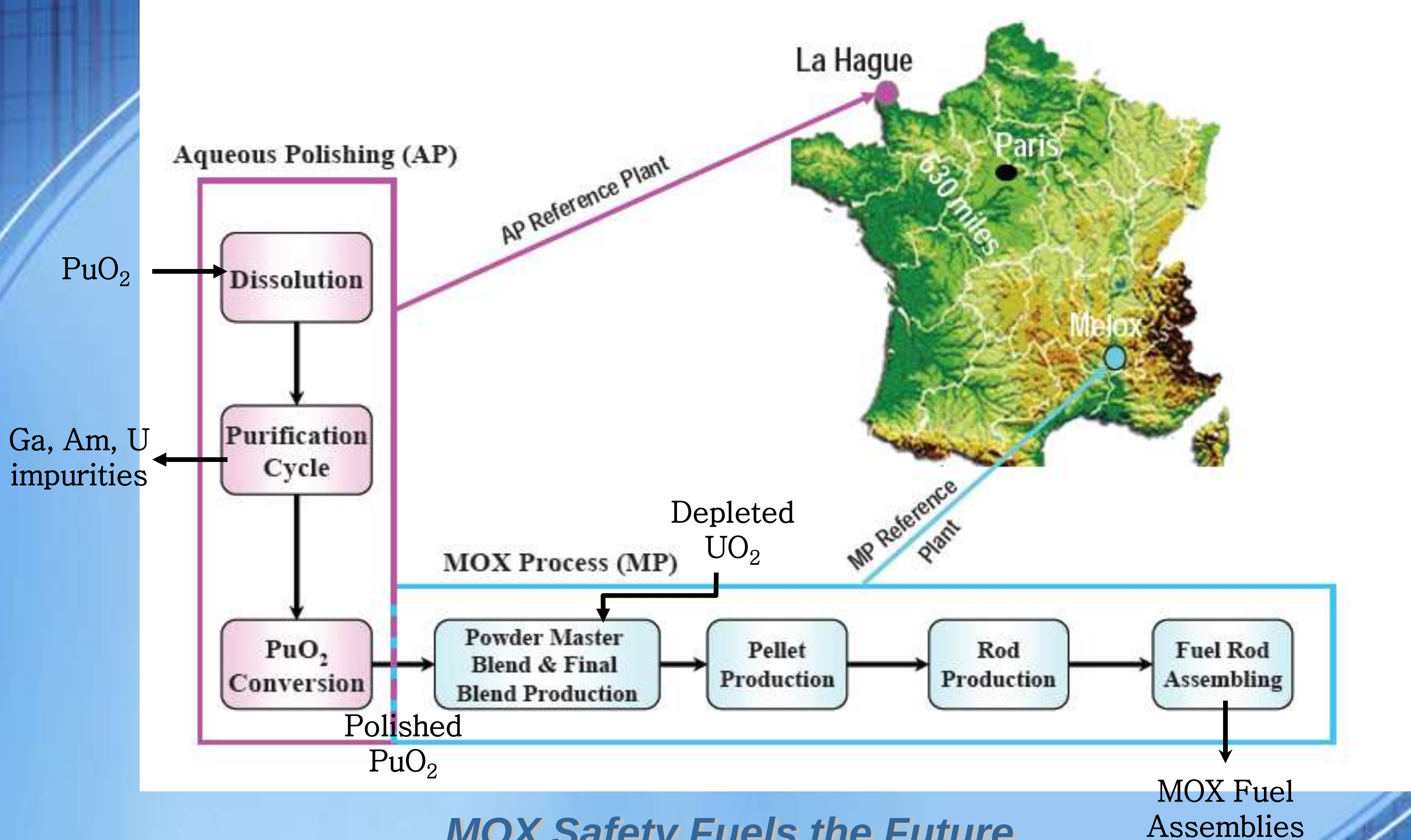

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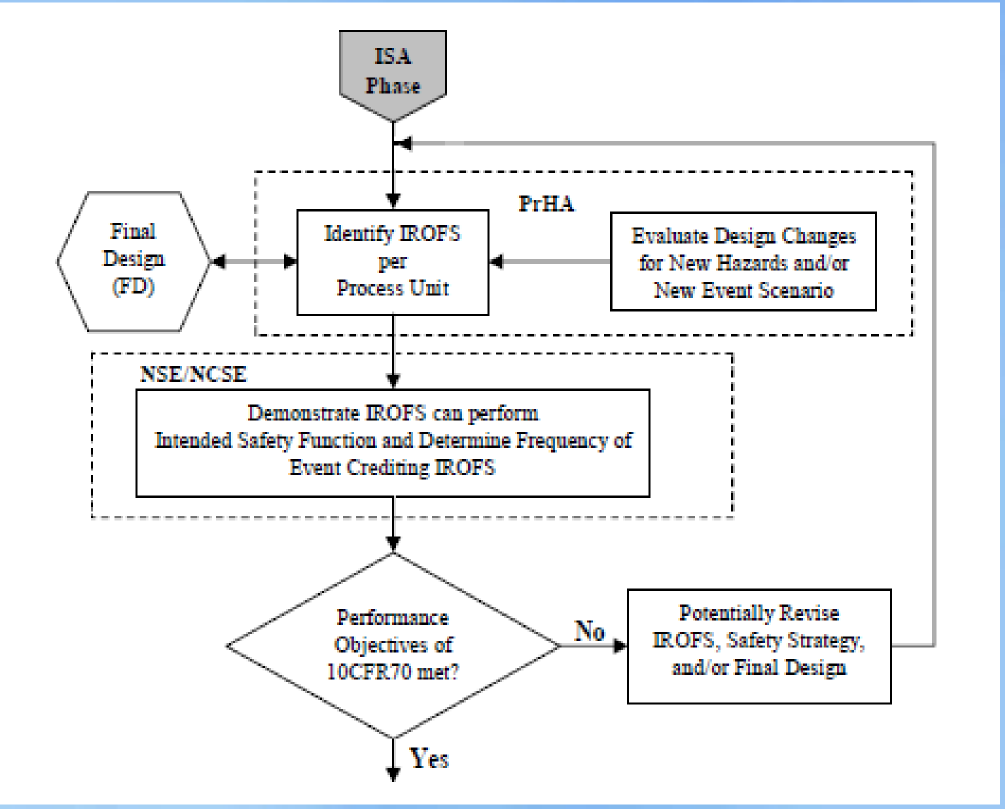
Integrated Safety Analysis (ISA)



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Integrated Safety Analysis (ISA)

- **The Process Hazards Analysis** represents a major component of the Integrated Safety Analysis developed to satisfy the applicable requirements of 10CFR70.
- **The Process Hazards Analysis** provides a systematic and comprehensive evaluation of the MFFF design that identifies events that can potentially result in safety consequences, including criticality accident events.
- **NCSEs** evaluate the final design for potential accident event scenarios that are identified in Process Hazards Analysis for MFFF process units and support systems handling fissile materials.

Process Hazards Analysis

- The Process Hazard Analyses were performed in accordance with the guidance provided in **AIChE**, *Guidelines for Hazard Evaluation Procedures* and **NRC NUREG-1513**, *Integrated Safety Analysis Guidance Document.*

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Process Hazards Analysis

- The ISA Team utilizes the AIChE **checklist methodology** of hazardous materials and hazardous energy sources in the hazard identification process.
- **ISA Team**
  - Team Leader
  - Team Scribe
  - Responsible Process Engineer
  - Discipline Experts (including **Criticality Safety**)

Process Hazards Analysis

- The ISA Team meets and together identifies event scenarios, causes, and prevention/ mitigation features (IROFS and their safety function) in a step by step manner.
- Recommendations are made to modify the design, identify additional analyses to be performed, or actions to be taken to support the identification of the IROFS that are required to satisfy the requirements of 10 CFR 70.

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Potential Critical Scenario Selection

- Qualified Senior NCS Engineer on Team
- Critical Mass
- All Units selected that contain or have the potential to contain fissile material
- Auxillary and Supporting Systems, i.e. HVAC
- Shipping, Receiving & Storage of Fissile Material
- IROFS/Control Selection were Criticality is credible

NUCLEAR CRITICALITY SAFETY EVALUATIONS

- Criticality Safety is included in the ISA through the PrHAs.
- NCSEs are the main source of information demonstrating the adequacy of criticality controls and the effectiveness of administrative practices.
- Criticality analysis methods comply with the technical guidance of ANSI/ANS-8.1-1998: *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*.

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NUCLEAR CRITICALITY SAFETY EVALUATIONS

- 48 NCSEs were performed to ensure that the entire process will be subcritical under both normal and credible abnormal conditions.
- NCSEs identify the controlled nuclear and process parameters and their associated limits upon which criticality safety depends.
- NCSEs evaluate each respective operation for credible accident sequences identified by the PrHA and identify sufficient controls such that double contingency protection is provided in those cases in which a criticality is credible.

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NUCLEAR CRITICALITY SAFETY EVALUATIONS

- Utilizing the results of validated calculational methodologies, the NCSEs demonstrate that both normal and accident conditions meet the required minimum margin of subcriticality.
- IROFS to provide double contingency protection were identified in NCSEs.
- Features that are required to ensure that the criticality controls identified in the NCSE are sufficiently available and reliable will be provided through the implementation of appropriate management measures.

IROFS
(Items Relied Upon for Safety)

Postulated credible high consequence events (such as criticality) are made <u>highly unlikely</u> based on the application of IROFS features:

- Application of the single failure criteria or double contingency
- Application of 10 CFR 50 Appendix B and NQA-1 quality assurance requirements
- Application of Industry Codes and Standards
- Management Measures, including surveillance of IROFS (i.e., failure detection and repair, or process shutdown capability)

Implementation of NCS Safety Strategy

Aqueous Polishing (AP) **WET** Units

- **Safe Geometry**
- **Spacing Requirements**

MOX Process (MP) **DRY** Units

- **Safe Mass**
- **Moderation Control**

Criticality Safety in AP Units

- Safe Geometry
  - **Annular Tanks**
  - **Slab Tanks**
- Spacing Requirements
  - **One Foot Minimum Spacing**
  - **Annular, Slab Tanks & Concrete Walls**

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Safe Geometry Annular Tank

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Annular Tank Spacing

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Annular Tank Top View

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Safe Geometry Slab Tank

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Slab Tank Top View

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Criticality Safety in MP Units

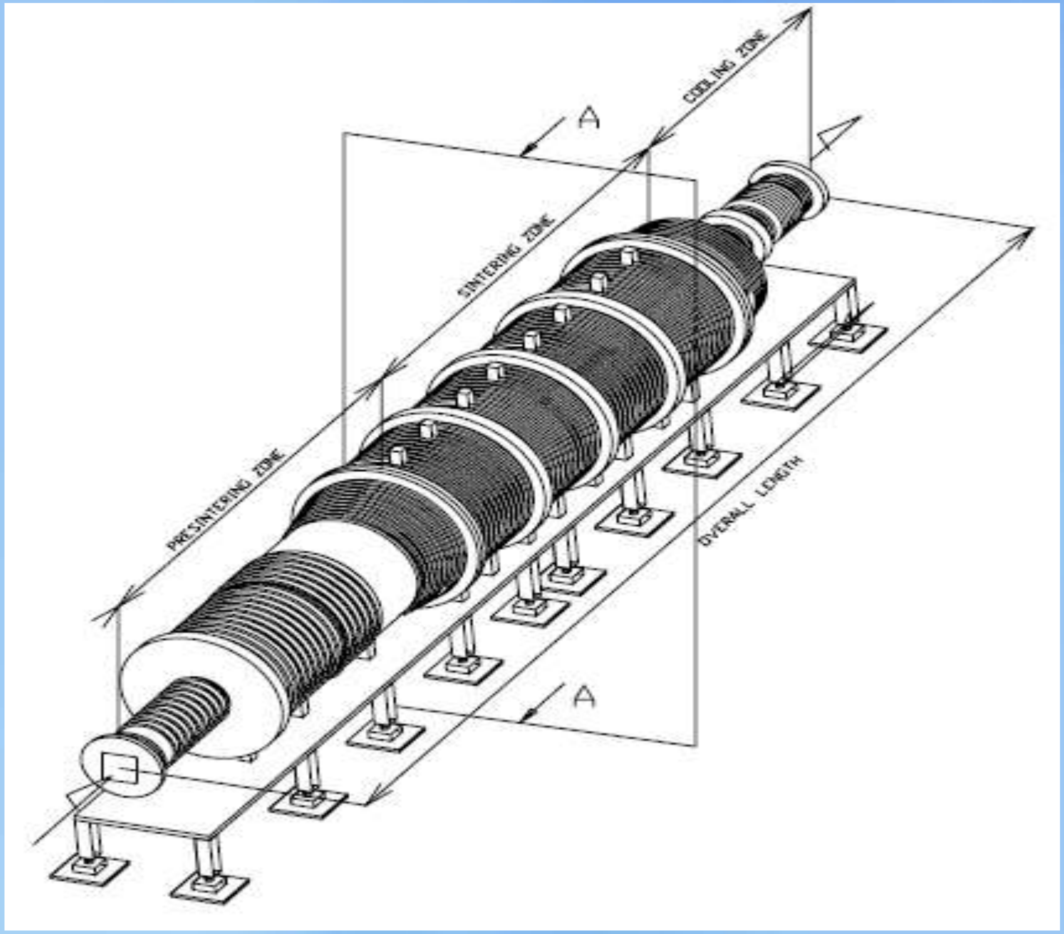
- Safe Mass
  - **Mass Limited Processes**
  - **Mass Limited Gloveboxes**
- Moderation Control
  - **Moderation Controlled Areas**
  - **Moderation Limited Gloveboxes**
- Example:
  - **NCSE-D of the Sintering Furnaces**

NCSE of Sintering Furnace

- The main purpose of the unit is to sinter green pellets or green scraps. In addition, the unit can be used to recycle or re-sinter pellets not reaching proper design specifications.

- This evaluation demonstrates compliance to the **Double Contingency Principle** (DCP) **and** provides detailed characteristics of process, engineering features, and administrative controls that are relied upon to ensure all postulated criticality accident scenarios are **highly unlikely**.

Sintering Furnace



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Criticality Safety of Furnace

Mass Control

- Configuration Control of the Sintering Furnace design limits the number of boats (pellet containers) that can physically be present in the furnace.

- Mass is controlled per boat and the number of boats in the furnace is limited providing overall mass control.

Criticality Safety of Furnace

Moderation Control

- Safety functions limit water equivalent moderation inside the furnace to only a humid gas mixture (argon-hydrogen).
- Passive design features and engineered controls labeled as Items Relied Upon For Safety (IROFS) are present to prevent the introduction of water equivalent moderation beyond humidity saturated process gas.
- The supporting criticality calculations use a bounding moisture value of 5 wt % water inside the pellets.

MOX Criticality Control Strategy

- **Double Contingency** Criticality Safety Criterion of ANSI/ANS-8.1, and the **"highly unlikely"** requirements of 10 CFR 70 are applied as well as all applicable ANSI Standards.
- **IROFS Control Hierarchy**: Preferred Passive Design, then Active-Engineered Controls, and finally as necessary Administrative Controls are applied.

Conclusion

- **NCSEs** are developed in accord with Integrated Safety Analysis to satisfy the applicable requirements of 10 CFR 70.
- **Process Hazards Analysis** were performed in accordance with the guidance provided in AIChE, *Guidelines for Hazard Evaluation Procedures* *and* NRC's NUREG-1513, *Integrated Safety Analysis Guidance Document.*

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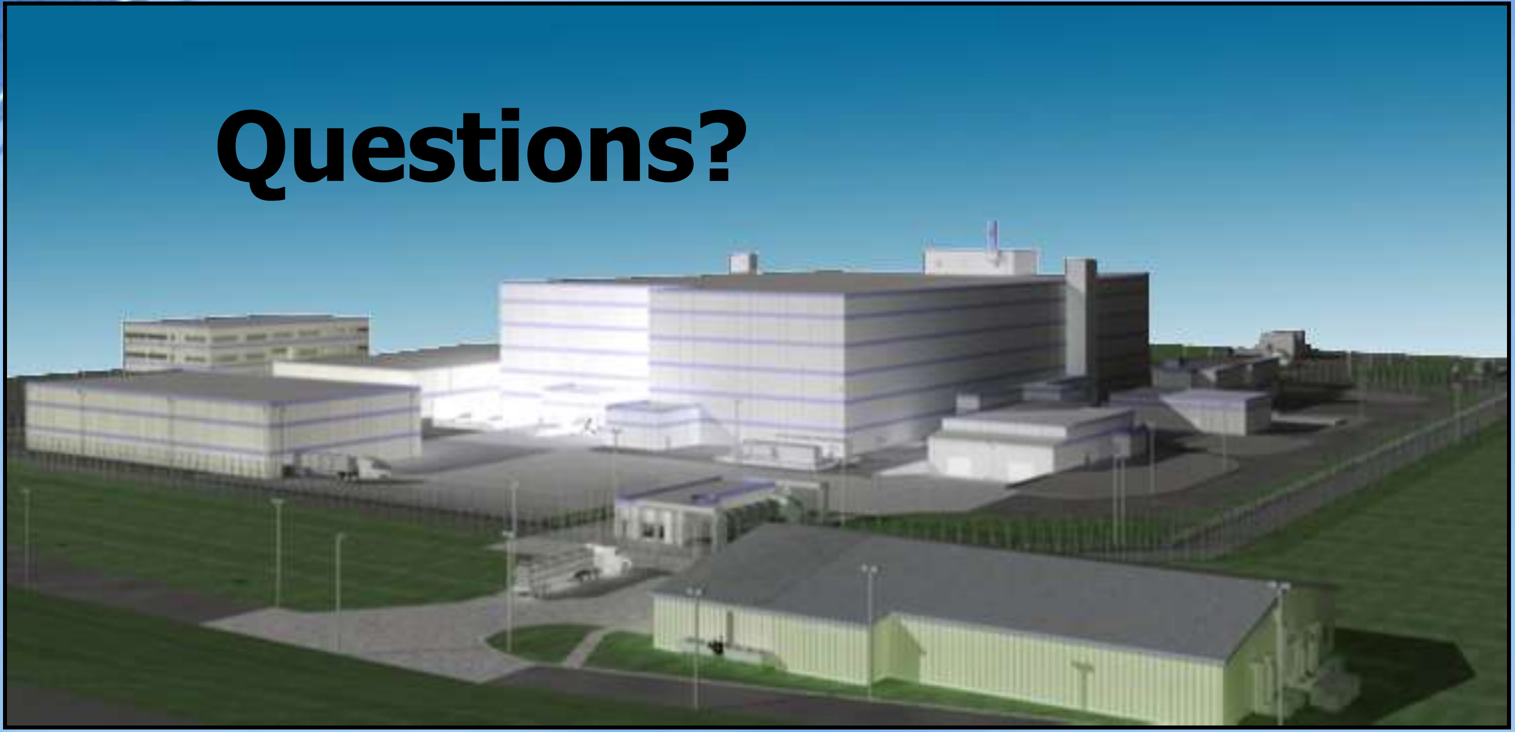

Questions?

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