Integrated Operations for Nuclear

LIGHT WATER REACTOR SUSTAINABILITY

Enabling Work Reduction Opportunities through Digital Modernization

December 4, 2024

Idaho National Laboratory

Background

The Idaho National Laboratory(INL) Light Water Reactor Sustainability Program (LWRS) Plant Modernization (PM) Pathway has been working with the industry to leverage modern digital technology and optimize plant operations.

Research Goals

Improve Operational Performance

Improve Economic Performance

Projects at Reference Plant

Implement Non-Safety DCS Platform

Optimize Report Creation with AI

ION Objectives and Goals

Plant Modernization Research Objectives and Goals				
Objectives	Extend the life and improve the performance of the existing fleet through modernized technologies and improved processes for plant operation and power generation. Develop modernization solutions that improve reliability and economic performance while addressing US nuclear industry's aging and obsolescence challenges. Deliver a sustainable business model that enables US nuclear industry to remain competitive.			
Research Areas	Digital Infrastructure	Data Architecture & Analytics	Human & Technology Integration	Integrated Operations for Nuclear
Outcomes	A multi-layered, sustainable digital foundation to enable plant modernization	Advanced monitoring and data processing to replace labor-intensive support tasks	Tools and methodologies that maximize efficiency while ensuring safety and reliability are maintained	Light water reactor fleet electric market competitiveness

ION Concept of Operations

The ION concept, developed by the LWRS PM Pathway, provides a **comprehensive, business case-driven strategy** to support plant modernization for the U.S. nuclear fleet. Its primary objectives are to:

- **Convert from Labor-Centric to Technology-Centric**
- **Maintain or Improve Plant Safety & Operating Capacity Factors**
- **Reduce Total Ownership Costs**
- **Enable Extended Plant Operational Lifetimes**

This strategy provides a framework for planning upgrades efficiently to extend the lifetimes of the plant and prioritize short- and long-term benefits.

Current State

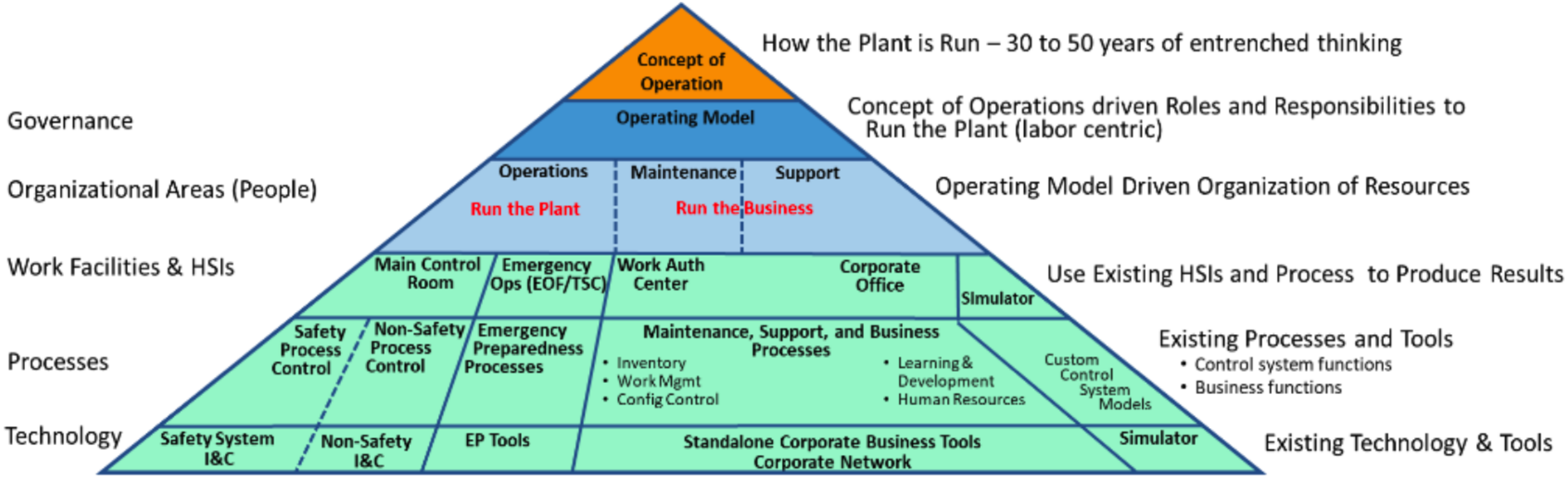

Figure 2. Current state concept of operations diagram.

New State

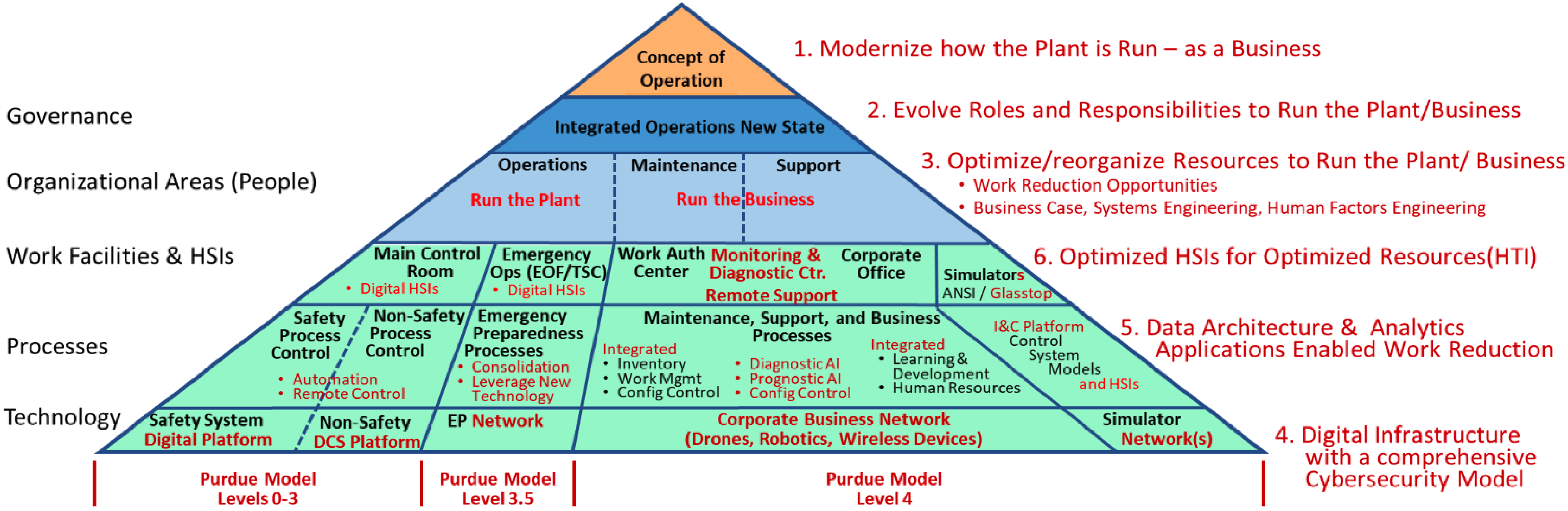

Figure 3. ION-enabled new state concept of operations diagram.

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Pilot Business Case

In earlier INL research **22 current safety-related and non-safety related I&C subsystems** by migrating function or interfacing equipment that performs their function into either a safety-related digital platform or a non safety related DCS platform. This two-platform solution is being pursued to **consolidate respective safety-related and non-safety related functions.**

Table 1. Net present value of I&C digital modernizations for 30 and 50 years.

Scenario Title	Payback Period	Net Present Value	Internal Rate of Return
Baseline (30 Years of Continued Operation)	17.8 years	$74M	8.1%
Baseline (50 Years of Continued Operations)	17.8 years	$685M	11.8%

The Business Case Analysis for applying the two-platform I&C solution provides a compelling case for these digital I&C upgrades.

Digital Non-Safety I&C Upgrades

The research scope of the non-safety related digital I&C upgrade strategy for the Pressurized Water Reactor Reference Plant includes the digital modernizations of the **subsystems** below:

- Westinghouse 7300 non-safety related **analog control system platform**
- **Existing electronic** (analog or obsolete digital), pneumatic, hydraulic, and **mechanical control systems or direct manual controls** that are either standalone or interface with other control systems
- **Sensing devices**, contained within the sensing circuits of both the non-safety related 7300 system and the safety-related 7300 system, used to provide indications to the non-safety related plant process computer (PPC)

Figure 9. Honeywell universal I/O module redundant configuration.

Figure 10. Emerson Ovation R-Line I/O module redundant configuration.

Figure 11. Honeywell C-300 redundant controller.

Figure 12. Emerson Ovation OCR1100 redundant controller.

Importance of Lifecycle Management

Representative vendor Network Level 2 platform hardware and software release history

Release	Microsoft Operating System: Version	Microsoft Operating System: End of Extended Support	Honeywell Software: Support Level	Honeywell Software: Released	Honeywell Software: Withdrawn From Sale	Honeywell Software: Latest Point Release	
Experion R30x	WS2003 Server SP2	Jul 14, 2015	Phased Out	1Q2006	3Q2010	R301.3 Dec 2008	Coordinated Hardware/Software Major Release
	XP SP3	Apr 08, 2014					
	SQL2000 SP4	Sep 04, 2013					
Experion R31x	WS2003 Server SP2	Jul 14, 2015	Phased Out	2Q2008	2Q2012	R311.3 Aug 2009	Software Feature Upgrade Minor Release
	XP SP3	Apr 08, 2014					
	SQL2005 SP3	Apr 12, 2016					
Experion R40x	WS2008 Server 32bit SP2	Jan 14, 2020	Phased Out	3Q2010	2Q2014	R400.8 Dec 2015	Coordinated Hardware/Software Major Release
	Windows 7 32bit SP1	Jan 14, 2020					
	SQL2008 SP3	Jan 08, 2019					
Experion R41x	WS2008 Server R2 64bit SP1	Jan 14, 2020	Phased Out	2Q2012	3Q2018	R410.9 April 2016	Software Feature Upgrade Minor Releases
	Windows 7 64bit SP1	Jan 14, 2020					
	SQL2008 R2 SP2 32bit	Jan 08, 2019					
Experion R43x	WS2008 Server R2 64bit SP1	Jan 14, 2020	Supported	2Q2014	NA	R430.6 Oct 2016 R431.5 Mar 2018 R432.2 Sep 2017	
	Windows 7 64bit SP1	Jan 14, 2020					
	SQL2012 SP2 32bit	Jul 12, 2022					
Experion R50x	WS2016 Server 64bit	Jan 11, 2027	Supported	1Q2017	NA	R500.2 Aug 2017 R501.4 Dec 2018	Coordinated Hardware/Software Major Release
	Windows 10 IoT Ent LTSB 2016	Oct 13, 2026					
	SQL2014 SP2 64bit	Jul 09, 2024					
Experion R51x	WS2016 Server 64bit	Jan 11, 2027	Current	3Q2018	NA	R510.1 Jul 2018	Software Feature Upgrade Minor Release
	Windows 10 IoT Ent LTSB 2016	Oct 13, 2026					
	SQL Server 2017 Standard	Oct 12, 2027					

Site-Specific I&C Function Migration Strategy

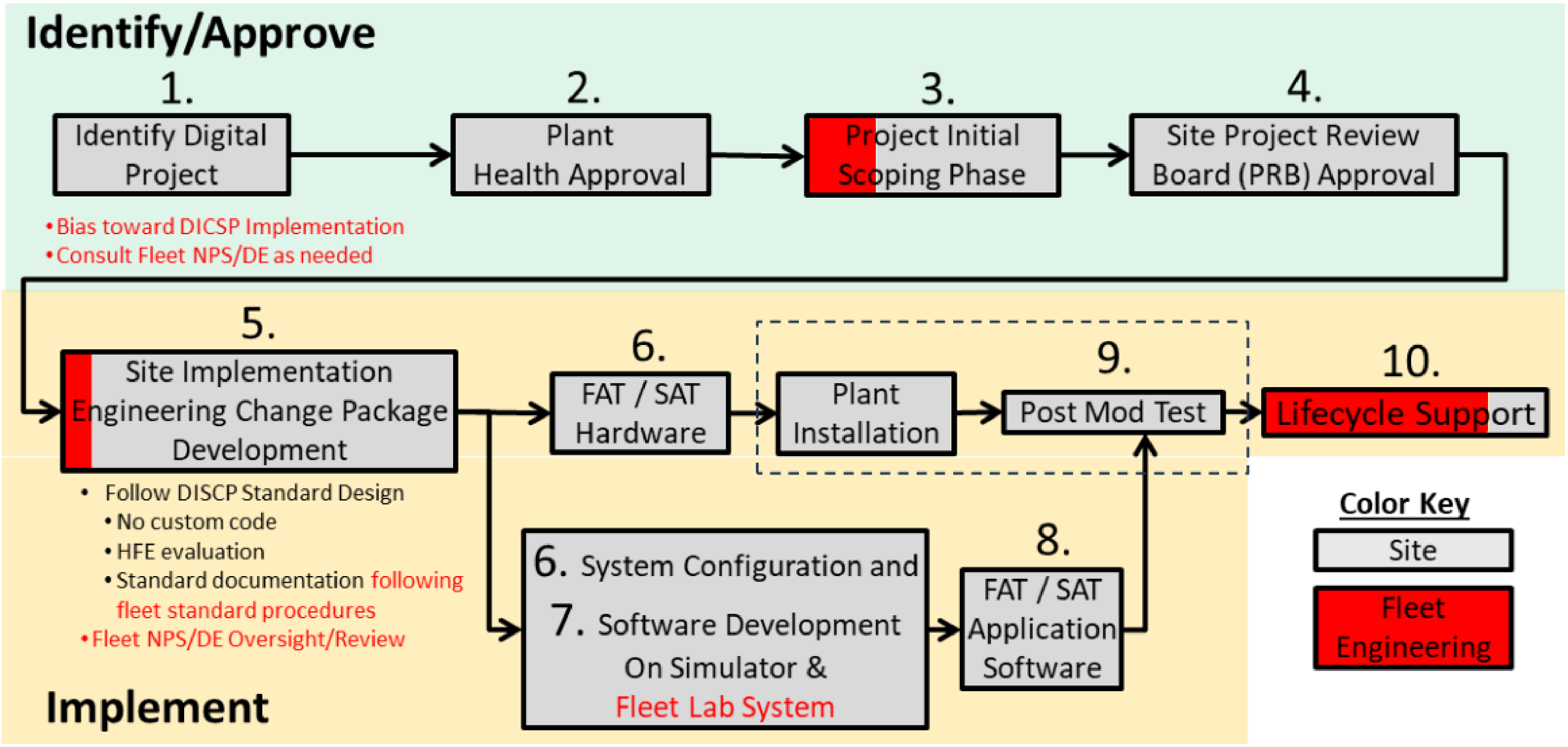

Figure 19. Process for site-specific I&C function migration to a non-safety related DCS.

Installation Process of I&C Function Migration

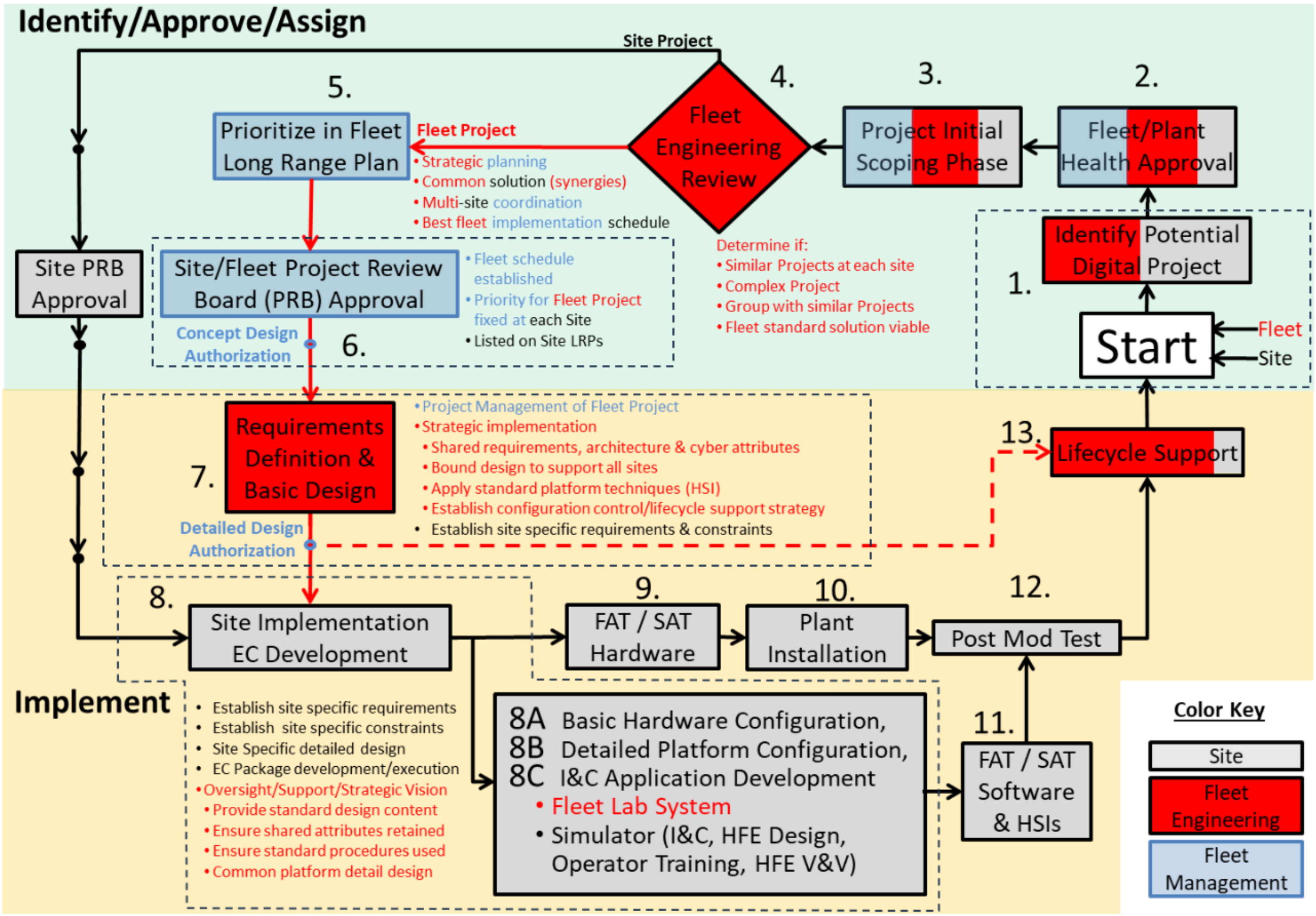

Figure 20. Standard process for installation of and I&C function migration to a non-safety related DCS.

DCS Platform Software Patching Process

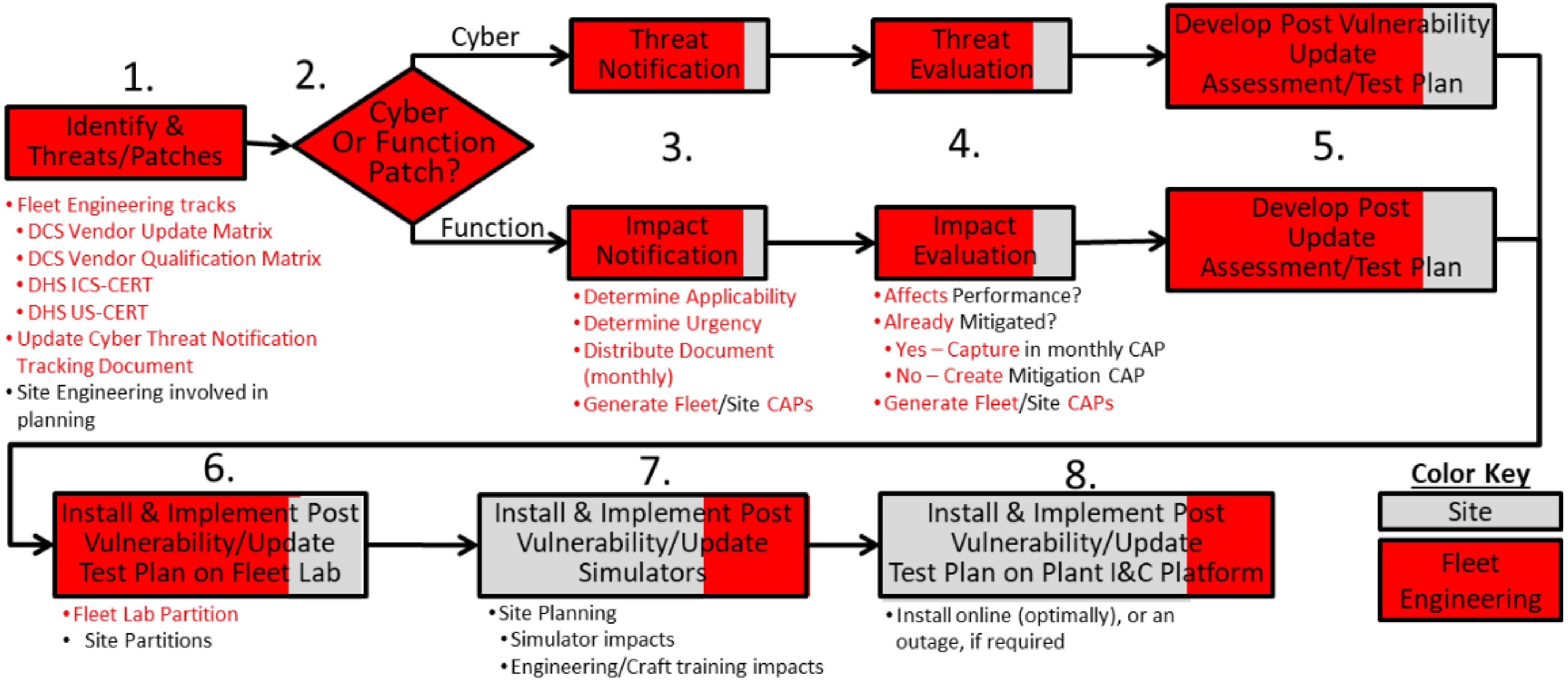

Figure 21. Process for non-safety related DCS software patching.

Fleet DCS Platform Upgrade Process

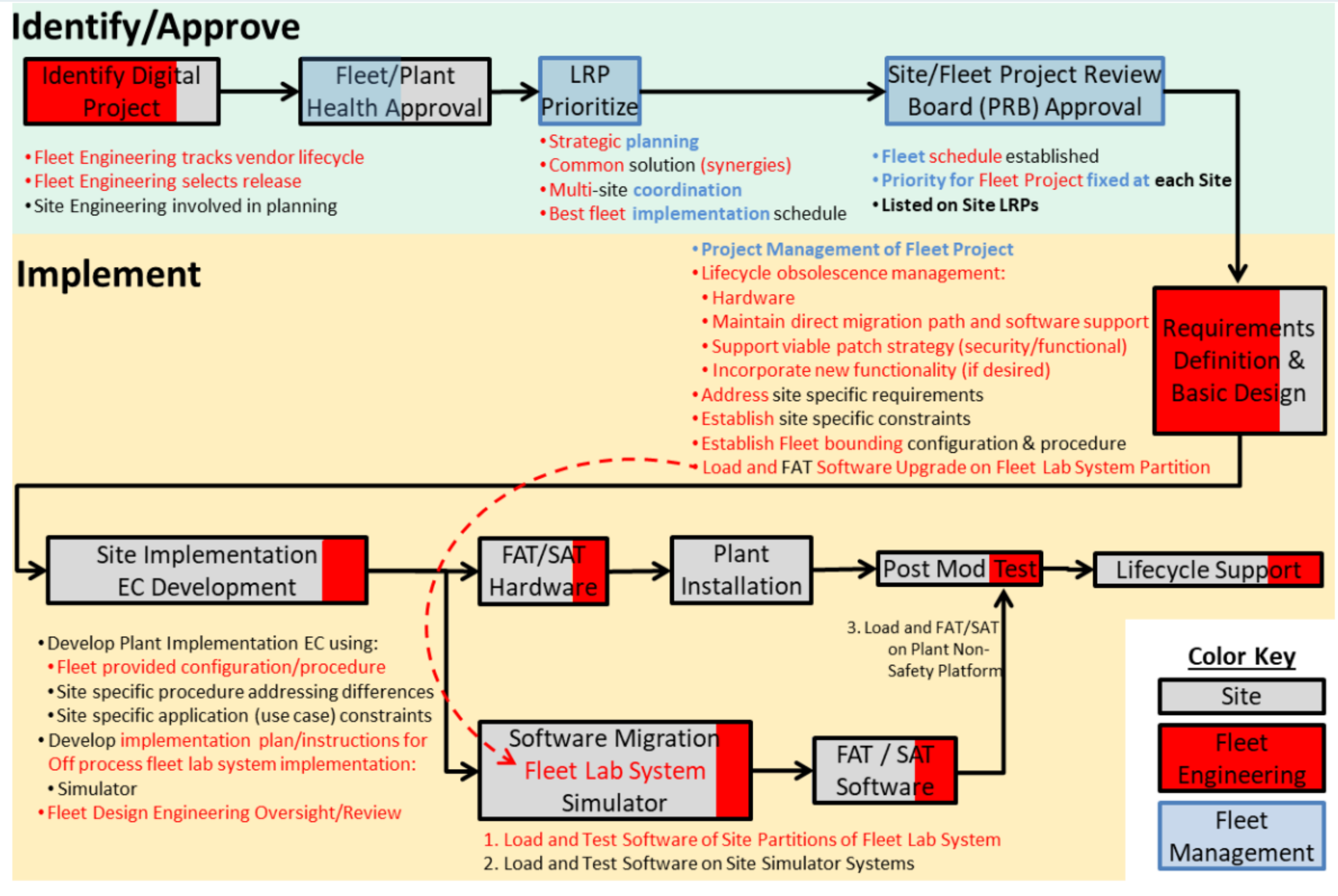

Figure 22. Process for fleet distributed process control system platform upgrade (Network Level 2).

AI Tool Evaluation

Pilot AI Tool Project Scope

In the nuclear power industry, AI is increasingly being used to automate and streamline human processes. For instance, AI is currently being used to **automate the work of the CAP screening committee**.

The project was undertaken to prove the applicability of AI tools for tasks **other than corrective action programs**.

The **scope** of this project was to test if a tool could draft equipment evaluation reports. The result of this project was an **AI chatbot** that creates a **sophisticated draft of an evaluation report**, which is validated by an experienced engineering and operations team without changing existing processes.

Pilot AI Tool Background and Process

Artificial Intelligence(AI) and Machine Learning(ML) tools combined with the resources to handle large amounts of data have revolutionized the ability to **make informed, data driven decisions** and to **automate human processes**. As nuclear power plants have progressively **digitized their data sources and documents**, there is now a wealth of well-organized information that can be used to train AI tools to complete tasks as well as humans do. In this project, the vendor(who has a background in nuclear power) created a **chatbot-style AI tool** to **automate the process of writing reports**. In collaboration with the vendor, the Reference Plant collected significant data to train the AI with, including:

- Completed Work Orders
- Procedures
- Design basis documents
- Vendor technical manuals
- Final safety evaluation reports
- Vendor correspondence
- Previous corrective action evaluation reports

Training the AI model on this data allowed it to achieve the capability to **write technically accurate drafts for reports**, allowing the operator to **author reports much more quickly** without extensive research through the company’s past records and documentation.

Examples of AI Tool Interface and Outputs

Examples of AI Tool Interface and Outputs

The following is a recommendation for the disposition of the boric acid leakage.

The boric acid accumulation is present on the set screw gasket, valve body, inlet flange, and flange fasteners. The boric acid accumulation is approximately 2 tablespoons and contains discoloration. The boric acid accumulation is localized at the set screw gasket and has not migrated to any other components.

The discoloration in the accumulation is the result of the boric acid contacting the carbon steel valve body and flange fasteners. There was no evidence of degradation or wastage to the set screw gasket, valve body, or the inlet flange. These components are constructed of stainless steel which is resistant to boric acid corrosion. The structural integrity of the components has not been affected.

The flange fasteners are constructed of carbon steel which is susceptible to boric acid corrosion. However, there was no evidence of degradation or wastage to the flange fasteners. The flange fasteners are coated to protect against contact with boric acid. The discoloration in the accumulation is the result of the boric acid contacting the carbon steel flange fasteners.

The source of the leakage can positively be identified, the leak site is not obstructed, and the leaking component and/or surrounding components and surfaces are not affected. The EPRI Boric Acid Corrosion Guidebook indicates that tests conducted (for carbon steel, low alloy steels and martensitic stainless steels) when exposed to boric acid crystals, exhibited very low corrosion rates. The highest rate observed on any of the alloys was 0.0005 inches per year. Because there was no evidence of degradation or wastage to the flange fasteners, their structural integrity has not been affected.

Work order [redacted] was generated to clean the boric acid accumulation and adjust the set screw gasket.

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Examples of AI Tool Interface and Outputs

Dialogue 3 Examples

B

Pretend you are boric acid program owner at [redacted] Write a boric acid eval to address.
The following was discovered during a walkdown on [redacted], Reactor Coolant Pump Seal Water Injection Filter [redacted] Outlet Valve
- wet boric acid at the valve packing
- 130 degrees F fluid temperature
- no current leak or fluid was observed, but the boric acid is a little wet
- boric acid observed on valve bonnet, packing gland, stem, and the yoke.
- 1 tablespoon, no discoloration only on packing

Examples of AI Tool Interface and Outputs

The following was discovered during a walkdown on [redacted] Reactor Coolant Pump Seal Water Injection Filter [redacted] Outlet Valve

- wet boric acid at the valve packing
- 130 degrees F fluid temperature
- no current leak or fluid was observed, but the boric acid is a little wet
- boric acid observed on valve bonnet, packing gland, stem, and the yoke.
- 1 tablespoon, no discoloration only on packing

Boric Acid Evaluation:

The observed boric acid accumulation is present on the valve bonnet, packing gland, stem, and the yoke. The boric acid accumulation is approximately 1 tablespoon and contains no discoloration. The boric acid accumulation is localized at the packing area and has not migrated to any other components or structures.

There was no evidence of degradation or wastage to the valve bonnet, packing gland, stem, or the yoke. These components are constructed of stainless steel which is resistant to boric acid corrosion. The structural integrity of the component has not been affected.

The source of the leakage can positively be identified, the leak site is not obstructed, and the leaking component and/or surrounding components and surfaces are not affected. This boric acid leakage meets the requirements for Minor Leakage as defined in procedure [redacted]

Work order [redacted] was generated to clean the boric acid accumulation and adjust the packing.

Initial Questions to be Answered in Possible Future Research

Workload

- How much time did the AI tool save engineer? Supervisor? Operations?
- How much additional time is spent if there is an error?
- How much time was spent to train engineers on tool? Initial? Continuing?

Business Case

- How much external spend to develop? Maintain?
- Benefits to the fleet? Consolidation of resources?
- Additional use cases?

Quality

- How do we know if the content of the draft evaluation report is right/wrong?