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Xe-100 Maintenance Staffing Optimization White Paper Overview

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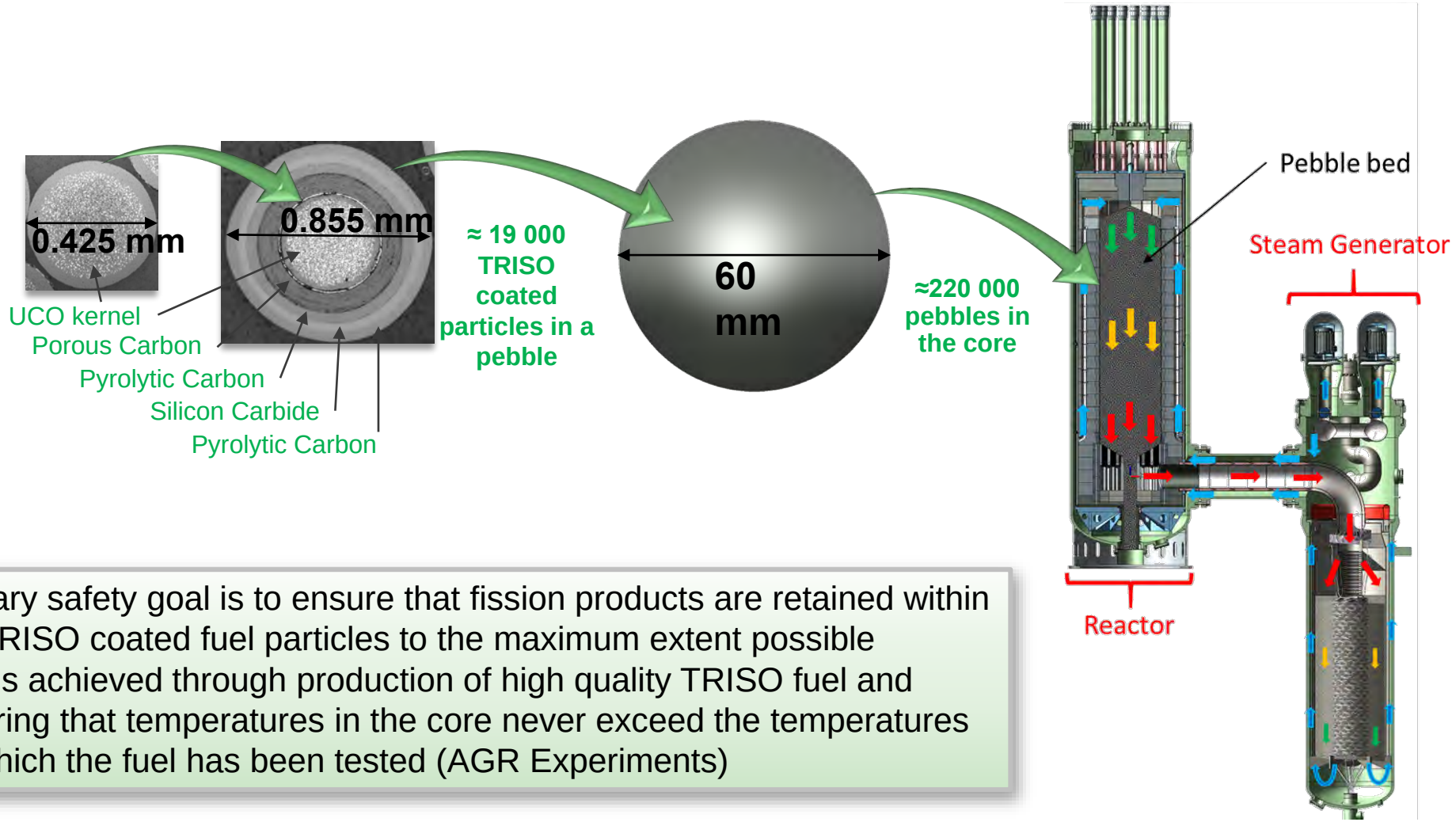
Agenda

- (10 min) X-energy and Xe-100 Background and Licensing Approach
- (30 min) Purpose & Scope of the Xe-100 Licensing Maintenance Staff Optimization White Paper (MSO White Paper)
- (20 min) Questions & Comments

- Purpose: The White Paper communicates X-energy's approach to determining the required Maintenance Staff for an Xe-100 plant

- Scope:
  - Reviewing Regulatory Requirements affecting Maintenance Staffing
  - Providing an Xe-100 Maintenance Philosophy Summary
  - Providing an Xe-100 Maintenance Strategy Summary
  - Identifying personnel that perform Maintenance at Xe-100 plants
  - Providing an example of the Maintenance Staffing Analysis Process

Background: UCO TRISO Particle – Primary Fission Product Barrier

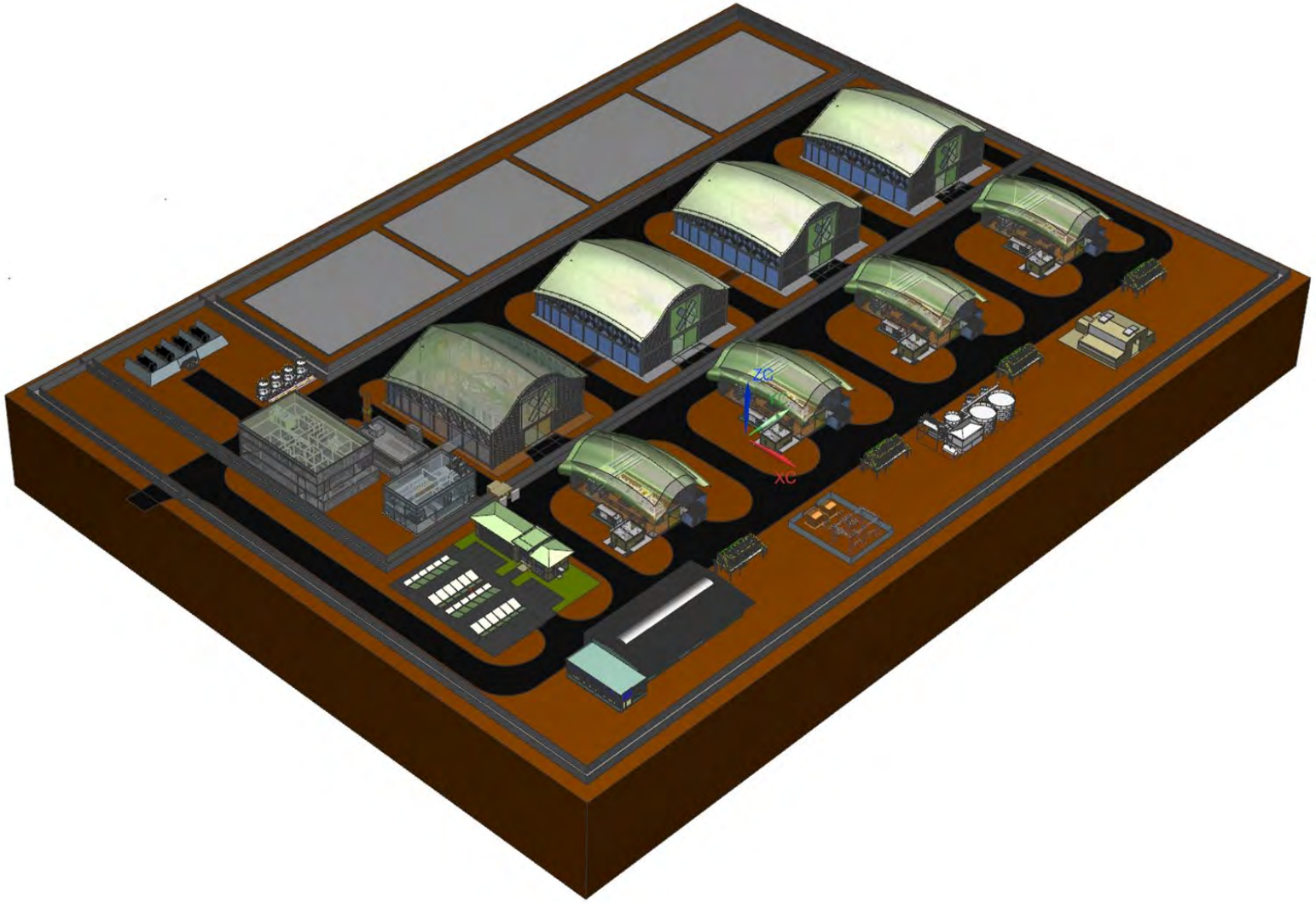


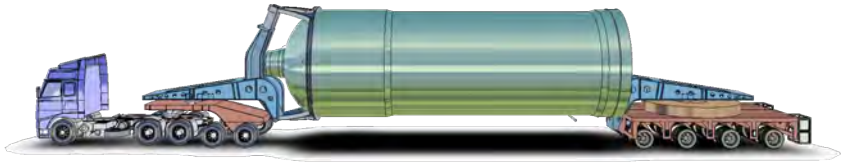
- Primary safety goal is to ensure that fission products are retained within the TRISO coated fuel particles to the maximum extent possible
- This is achieved through production of high quality TRISO fuel and ensuring that temperatures in the core never exceed the temperatures for which the fuel has been tested (AGR Experiments)

Background: Xe-100 Plant Overview

Standard X-energy plant have 4 Reactors - 4 Turbines producing 320 MWe, attributes include:

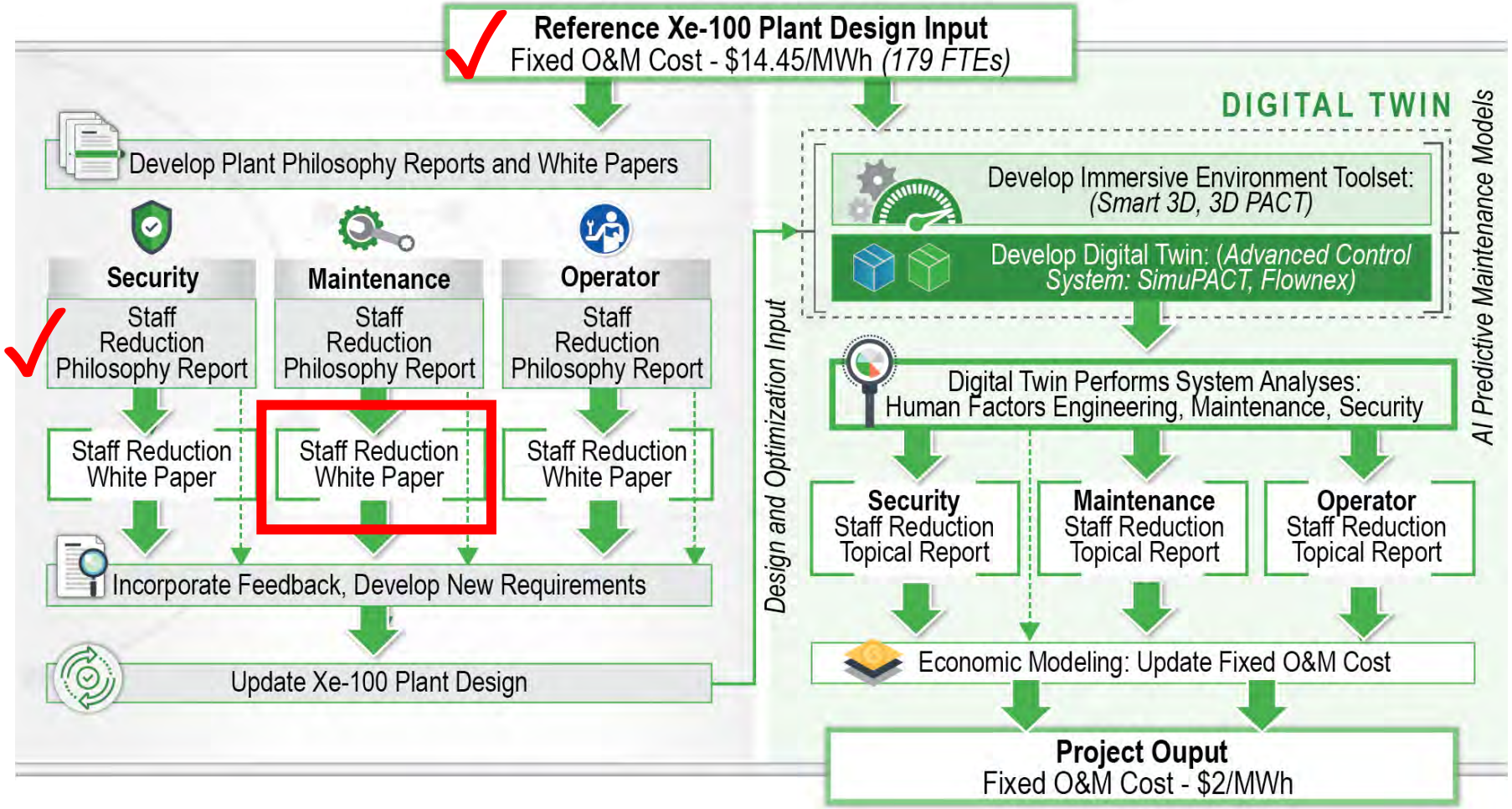
- 200MWth/80MWe Per Module
- Process heat applications
- Proven intrinsically safe
- Meltdown proof
- Walk-away safe
- Modular construction
- Requires less time to construct (2.5-4 years)
- Road transportable for diverse geographic areas
- Uses factory-produced components
- Load-following to 40% power within 15 minutes
- Continuous fueling; resilient on-site fuel storage



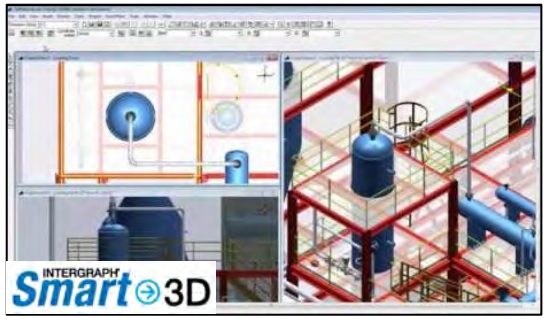


ARPA-E GEMINA Project Progress Summary

- Project Title: *Advanced Operation & Maintenance Techniques Implemented in the Xe-100 Plant Digital Twin to Reduce Fixed O&M Cost*
- $7.5 Million award from DOE for Digital Twin (DT) and Central Maintenance Model (CMM) concepts



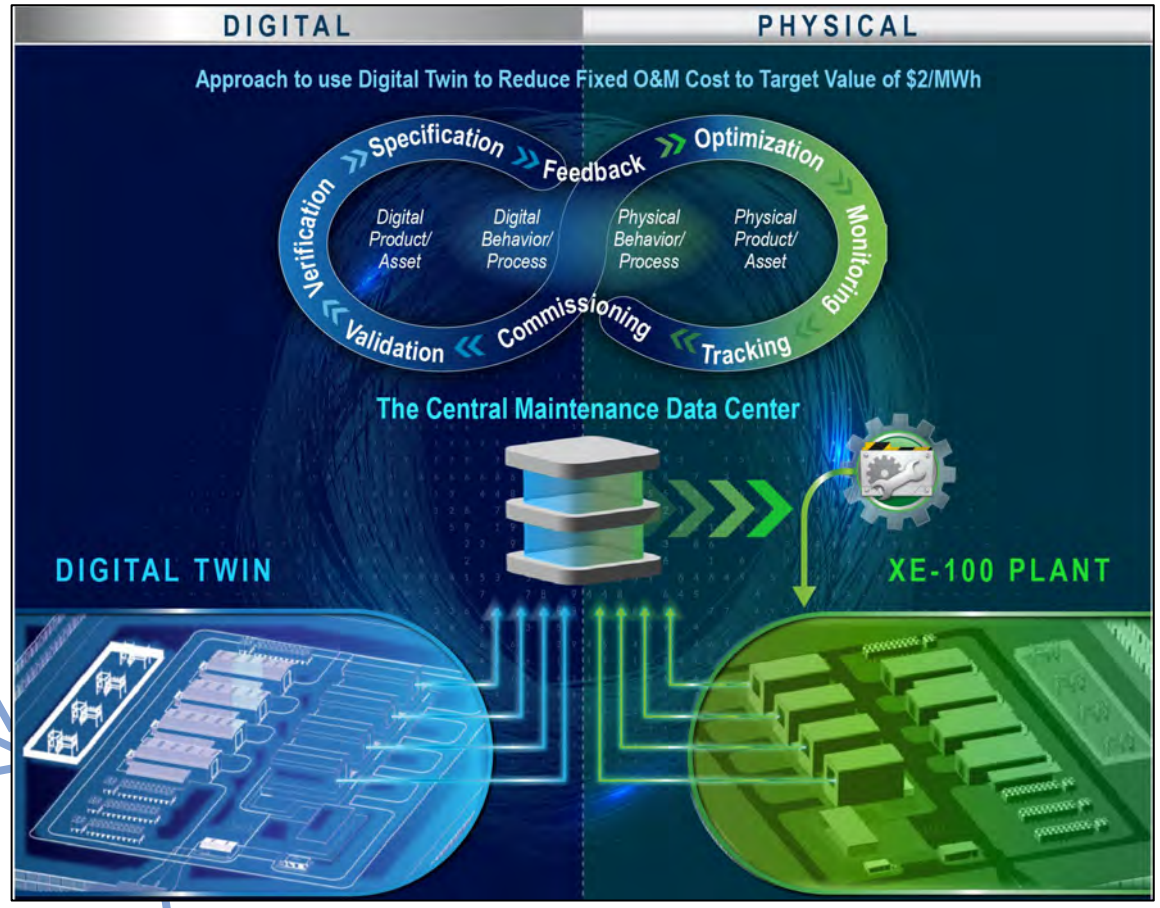
Xe-100 Digital Twin Tools

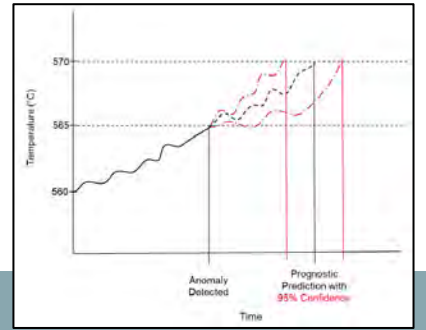


3D Models with AR / VR

Operator Training Simulator

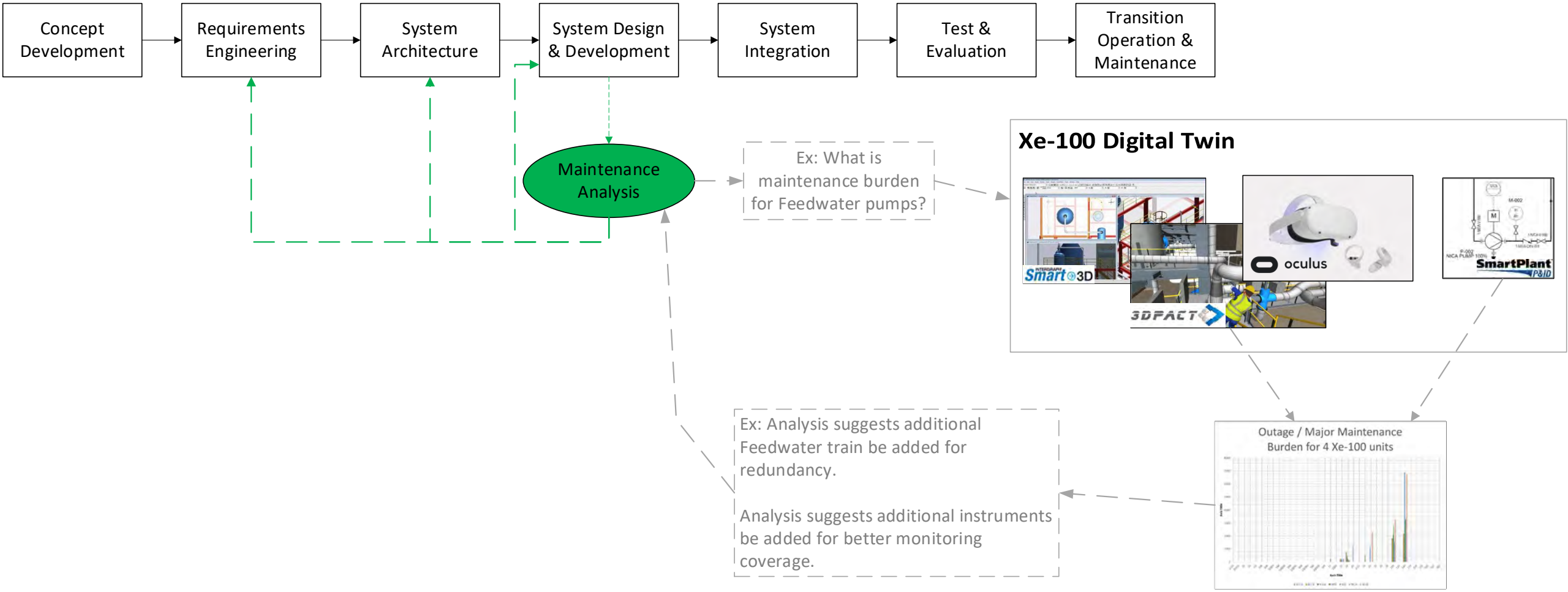
Plant Historian





AI / ML Models

Systems Engineering with Digital Twin: Maintenance



Reviewing Regulatory Requirements affecting Maintenance Staffing

- 10 CFR 50 Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants
  - Provides requirements for a quality assurance program
  - Notes staffing of personnel performing maintenance must be sufficient for tasks

- 10 CFR 50.65, Requirements for monitoring the effectiveness of maintenance at nuclear power plants
  - Defines the requirements to maintain SSCs to ensure they are capable of fulfilling their intended functions as described in the plant's license
  - Staffing of personnel performing maintenance activities supporting the activities required by Maintenance Rule must be sufficient to perform the required tasks

Reviewing Regulatory Requirements affecting Maintenance Staffing (continued)

- DRAFT 10 CFR Part 53 Licensing And Regulation Of Advanced Nuclear Reactors
  - Subpart F - Requirements for Operations
    - Requires submittal of staffing plans to contain the numbers, positions, and responsibilities of personnel providing support in areas such as Emergency Response Organization (ERO), Training, Operations, Maintenance, Engineering, Radiation Protection, and Chemistry Control
    - Requires the ability must exist to promptly dispatch operations and maintenance personnel

Xe-100 Maintenance Philosophy Summary

- Consolidates best practices through design, construction, and implementation to improve maintenance, reliability, and reduce costs (ARPA-E GEMINA goal) in for new nuclear SMR plants

- Collected by EPRI Nuclear Maintenance Application Center (NMAC) from:
  - EPRI SMEs in both Nuclear and Non-Nuclear sectors
  - EPRI Members in both Nuclear and Non-Nuclear sectors
  - Literature on various strategies on improving maintenance efficiency
    - Examples: Augmented Reality, Cross-training, and Operator Based Maintenance
  - Organizations beyond the electric power / energy industry
    - Examples: Military, refineries, manufacturing, airline, and automotive

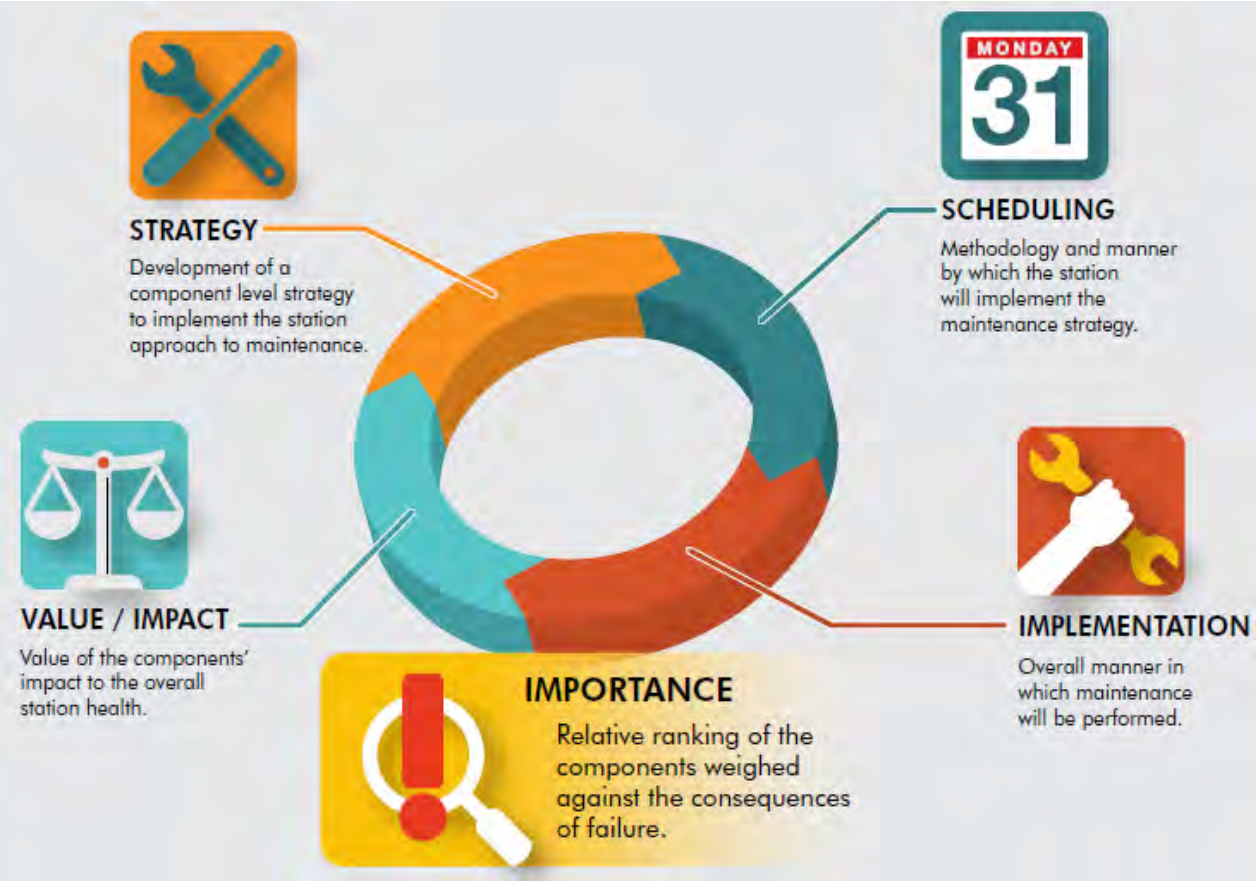
Xe-100 Maintenance Philosophy Summary (continued)

- Core concepts relevant to Maintenance Staff optimization from Xe-100 Philosophy Report are:
  - Prioritize Reliability and Maintainability during Design and Construction
  - Standardize the Xe-100 Systems, Structures and Components (SSCs)
  - Utilize cross-trained personnel to perform functions of Operations and Maintenance
  - Centralize departments and functions that support Xe-100 plants remotely
  - Automate activities historically performed by personnel
    - Examples: Robotics, sensors, and cameras
  - Apply advanced technologies
    - Digital Twin & Augmented/Mixed Reality
    - Electronic Work Management
  - Utilize Long Term Service Agreements (LTSA)
    - Outsource frequently and/or infrequently performed specialty skill and labor-intensive tasks

Xe-100 Maintenance Strategy Summary

- A Maintenance Strategy is the process that exists in an organization to maintain the overall facility at the desired level of reliability

- The Maintenance Strategy is determined using the “Criticality Ranking” created from the Xe-100 Equipment Reliability Process, that identifies the Importance, Value, and Impact of all SSCs at the Xe-100



Xe-100 Maintenance Strategy Summary (continued)

- The process in the table is the process proposed for developing a Maintenance Strategy
  - This process has been used and refined by EPRI via the Preventive Maintenance Basis Database (PMBD) for 25+ years
- The Criticality Ranking is used as an input to decide what strategy is applied to each SSC
  - Condition Monitoring with Time-Based Maintenance (TBM) and Feedback Process
  - Condition Monitoring with Condition Based Maintenance (CBM)
  - Run-to-Maintenance (RTM)

Maintenance Strategy Analysis Process	
1. Classify the component	8. Determine the most effective Maintenance Tasks that address the failure modes
2. Define the boundary of component	9. Assign task effectiveness against the failure modes
3. Collect references	10. Evaluate Sensors and Predictive Monitoring as an alternative to performing PM Tasks via a Continuous Online Monitoring (COLM) approach
4. Define Criticality	11. Determine tasks that can be performed as required following a “Run to Maintenance” strategy
5. Define Duty Cycle	12. Determine the necessary frequency for the Time-based maintenance tasks
6. Define Service conditions	13. Determine if Condition-Based Maintenance can be performed in lieu of Time-Based Maintenance.
7. Perform Failure Modes and Effects Analysis (FMEA)	14. Finalize the Maintenance Strategy in a living PM Basis Document

Identifying personnel that perform maintenance at Xe-100 plants

- Introduce baseline onsite staff that perform maintenance tasks
- Introduce baseline offsite staff that perform maintenance tasks
- Introduce contracted personnel that perform maintenance at Xe-100 plants

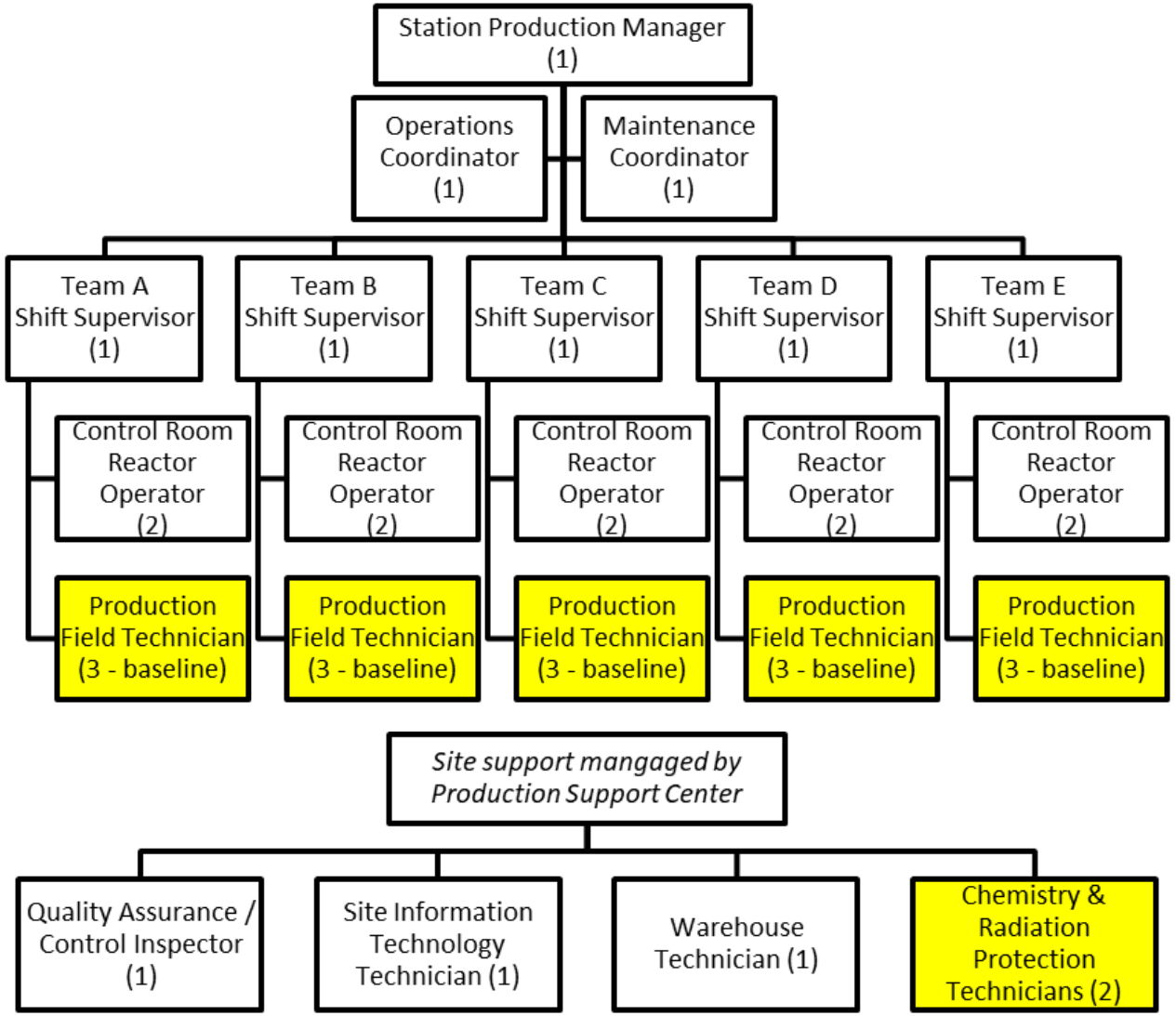
Onsite Personnel that perform maintenance at Xe-100 plants

Production Field Technician (PFT)

- Cross-trained personnel performing functions of:
  - Nuclear Building Operators
  - Fix-it-Now (FIN) technicians

- On-Shift Roles:
  - Operator Rounds
  - Supports Control Room Personnel
  - Minor and Routine Maintenance tasks that can be completed in less than 3 hours

- ***NOTE**: Baseline staff has 3 PFT/Shift but will expand as determined by the results of the Maintenance Staffing Analysis Process*



Onsite Personnel that perform maintenance at Xe-100 plants

Maintenance / Training Week (MTW) Rotation:

- Shift rotation proposed with a 5x8 week for Training and Maintenance every 5th week per Production Team.
- Maintenance can be performed **~155 shifts** per year (based on current training estimates)

Production Field Technician (PFT)

- Maintenance / Training Week Role:
  - Performs
    - Maintenance tasks that require more than 3 hours to complete

Weekday	Team A	Team B	Team C	Team D	Team E
Mon	TRNG	OFF	NIGHT	OFF	DAY
Tue	TRNG	OFF	NIGHT	OFF	DAY
Wed	TRNG	NIGHT	OFF	DAY	OFF
Thu	MTW	NIGHT	OFF	DAY	OFF
Fri	MTW	OFF	NIGHT	OFF	DAY
Sat	OFF	OFF	NIGHT	OFF	DAY
Sun	OFF	OFF	NIGHT	OFF	DAY
Mon	DAY	TRNG	OFF	NIGHT	OFF
Tue	DAY	TRNG	OFF	NIGHT	OFF
Wed	OFF	TRNG	NIGHT	OFF	DAY
Thu	OFF	MTW	NIGHT	OFF	DAY
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Sun	NIGHT	OFF	DAY	OFF	OFF
Mon	OFF	NIGHT	OFF	DAY	TRNG
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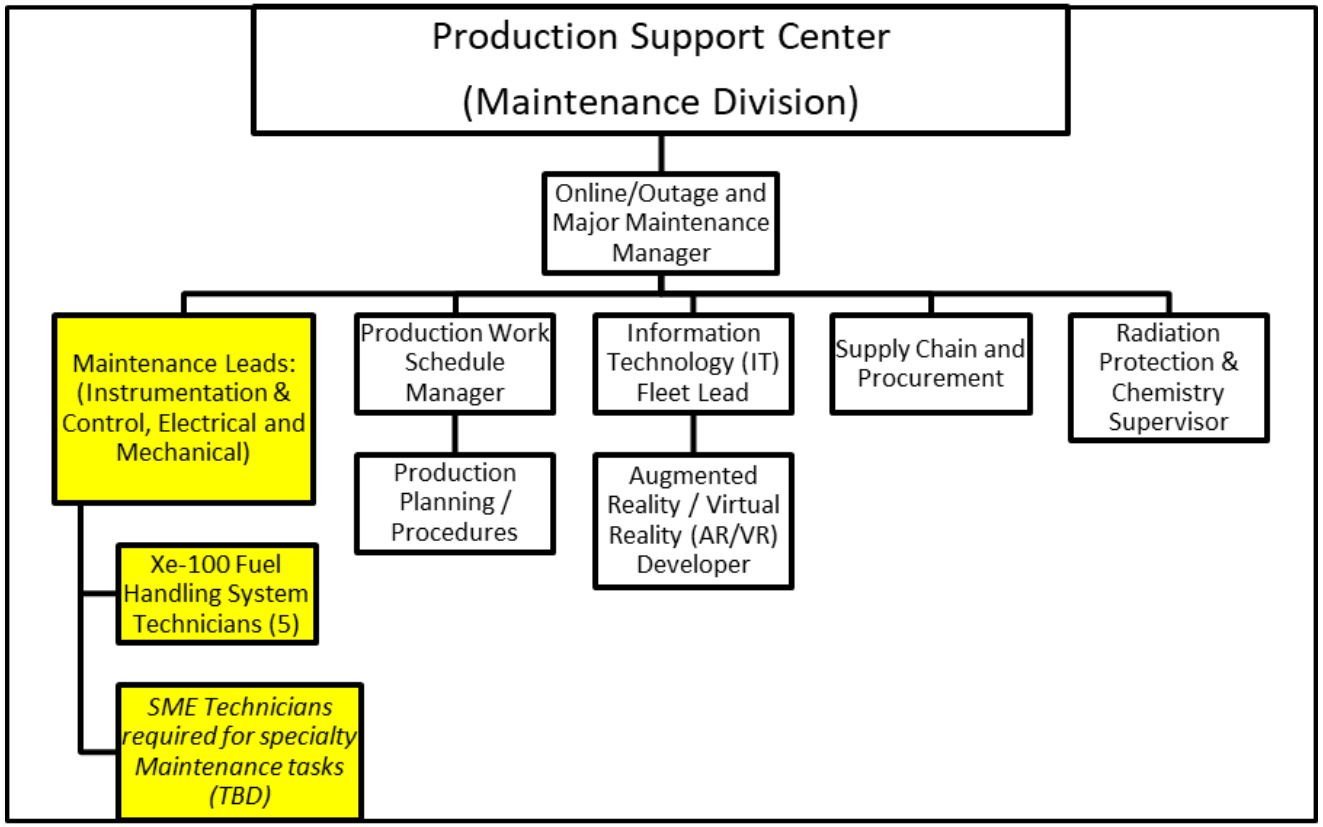
Thu	MTW	NIGHT	OFF	DAY	OFF
Fri	MTW	OFF	NIGHT	OFF	DAY

Offsite Personnel that perform maintenance at Xe-100 plants

Maintenance Leads: (Instrumentation & Control, Electrical and Mechanical)

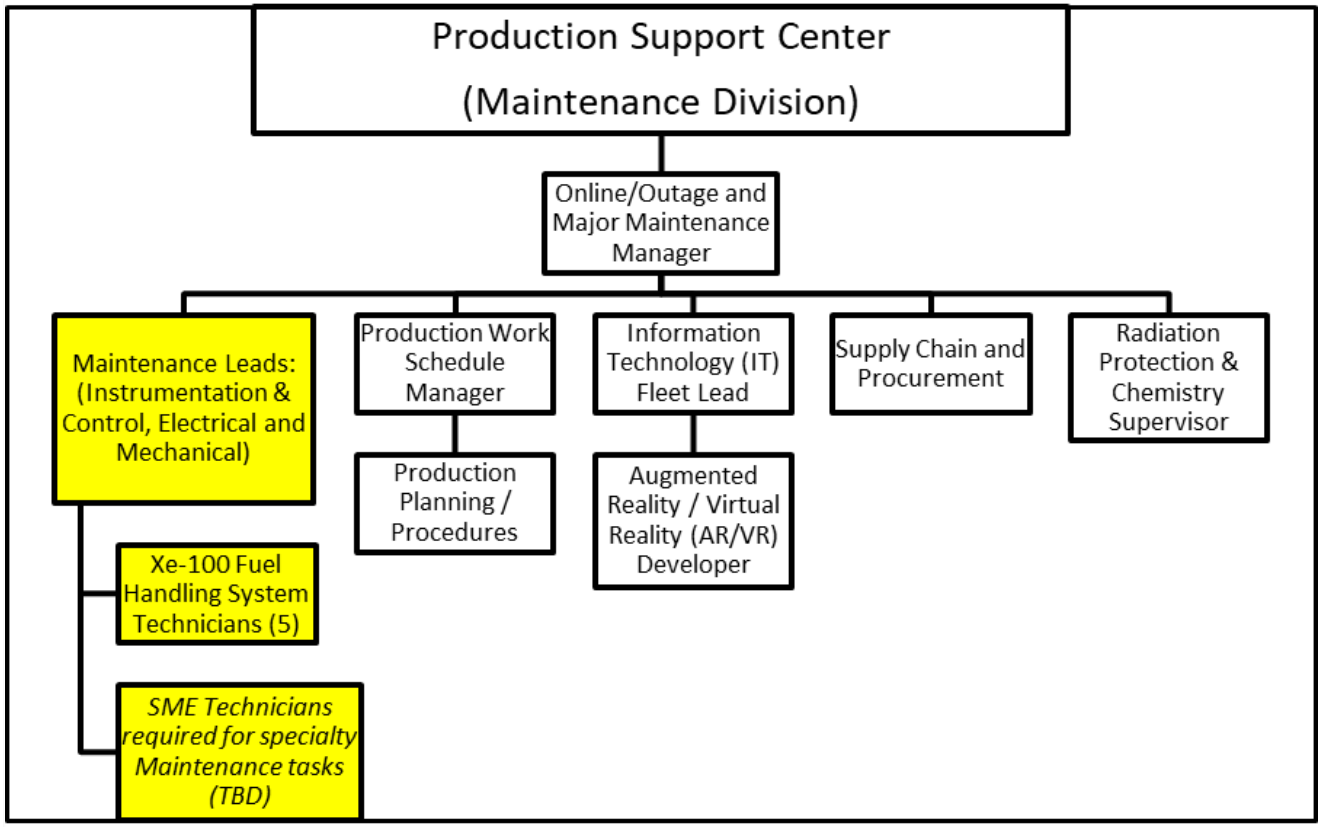
- Centrally based Maintenance personnel in the PSC
- Primary technical support contact for PFTs during performance of maintenance tasks
- **Perform** or **Oversee** more complex Online, Outage, and Major Project maintenance tasks
  - Work primarily with contracted personnel support PFTs



Offsite Personnel that perform maintenance at Xe-100 plants

Xe-100 Fuel Handling System Technicians

- Centrally based Maintenance personnel in the PSC
- Possess the technical skills and expertise in the FOAK components in the Reactor and Fuel Handling systems in the Xe-100 plants.
- Travel to the stations as required to perform maintenance tasks, provide onsite support, or oversight for the Online, Outage and Major Maintenance activities on the Xe-100 Fuel Handling SSCs.



NOTE: If required, other SME Technicians can be added to PSC staff to support/perform specialty Maintenance tasks. Examples of specialty Maintenance tasks are Turbine/Generator and Steam Generators major and minor maintenance tasks.

Contracted Personnel that perform maintenance at Xe-100 plants

Long-Term Service Agreements (LTSAs) contracted personnel

- Long-Term Service Agreements (LTSAs) are being evaluated as an option to reduce the size of the Xe-100 full-time Production staff during online and outage periods
- LTSAs are very common in non-nuclear stations to manage a defined scope of Maintenance or provide specialty skills in support of Maintenance Tasks
- LTSA contract can includes functions like:
  - Performance Monitoring and Diagnostics
  - Planned and Unplanned Maintenance (providing all parts and personnel)
  - Technical Field Assistance

Contracted Personnel that perform maintenance at Xe-100 plants (continued)

- Some Examples of SSCs maintained and tasks performed by LTSAs are:

SSCs maintained by LTSAs	Tasks performed by LTSAs
• Main Turbine/Generator	• Welding Tasks
• Demineralized Water Facility	• Scaffolding Tasks
• Heat Exchangers	• Radiography Tasks
• Station Air compressors	• Coating Tasks
• Switchyard and Transformers	• Complex Rigging tasks
• Cooling Towers	• Flow Accelerated Corrosion (FAC) piping inspections

Example of Maintenance Staffing Analysis Process
"A" Train of the Nuclear Island Cooling Water (NICA) system, Circulating Pump "A"

Xe-100 NICA Circulating Pump "A"

- Horizontal - Single Stage - Single Suction Pump
- Circulates water in the NICA system to the various heat loads and heat-removal heat exchanger
- In this example, determined to be a Critical SSC via X-energy Equipment Reliability Process

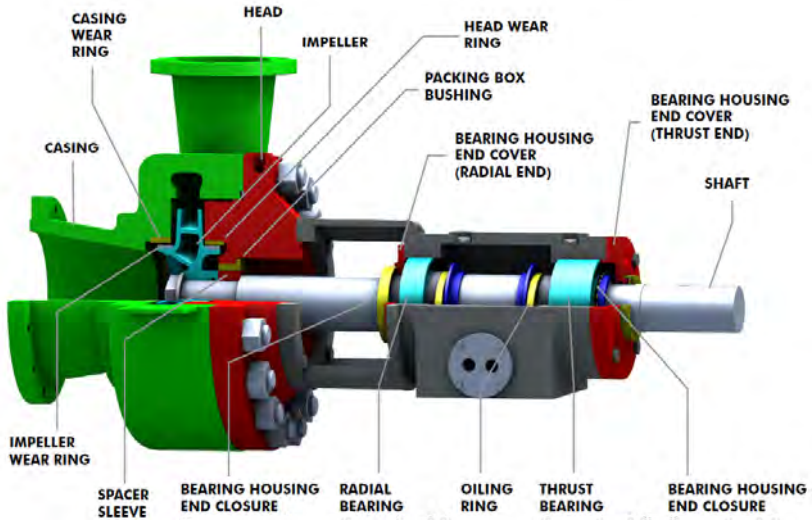


Table 4: Example Maintenance Strategy for the Xe-100 Nuclear Island Cooling Water (NICW) system, Circulating Pump A

Task Name	Crew	Number of Technicians	Labor hours / technician	Frequency
Acoustic Monitoring	COLM	N/A	N/A	continuous
Functional Testing	COLM	N/A	N/A	continuous
Oil Analysis	PFT	1	1	6M
Operator Rounds	PFT	1	0.01	1S
Packing or Seal Replacement	MTW	2	8	AR
Performance Trending	COLM	N/A	N/A	continuous
Refurbishment/Replacement	LTSA	4	30	AR
Vibration Analysis	COLM	N/A	N/A	continuous

Crew Legend:
PFT: Production Field Technician, COLM: Continuous Online Monitoring, MTW: Maintenance/Training Week Team, & LTSA: Long-term Service Agreement

Frequency Legend:
AR: As Required, 1S: 1 Shift, 6M: 6 Months

Example of Maintenance Staffing Analysis Process
"A" Train of the Nuclear Island Cooling Water (NICA) system, Circulating Pump "A"

- The PFT position is assigned the following scheduled tasks:
  - Operator Rounds
    - An anomaly detection inspection and data collection task performed by all PFT personnel on-shift either every shift or everyday
  - Oil Analysis
    - Performed once every 6 months by collecting oil from a drain tap on the oil sump.
- The MTW team will be assigned the "Packing or Seal Replacement" task via an Emergent or Corrective Maintenance task IF if a leak or other faults is detected by the "Operator Rounds," "Vibration Analysis," or "Acoustic Monitoring," requiring action.
- The LTSA contractor will be assigned the "Replacement/Refurbishment" via an Emergent or Corrective Maintenance task IF the other tasks indicate it is necessary.

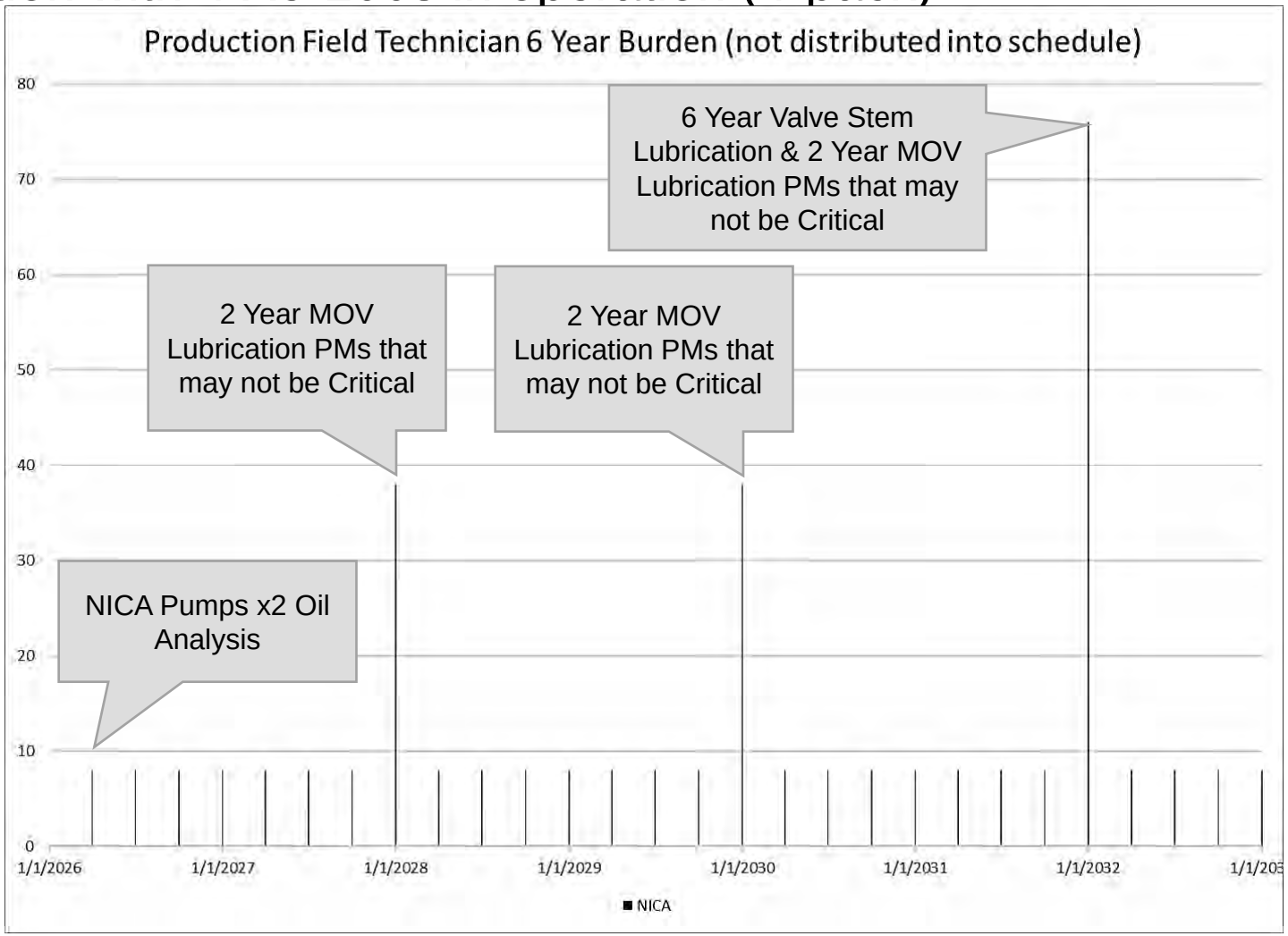
Example Crew Burden based on Example Maintenance Strategy for the Xe-100 Nuclear Island Cooling Water (NICW) system, Circulating Pump A

Crew	1S	3M	6M	2Y	AR
PFT	1 x 0.01	0 x 0	1 x 1	0 x 0	0 x 0
MTW	0 x 0	0 x 0	0 x 0	0 x 0	2 x 8
LTSA	0 x 0	0 x 0	0 x 0	0 x 0	4 x 30

Note: Burden is shown as "Technicians x Hours"

Example of Maintenance Staffing Analysis Process

- As an example, the entire PFT burden for the NICA system across a 6-year schedule is shown for a station with 4 Xe-100s in operation (4-pack)



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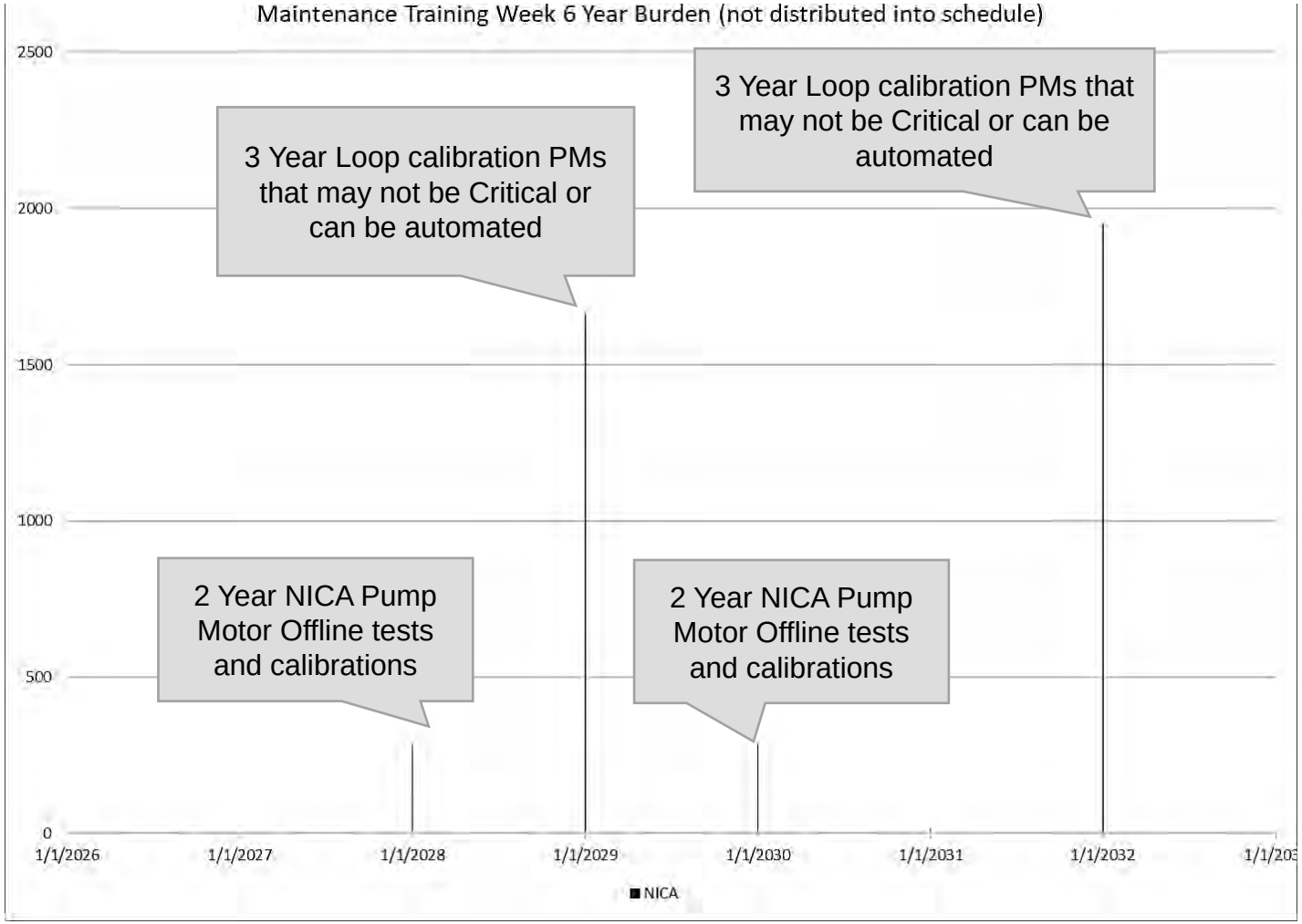

Example of Maintenance Staffing Analysis Process Summary

- Based on BASELINE Staff and 5-Week Maintenance Training Week Rotation schedule, ~19,551 hours of Maintenance tasks can be performed every year.

- Further refinement of Maintenance Staffing numbers will be performed as:
  - Maintenance Strategy Analysis continues for the Xe-100 plant design
  - Criticality Rankings are developed via the Xe-100 Equipment Reliability Program

- This approach provides justification for each staff member hired or contracted to perform maintenance tasks in the Xe-100.

Next Steps

- Develop SSC Criticality Rankings via the Xe-100 Equipment Reliability Program
  - Allows classification of SSCs for finalization of Maintenance Strategies
- Continue Maintenance Strategy Analysis Phase 2 in 2022
  - Coordinating contract support to increase rate of analysis, targeting completion in 2023 for all Xe-100 Systems
- Coordinating with Training team to determine inputs needed for Training Needs Analysis for Maintenance Training Program development

Questions Comments

- Thank you for your time

energy

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