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Digital Procedure Systems for Nuclear Reactors

Human Factors and Organizational Considerations Beyond Crew Operations

PSAM 18, July 19-24, 2026, Pittsburgh, Pennsylvania

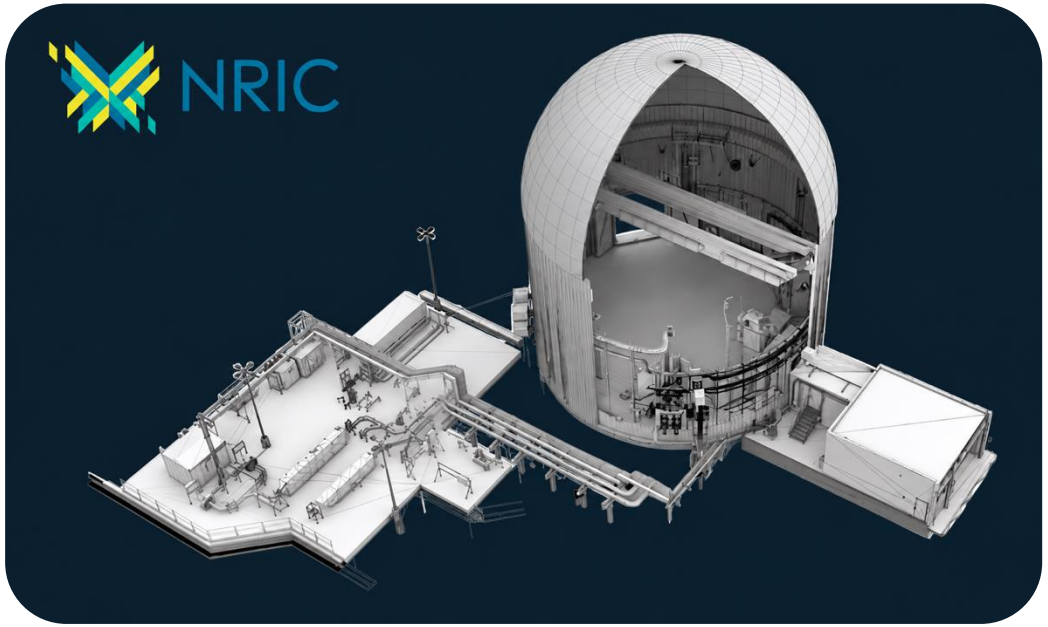
Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

Idaho National Laboratory

INL/CON-26-93460 Rev:001

DOME Digital Procedure Deployment

- **NRIC-DOME** – a test bed for demonstrating and evaluating advanced reactor technologies in a controlled facility environment.
- **Project Overview** – Assess the feasibility of implementing digital procedures for NRIC-DOME operations.
  - Define **system requirements** based on existing operations, facility constraints, and procedural needs.
  - Install and integrate a digital procedure system with prototype procedures on INL systems and networks (DOME control room)
  - Evaluate procedure authoring workflow and integrate with document management process for document approval compliance
  - Develop a standard NRIC-DOME digital procedure template.
  - Establish verification and validation methods.



Paper Versus Digital Procedures

Traditional Paper Procedure

Example: EOP Two-Column Paper Procedure

RESPONSE OBTAINED	RESPONSE NOT OBTAINED
3.1 Verify Reactor Trip A. Confirm all control rods fully inserted. B. Verify RCS pressure is decreasing.	**3.1 Verify Reactor Trip** A. Confirm all control rods fully inserted. B. Verify RCS pressure is decreasing. C. Pressurize PORVs.
3.2 Verify Steam Generator Isolation A. Verify MSIVs closed. B. Verify feedwater isolation.	**3.2 Verify Steam Generator Isolation** A. Verify MSIVs closed. B. Verify feedwater isolation. C. Align AFW system.
3.3 Monitor and Record A. Record RCS pressure. B. Notify Shift Supervisor.	**3.3 Monitor and Record** A. Record RCS pressure. B. Notify Shift Supervisor.

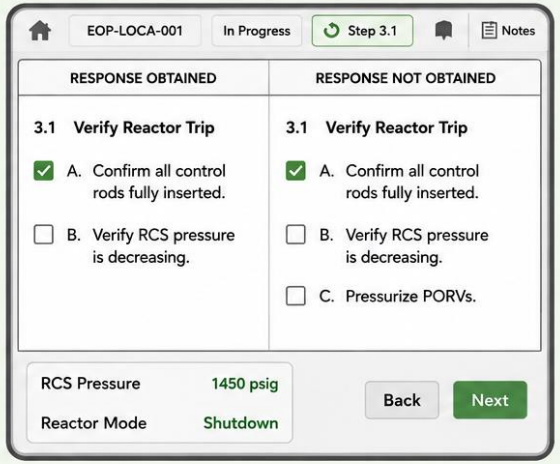
- Static content on paper
- Linear, page-by-page navigation
- Two-column format for divergent actions (Response Obtained / Not Obtained)
- Operator manually tracks progress (placekeeping)
  - References to plant parameters, components, and actions

SIMILARITIES

- Provide step-by-step instructions to guide operator actions
- Based on approved plant procedures
- Use plant-specific terminology and abbreviations
- Include safety precautions and prerequisites
- Reference plant parameters, systems, and components
- Support safe and consistent plant operations
- Subject to review, approval, and change control

Computerized Operating Procedure

Example: EOP Two-Column Computerized Procedure

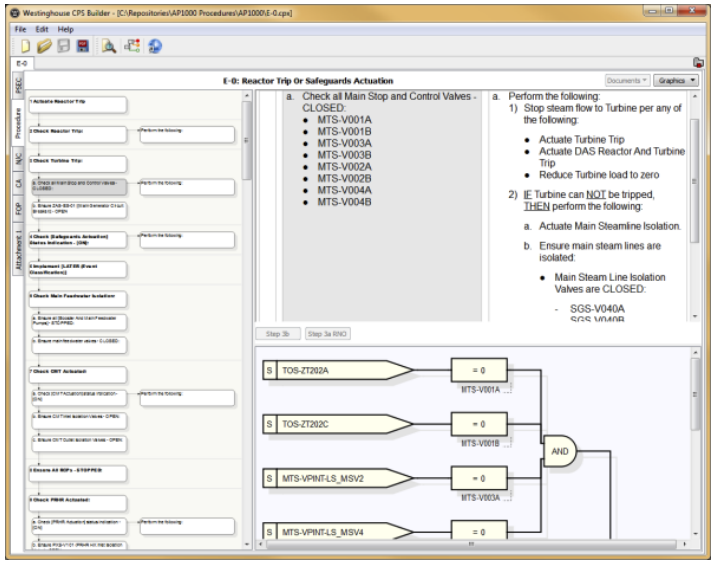


- Electronic display on computer/tablet
- Interactive navigation and branching logic
- Two-column format with dynamic path selection
- Automatic placekeeping and step tracking
- Real-time plant data integration and validation
- Built-in alerts, prompts, and links to references
- Electronic signature, audit trail, and reporting

Many names, one concept

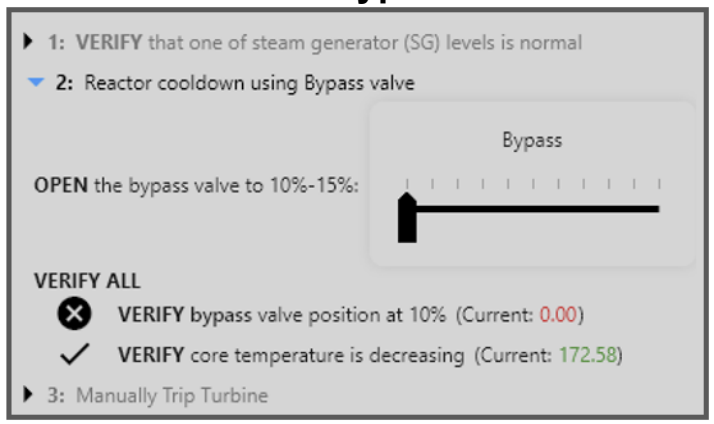
- Computer-Based Procedures
- Computerized Procedures
- Electronic Procedures
- Dynamic Instructions
- Dynamic Procedures
- Dynamic Work Instructions
- Smart Electronic Procedures
- Computer-Guided Procedures and Instructions
- Electronic Work Packages
- Digital Work Execution

Digital Procedures – Key Advantages



Westinghouse CPS

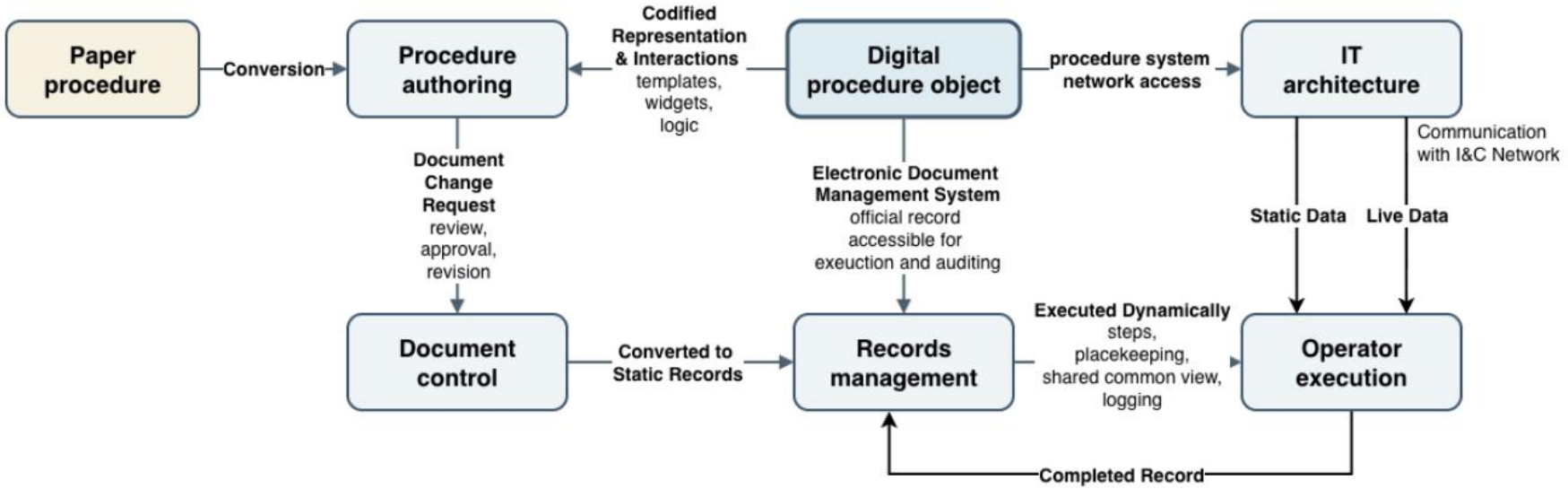
Rancor Prototype Procedure



Automatic placekeeping	Tracks completed, current, and pending steps	Lower workload; fewer missed or repeated steps
Integrated plant data	Embeds values, equipment status, and trends	Less display searching; improved situation awareness
Logic and decision support	Evaluates conditions and identifies applicable paths	Faster, more consistent decisions
Role-based procedure execution	Assigns execution and approval permissions; provides shared crew view	Clear responsibilities; improved coordination and oversight
Automated checks and calculations	Evaluates limits, prerequisites, and derived values	Less manual effort; fewer evaluation errors
Information access and navigation	Links steps, references, cautions, figures, and procedures	Faster access to supporting information
Procedure-based automation	Executes specified actions or procedure-step sequences	Lower execution workload; faster and more consistent response

Project Activities – Activities

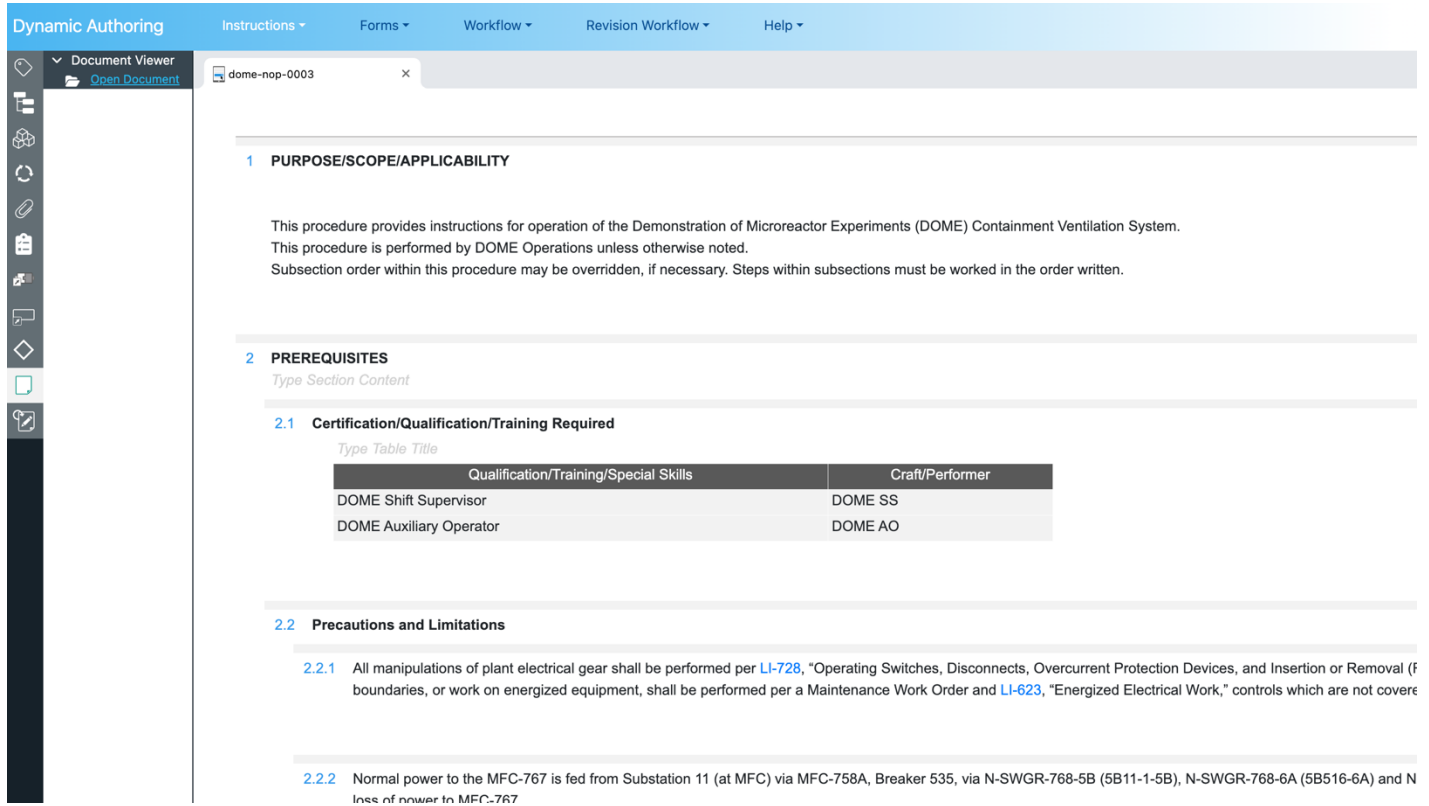
1. Define system requirements based on existing operations, facility constraints, and procedural needs.
2. Install and integrate a digital procedure system with prototype procedures on INL systems and networks (DOME control room)
3. Evaluate procedure authoring workflow and integrate with document management process for document approval compliance
4. Develop a standard NRIC-DOME digital procedure template.
5. Establish verification and validation methods.



Remained of presentation will present outcomes and lessons learned.

Lessons Learned – Procedure Authoring and Curation

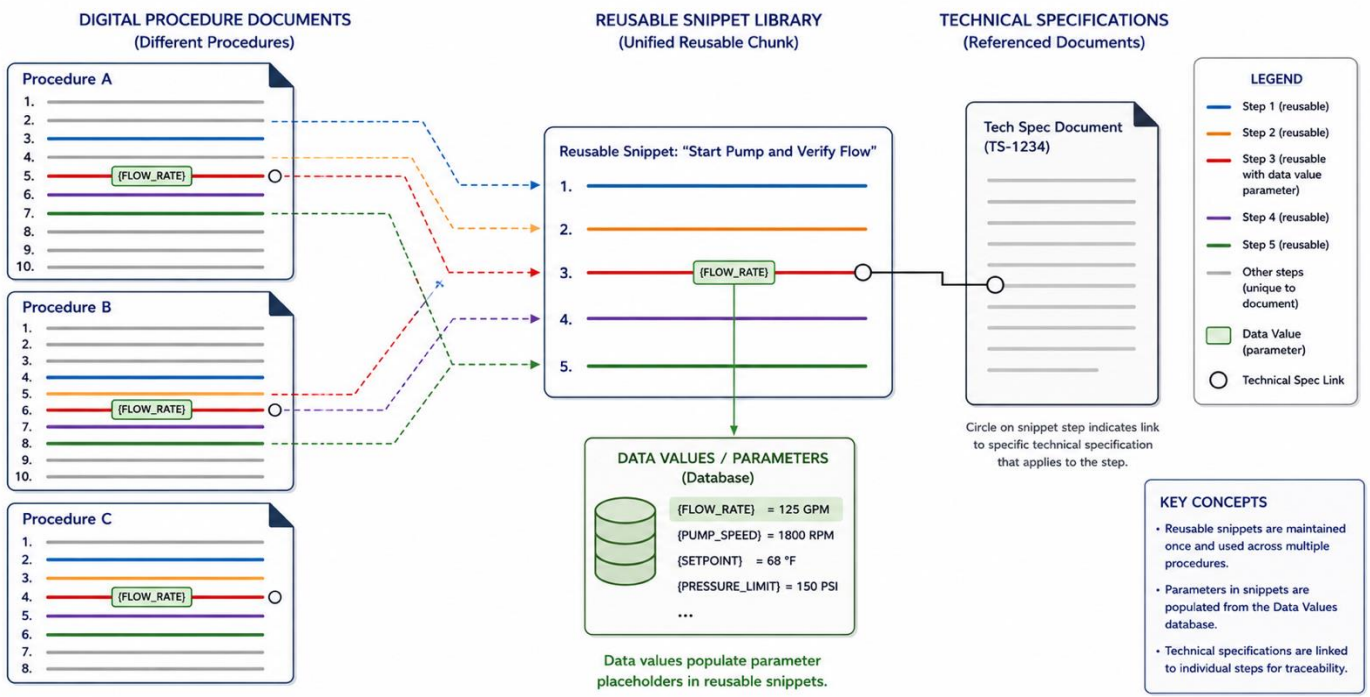
- **Authoring complexity**
  - Content distributed across procedure files, runtime behavior, live-data checks, user roles, and calculations
  - Dynamic presentation based on plant conditions, reducing reliance on operator interpretation
  - Writers must define both procedure text and object behavior
  - Configuration of widgets, logic, acknowledgments, branching, required inputs, logged fields, and status displays
    - Developed Writers Guide procedure
  - Greater need for software, database, and nuclear operations expertise
    - “You almost have to be an operator to build these [procedures]”



Procedure Elements Data Structures

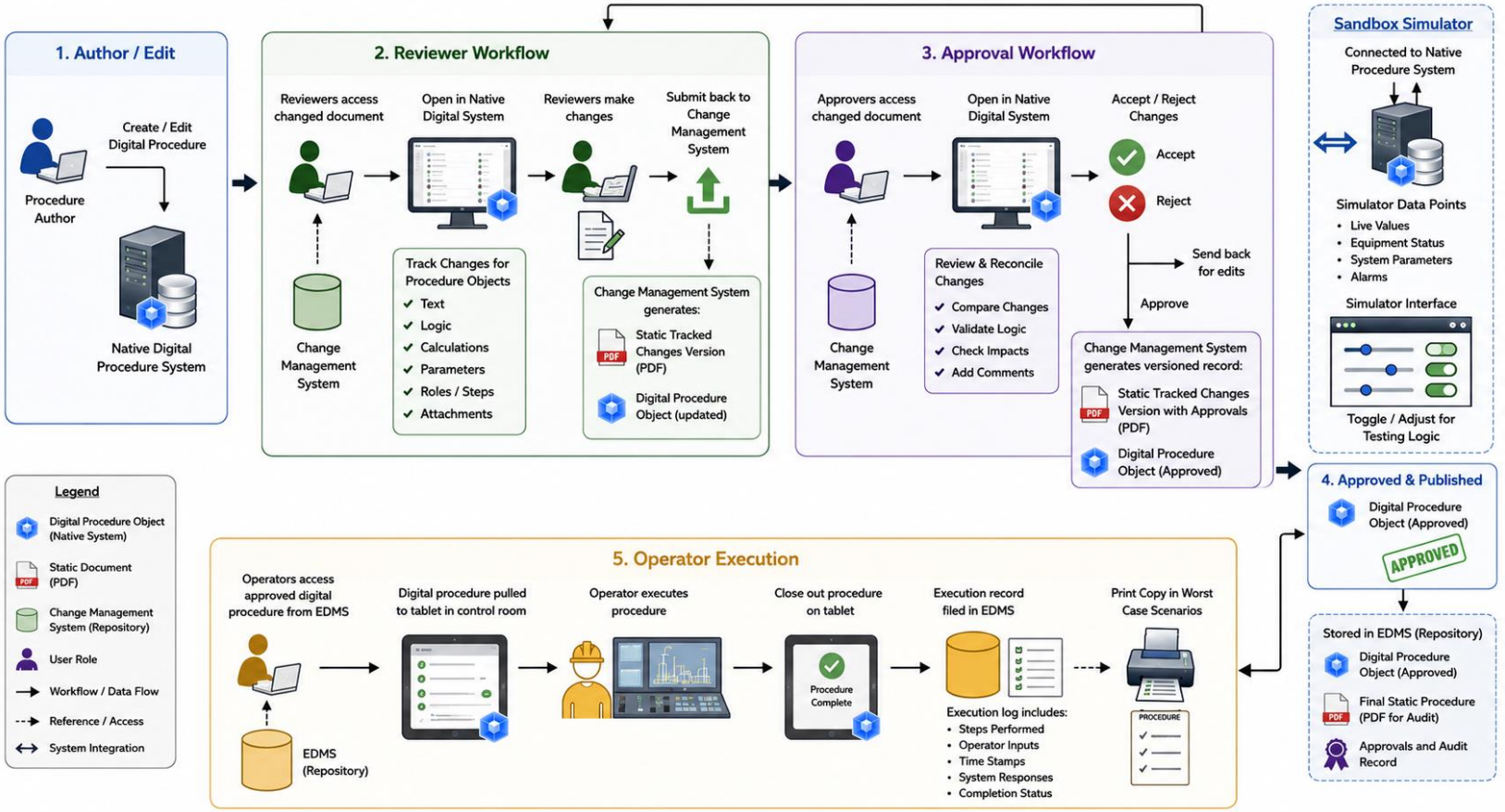
- **Knowledge Graph Database**
  - Reusable procedure objects allow content to be defined once and used consistently
  - Significant upfront effort to build supporting knowledge-graph database infrastructure
    - Initial proof-of-concept developed with technical specification

- **Authoring with Templates → Grouping**
  - Templates and reusable functional blocks require strict configuration control because changes may propagate globally
    - Procedure sequence grouping moves beyond traditional document structures
      - What is the atomic procedure element? → Instruction?
      - What is a manageable procedure collection, i.e. “snippet” → object orientated procedure authoring

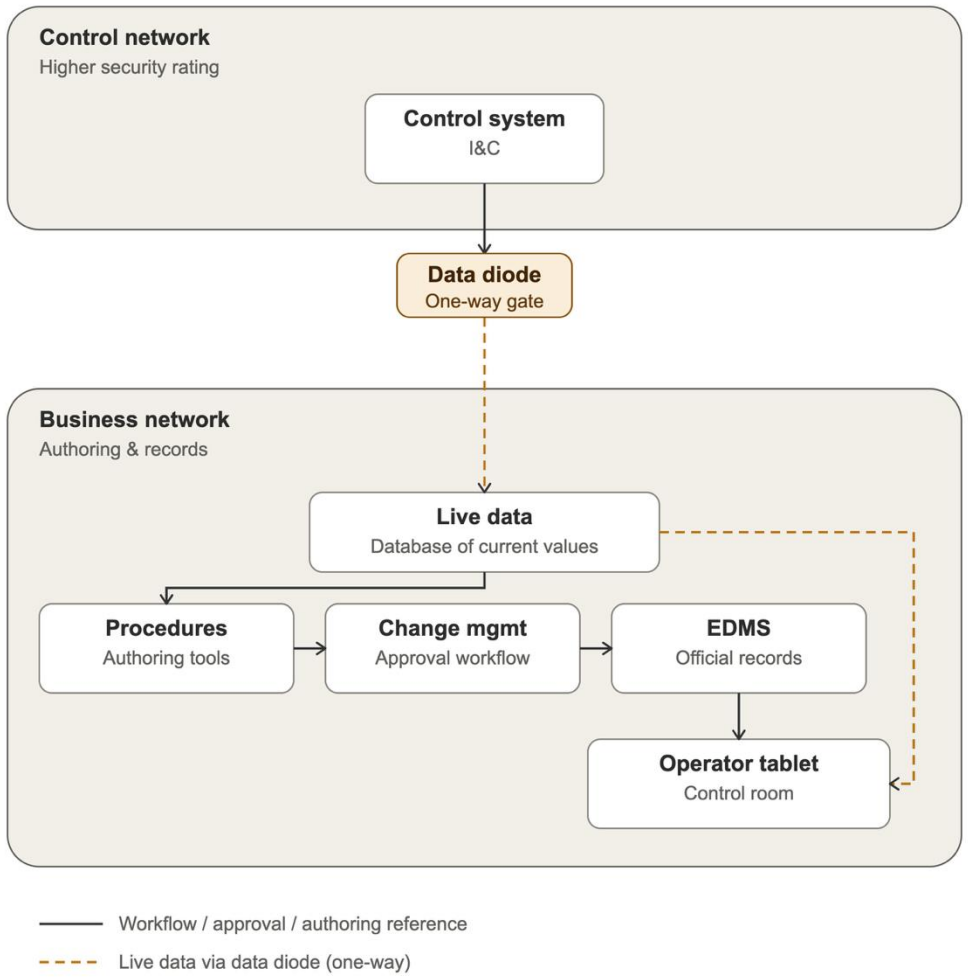


Assessment Results – Change Management System

- Regulations require storing procedure for operational access and audit – static or dynamic or **both**?
- How to track changes for dynamic procedure?
  - Changes made to procedure object must be tracked for approval
  - Use digital procedure authoring tools for tracking changes and approvals
  - Output static tracked change style document for records



Assessment Results – Infrastructure Integration



- Where should procedures be stored and accessed?
  - Authoring and approvals occur on **business network**
  - Live data exists on **control network**…
  - Operators use tablets in control room to access procedures
- Identified network isolation pathway to access data for live values and procedure logic evaluations

Results – Operations Study

- Formal **validation study** planned for early FY27
- **Experimental protocol** under development
  - Scenario based evaluation in simulator (not actual control room)
  - Widget implementation alternatives and credentialing microtasks
  - Prototype procedure displayed on tablet and 2-in-1 laptop
- Conducted **preliminary control room operations observation**
  - Display lag induced by data access report as nonconsequential
  - **Operator logging** identified as most beneficial use case for digital procedures
    - Portability reported
  - Operators will have a **dedicated tablet**
    - IT/networking device requirements for credentialling
    - Control room space constraints and mobility factors

Next Steps

- Developing a simulation testbed based on existing control room
  - NRIC-DOME is engaged in preparation for criticality test with vendor
    - Dedicated simulator based on emulated control system and human-machine interfaces from actual control room
- Integration with digital engineering ecosystem
  - Technical specification tracing
    - Proof-of-concept → implementation in deeplynx and digital procedure
- Live data
  - Develop Type-2 digital procedure specification and writer's guidance
  - Couple vendor API service with data acquisition application
  - Develop additional visualizations for timeseries data (trends, conditional logic)

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