Facility Risk Review of a Uranium Processing Complex: A Risk-informed Decision-making Process

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Outline

- Existing facility status/options
- Purpose of Facility Risk Review (FRR)
- Technical approach – three-step approach
- Risk matrix: consequences/frequency categories
- Analytical Hierarchy Process (AHP) to rank potential recommendations
- Evaluation criteria
- Lessons learned/keys to success

Existing Complex Status

- Existing complex is an aged facility structure not designed or constructed to current nuclear hazard category 2 requirements (PC-3, confinement ventilation, etc.)
- Process equipment is reaching end of life (for the most part)
- Due to the unreliability of process equipment, nuclear materials in more hazardous forms have accumulated
- Until other storage is operational, this complex will continue to store large quantities of uranium metal and oxides

Options

- Upgrade building to meet current nuclear hazard category 2 requirements
  - PC-3 – significant cost
  - Significant impact to ability to continuously meet mission requirements
  - Impact to security and other operations
- Aggressively proceed with designing and constructing new complex
  - Total project cost expected to be << than upgrading older facility
  - Allows for continuously meeting mission requirements
  - Supports NNSA Complex 2030

With either option, existing complex must continue to operate safely in the interim to meet ongoing mission requirements and reduce the safety risk

Original Plan

- Phase I – Maintenance type repairs and focused risk reduction upgrades
- Phase II – Expert review of seismic analysis
- Phase III – Risk-based analysis of seismic upgrades with yearly evaluation (i.e., FRR)

Purpose of FRR

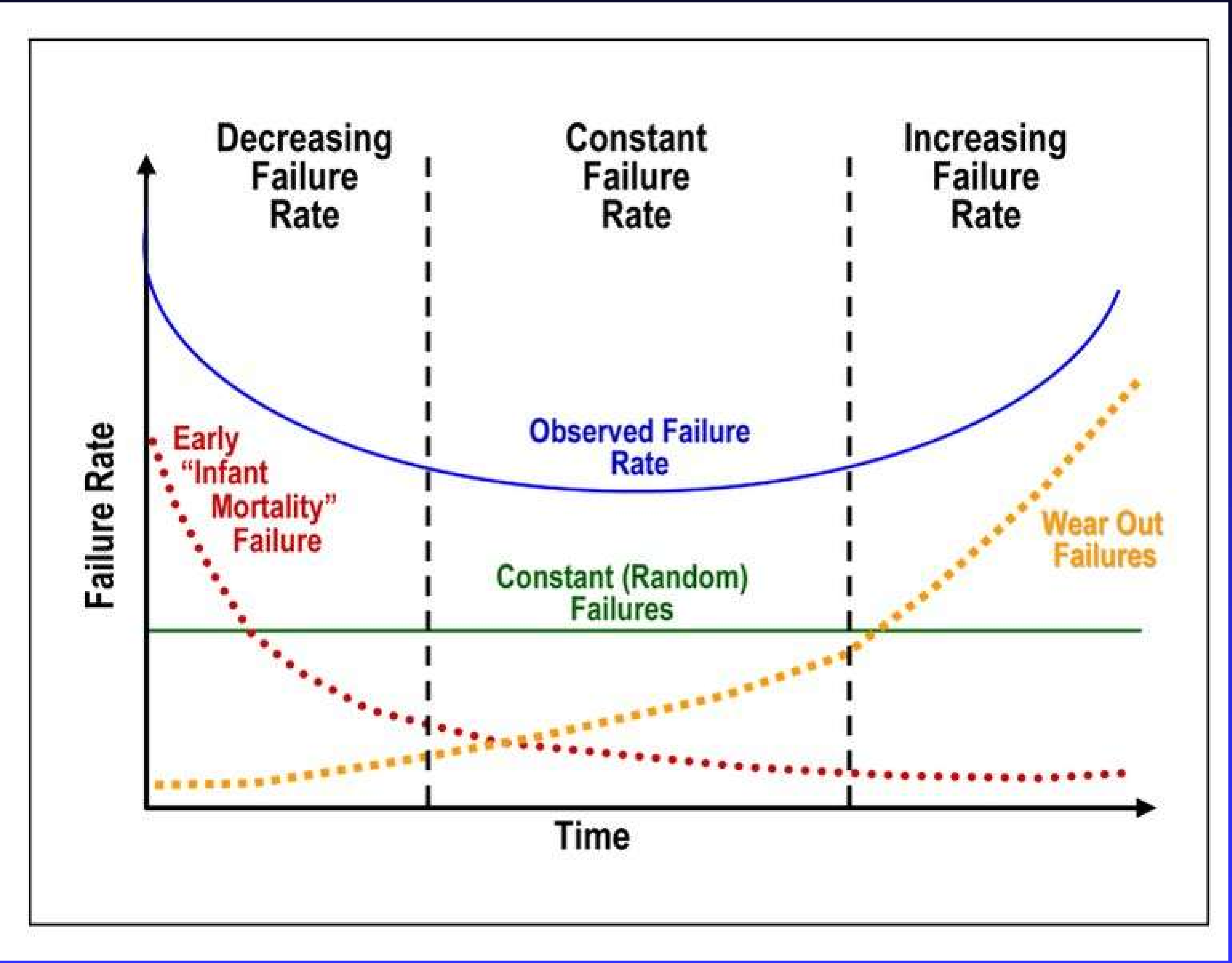
Identify what investments are required to continue to operate existing complex safely during the next 15 years, while the new complex is being constructed, using a risk- informed decision-making process

Facility Risk Review Approach

- Three-step process following DOE Risk Management Planning and Execution Guidance
- Step 1 – Risk of Safety System Failure
- Step 2 – Production Risk
  - Metal Production & Material Recovery
- Step 3 – Identify Risk Acceptance Level and Prioritized Project List
- Independent Peer Review – Robert Budnitz & Paul Amico

Step 1- Risk of Safety System Failure

- Purpose – To determine the likelihood of safety system failure concurrent with event and what are the effects of aging
- Scope - All credited safety systems, seismic, ventilation, and electrical as it contributes to fire initiation (did not include SIH except for post-seismic events)
- Considered both risk to public (includes co-located workers) (REM & ERPG) and facility workers (SI/D)
- Included the effects of aging on components
- Created event trees and then binned outcome of event trees on risk matrix


Decreasing Failure Rate
Constant Failure Rate
Increasing Failure Rate
Failure Rate
Early "Infant Mortality" Failure
Observed Failure Rate
Constant (Random) Failures
Wear Out Failures
Time

Safety Risk Outcome

- Public Receptor (Collocated Worker)
  - Seismic in certain areas
  - Fire in unsprinklered areas and areas w/dry pipe fire sprinkler system
- Facility Worker Receptor
  - Seismic in all areas
  - Gas furnace
  - Dock scrubber
  - Fires

Step 2 - Production & Material Recovery Risk

- Metal part production
- Material recovery
- Bulk process operations
- Critical assumptions
  - Sufficient inventory of clean uranium metal inventory to supplement product quality requirements
  - Without clean metal production for 2 years, consequences for metal production systems move to higher bin

Step 2 - Production & Material Recovery Risk (continued)

- Developed risk matrices
  - Likelihood of equipment failure and impact to production capability (in days) from failure
- Developed projected MAR reduction curves

Production Risk Outcome

- Electrical distribution and panels
- Maintenance capacity/critical spare parts
- Vacuum system
- Ventilation systems
- Failure/degradation of utility/support systems (steam and tower water)
- No recovery/disposal process for chip cleaning fluid
- Gas furnace
- No disposition process for reduction slag

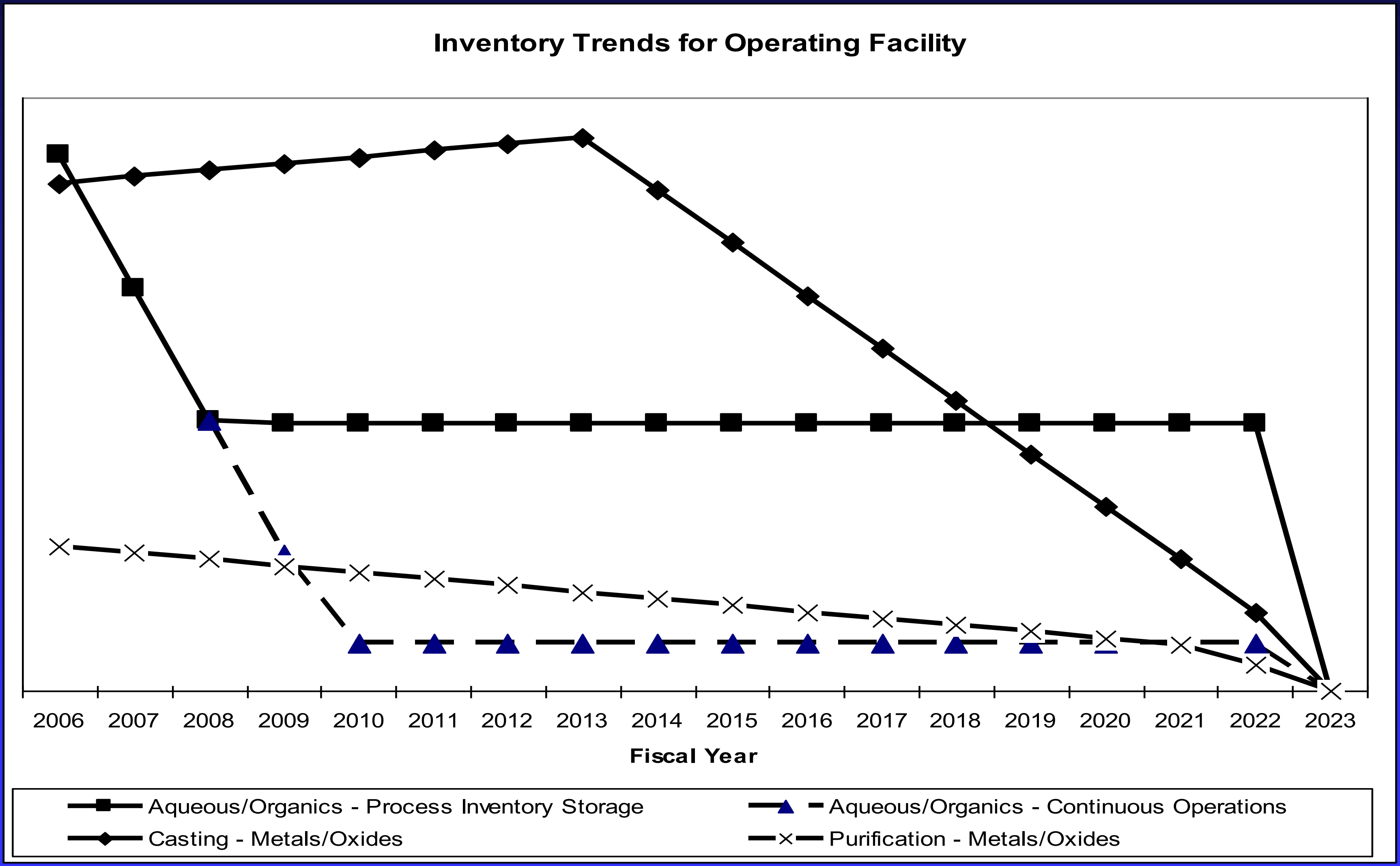
Step 3 - Identify Risk Acceptance Level and Prioritized Project List

- Determined level of risk acceptance
- Identified list of projects to address the higher risk events with ROM cost estimates and schedules for completion
- Used the Analytical Hierarchy Process (AHP) pairwise comparison process to rank the projects into a prioritized project list
- Performed sensitivity analysis

<table>
<tr><td colspan="3">Consequence Categories</td><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="3">Facility Worker Consequences</td><td><0.1SI/D</td><td>$0.1 \leq$SI/D<0.3</td><td>$0.3 \leq$SI/D<1</td><td>$1 \leq$SI/D<3</td><td>$3 \leq$SI/D<10</td><td>$\geq$10SI/D</td></tr>
<tr><td colspan="3">Public Consequences</td><td>Negligible</td><td>Tc<ERPG-1
Rc<0.1 rem</td><td>ERPG-1$\leq$Tc<ERPG-2
0.1 rem$\leq$Rc<1 rem</td><td>ERPG-2$\leq$Tc<ERPG-3
1 rem$\leq$Rc<5 rem</td><td>ERPG-3$\leq$Tc< 10×ERPG-3
5 rem$\leq$Rc<100 rem</td><td>Tc$\geq$10×ERPG-3
Rc$\geq$100 rem</td></tr>
<tr><td rowspan="6">Safety Risk Frequency (F) Category</td><td>5</td><td>F$\geq 10^{-2}$/yr</td><td colspan="2" rowspan="2">High/Low</td><td colspan="2" rowspan="2">High/Moderate</td><td colspan="2" rowspan="2">High/High</td><td rowspan="2">High – Expected to happen</td><td rowspan="6">Manufacturing Risk Frequency (F) Category</td></tr>
<tr><td>4</td><td>10^{-3}/yr $\leq$F<10^{-2}/yr</td></tr>
<tr><td>3</td><td>10^{-4}/yr $\leq$F<10^{-3}/yr</td><td colspan="2" rowspan="2">Moderate/Low</td><td colspan="2" rowspan="2">Moderate/Moderate</td><td colspan="2" rowspan="2">Moderate/High</td><td rowspan="2">Moderate – May or may not happen</td></tr>
<tr><td>2</td><td>10^{-5}/yr $\leq$F<10^{-4}/yr</td></tr>
<tr><td>1</td><td>10^{-6}/yr $\leq$F<10^{-5}/yr</td><td colspan="2" rowspan="2">Low/Low</td><td colspan="2" rowspan="2">Low/Moderate</td><td colspan="2" rowspan="2">Low/High</td><td rowspan="2">Low – Not expected</td></tr>
<tr><td>0</td><td>F$\leq 10^{-6}$/yr</td></tr>
<tr><td colspan="3">Material Recovery</td><td colspan="2">Low - < 3 months delay</td><td colspan="2">Moderate – 3 months to 6 months</td><td colspan="2">High – 6 months and greater delay</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="3">Metal Parts Production</td><td colspan="2">Low - < 5 days delay</td><td colspan="2">Moderate – 5 days to 30 days delay</td><td colspan="2">High – 30 days and greater delay</td></tr>
<tr><td colspan="3">Facility Op/Process Support</td><td colspan="2">Low - < 5 days delay</td><td colspan="2">Moderate – 5 days to 15 days delay</td><td colspan="2">High – 15 days and greater delay</td></tr>
</table>

Accepted Risks

- Seismic consequences if facility worker only
- Existing LCOs/credited safety controls – assume will be maintained at current level
- Major PC-2 seismic upgrades – planned material at risk reduction in areas of concern and line-item cost coupled with the duration of the benefit do not support making the PC-2 upgrades. Relatively small overall risk benefit to upgrades and still not meet PC-3 requirements


Inventory Trends for Operating Facility
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Fiscal Year
Aqueous/Organics - Process Inventory Storage
Aqueous/Organics - Continuous Operations
Casting - Metals/Oxides
Purification - Metals/Oxides

Evaluation Criterion (1 of 5)

- **Maximum Safety Benefit (0.243): Beneficial change in the safety level for the facility worker and/or the public (a reduction in the frequency and/or consequence of safety equipment failure), or a qualitative safety improvement (e.g., MAR reduction, initiating event reduction). Considers degree of compliance with applicable requirements and codes**

Evaluation Criterion (2 of 5)

- **Maximum Operational Reliability (0.196): Beneficial change in the operational reliability for metal production, material reduction (MRR), and/or facility operations & process support (reduction of likelihood and/or consequence of process equipment failure). Considers degree of compliance with applicable requirements and codes**

Evaluation Criterion (3 of 5)

- **Minimum Implementation Cost (0.072): Total cost (initial capital and operating) to implement the project improvements for risk mitigation**

Evaluation Criterion (4 of 5)

- **Maximum Duration of Benefit (0.395): Time required to realize benefit of project improvements.**

Evaluation Criterion (5 of 5)

- **Minimum Impact to Operations During Implementation (0.093): Impact on production during project implementation. Assume (1) maintenance outages and process improvements will be planned to minimize disruption to operations and meeting programmatic requirements and (2) all project work will have no adverse safety consequences when compared with normal operations**

Prioritized Project List – ROM Costs

AHP Ranking	Initiating Events	Mitigating Actions or Projects			
		Description	Time to Implement (years)	Duration of Benefit (years)	ROM Estimated Cost
1	Maintenance support/critical spares	Increased future expenditure on maintenance activities and inventory of critical spare parts	2	13	$4,000,000/yr (approx $60,000,000 total)
2	Degradation of key utility systems – tower water & steam	Replace lines 2 inch and smaller (tower water): repair numerous leaks, remove old abandoned piping (steam)	4	11	$1,000,000
3	MCC failure	Replace motor control centers	4	11	$1,500,000
4	Failure of switchgear	Replace switchgear	4	11	$7,000,000
5	Loss of electrical panels – process area (18 panels)	Replace lighting panels	5	10	$1,800,000
6	Power panel failure	Replace power panel 230-5A	3	12	$200,000
7	Loss of process exhaust – Stack X	Replace airflow control system	4	11	$600,000
8	Loss of casting furnace vacuum system	Refurbish and upgrade in place	4	11	$700,000
9	Electrical panel failure (5 panels)	Replace lighting panels	2	13	$500,000
10	Ventilation-4 Stack Y	Replace fans and motors, replace 2400V electrical breaker, install new damper, replace baghouse filter, replace HEPA filter housing	4	11	$4,400,000
11	Ventilation-1 Stack Z	Replace ductwork in basement	3	12	$900,000
12	Loss of ventilation – Stacks A & B	Upgrade fan motor spare parts, etc.; replace filter housing with HEPA housing	4	11	$2,400,000
15	No chip cleaning process fluid disposal	Design and install new process	5	10	$3,000,000
16	LCO-6 Gas Furnace	Replace with new furnace using current technology	9	6	$15,000,000
17	Ventilation-3 Stack C	Upgrade fan motor spare parts, etc.; replace filter housing with HEPA housing	4	11	$1,200,000
18	Reduction salvage disposition	Refurbish and reconfigure existing equipment into a new process system to replace existing system	6	9	$4,000,000
				Total:	$104,200,000

Lessons Learned

- Communication, cooperation, and integration are necessary for success
- Use preliminary risk analysis technique to perform FRR
  - Good technique to combine events that result in different consequence categories
- There are minimal tradeoffs between safety risk and production risk
  - Healthy production = healthy safety
- Some level of risk must be accepted (both in the safety world and production world)

Keys to Success

- Accurate operations and engineering information
- Strong NNSA planning and management support
- Strong technical and process professional input
- Willingness to brainstorm “what could happen”