What Plants Need: Real Needs Analysis & Requirements Overview

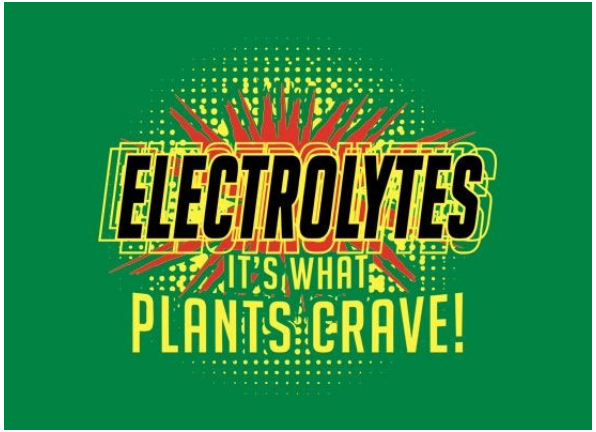
Ray Herb, Digital Principal, Southern Nuclear

Digital Safety Systems Seminar
Clearwater Beach Florida
1/30/2020

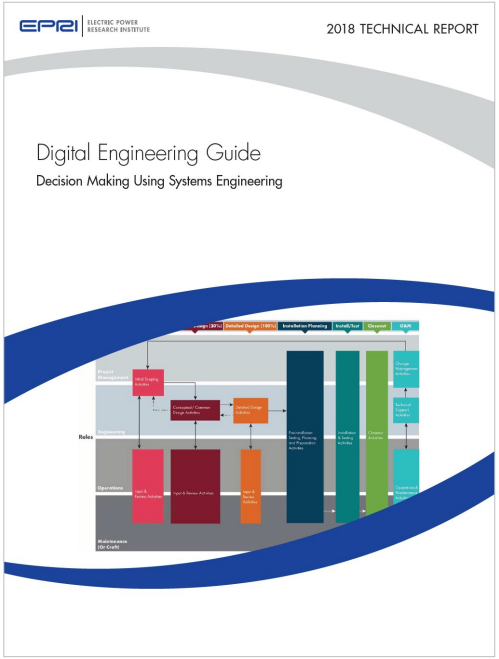
Southern Nuclear

What Plants Need

- Electrolytes?
  - Only in the movies!



- Requirements!
  - A Needs Analysis is Required to inform Requirements Analysis, and the subsequent platform selection and design
  - EPRI Digital Engineering Guide (3002011816) and NISP-EN-04 recommends well before the design starts
  - Detailed Elicitation of Needs of all stakeholders including the plant strategy and future concepts of operation



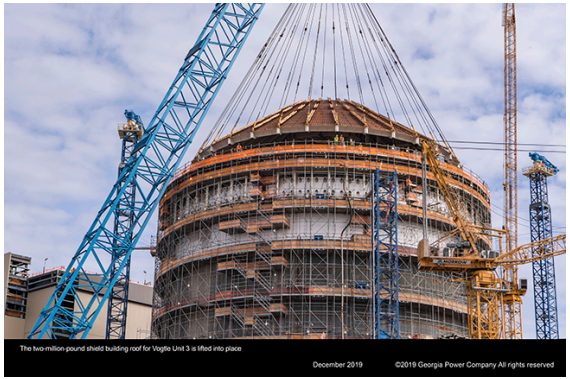
What is Needs Analysis? (real world examples)

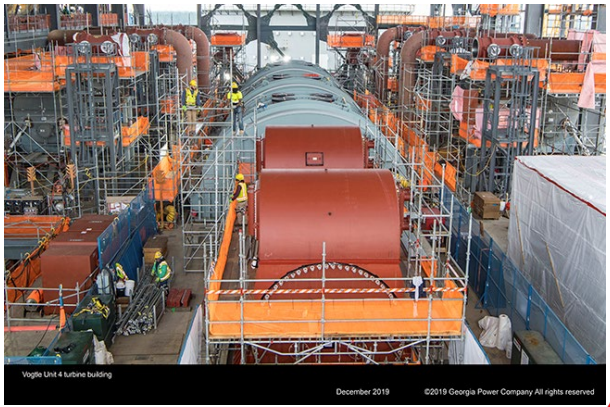
- Dinner for two
  - Need: You're hungry so you have to eat
  - Analysis: Steak or Burger?
  - Risk: Low, Poor decision impact is short term, you get to decide again tomorrow

- Personal Vehicle Purchase
  - Need: You need a new car
  - Analysis: Could be extensive, Car or Truck?
  - Risk: Higher, Poor decision could cost 10s of thousands, impact lasts 3-10 years

Protection System Needs Analysis

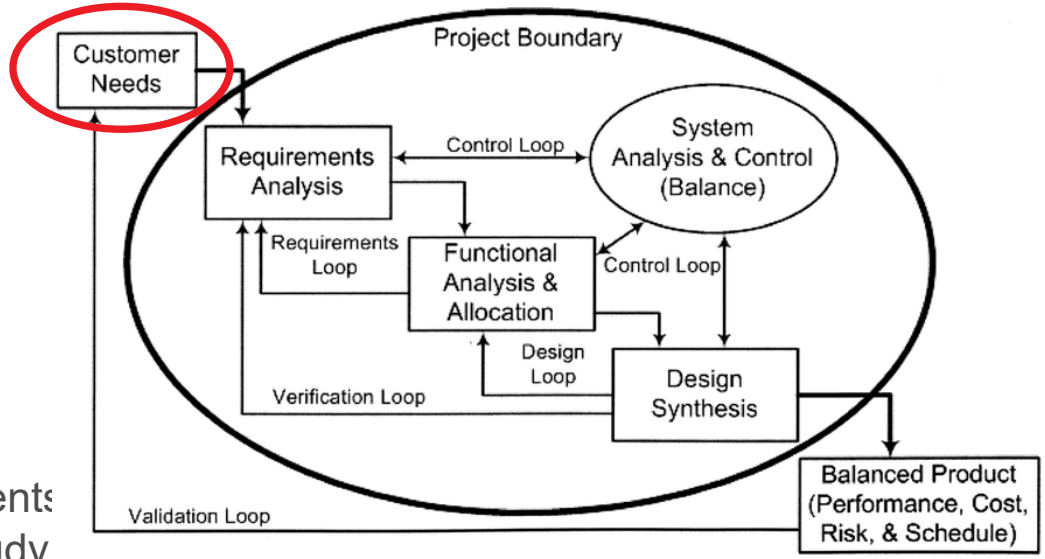
- Need:
  - New protection system to support Long Term Operation
- Analysis:
  - Consider the full range of Digital Capabilities
  - Consider the Plant Strategy, Concept of Operations, Lifecycle expectations
  - Consider the existing system and constraints
  - Identify potential benefits to offset costs of new system
- Risk: Huge! Project costs in 10s of Millions
  - Cost of mistakes that result in a change is Millions
  - Must show a return on investment,
  - Long term, must live with decision for 20+ years,
  - Mistakes could result in project cancellation.





Needs Analysis as Part of Systems Engineering

- Formal Elicitation of Needs from All Stakeholders
  - Plant Management/Owner
  - Operations
  - Maintenance
  - Engineering
  - Design AE, Installer
  - Financial Services
  - Human Resources
  - Licensing/Regulator
  - Training
- Two deep (What and Why)
  - Sufficient Detail to support Requirements
  - Cost Benefit to support and Trade Study
  - Multiple viewpoints from each stakeholder
  - Risks Ranked
- Validated by Plant Strategy and Project Goals

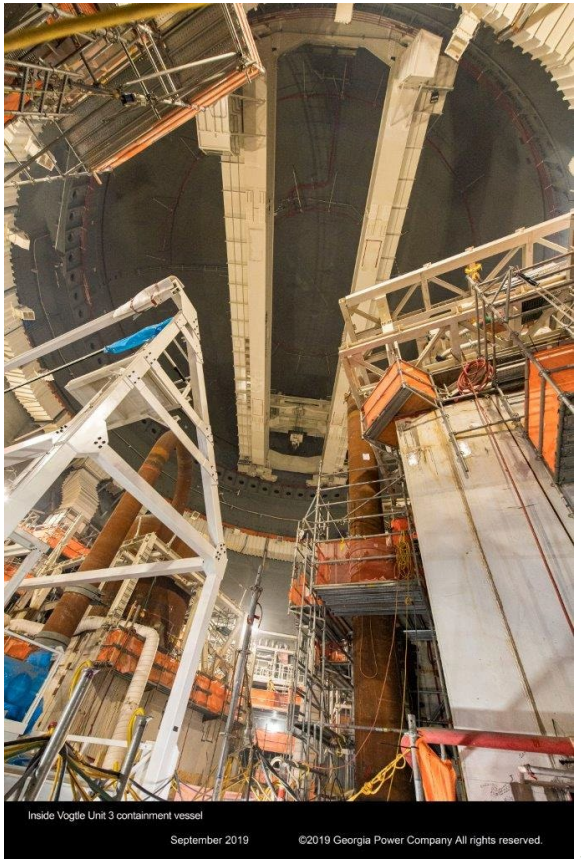


Who Does The Needs Analysis?

- Who performs this Activity?
  - Depends on the Risk from getting it wrong!
- Dinner?
  - Low risk,
    - » Safe to pass it onto another
- Car?
  - Medium Risk, depends on the money you spend
    - » Who do you trust to make decisions for you?
- Protection System?
  - High Risk, The wrong decision could cost Millions
    - » Will you let the OEM tell you what you want?
    - » The AE?
    - » The System owner?
  - Should be a multi discipline team!

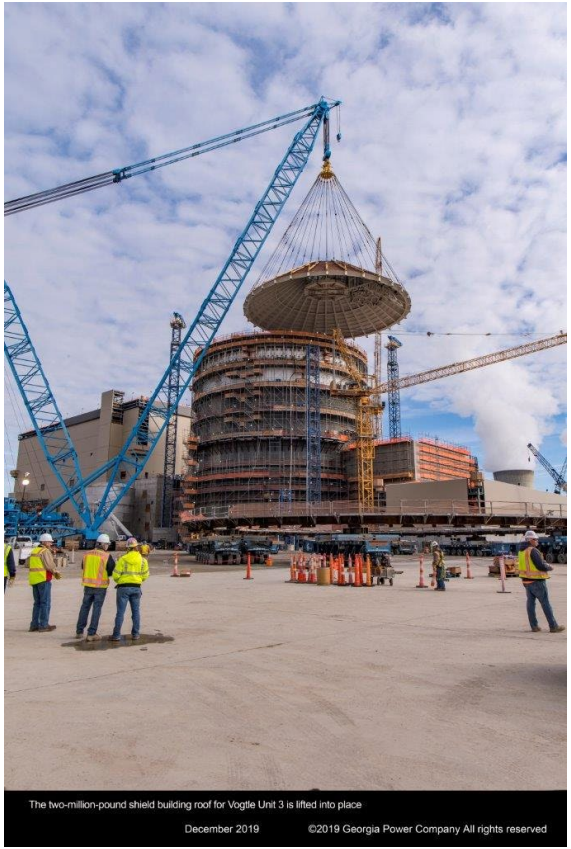
Southern Nuclear Strategy

- Common Platform for the Fleet
- Criteria based on 3 Loop, 4 loop PWR and BWR
- Supported for 20+ years
- Full set of Platform diagnostics for offline health monitoring by fleetwide monitoring center
- Platform and Application diagnostics to support elimination of STs
- Expandable for future concepts of operation (additional trips, runbacks, etc.)
- Fit into existing cabinet footprint
- Minimal Impact on Main Control Room
- Compatible with existing HVAC
- No Field Cable pulls (uses existing power and field sensors)



Southern Nuclear Strategy (continued)

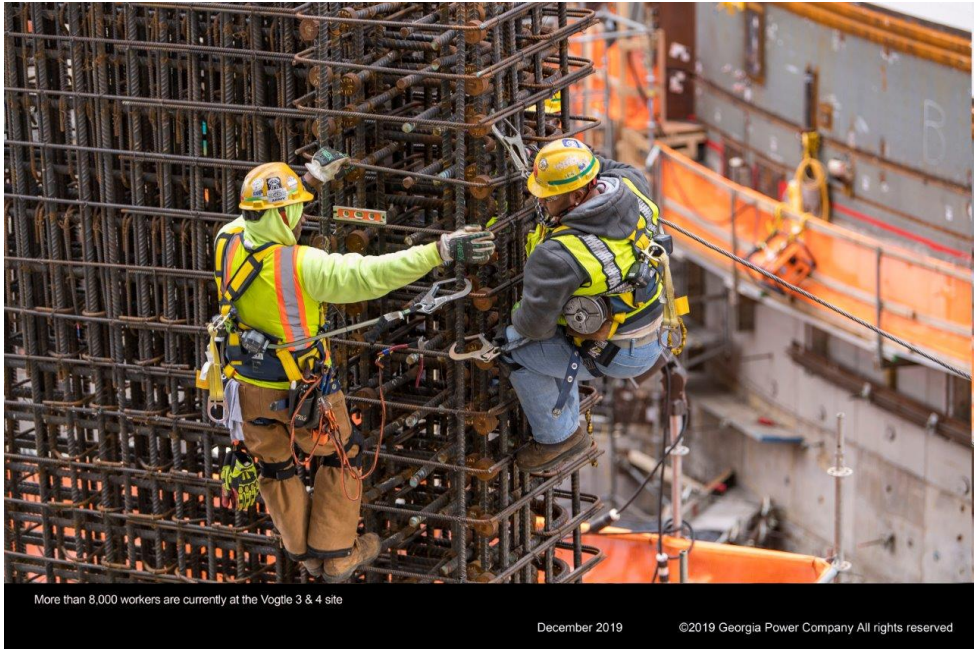
- Consider Accident Tolerant Fuel
- Supported by 10 CFR 50.69 Analysis
- Elimination of existing SPVs
- Support for Flexible Operations (load following)
- Installed in normal Outage window
- Limited or no DAS needed
- Cyber Security considerations
- ISG-06 Alternate Review Process
- Use of Common Design Elements
- Use of DEG/NISP


The two-million-pound shield building roof for Vogtle Unit 3 is lifted into place

December 2019

Conclusion

- Get started early, before design starts
- Needs Analysis is required for Requirements Analysis
- Think Long Term (80+)
- Huge Risk to skipping
- Multidiscipline team




Southern Nuclear

Nuclear Transformation

John Connelly, Engineering Manager

January 2020

Exelon Generation®

An Industry-wide Problem:

- Original construction systems are reaching the end of their practical service life and performance issues are becoming more common
- Modernization of safety systems has stalled over time, resulting in obsolete technology and equipment that is costly to maintain
- The industry is facing economic challenges and must find innovative ways to reduce labor and material costs while increasing safety and reliability

An Industry-wide Solution:

- Public/Private partnership to research safety-related component modernization approaches and costs

Foundational Research

- No single entity has the capability or resources to develop a comprehensive modernization strategy

- This research was structured as a public / private partnership with the following organizations:
  - Exelon Generation
  - Idaho National Labs
  - Department Of Energy
  - MPR
  - Scott Madden and Associates

The DOE recognizes the financial challenges the industry is facing and has partnered with Exelon Generation through the Light Water Reactor Sustainability Project (LWRS) to fund the research necessary to develop an actionable modernization roadmap for the industry

Objectives and Deliverables

- Apply the EPRI Cost Benefit Analysis (CBA) tool to systematically deconstruct and analyze each candidate system to quantify labor and materials cost savings opportunities

- Using the insights gained from the CBA, develop technical attributes necessary to garner savings opportunities in the form of a Technical Requirements Specification (TRS)

- This research was structured after two key industry initiatives:
  - The NRC Integrated Action Plan (IAP)
  - *Delivering The Nuclear Promise* (DNP) standardized digital engineering process (NISP-EN-04)

This strategy will help make these concepts replicable across the industry

Candidate Systems

- Five first-echelon safety-related systems were systematically analyzed:
  - Reactor Protection System (RPS)
  - Redundant Reactivity Control System (RRCS)
  - Nuclear Steam Supply Shutoff System (NSSSS)
  - Emergency Core Cooling System (ECCS)
  - Nuclear Instrumentation System

Savings Opportunities

- Savings opportunities were divided into two categories:
  - Labor savings achieved through automation or elimination of manual activities
  - Component count reduction by displacing hardware with software – hardware that does not exist requires no periodic maintenance or fixed interval replacement and does not fail

- No value was assigned to “soft” savings opportunities despite the tangible value these attributes provide. These include:
  - SCRAM avoidance
  - Improved situational awareness
  - Performance monitoring / analytics

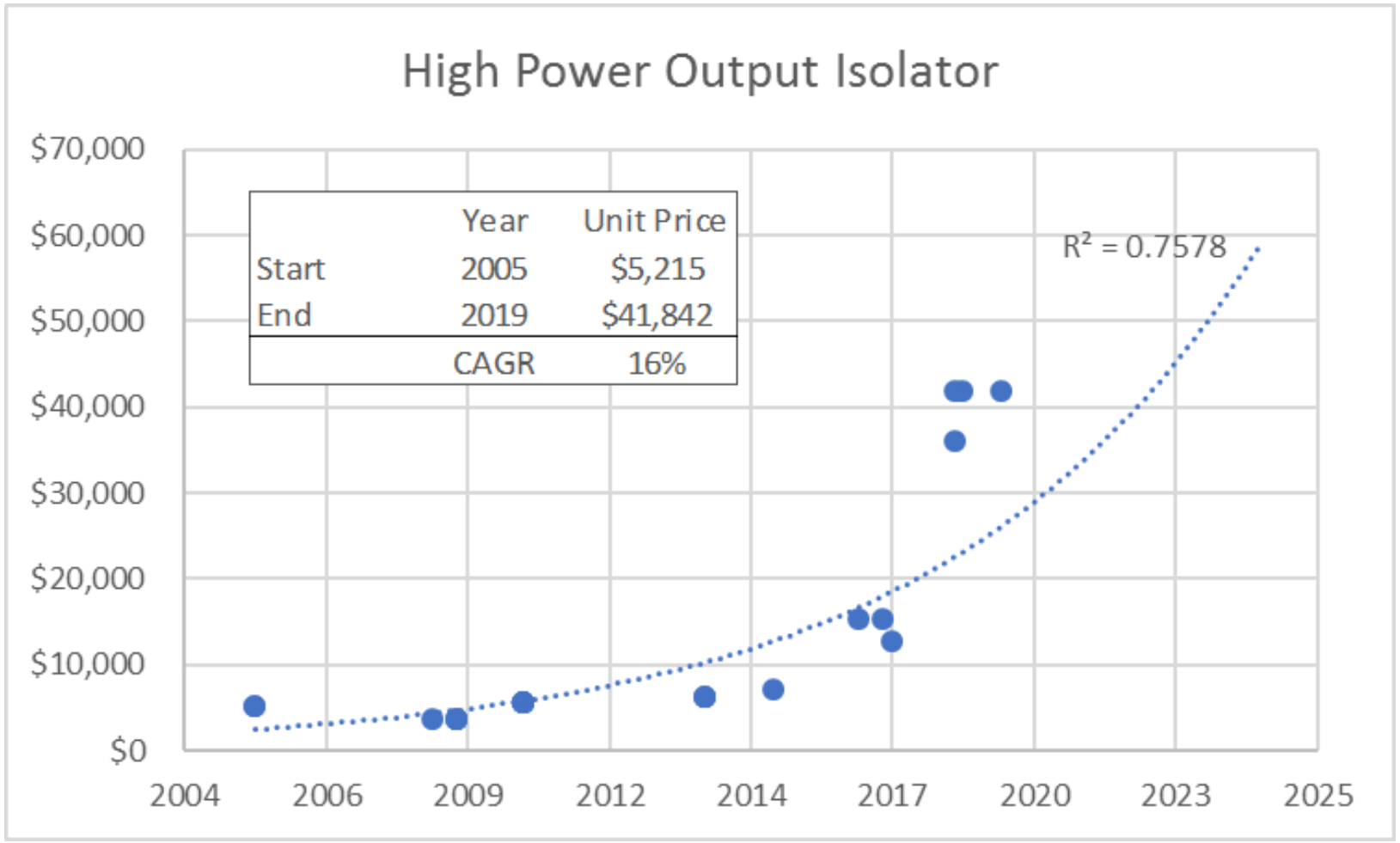
This work will serve as an enabler for broader modernization strategies beyond the systems themselves – the whole is greater than the sum of the parts

Observations - Preliminary

- Labor savings are much larger than anticipated
- Cost of maintaining the systems in their current form is much greater than expected due primarily to obsolescence management costs
- Significant performance improvement opportunities exist in many forms

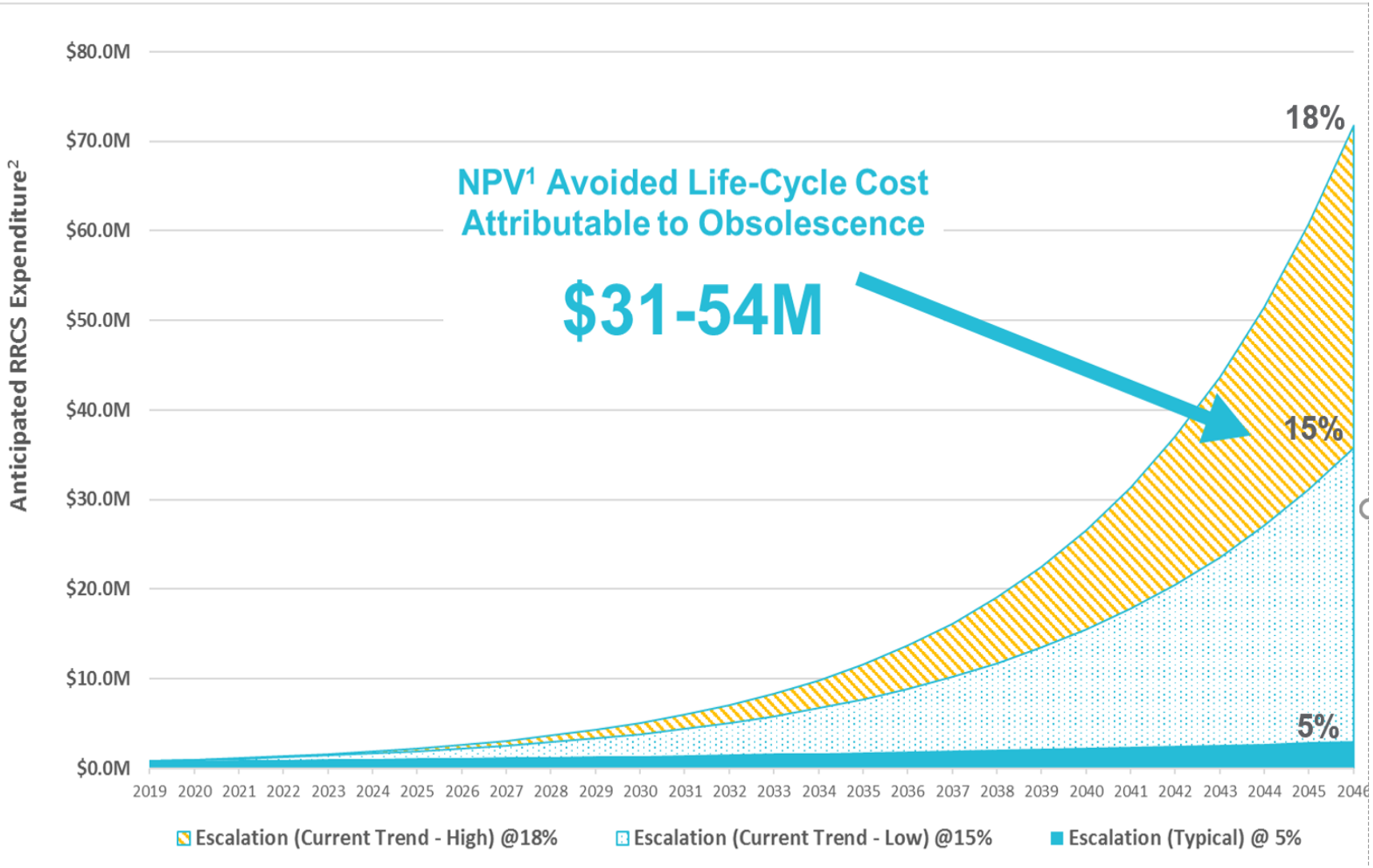
While this is not a risk-free undertaking, this research has demonstrated a significantly positive Net Present Value (NPV) for modernization

Obsolescence Cost - Representative Example



Exelon Generation

Cost to maintain the status quo? More than you think



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Questions?

10 CFR 50.59 Applied to Digital Plant Changes

Neil Archambo, P.E. – Principal Engineer, Fleet Digital Engineering

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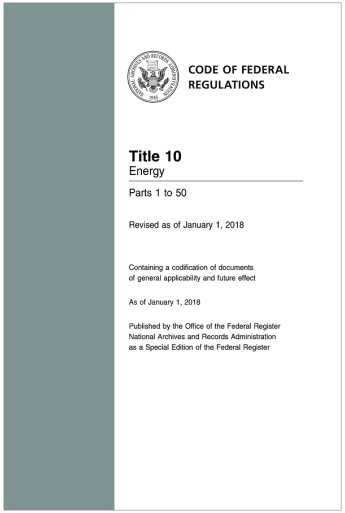
Discussion Topics

- Overview of the 10 CFR 50.59 rule
- Existing 10 CFR 50.59 review guidance for digital
- Why the hysteria surrounding digital plant changes and 10 CFR 50.59 reviews
- Problems with existing industry guidance
- New short-term guidance for addressing CCF in digital equipment
- New 10 CFR 50.59 guidance for digital plant changes
- New long-term technical guidance for addressing CCF in digital equipment
- Other new digital I&C industry guidance being developed
- Summary
- Conclusions

Overview of the 10 CFR 50.59 Rule

Why do we do them?

- The NRC issues operating licenses based on information describing plant design, construction, analysis and operation
- Changes are necessary for continued plant operation
- 10 CFR 50.59 is the process that ensures plant changes either remain within the licensed bases the NRC understands or involves the NRC when the rule criteria are met
- 10 CFR 50.59 is a licensing test



Overview of the 10 CFR 50.59 Rule

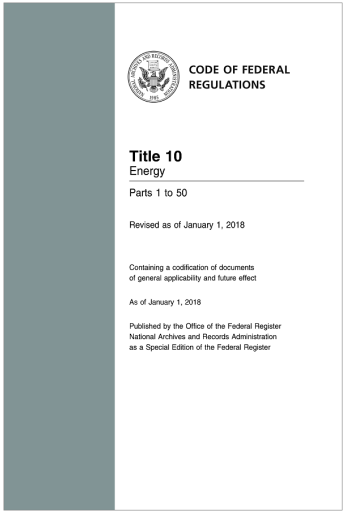
Without prior NRC approval, a licensee may:

- Make changes to the facility or procedures that are described in the UFSAR
- Conduct a test or experiment not described in the UFSAR

So long as:

- A change to the Technical Specification is not required
- The change, test, or experiment does not meet any of the 10 CFR 50.59 (c)(2) criteria

Note that 10 CFR 50.59 does not apply to changes to the facility or procedures when applicable regulations establish more specific criteria for accomplishing such changes

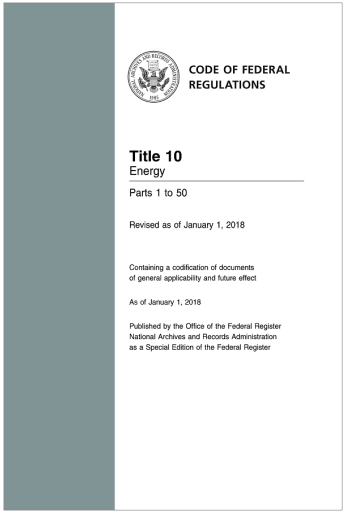


A Two-Step Process

I. 10 CFR 50.59 Screen – Four Questions

1. Adverse to a design function?
2. Change to a procedure that adversely affects how UFSAR-described design functions are performed or controlled?
3. Involve an evaluation methodology described in the UFSAR?
4. Involve a test or experiment not described in the UFSAR?

A “Yes” answer to any of these four questions requires evaluation of the activity against the eight criteria in 10 CFR 50.59 (c)(2)

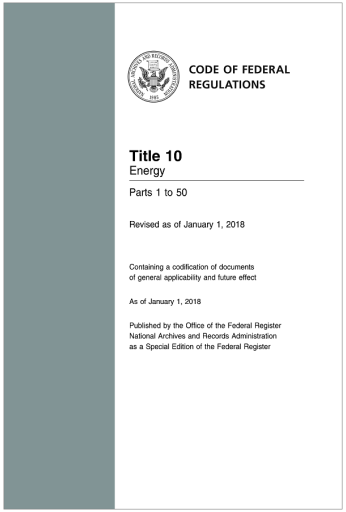


A Two-Step Process

II. 10 CFR 50.59 (c)(2) – Eight Evaluation Criteria Addressing:

i. Accident frequency
ii. Malfunction likelihood
iii. Accident consequences (dose)
iv. Malfunction consequences (dose)
v. Accidents of a different type
vi. Malfunctions with a different result
vii. Fission product barriers
viii. Departure from a method of evaluation

A “Yes” answer to any of the eight criteria requires prior NRC review and approval before implementing the proposed change

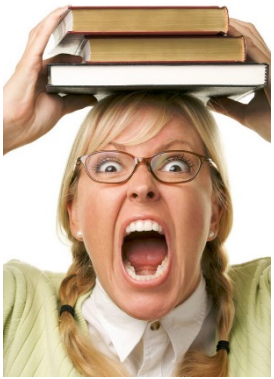


Existing 10 CFR 50.59 Review Guidance for Digital

- NEI 96-07, Revision 1 – Guidelines for 10 CFR 50.59 Implementation (NRC endorsed via RG 1.187)
- NEI 01-01 – Guideline on Licensing Digital Upgrades, TR-102348, Revision 1 (NRC endorsed via RIS 2002-22)

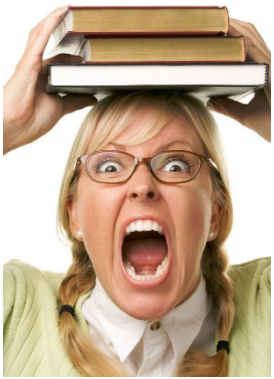
Why the hysteria surrounding digital changes and 10 CFR 50.59

- In 2009, NRC inspectors identified a concern regarding the replacement of a non-safety-related analog-based rod control management system with a computer based system – an unresolved item (URI) was initiated due to 10 CFR 50.59 concerns
- In 2013, NRC inspectors identified a concern regarding an analog-to-digital circuit card replacement in the safety-related solid state protection system (SSPS) resulting in a 10 CFR 50.59 violation
- In 2013, NRC inspectors identified a concern with a non-safety-related analog-to-digital fuel transfer control system system modification – a URI was initiated due to 10 CFR 50.59 concerns
- NRC inspectors began focusing more on digital plant changes during subsequent inspections



Why the hysteria surrounding digital changes and 10 CFR 50.59

- Each of these inspection findings involved software quality and the potential for software CCF
- Each of these inspection findings involved 10 CFR 50.59 and application of the guidance in NEI 01-01
- NRC concluded that the guidance in NEI 01-01 was not being interpreted in a way that leads to appropriate application of 10 CFR 50.59
- Also, it became readily apparent that even non-safety-related digital changes could require a license amendment to implement
- Inspection findings, insufficient guidance, and the associated regulatory uncertainty prompted many licensees to avoid digital modifications altogether



What is the problem with existing guidance?

- NEI 96-07 Revision 1 provides generic guidance for 10 CFR 50.59 reviews but is not detailed enough for most digital applications
- Further, the terminology used in NEI 01-01 does not always coincide with the terminology used in NEI 96-07
- NEI 01-01 states that a licensee can qualitatively assess software CCF, but does not provide guidance on how to develop a qualitative assessment
- The current regulatory position offers only two alternatives for eliminating consideration of software CCF – 100% testing of equipment or use of sufficient diversity
- And incidentally, the NRC considers 100% testing of software unachievable, even in applications that make use of very simple code

What is the problem with existing guidance?

- Thus, with the current regulatory position, the only way to eliminate further consideration of software CCF is to employ sufficient diversity
- In the absence of sufficient diversity, you must assume the CCF occurs
- Assuming a CCF occurs can make it very difficult to get through the eight evaluation criteria in 10 CFR 50.59 (c)(2) without a “Yes” answer
- No other guidance existed on how to address CCF in the 10 CFR 50.59 review process
- Industry concluded that the guidance in NEI 96-07 and NEI 01-01 was insufficient for use on most digital plant changes
- In late 2013, NEI assembled an industry group to address these issues

New Guidance – RIS 2002-22 Supplement 1

- RIS 2002-22 Supplement 1 provides a method, defined by and thus acceptable to the NRC, to develop and document an adequate qualitative assessment to determine digital equipment failure likelihood
- If the qualitative assessment concludes that an SSC has a sufficiently low likelihood of failure, then by extension the SSC has a sufficiently low likelihood of experiencing a CCF, including a software CCF
- Primarily developed for low safety-significant safety-related digital SSCs
- Can be used to support conclusions in a 10 CFR 50.59 Evaluation
- Cannot be used to support arguments in a 10 CFR 50.59 Screen
- Sixteen industry workshops were conducted on RIS 2002-22 Supplement 1 in 2018 and 2019

New Guidance – NEI 96-07 Appendix D

- Appendix D provides digital-specific 10 CFR 50.59 Screen guidance for:
  - Question 1 – Adverse to UFSAR-described design function?
  - Question 2 – Adverse to how a design function is controlled or operated?
- Screen Questions 3 and 4 are not digital-specific – guidance in NEI 96-07 is adequate
- Appendix D provides criteria for use in screening-out certain digital plant changes – digital activities do not default to an adverse condition
- Appendix D also provides substantial guidance on assessing human factors within the screening process

New Guidance – NEI 96-07 Appendix D

- Appendix D addresses the following 10 CFR 50.59 Evaluation criteria:
  - Criterion 1 – Accident frequency
  - Criterion 2 – Malfunction likelihood
  - Criterion 5 – Accidents of a different type
  - Criterion 6 – Malfunction with a different result
- Evaluation Criteria 3, 4, 7 and 8 are not digital-specific – the guidance in NEI 96-07 is adequate
- Criteria 1 and 2 are linked primarily with reliability
- Criteria 5 and 6 are linked primarily with CCF as a CCF is more likely to create the possibility for an accident of a different type or a malfunction with a different result

New Guidance – NEI 20-XX, Addressing CCF in DI&C Systems

- NEI 20-XX will provide a long-term solution for addressing CCF in DI&C systems
- Will apply to SSCs of all safety significance
- Can be used when in the 10 CFR 50.59 review process or to support development of License Amendment Requests
- Will align with guidance in the EPRI Digital Engineering Guide
- When NEI 96-07 Appendix D and NEI 20-XX are endorsed, NEI 01-01 will be retired
- When NEI 01-01 is retired, RIS 2002-22 Supplement 1 will be retired
- Endorsement of NEI 20-XX likely in late 2020

Other New Industry Guidance Related to DI&C

- ISG-06, Revision 2, NRC Review Guidance for Digital LARs – Issued December 2018
- NEI 06-02, Revision 6, Industry Guidance on the Digital LAR Process – Issued August 2019
- NEI 17-06, Use of Safety Integrity Level (SIL) Certification in CGD Process – Projected NRC Endorsement in 2020
- BTP 7-19, Revision 8 – Projected NRC Approval in 2020

Summary

- Inadequate guidance led to inadequate development of 10 CFR 50.59 reviews for digital plant changes
- NRC inspectors found inconsistencies with development of 10 CFR 50.59 reviews when inspecting digital plant changes
- This led to regulatory uncertainty causing many licensees to abandon digital plant changes altogether
- NEI established an industry group to develop new industry guidance specific for digital plant changes
- Some of the new guidance has been rolled out to industry and is currently in use
- Other guidance documents are in various stages of development and are expected to be issued in 2020

Conclusion

- It is now safe to jump back into the digital-upgrade pool
- Using the new guidance, industry has successfully implemented a number of safety-related digital plant changes under 10 CFR 50.59
- NEI, industry representatives, and NRC staff continue to work together on development of guidance to address CCF when implementing digital plant changes
- New guidance being developed will align with the EPRI Digital Engineering Guide and thus the new Standard Digital Design Process (NISP-EN-04)
- Appendix D industry workshops on development of 10 CFR 50.59 reviews for digital plant changes are being considered for rollout in 2020

Thank You!
Any Questions?

10 CFR 50.59 Applied to Digital Plant Changes

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BUILDING A **SMARTER** ENERGY FUTURE™

Making the Modification

Best Practices for Digital Upgrades

Daniel Peacock, P.E.
Senior Project Engineer

Matthew Burian, P.E.
Senior Engineer

Agenda

Sargent & Lundy

Introduction

Industry Trends

Digital Project Lifecycle

Licensing Digital Modifications

About Us

Daniel Peacock, P.E.

- Husband and pet dad
- BS Electrical Engineering, Northwestern University
- 11 years in nuclear I&C
- ISA SP67 Vice-Chair
  - WG 67.04 Chair
- Digital upgrades, setpoint analysis, PWR system engineering & license bases
- I&C Lead, NuScale SMR Standard Plant Design

About Us

Matt Burian, P.E.

- Avid golfer
- BS & MS Chemical Engineering, University of Iowa
- 5 years in nuclear I&C
- Digital upgrades support & uncertainty analysis
- I&C Senior Engineer, DC Cook Digital Projects Team

Industry Needs and Trends

Infrastructure to Support Digital Mods

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- Personnel
  - Engineering
  - Maintenance
  - Operations & Training – Not just “impacted stakeholders”
  - Other support organizations
- Staging area – not just for staging
  - Venue for SAT, planning, receipt inspection, changes, and PMT development
  - Controlled environment
  - Access-controlled

Digital Lifecycles

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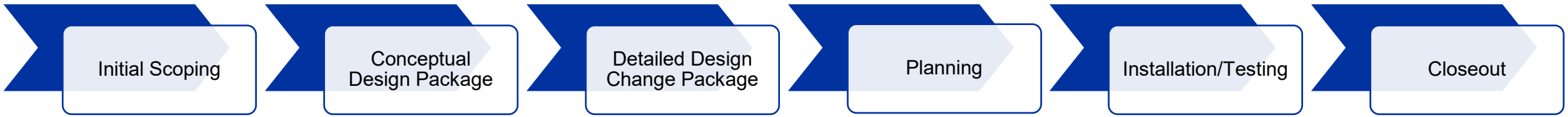
- Rule of thumb: **Seven Years**
- Hardware revisions
- Commercial-type equipment
  - Servers
  - Workstations
  - Operating systems
- HMIs
- *Plan* for your mod's eventual replacement
  - Manage obsolescence up-front

Digital Discovery

- Digital system advantages:
  - Response time
  - Data resolution
  - Signal precision
  - Time history
- Digital upgrades often unmask legacy issues

The Digital Project Lifecycle

Design Phases



Scoping and Concept

- Relate target system functions to plant/process functions
- Investigate and understand license basis during scoping and concept development
  - What functions *can* be automated
  - What functions *should* be automated
  - These decisions inform the level of rigor demanded in 50.59 products
- Manage up front to make future changes easier
  - Obsolescence
  - Upgrades, expansion, etc.

Digital Modification Stakeholders

- Design Engineering
  - Responsible for maintaining the design basis
- Plant/System Engineering
  - Your future Subject Matter Experts
- Maintenance
  - End users responsible for upkeep and troubleshooting
- Operations
  - Key stakeholder for HMI design

Software Design

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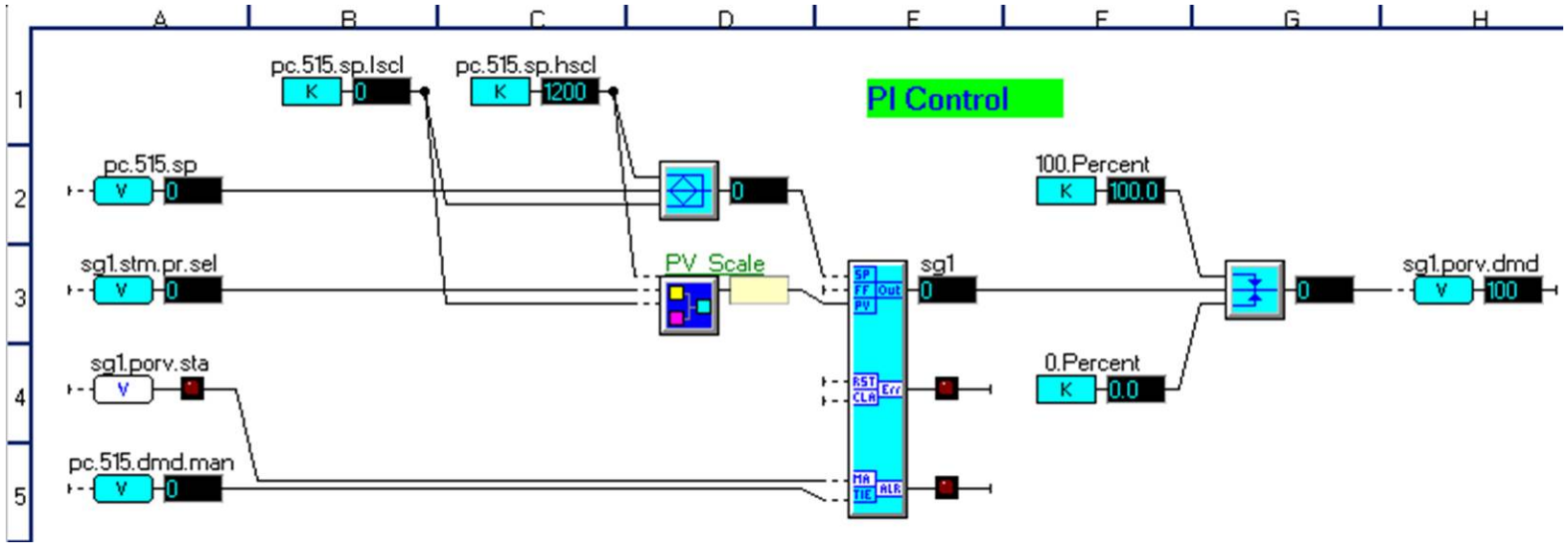
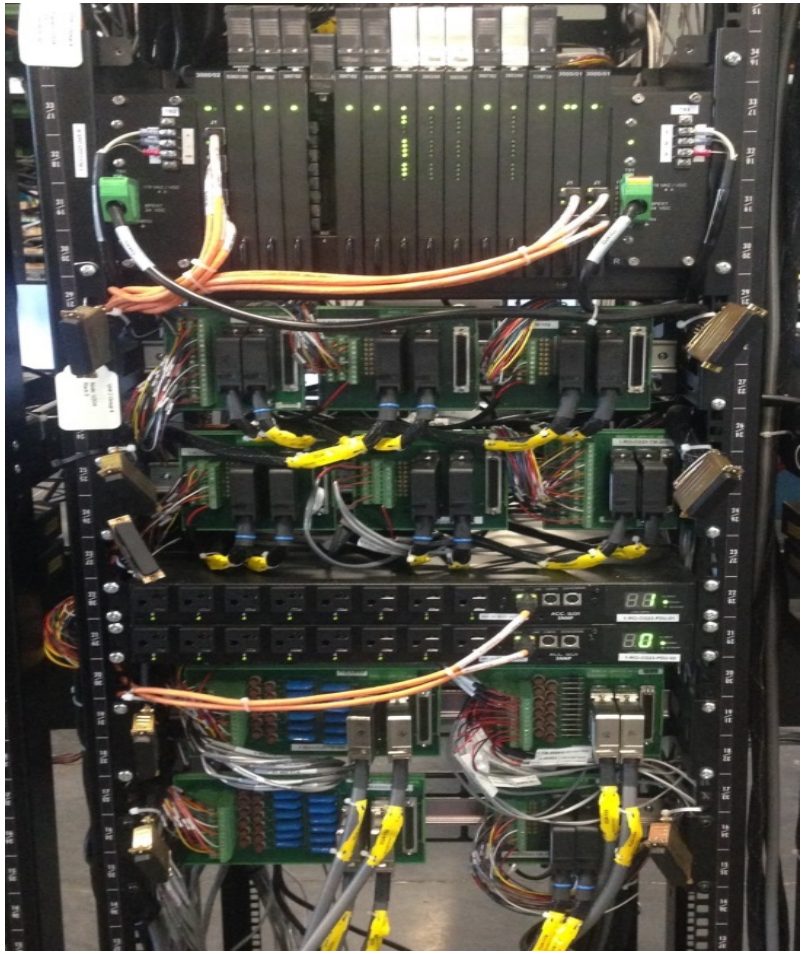
- Developed based on software requirements document
- Maintain similar control characteristics as existing system
- Train Project REs/SMEs in control and HMI software platforms



Pre-Installation Testing

- Demonstrate design requirements are met
- Factory Acceptance Testing
  - Software
  - Hardware
  - Cyber Security
  - Familiarization
- Site Acceptance Testing within dedicated digital staging area



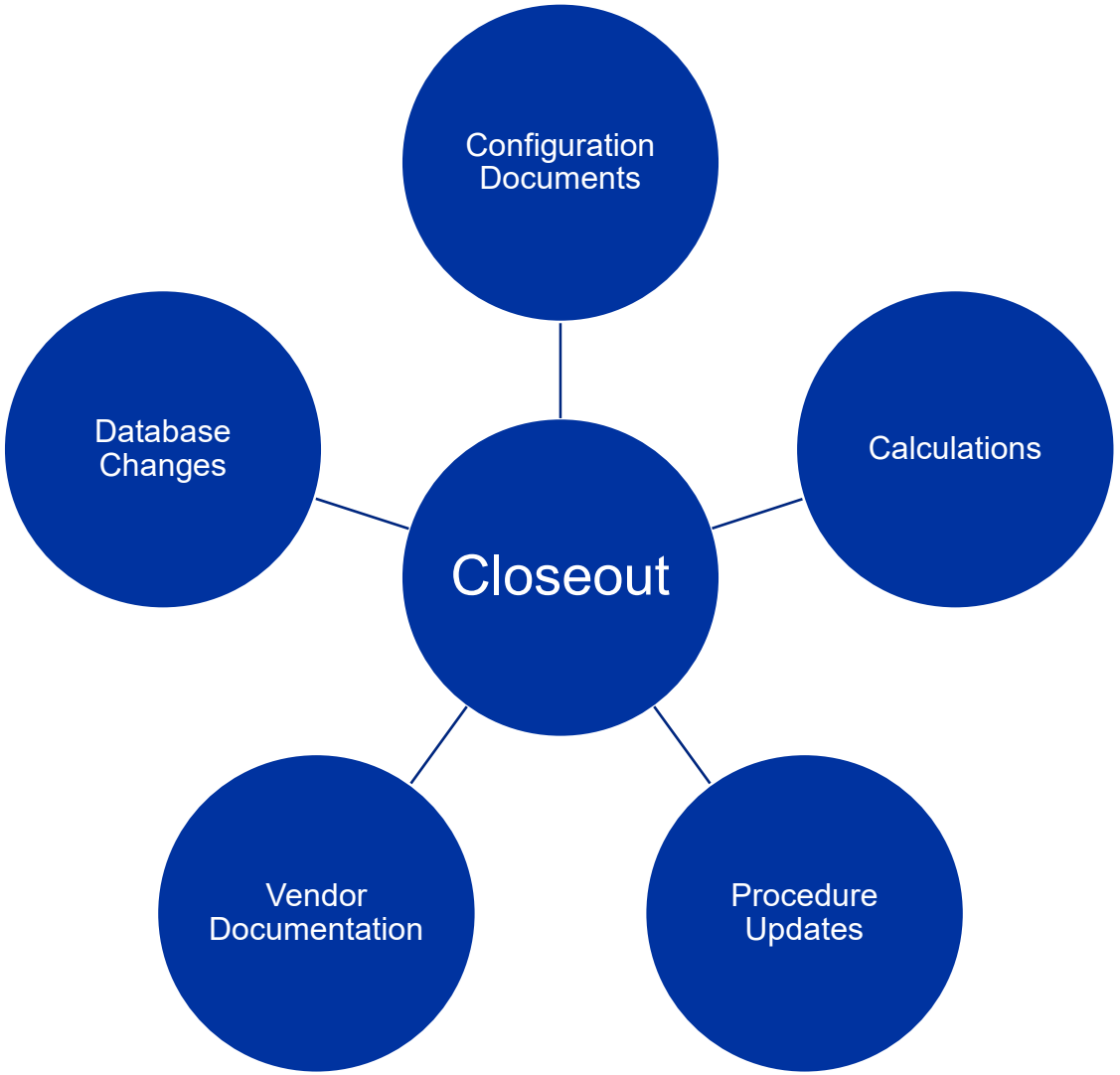
Implementation

- Practice, practice, practice
- Project specific training
- Post-modification implementation support
  - Procurement
  - Materials
  - Planning
- Dedicated “war room” for tracking, prioritizing, and resolving issues
- Keep digital experts involved
  - Project RE/SME
  - Interfacing System Owners

Post-Installation Testing

- System integration with existing plant equipment
  - Start learning new information about the plant
  - Legacy issues
  - Latent plant conditions
- Verify hardware is installed as designed
- I/O calibrations
- Diagnostic checks
- As-left configurations

Closeout


Configuration Documents
Database Changes
Calculations
Closeout
Vendor Documentation
Procedure Updates

License Basis and Digital Modifications

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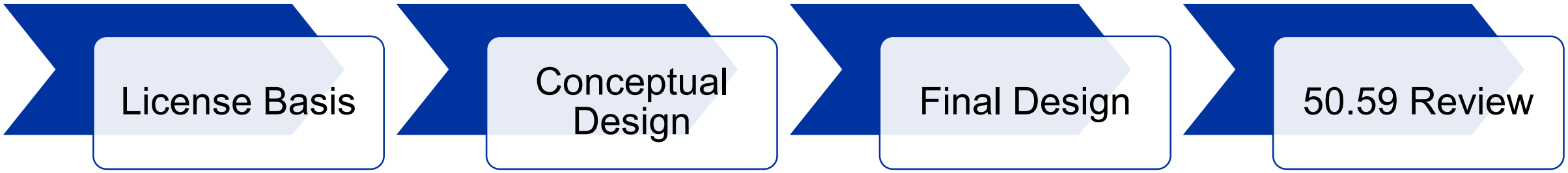
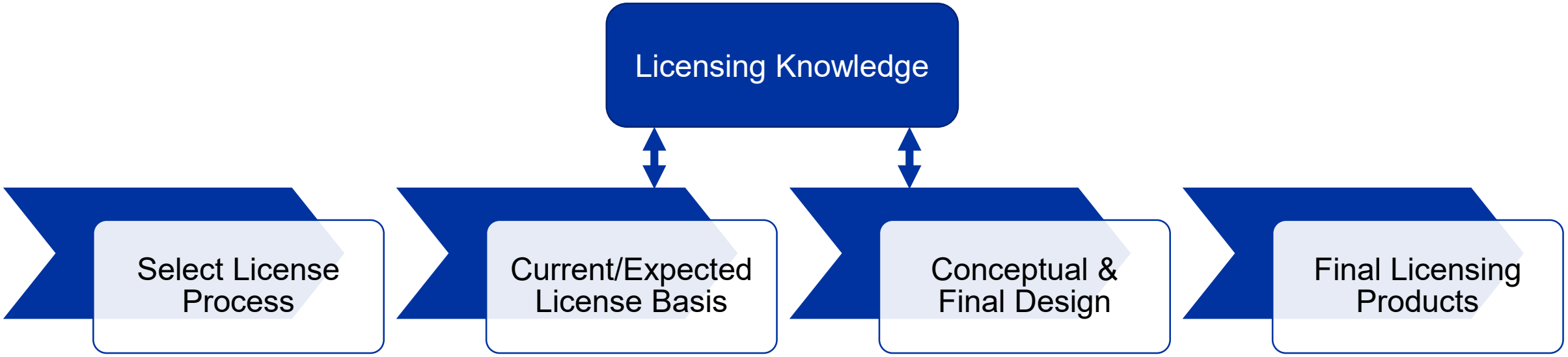
License Basis – Traditional Project

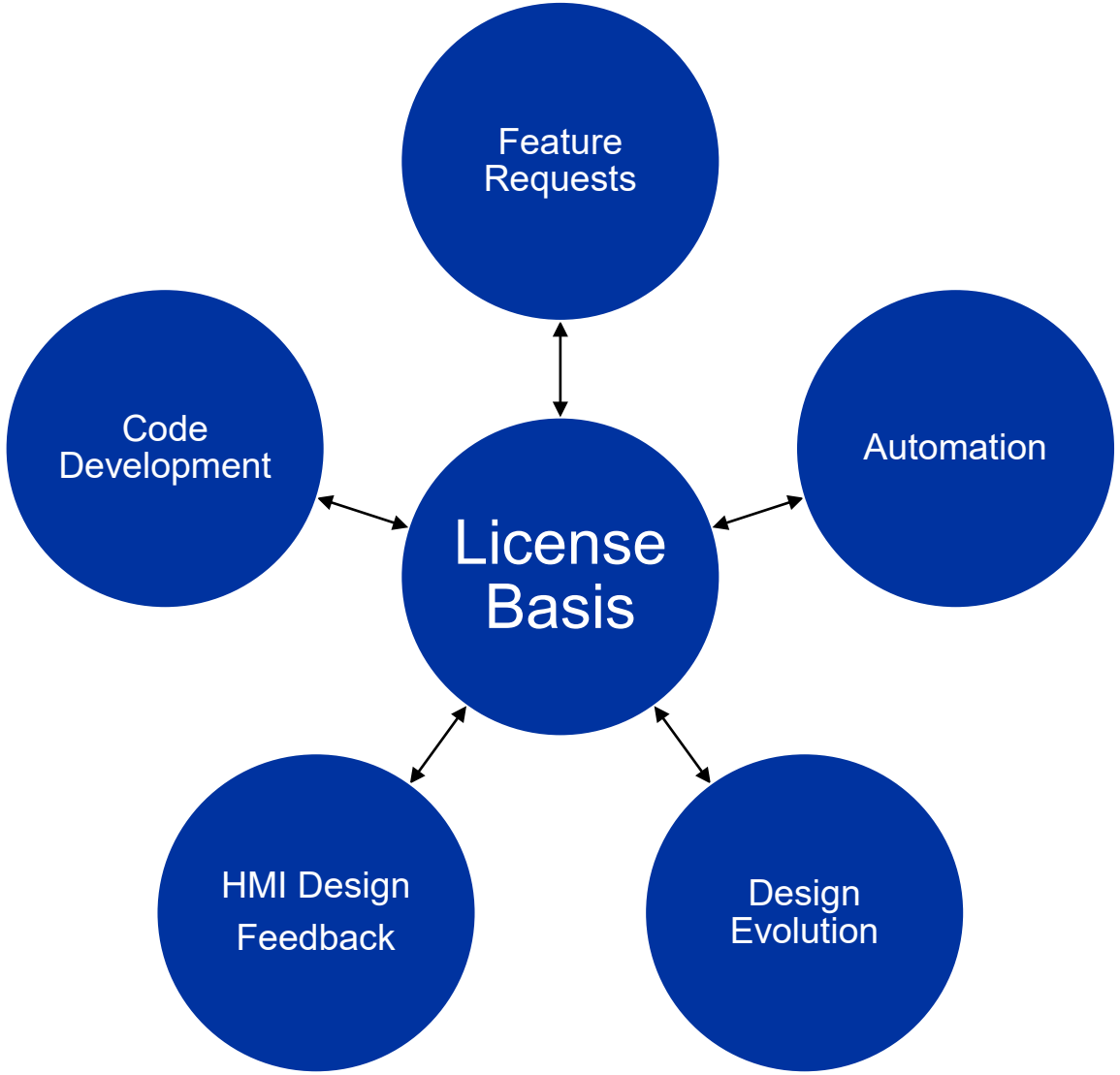


License Basis – Digital Modernization



The End!

License Basis – Digital Modernization



Sargent & Lundy

Thank You

Curtiss-Wright
Digital Safety Systems Seminar
Clearwater Beach, Florida
January 30, 2020

Digital I&C Safety Licensing Alternatives
Barriers & Opportunities

Mark Burzynski

NewClear Day Inc.

Agenda

- Guidance Documents
- DI&C-ISG-6 Review Options
- Pre-Application Meetings
- Review Areas for the LAR Process

NewClear Day Inc.

Guidance Documents

Guidance documents for digital I&C license amendment requests

- NRC DI&C-ISG-06, Revision 2, provides guidance for staff review activities performed for digital I&C LARs to evaluate compliance with NRC regulations
  - Developed by NRC as part of the Digital I&C Modernization Plan #4 with input from NEI's Digital I&C MP#4A Task Group
- NEI 06-02, Revision 6, incorporates guidance for developing LAR content for digital I&C engineering changes utilizing the Alternate Review Process described in DI&C-ISG-06, Revision 2
  - Developed by the Digital I&C MP#4A Task Group as part of the NEI's Digital I&C Working Group efforts to support NRC Digital I&C Action Plan efforts

Guidance documents describe information required to address compliance with regulations and how to construct a successful LAR

NewClear Day Inc.

DI&C-ISG-6 Review Options

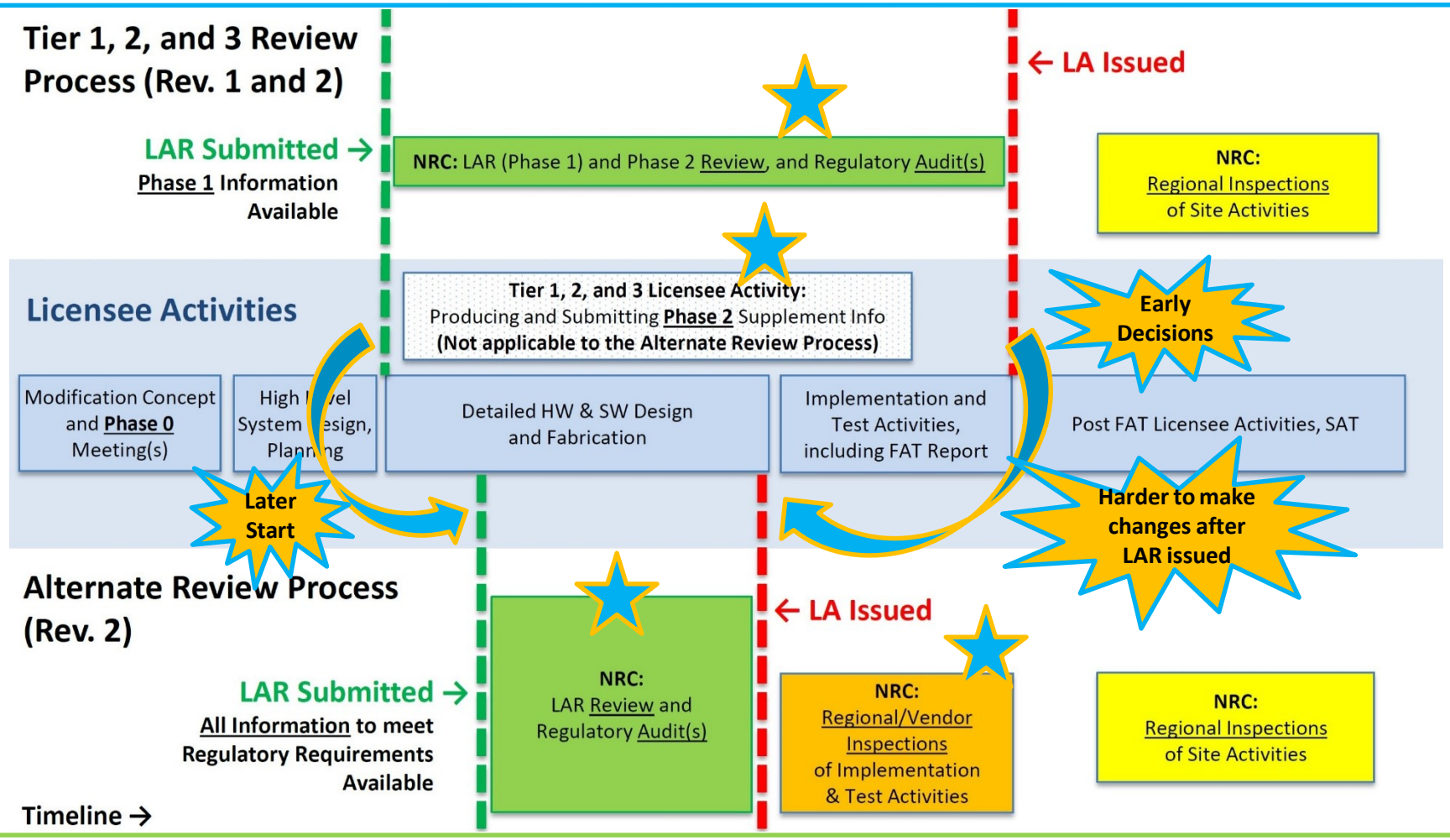
DI&C-ISG-6 provides review options for different scenarios and licensee needs

- Tier 1 – Referencing Topical Report with little or no changes
- Tier 2 – Referencing Topical Report with more changes or deviations
- Tier 3 – No Topical Report to reference
- Alternate Review Process – Can be used in lieu of Tier 1 or 2 but requires Vendor Oversight Plan and Completion Commitments

Options require different submittal information, have different review schedules, and approval decision made at different points that need to be understood by licensees

NewClear Day Inc.

Comparison of Review Options



Key Decision on Review Options

- Key Decision 1 – Review Option Path – Based on availability and age of referenced Topical Report
- Key Decision 2 – Early Decision or Not – Based on scope and certainty of project definition and confidence in post-LAR execution
- Other Factor to Consider: Clear Reasons to Upgrade and Desired Enhancements

The other factors can affect project scope, schedule, risks, and review options

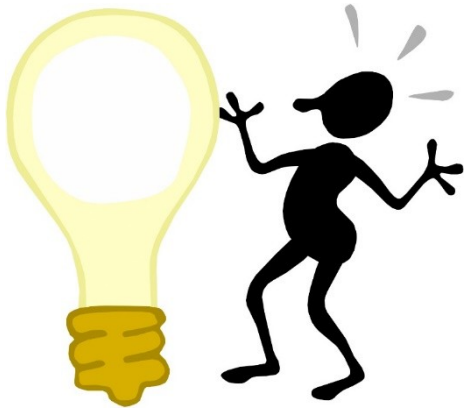
Pre-Application Meetings (1/2)

NRC guidance supports use of Pre-Application (Phase 0) Coordination Meetings to help plan a LAR and align NRC review resources. Key topics to discuss should include:

- Selection of the appropriate review process
- Key design concepts, including the four fundamental design principles
- Significant deviations from current guidance
- Significant deviations from a referenced NRC-approved topical report
- Application of the selected system (platform) to the plant system

Pre-Application Meetings (2/2)

- Definition of plant system(s) to be replaced, changes to FSAR necessary to reflect replacement, and impact of replacement on plant, calibration, and surveillance testing
- Level of licensee involvement in modification project, including oversight of vendor activities
- Establishment of licensee living document schedule
- Other unique or complex topics associated with proposed design



Goal is to communicate plans and objectives for project and achieve alignment on how to address key issues

Review Areas for LAR Process (1/5)

DI&C-ISG-06 defines a format and content structure for a digital I&C LAR, including specific technical topics:

- System Architecture: It is the most important section of a LAR
  - Existing Architecture: Provides context for assessing changes
  - New System Architecture: Reliability, availability, and economic benefits along with defense-in-depth and diversity strategies will likely affect architecture
  - System Interfaces: New interfaces are often added for maintenance interfaces, new diagnostic and alarm features, and data export capabilities.
  - New System Functions: Self-testing and diagnostics features
  - Functional Allocation: Based on architecture changes and new functions

Suggests Integrated System Requirements Documentation

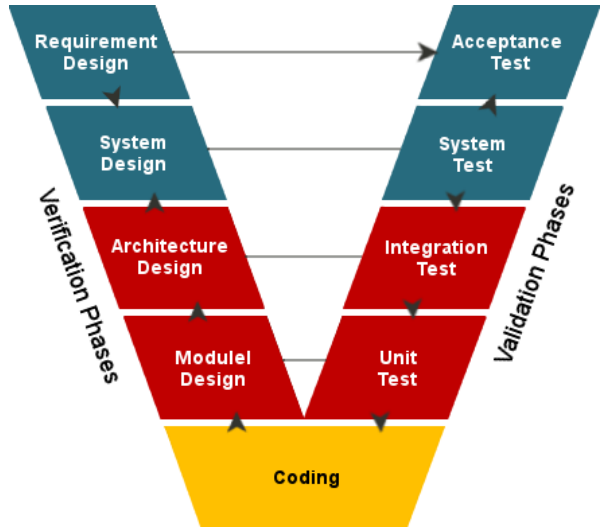
Review Areas for LAR Process (2/5)

- Fundamental Design Principles in the New Architecture
  - Redundancy: Including any new redundancy added for reliability improvements
  - Independence: At all system interfaces in the proper way
  - Deterministic Behavior: Addressing response time requirements
  - Defense-in-Depth and Diversity: To address common cause failure vulnerabilities
  - *Simplicity: As a frame of reference for why and how things were done*

Understanding the why and the how is critical before understanding the requirements imposed to mitigate hazards imposed by the how.

Review Areas for LAR Process (3/5)

- Digital Instrumentation and Control System Development Processes: It is the second most important section of a LAR
  - System and Software Development Activities
  - Project Management Processes
  - Software Quality Assurance Processes
  - Software Verification and Validation Processes
  - Configuration Management Processes



Forms the basis for implementation process regulatory commitments and scope for vendor oversight activities

Review Areas for LAR Process (4/5)

- Compliance/Conformance Matrix for IEEE Standards 603-1991 and 7-4.3.2-2003: It is the third most important section of a LAR
  - Need to address each clause requirement not fully addressed by the referenced platform topical report
  - Need strategy to retention of or interface boundaries with legacy IEEE Std 279 requirements
  - Use NEI 06-02, Revision 6, guidance and examples to organize compliance/conformance discussion

Forms the basis for design implementation regulatory commitments and scope for technical oversight activities

Review Areas for LAR Process (5/5)

- Applying a Referenced Topical Report Safety Evaluation
  - Addressing Platform Changes after Approval of a Topical Report
  - Resolution of Topical Report Plant-Specific Action Items
- Technical Specifications
  - Change resulting from architecture changes, addition of new functions, crediting self-testing to modify surveillance requirements, or setpoint changes
- Secure Development and Operational Environment
  - Address safety systems using RG 1.152, Revision 3
- Hardware Equipment Qualification
  - At a minimum demonstrate generic platform qualification envelopes bound plant-specific requirements

Topical Report issues can affect NRC review category

NewClear Day Inc.

Summary

- Use the NRC and NEI guidance documents to plan and execute your project
- Pick the right NRC review option that fits your needs and wants
- Take full advantage of pre-application meetings to achieve alignment on important issues
- Recognize the importance of system architecture, system design details, and the development process, especially if you use the NRC's alternate review process

The tools are there to make digital I&C modernizations for safety-related systems successful, so use them wisely.

NewClear Day Inc.

Contact Information

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mjburzynski@newcleardayinc.com

Plant Modernization Pathway

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Control Room Modernization

Elevating Operator Performance

Ken Thomas
January 30, 2020

Characteristics of Analog Control Rooms

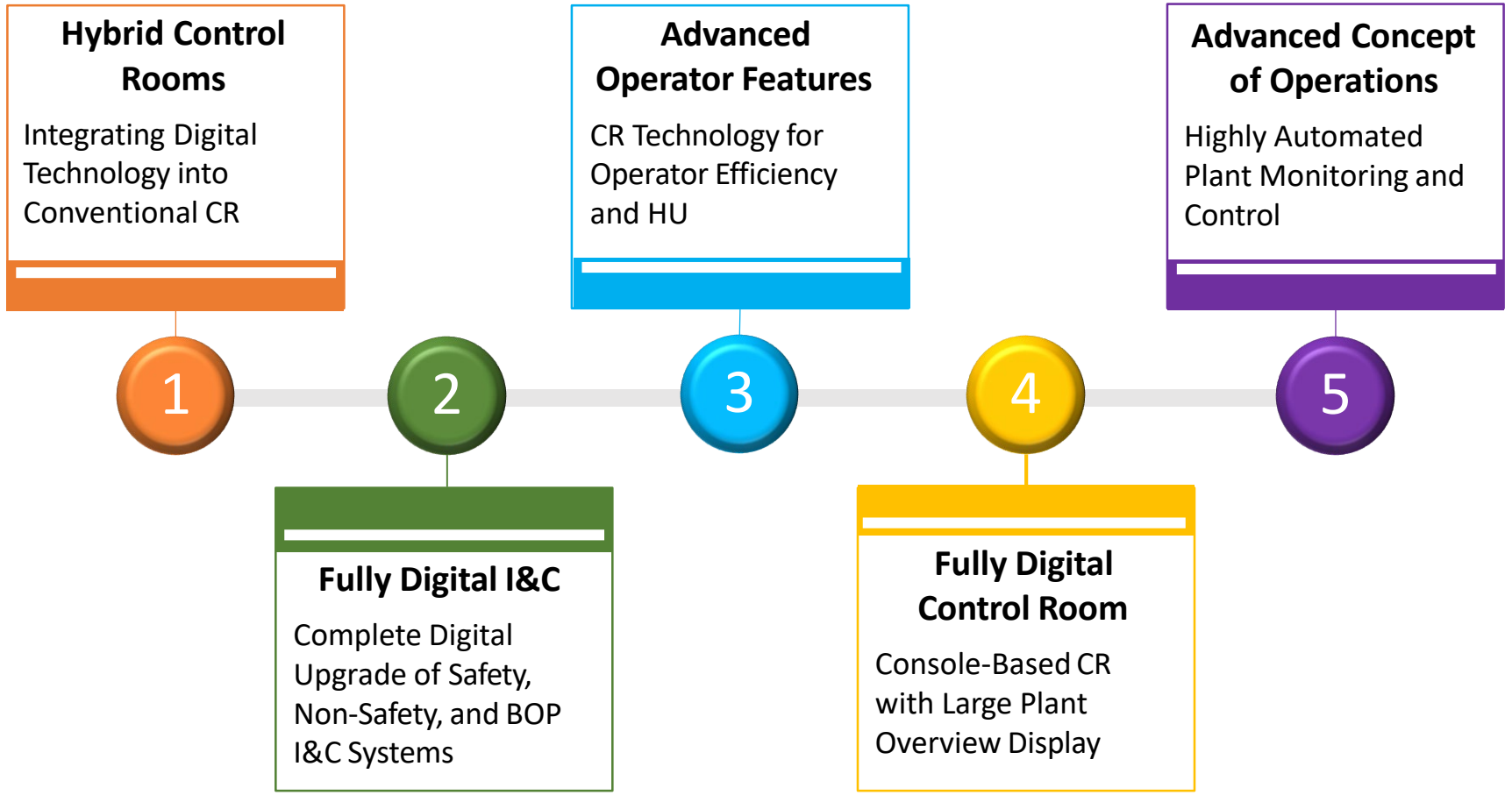
- Expansive
- Static, one-for-one arrangement
- Simple indicators/controls
- Triple-layer design (bench boards and vertical boards)
- Basic alarm system
- Component-level control
- Paper procedures
- Requires multiple operators

Characteristics of Digital Control Rooms

- Compact
- Multi-purpose displays and soft-controls
- Information integrative indicators
- Complex or automated controls
- Console or workstation operation
- Overview displays
- Alarm management
- Consistent operator interface

LWRS LIGHT WATER REACTOR SUSTAINABILITY

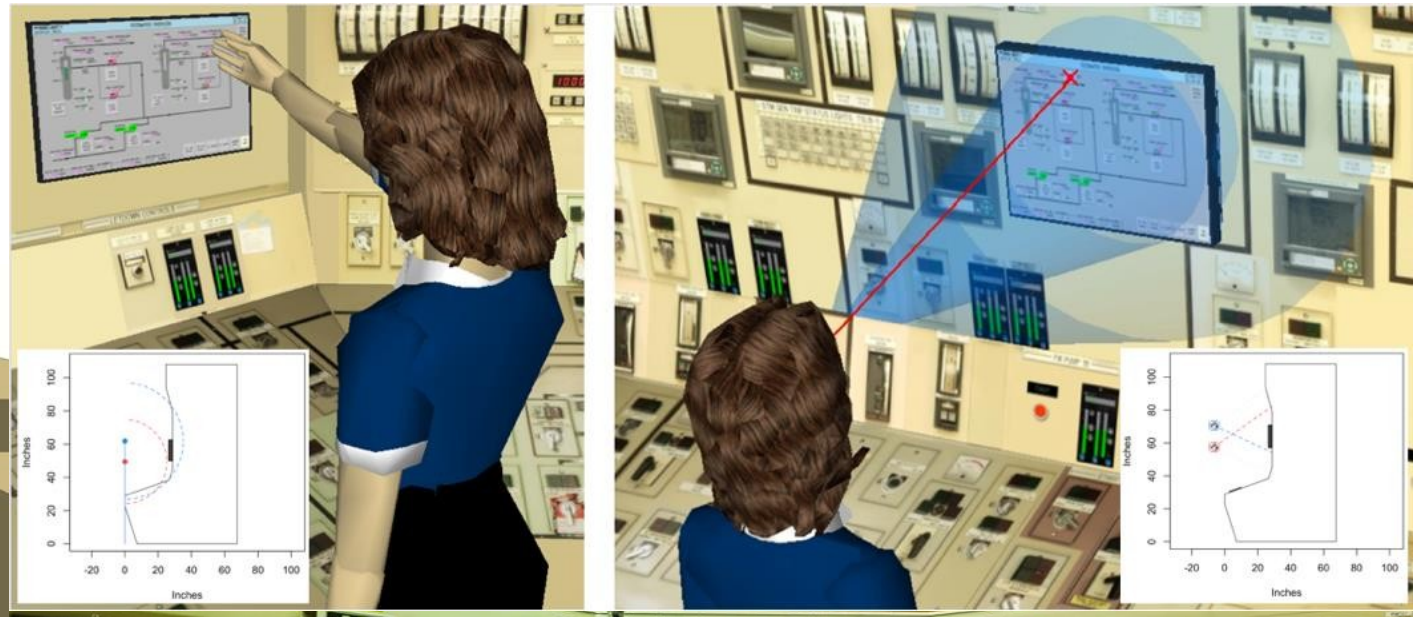
Control Room Transformation



Hybrid Control Room

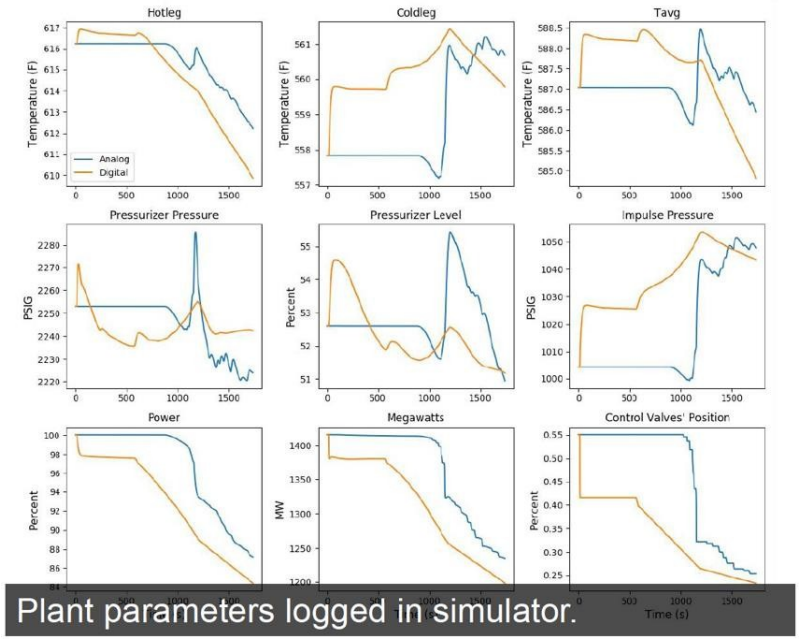
Human Factors Verification

3-D Modeling
HFE Analyses Using NUREG-0700
Operator-in-the-Loop Studies

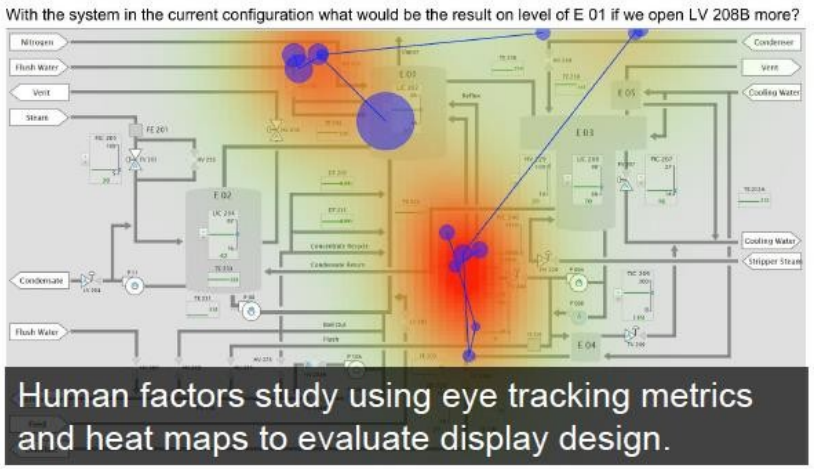


Objective Operator/Plant Performance Measurement

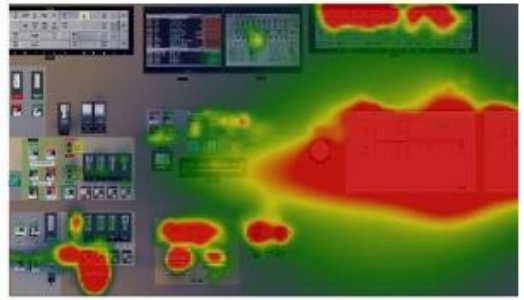
The 3-D visualizations developed illustrate the advantage of maximizing space for intuitive digital interfaces



Plant parameters logged in simulator.



Human factors study using eye tracking metrics and heat maps to evaluate display design.

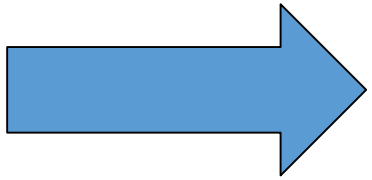


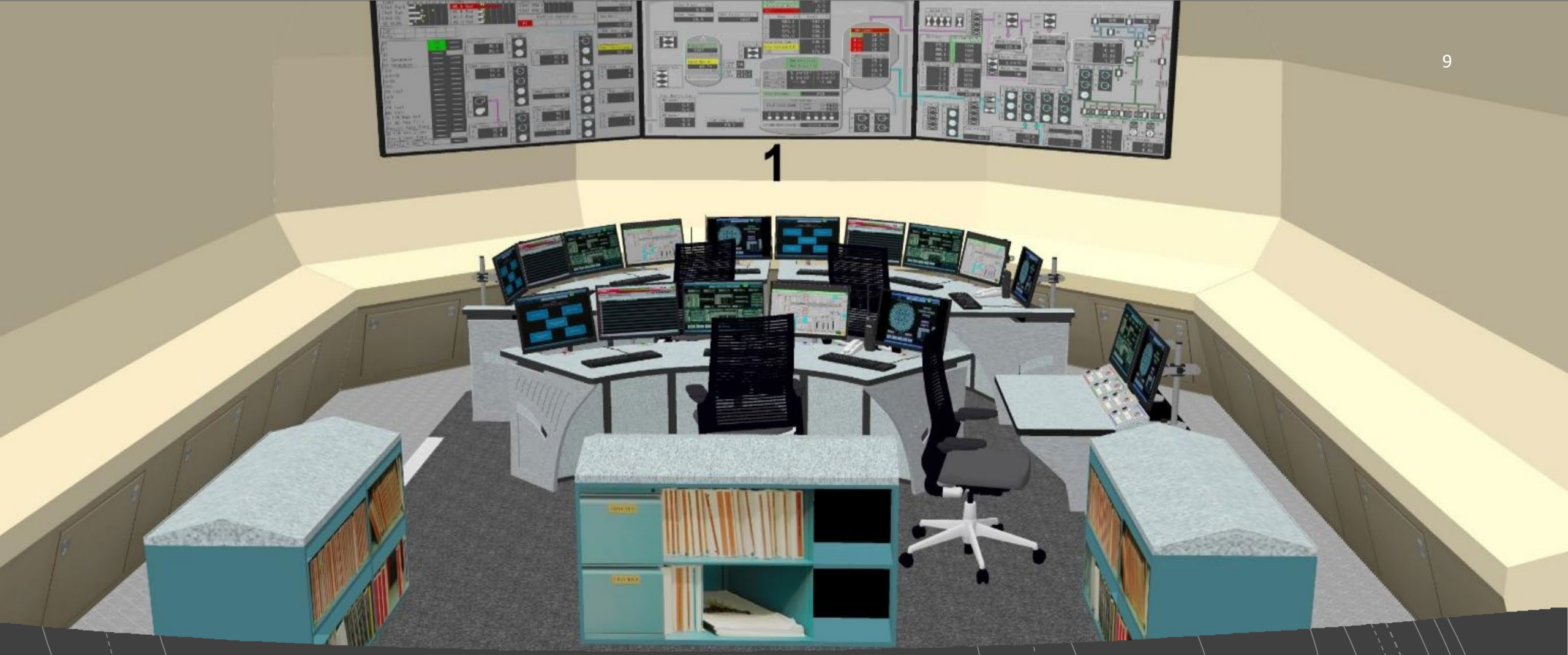
Heat maps used in full-scale simulator study.

The qualitative feedback and quantitative performance data collected provided criteria for managing design tradeoffs and traceable documentation for regulatory purposes.

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Migration to a Fully-Digital Control Room

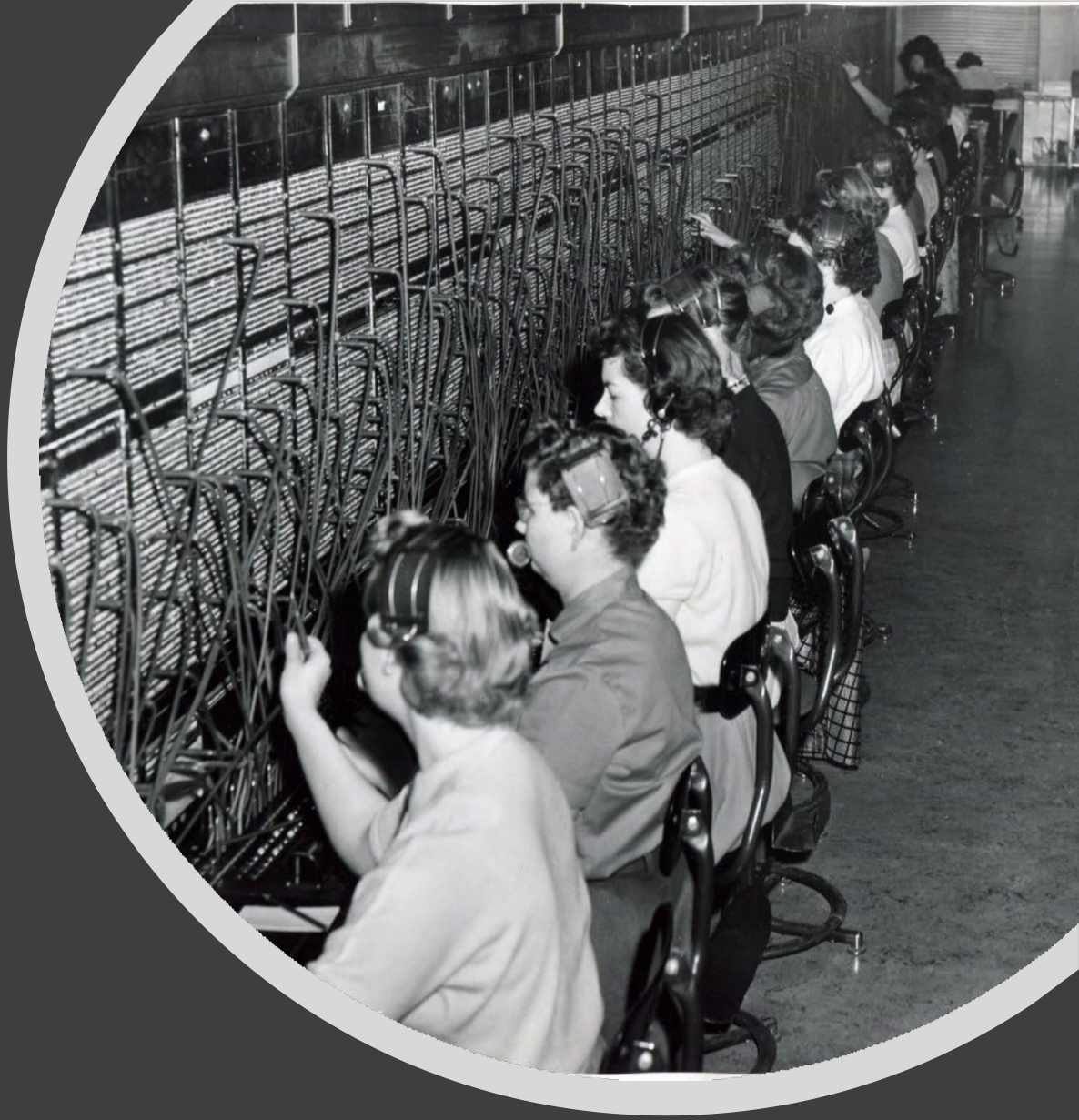




Fully Integrated Control Room

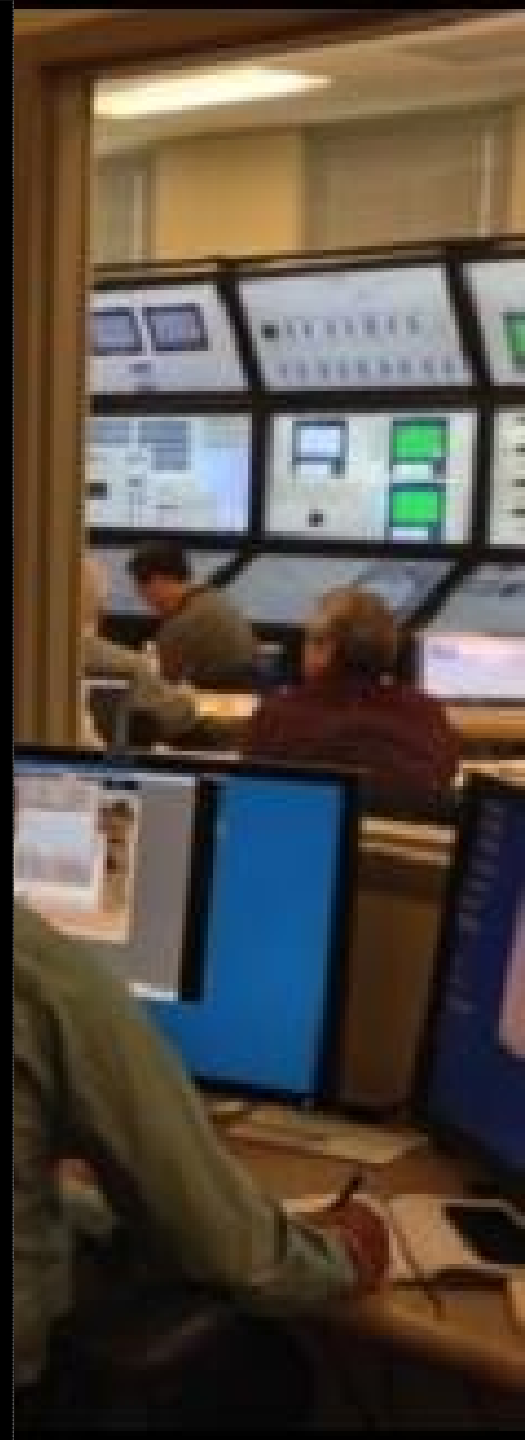
Revisiting Function Allocation

- In the control room design of the operating fleet, function allocation was based on 1960's I&C technology.
- Modernization that preserves this function allocation makes as much sense as having switchboard operators for modern digital communications systems.
- A new function allocation will optimize the roles of operators and technology.



Advanced Operator Features

- Automated Logs
- Task-based displays
- Extensive human error prevention
- Alarm management
- Computer-based procedures
- Computerized operator support systems – comprehensive plant monitoring
- Control automation
- Control system failure detection
- Virtual sensors/adaptive controls
- Digital twin with look-ahead
- Plant work interface



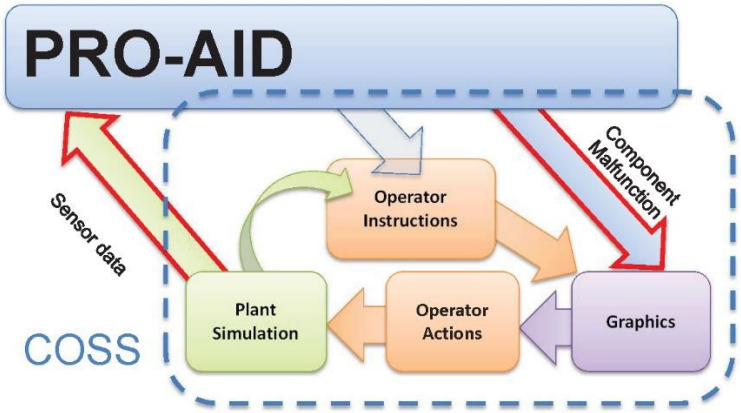
Computerized Operator Support Systems

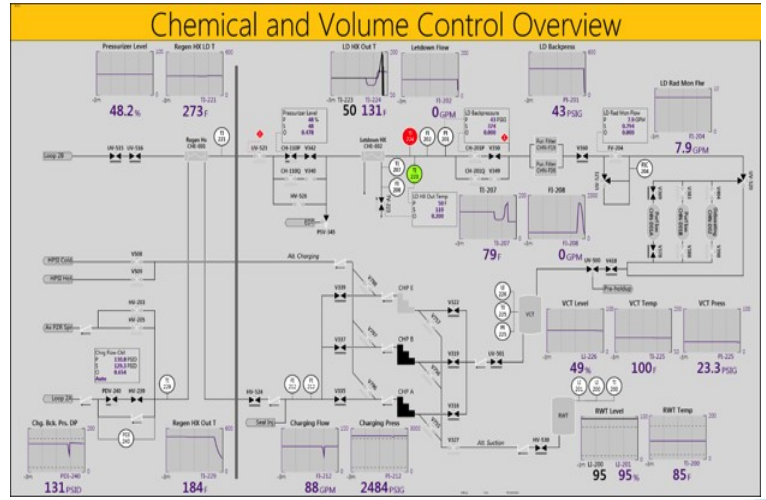
Operator Aid System to Provide Real-Time Event Diagnosis and Mitigation Strategy

$$[dQ_{mass}] = [dw_{in}] - [dw_{out}]$$

$$[dQ_{mom}] = \left[-d\,\Delta P + \frac{2w_0}{(Q_{mom})_0} dw \right]$$

Sensor Trend	Status Indicators	Fault Diagnosis
$[\Delta P] = /-$ and $[dw] = -$	n/a	Sensor Error
$[\Delta P] = -$ and $[dw] = /-$	n/a	Sensor Error
$[dw_{in}] = \downarrow$ and $[dw_{out}] = \uparrow$ and $[P] = \uparrow$	$\Rightarrow d[Q_{mass}] = \uparrow$ and $d[Q_{mass}] = \downarrow$	Leak
$[dw_{in}] = \uparrow$ and $[dw_{out}] = \downarrow$ and $[P] = \downarrow$	$\Rightarrow d[Q_{mass}] = \downarrow$ and $d[Q_{mass}] = \uparrow$	Leak
$[\Delta P] = \uparrow$ and $[dw] = \downarrow$	$\Rightarrow d[Q_{mom}] = \downarrow$ and $d[Q_{mass}] = -$	Blockage
$[\Delta P] = \downarrow$ and $[dw] = \uparrow$	$\Rightarrow d[Q_{mom}] = \uparrow$ and $d[Q_{mass}] = -$	Opposite of Blockage





Plant State Control

- Operator is in a “operations management” role
- Technology performs component control
- Hold points, concurrences, and other authorizations are built into the automation
- Transparent to the operator
- Can revert to manual control at any time

Advanced Concept of Operations

- Control room is simplified and intuitive
- Operators in an operations overview and management role
- Tedious functions are performed by reliable technology
- Technology enables plant state control rather than plant component control
- Information is displayed in graphical formats most suited to human comprehension
- Off-normal conditions are detected at very low levels and brought to the attention of the operator at an appropriate threshold

Remaining Challenges

- Business Cases for Full Digital Modernization
- Demonstration of Predictable Licensing for Digital I&C/CR
- Conversion of I&C Field Logic to Software
- Robust Human Factors Engineering for Digital Control Rooms

Nuclear Plant Economics: Digital Protection System Feasibility

January 30, 2020

Pareez Golub

Senior Manager

Myth: Protection System Economics

Protection System digital upgrades do not provide a good return on investment – only address analog obsolescence issues

Protection System Economics

Sargent & Lundy

"The Operators of the future have not been born yet; we must be ready for them."

- Unknown

Scope of Study

Sargent & Lundy

Feasibility study commissioned by utility to determine ROI for replacing the current analog protection system:

- Examines costs and benefits of replacing two-unit site's analog protection system with a digital protection system.
- Current protection system incorporates a WEC analog 7300 Process Control System (PCS) for independent protection channel inputs, combined with the Solid-State Protection System (SSPS) for safety train actuation logic.
- Does not include replacement of sensors/transmitters, field cables, or actuated devices.
- Assumes minimal physical changes to the main control room boards and control room interface.

Cases Evaluated

Sargent & Lundy

Case 1:

Installation of system in 2029 with evaluation of benefits – current plant license end of life

Case 2:

Installation of system in 2029 with evaluation of benefits – Subsequent License Renewal end of life

Methodology

Sargent & Lundy

Determined Cost of I&C Technician Labor

- Surveillance Testing
  - VEGP Units 3 & 4 LAR 19-001 precedent
  - Tens of thousands of tests avoided over life of plants
- Planned Maintenance Testing
- Work Order Soft Costs

Determined Cost of 7300 / SSPS Parts to be Replaced

- Planned component replacements – material & labor costs
- Thousands of avoided replacements over life of plant

Study Conservatism

Sargent & Lundy

- Only included savings which could be monetized
- Evaluated subset of 7300 components
- Did not include Corrective Maintenance labor
- Feasibility analysis only includes I&C Technician manpower costs, not other organizations
- Assumes analog system work is done on straight time
- Assumes power supply replacement will continue with digital system
- Assumes use of DI&C-ISG-06 Alternate review process for NRC licensing review

Precedent: VEGP 3&4 PMS TS SR Elimination

LAR-19-001 (approved November 2019) proposed changes to VEGP 3&4 PMS TS surveillance requirements:

- Eliminated manual Channel Checks, Channel Operational Checks (COTs), Actuation Logic Tests (ALTs) and Actuation Logic Output Tests (ALOTs), revised Response Time Tests (RTTs)
- Credited continuous self-diagnostic features allowing the elimination of the PMS manual surveillance testing required for regulatory compliance

LAR-19-001: PMS SR Testing Elimination

Sargent & Lundy

PMS equipment functionality maintained by:

- Remaining manual TS surveillance testing
- Continuously running, hardware and software self-diagnostic features

Results of Financial Analysis

	Average Net Present Value (NPV) per Unit	Schedule
Case 1: Potential returns – Current plant license end of life	~($1.7M)	Project starts in 2020. System operational in 2029.
Case 2: Potential returns – SLR end of life	~5M	Project starts in 2020. System operational in 2029.

Conclusion

Sargent & Lundy

Proposed PWR protection system digital upgrade is a good investment:

- Positive ROI
- Reduction of human error
- Increase in plant safety
- Support of workforce of the future

Sargent & Lundy

Thank You

Digital Safety Systems: A Regulatory Perspective

Digital Safety Systems Seminar
January 30, 2020

Eric Benner, Director, Division of Engineering
Office of Nuclear Reactor Regulation, USNRC

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

What I'll Be Covering Today

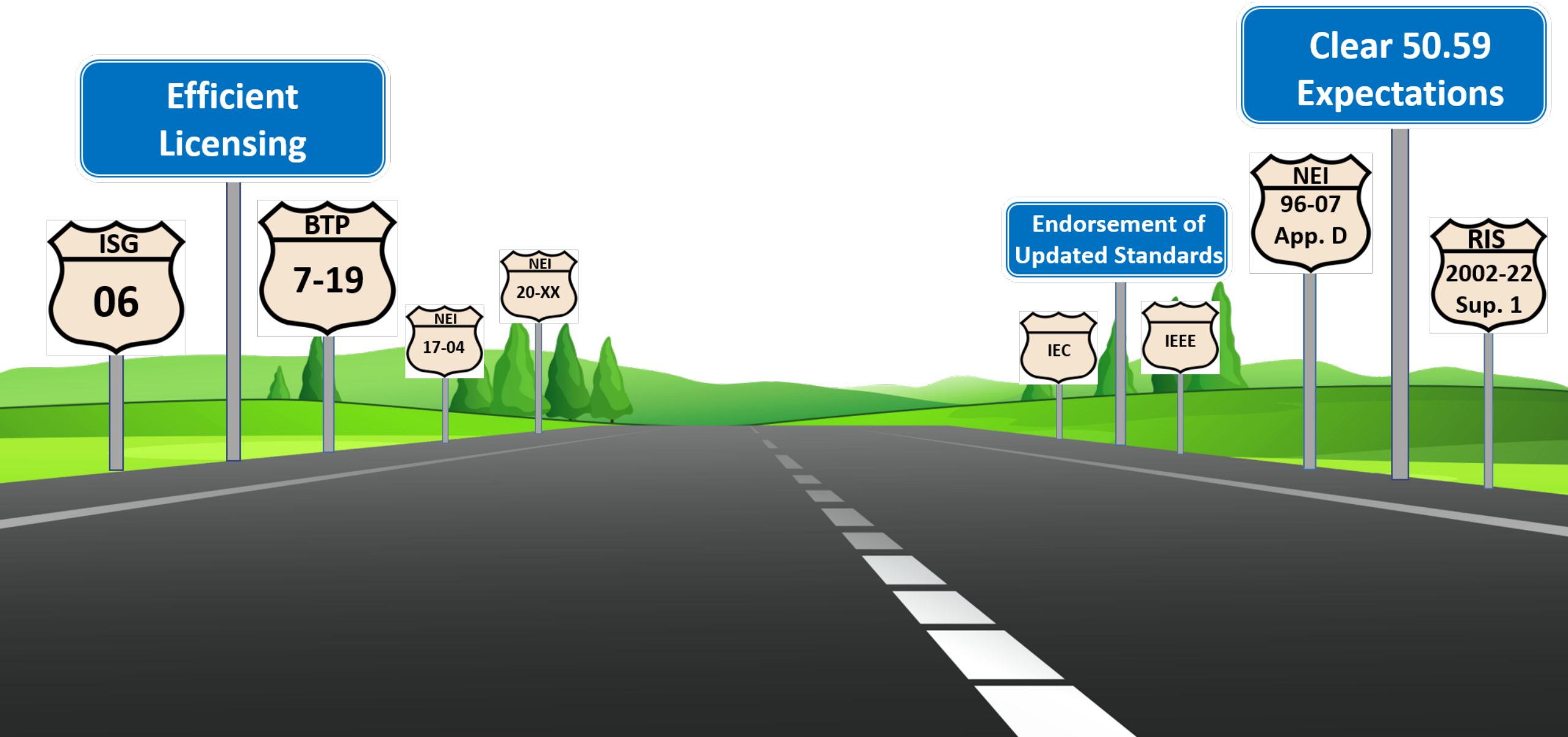
- NRC Vision
- Accomplishments
- Ongoing Initiatives
- What's Next

NRC Vision for Digital I&C

"A clear regulatory structure with reduced regulatory uncertainty that enables the expanded safe use of digital I&C in commercial nuclear reactors while continuing to ensure safety and security."

From NRC SECY-19-0112

The Road We're On



ACCOMPLISHMENTS

NRC Regulatory Issue Summary 2002-22 Supplement 1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
OFFICE OF NEW REACTORS
WASHINGTON, DC 20555-0001

May 31, 2018

NRC REGULATORY ISSUE SUMMARY 2002-22, SUPPLEMENT 1, CLARIFICATION ON ENDORSEMENT OF NUCLEAR ENERGY INSTITUTE GUIDANCE IN DESIGNING DIGITAL UPGRADES IN INSTRUMENTATION AND CONTROL SYSTEMS

ADDRESSEES

All holders of operating licenses under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities."

All holders of combined licenses under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

INTENT

The U.S. Nuclear Regulatory Commission (NRC) is issuing a supplement to Regulatory Issue Summary (RIS) 2002-22, "Use of EPRI/NEI Joint Task Force Report, 'Guideline on Licensing Digital Upgrades: EPRI TR-102348, Revision 1, NEI 01-01: A Revision of EPRI TR-102348 To Reflect Changes to the 10 CFR 50.59 Rule,'" dated November 25, 2002 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML023160044). RIS 2002-22 endorses Nuclear Energy Institute (NEI) 01-01, "Guideline on Licensing Digital Upgrades: EPRI TR-102348, Revision 1, NEI 01-01: A Revision of EPRI TR-102348 To Reflect Changes to the 10 CFR 50.59 Rule," issued March 2002 (ADAMS Accession No. ML020860169). NEI 01-01 provides guidance for designing, licensing, and implementing digital upgrades and replacements to instrumentation and control (I&C) systems (hereinafter referred to as "digital I&C") in a consistent and comprehensive manner.

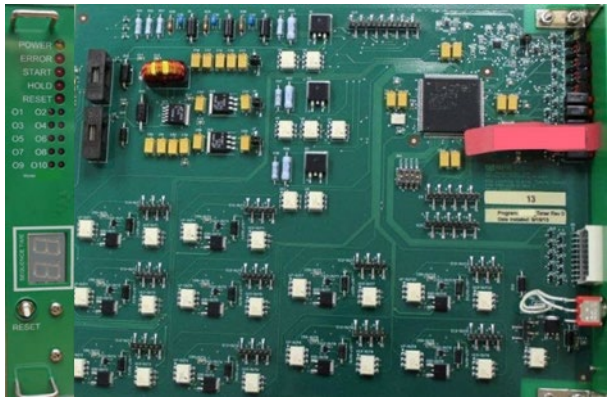
The RIS supplement clarifies RIS 2002-22, which remains in effect. The NRC continues to endorse NEI 01-01 as stated in RIS 2002-22, as clarified by this RIS supplement. Specifically, the guidance in this RIS supplement clarifies the NRC staff's endorsement of the guidance pertaining to NEI 01-01, Sections 4 and 5 and Appendices A and B. This RIS supplement clarifies the guidance for preparing and documenting "qualitative assessments" that can be used to evaluate the likelihood of failure of a proposed digital modification, including the likelihood of failure due to a common cause (i.e., common-cause failure (CCF)). Licensees can use these qualitative assessments to support a conclusion that a proposed digital I&C modification has a sufficiently low[1] likelihood of failure. This conclusion and the reasons for it should be documented, as required by 10 CFR 50.59(d)(1), as part of the evaluations of proposed digital

[1] On page 4-20 of NEI 01-01, NEI defines "sufficiently low" to mean much lower than the likelihood of failures that are considered in the updated final safety analysis report (UFSAR) (e.g., single failures) and comparable to other CCFs that are not considered in the UFSAR (e.g., design flaws, maintenance errors, calibration errors).

ML18143B633

Chiller Controls

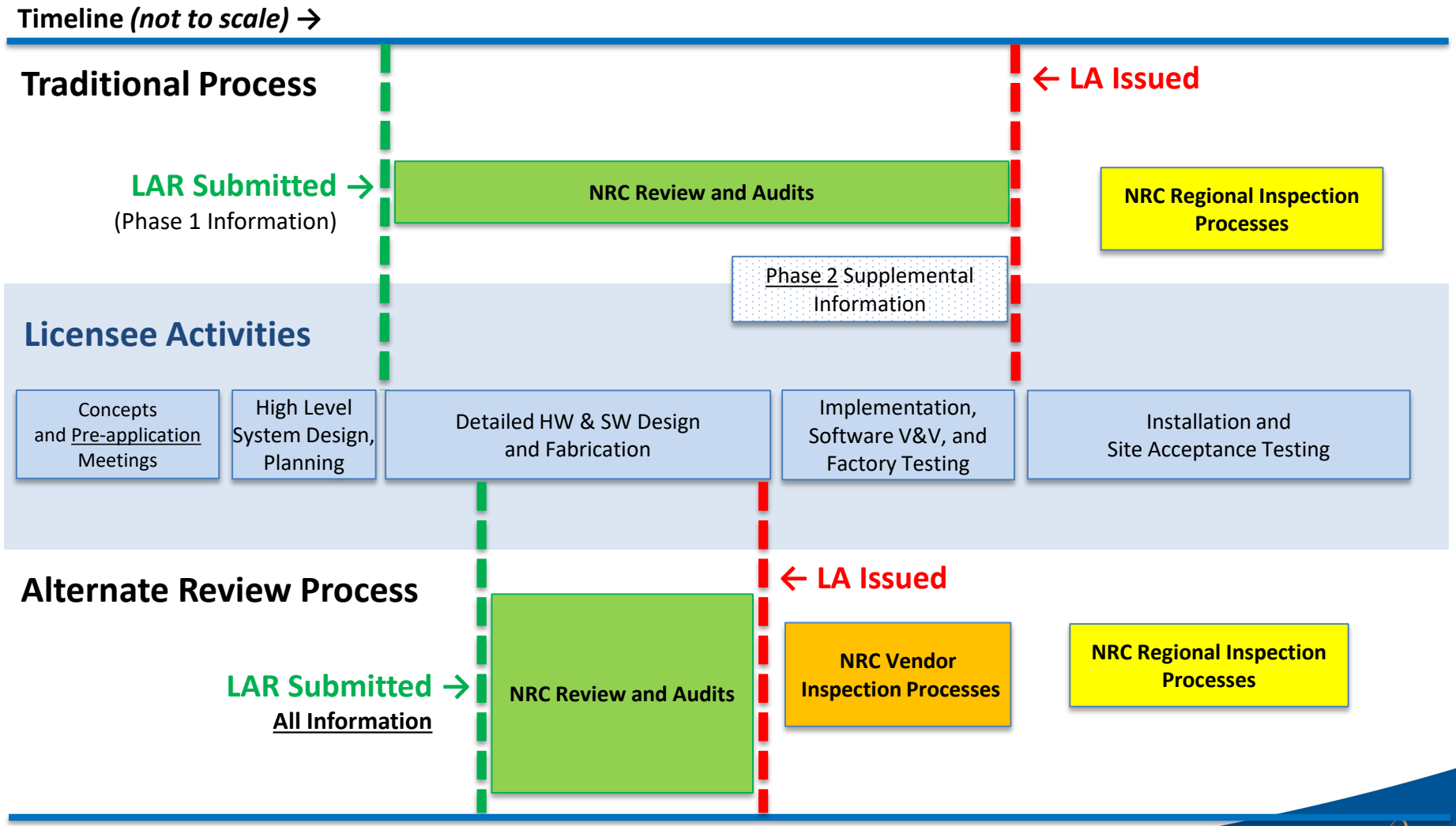
Feedwater/Turbine Control System



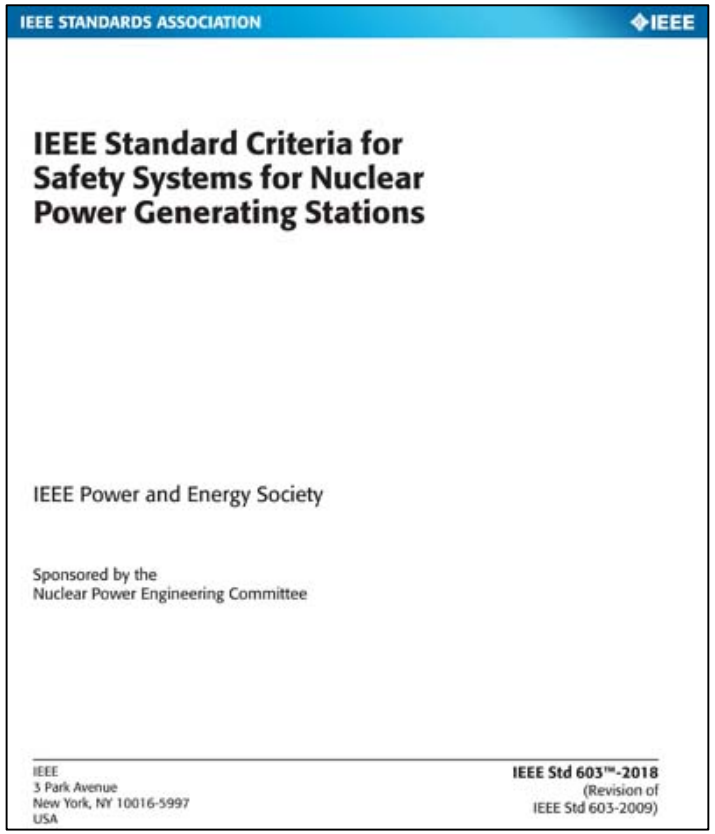
Diesel Generator Controls

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NRC DI&C Interim Staff Guidance (ISG) 06 Revision 2



Institute of Electrical and Electronics Engineers Standard 603



NRC staff participated extensively with IEEE during the development of the latest version of IEEE-603, which was issued in September 2018

Recent Licensing Accomplishments

- **New Reactors:**
  - APR1400 Design Certification
  - NuScale Design Certification
- **Research Reactors:**
  - Purdue
  - MIT
- **Topical Reports:**
  - Lockheed Martin (Nuclear Protection & Control)
  - Mitsubishi Heavy Industries (Mitsubishi Total Advanced Controller)
  - Radiy (RadICS Digital I&C Platform)
- **Operating Reactors:**
  - Hope Creek Power Range Neutron Monitoring System

ONGOING INITIATIVES

NEI 96-07 Appendix D

- Enhances guidance for 10 CFR 50.59 evaluations
- Provides guidance for DI&C 50.59 screening
- Currently finalizing revisions to ensure NRC endorsement without conditions
- NRC will provide training to our inspectors and support industry workshops

NRC Branch Technical Position 7-19

Risk-Informed Graded Approach

	Safety-Related	Non-Safety Related
Safety-Significant Significant contributor to plant safety	A1 **Analysis Needed:** D3 Assessment	B1 **Analysis Needed:** Qualitative Assessment
Non-Safety-Significant Not a significant contributor to plant safety	A2 **Analysis Needed:** Qualitative Assessment	B2 **Analysis Needed** None may be needed

Currently published for public comment and a public meeting is scheduled for February 11

NEI 17-06

- Provides guidance on using 3rd party certifications to determine acceptability of digital equipment
- NEI provided draft document in September
- Public meeting held October
- NRC provided comments in November and December
- NEI currently reviewing comments

Standards

- Endorsement of IEEE-603-2018
- Update of IEEE 7-4.3.2-2016 and subsequent endorsement
- Considering broader use of International Electrotechnical Commission standards

NEI 20-XX

- New guidance for addressing common cause failure
- Particularly focuses on the use of defensive measures as a way to demonstrate quality of digital systems
- NEI expects to provide a draft to NRC in March

Strategic Assessment

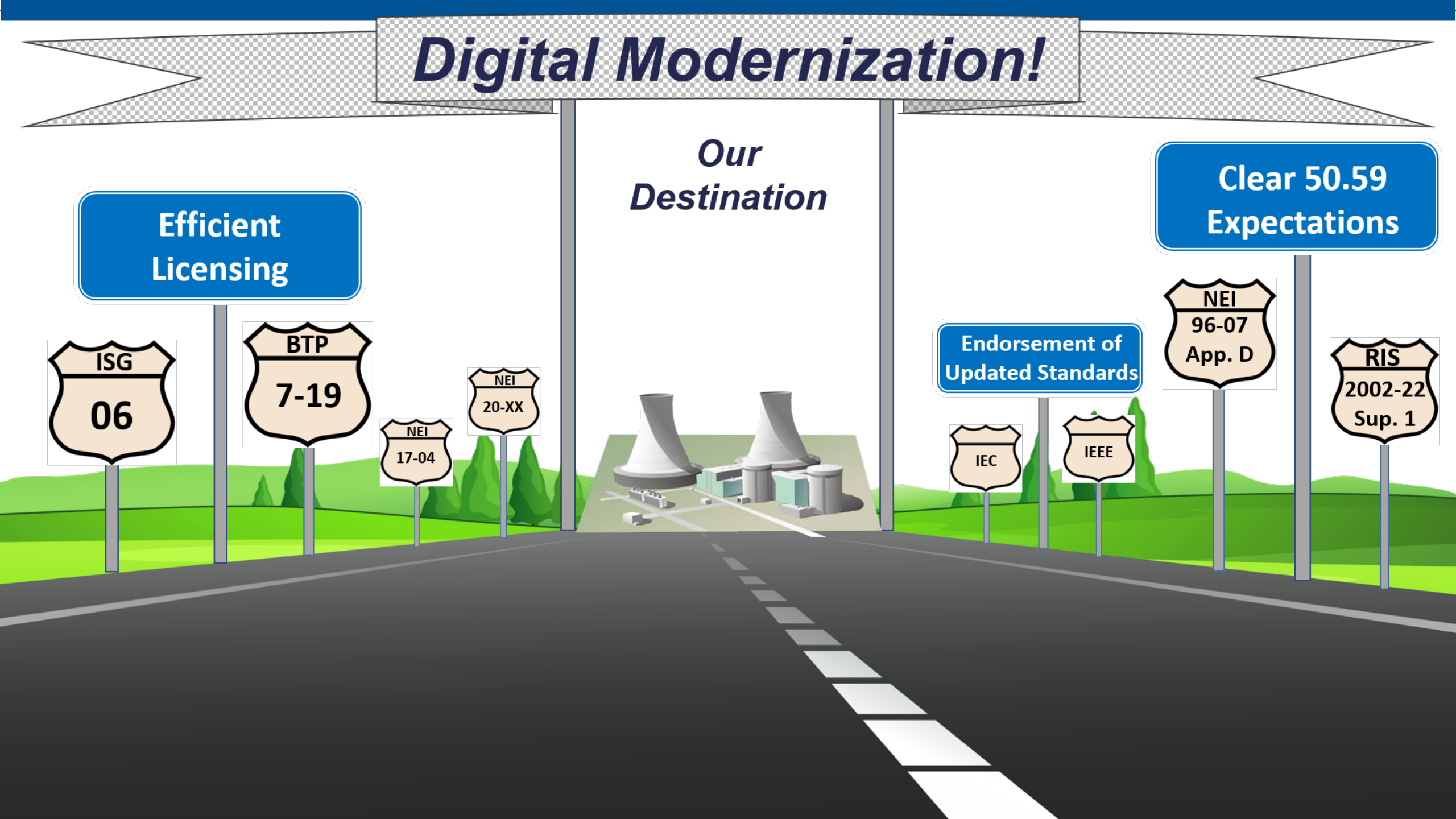
- Intended to identify potential longer-term improvements
- Held stakeholder meetings last year in January, April & November
- NRC staff issued recommendations in December
- NRC management currently considering recommendations and path forward

WHAT'S NEXT?

- Finish ongoing initiatives
- Prepare for license applications:
  - Developing NRC safety evaluation report templates
  - Assessing inspection procedure enhancements
  - Preparing staff in all relevant disciplines (I&C, human factors, systems engineers, lawyers)
  - Conducting pre-application meetings:
    - Waterford Core protection Calculator application expected in June
    - Anticipating a second licensee to request a pre-application meeting in February

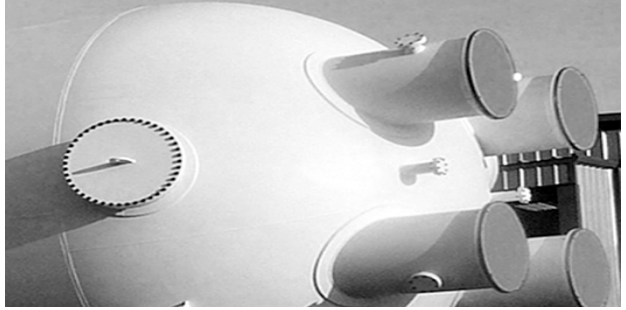
"I&C…Analog Need Not Apply" March 12th

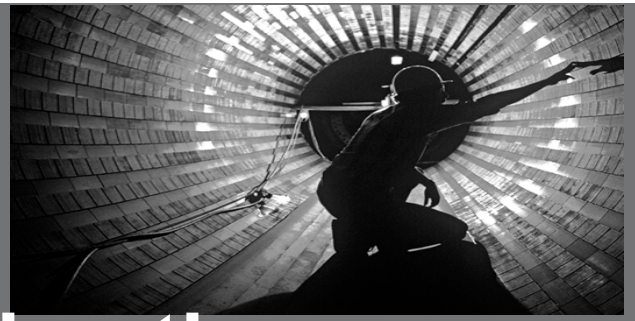
Digital Modernization!



CURTISS-WRIGHT

Nuclear Division





Digital Safety System Implementation Considerations

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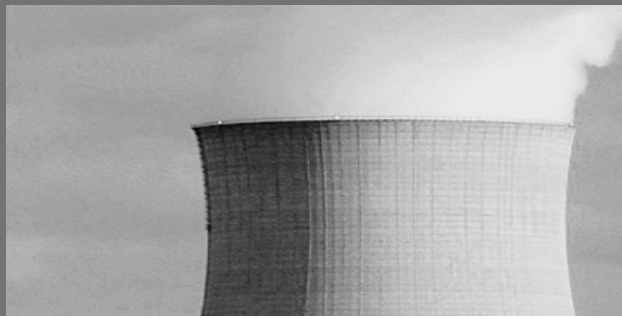

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Digital Safety System Implementation Considerations

Considerations when implementing Digital Safety Systems

- Requirements Definition
- Project Organization
- Implementation
- Training
- Testing / Installation
- Support

Requirements Definition

- **Determine Digital System Capabilities that can provide a Return on Investment**
  - Automated Channel Checks
  - Automated Channel Operability Tests
  - Automated Activation Operability Tests
  - Interfaces to Plant Data Systems
    - Performance Based Sensor Calibrations
    - Condition Based Maintenance
  - Automated Response to Failures
    - Example, change from 3 sensor average to 2 sensor average on input failure
  - Resist Like for Like Replacement with Analog System
    - Don’t take the easiest licensing path

Requirements Definition (cont.)

- **HMI Capabilities**
- **Consider Out of the Box Ideas**
  - Integrate RPS and ESFAS into a single system
  - Involve system suppliers and A/E firms in the requirements definition before the RFP
  - Change non-safety system interfaces from analog to digital?
    - Reduce size and scope of safety-related components
  - Downgrade functions from safety to non-safety where possible?
- **Eliminate components where possible**
- **Carefully evaluate requirements before issuing the RFP**
- **Include only applicable standard and regulations**

Requirements Definition (cont.)

- **Identify Single Point Vulnerabilities that should be addressed in the replacement system**
- **Define all system specific Cyber Security Requirements**

Project Organization

- **Inclusion of all relevant plant organizations**
  - Operations
  - Design and System Engineering
  - Maintenance
  - Licensing
  - Training
  - IT?

Project Organization (cont.)

- **Dedicate project team members to project**
  - Minimize personnel turnover
- **Consider how information will be shared with supplier and A/E firm**
  - Facilitate and encourage subsupplier communication to ideate system innovations for consideration by system managers
- **Define supplier management requirements**
  - Engineer, Procurement & Construction (EPC)
  - Utility Managed Sub-suppliers

Implementation

- **Consider embedding utility personnel into supplier development and testing teams**
  - Include craft positions (I&C technicians and maintenance personnel) in addition to engineering, quality assurance and licensing personnel
- **Consider providing utility development / training system during implementation**

Training

- **Determine which plant personnel require training**
- **Is a separate “training system” required?**
  - If so, will it be a full function system?
- **When will training be performed?**
  - Before delivery? Before FAT? After delivery?
- **Who develops the training materials?**
  - Supplier? Utility Training Department?

Testing / Installation

- **Mandate that utility personnel participate in all in-formal and formal vendor testing activities**
- **Consider how utility provided components (if any) will be tested**
- **Consider how plant procedures will be updated and verified**
- **Consider staging system in “clean-room” facility at the plant site before actual plant installation**
- **Consider utilizing specialized installation personnel**
  - I&C technicians instead of craft electricians

Support

- **Consider / plan for ability to support the system after delivery**
  - Utility support / Vendor support or hybrid approach
  - If Utility Supported
    - Require supplier to provide all tools to modify / maintain the system
    - Develop utility personnel for IV&V activities
    - Procure development / testing systems