Operational Data Analysis

Operational Experience Review and Application

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MOTIVATION - Why Operational Data Analysis?

ISSUE: Ineffective OpEx Reviews

- Not adequately scoped
- No effective process in place
- No incentive to improve process, or correct the scope

Feels like looking for a needle in the haystack

OBJECTIVE: build Operational Data Knowledge model to

Facilitate the extraction of validated insights that:

- Effectively inform I&C lifecycle activities
- Allow us to identify emergent issues
- Facilitate adoption of Risk-Informed, Performance-Based methods

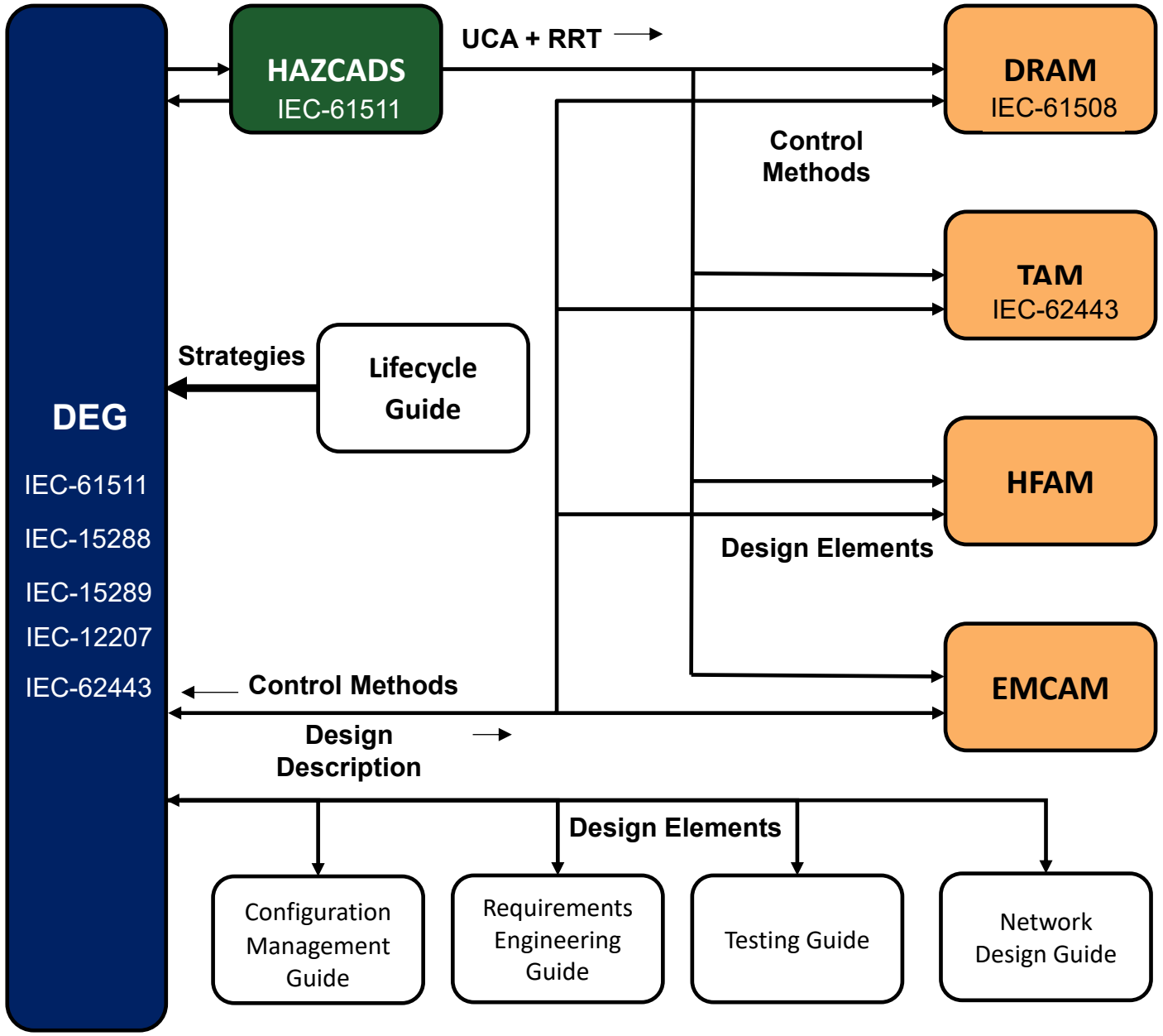
How does this research inform the DEG activities and other DSE processes?

EPRI's Digital Framework Elements

EPRI's ***high-quality engineering process*** uses the same modern methods and international standards used in other safety related industries to improved efficiency and reduce implementation cost

Utilize Industry Standards	Use the same proven design and supply chain structures that non-nuclear safety related industries use (IEC-61508/61511/62443). This leverages the economies-of-scale achieved in other industries.
Use of Systems Engineering	Use of a modern, high performance, single engineering process that leverages systems engineering in the transition to team-based engineering for conception, design, and implementation.
Risk Informed Engineering	Making effective engineering decisions via hazards and risk analysis to integrate all engineering topics (such as cyber security and SCCF) into a single engineering process.

Capable Workforce



DEG – Synthesizes the Systems Engineering framework from IEC-15288. Includes all relevant Lifecycle topics. Takes strategic input from the Lifecycle guide and formulates design description.

HAZCADS – Uses STPA/FTA to identify hazards and associated UCA. FTA and Risk Matrices develop a Risk Reduction Target (RRT) which informs the downstream processes. Implements a PHA/LOPA from IEC-61511.

DRAM – Identifies Hardware and Software reliability vulnerabilities and develops Loss Scenarios. Formulates and scores Control Methods to protect, detect , and respond/recover from UCA to meet the RRT.

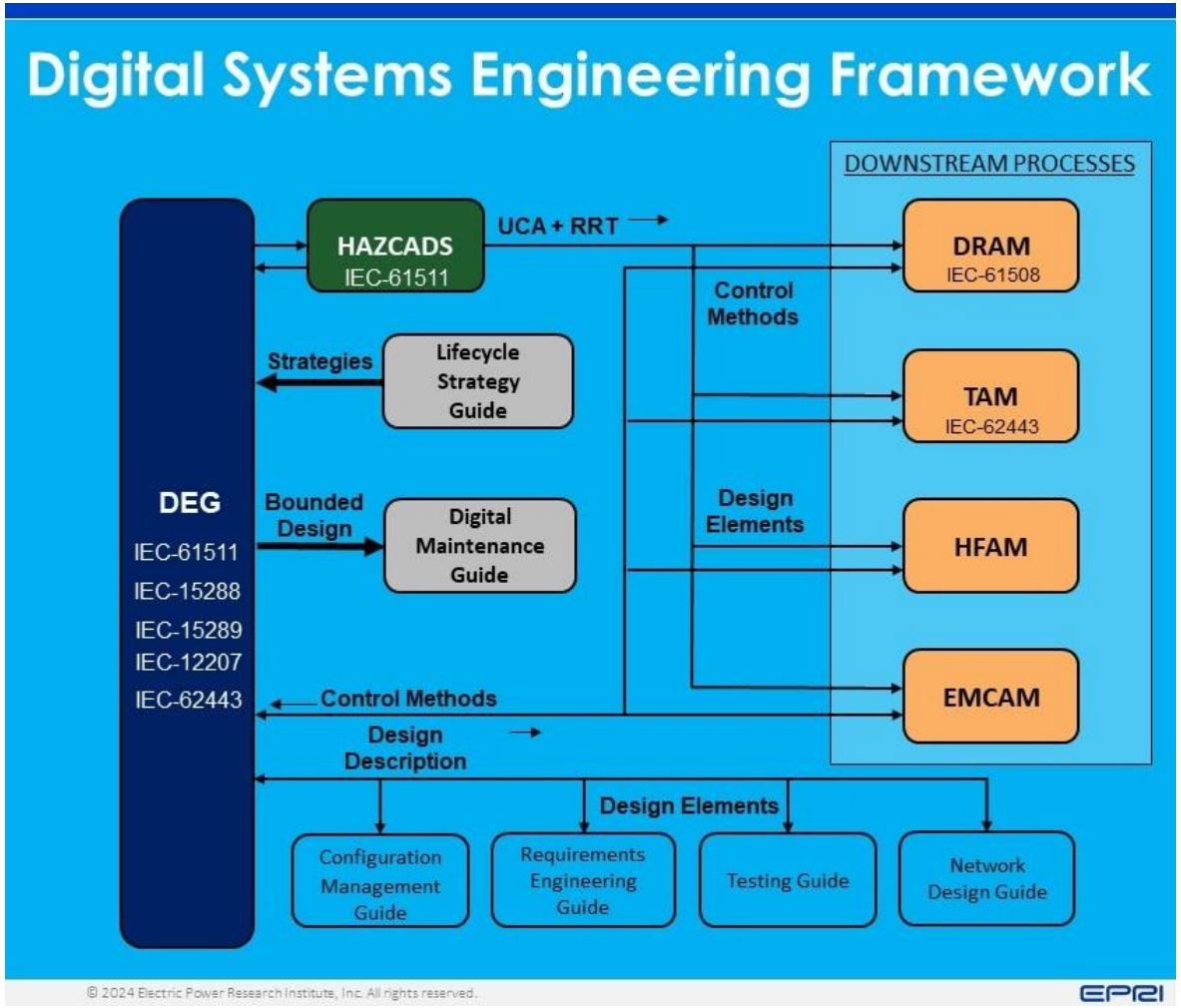
TAM – Identifies cyber security vulnerability classes and develops Exploit Sequences. Develops and scores control methods to protect, detect and respond/ recover from UCA to meet the RRT.

HFAM – Identifies important human actions and develops Loss Scenarios. Identifies and scores control methods to “design out” Human Error until meeting the RRT.

EMCAM – Identifies EMC vulnerability classes. Develops and scores protect, detect , and respond/ recover control methods using the RRT

RRT= Risk Reduction Target
UCA= Unsafe Control Action
STPA=System Theoretic Process Analysis
FTA= Fault Tree Analysis
LOPA= Layers of Protection Analysis
EMC= Electromagnetic Compatibility
PHA=Process Hazards Analysis

How Operational Data informs the DSE framework elements?



- The Operational Data Research conducted is being used to inform several of the guides. Most relevant:
  - Digital maintenance needs to be addressed (DMG)
  - Development and characterization of unsafe control actions (HAZCADS)
  - Software failures library and characterization (DRAM)
  - Human loss scenarios (HFAM)
  - EMI loss scenarios (EMCAM)
  - Supplementing OE reviews conducted by DEG practitioners.

For details, see public wiki https://icwiki.epri.com , Digital Systems Engineering Framework subpage

DI&C Operational Data Analysis Process and Results

Process carried by SMEs

SOURCES
INPO
WANO
NRC
MEMBERS

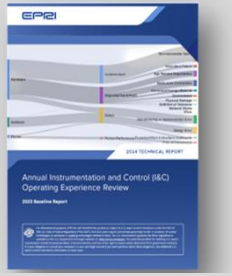
COLLECT

CURATE

CATEGORIZE

ANALYZE

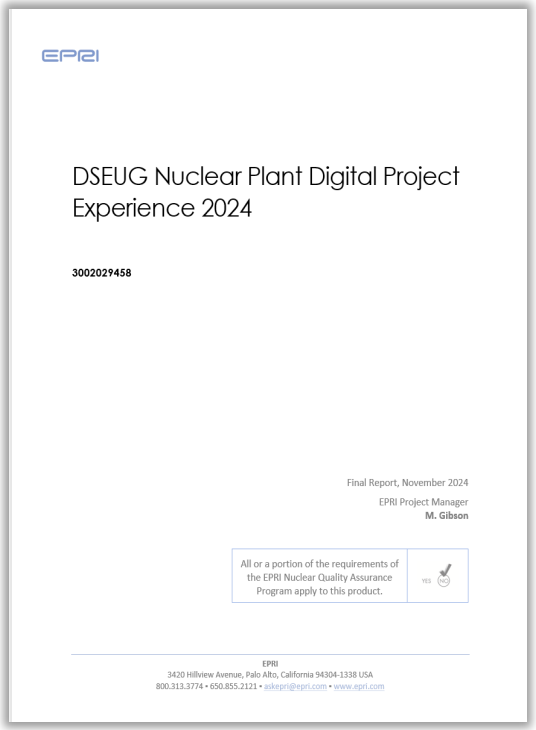
Report



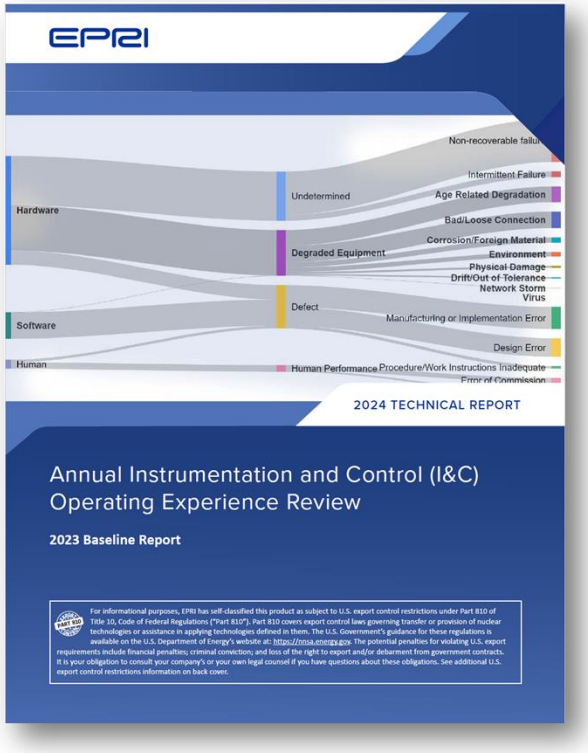
Data Set

Two approaches to learning from experience

- The Digital Project Experience Report was developed to gather digital project related experience to facilitate information sharing amongst DSEUG members

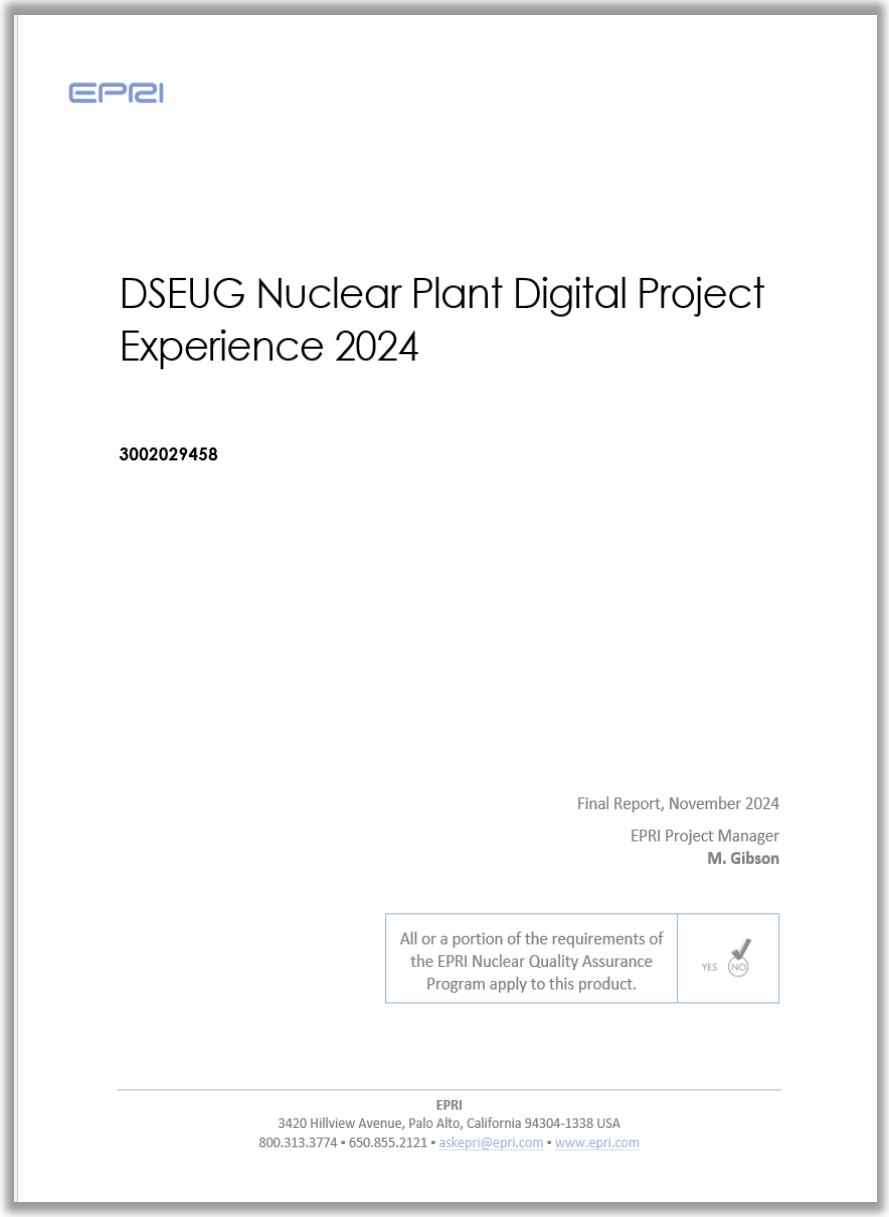


- The Annual I&C Operating Experience Review was developed to aid in the review and of application of nuclear digital-related OpEx.



Digital Project Experience Report

- The Digital Project Experience Report was commissioned by the DSEUG to gather digital project related information for common DSEUG member use
- This project is solely funded by the DSEUG
- Access limited to only DSEUG members
- The primary purpose of the report is to facilitate information sharing amongst DSEUG members
- Specific licensees or vendors are not identified in the report – in other words, all information provided is confidential


EPRI

DSEUG Nuclear Plant Digital Project Experience 2024

3002029458

Final Report, November 2024

EPRI Project Manager
M. Gibson

All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.

YES NO

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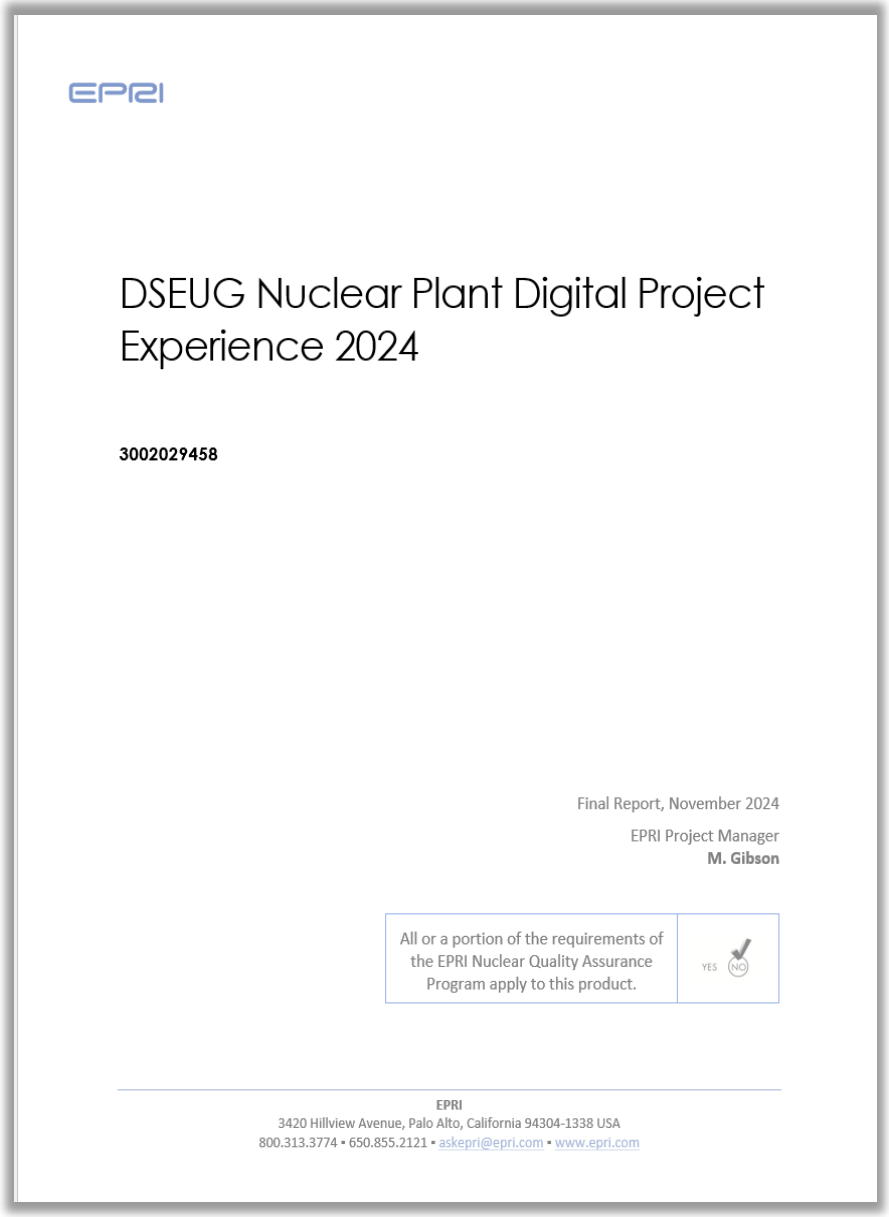
Digital Project Experience Report

- DSEUG now covers 49 plants with a combined 91 units (56 PWR units, 27 BWR units, 8 CANDU units)
- 97% of US units / 42% of Canada's units
- The goal is to collect data from all DSEUG member licensees for report input
- New DSEUG members are asked to complete the Digital Project Experience Report survey
- Ultimately, this report is for the benefit of DSEUG members to aid in the implementation of digital modifications through the application of industry OpEx.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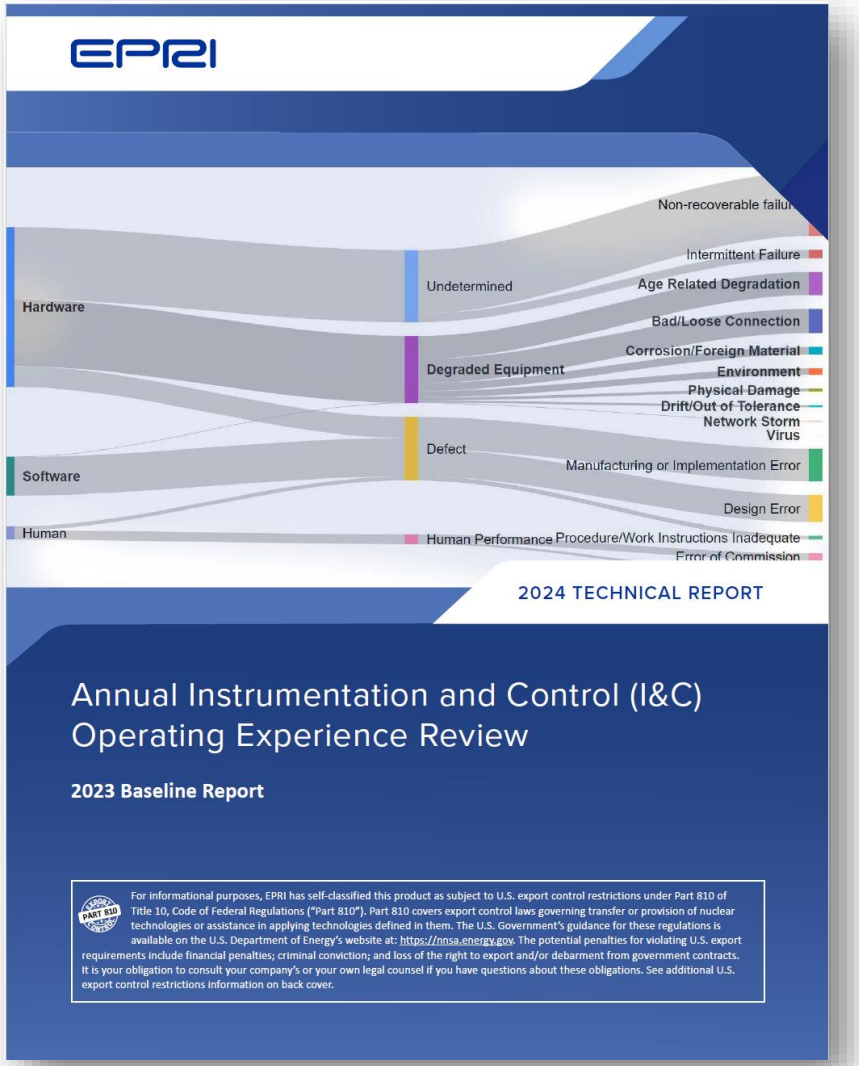
DSEUG Digital Project Experience Report Overview

- The Current State of Digitization
- Plans for Future Digital Upgrades
- Long Term Modernization Plans and Strategies
- Digital Equipment Selection Methods and Criteria
- Digital Project Division of Responsibilities
- Digital Projects Lessons Learned
- Digital Projects Good Practices

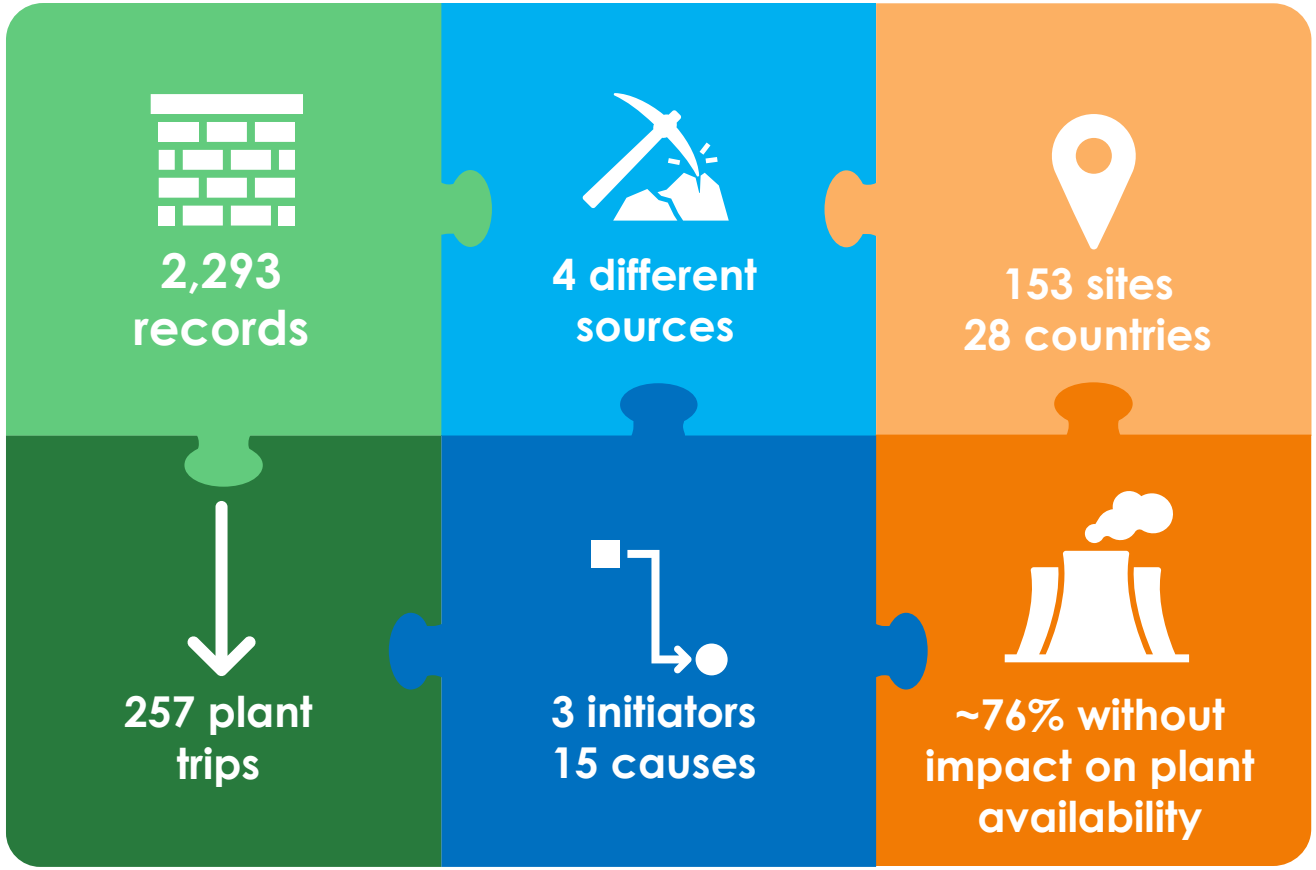
The Digital Project Experience Report is an Exclusive Member Benefit

Researching I&C Operational Data TODAY - 3002030408



- Targets Digital I&C events from multiple sources
- Produces a curated categorized Data Set of I&C events
- Provides analysis insights: Reasons, Impacts, Lessons

What does our 2024 data set Rev. B contain?



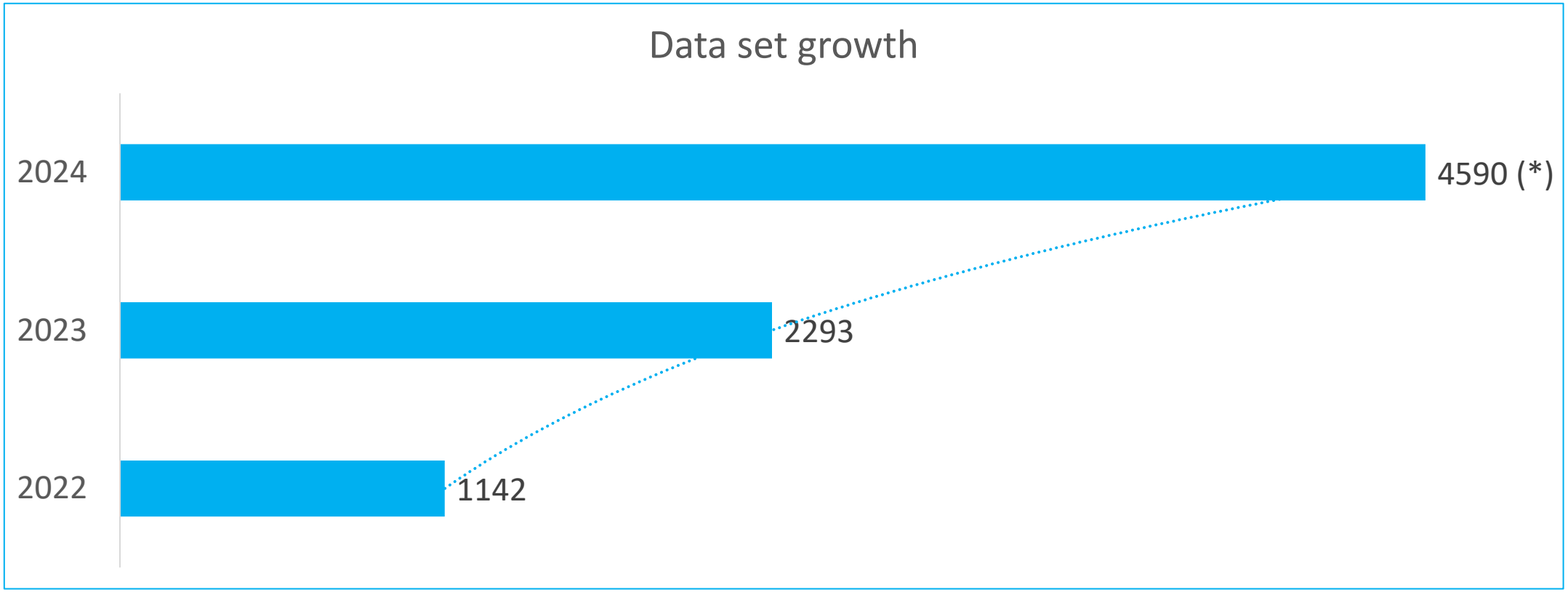
Our goal is to grow and give access to the data set to the industry

Topical learning areas

- Design and Requirements Management
  - Covers project scope development, system requirements traceability, and design considerations.
  - Emphasizes accurate requirements identification and configuration management.
- Testing and Validation
  - Includes software development and testing, failure modes and effects analyses (FMEA), and use of simulators or maintenance test systems.
  - Focuses on validating system behavior before deployment.
- Lifecycle and Maintenance
  - Addresses lifecycle management, digital recovery, software version control, and environmental considerations.
  - Managing aging components and system updates.
- Human and Organizational Factors
  - Encompasses human factors, training, division of responsibilities, and vendor reliance.
  - Stresses the role of clear procedures and cross-functional understanding.
- Operational Reliability and Risk Management
  - Involves operation, input sensors, broadcast storms, and handling of miscellaneous faults.
  - Supports proactive risk assessment and mitigation strategies.

Data set growth over the years

PRELIMINARY



(*) 2024 records review still in progress

Geographical Data Representation

PRELIMINARY

63%

America

17%

Europe

0.2%

Africa

19%

Asia

2025 data brings an increase on global experience

What have we learned so far – A data perspective

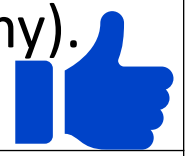
Each source of OE offers a particular perspective that might bias analyses. Reporting trends have been reducing every year.

Additional sources of Operational Data supplement and enable new use cases, increasing value allowing for statistical significance. This is required to inform risk-informed, performance-based methods.

All Operational Data sources need processing prior to analysis so that insights avoid anecdotal evidences produced by raw data feeds and data context and taxonomy are clear for the analyst.

Member access to curated, categorized data set will deliver a higher collective value

Why can we succeed with Generative-AI now?

Method	Available Materials
RAG: connect the language model to a knowledge base.	Relevant EPRI I&C research and current data set attributes and definitions (taxonomy). To generate vector database. 
Fine tuning: train an existing LLM on a domain-specific dataset, to better understand and generate text within that domain.	Available domain-specific SME validated data set for training and testing purposes. To fine tune a domain specific model. 
Prompt Engineering: crafting specific questions or prompts that guide the generic LLM to generate outputs tailored to the desired domain.	Utilization of report insights for effective prompting, workshops with members and SMEs to test and refine curated queries. 

Facilitate users' analysis of anonymous, curated and categorized data

ROADMAP - What have we done so far?

A path to data and tools, while delivering value from day 1 with yearly report updates

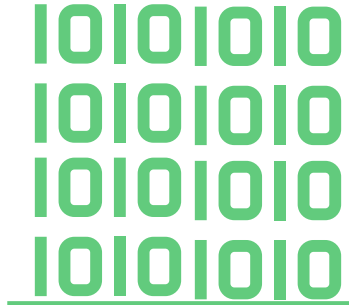
Current report
300203048

Updated report
October 31st, 2025

2023

New report coming up. Completes Baseline Data Set!

2025



2026

2027

Process ✓

Digital I&C specific data collection

1,400 events

Data Model ✓

Digital I&C specific data collection

2,300 events

Baseline Data Complete

Digital I&C specific data collection

~5,000 events

GenAI

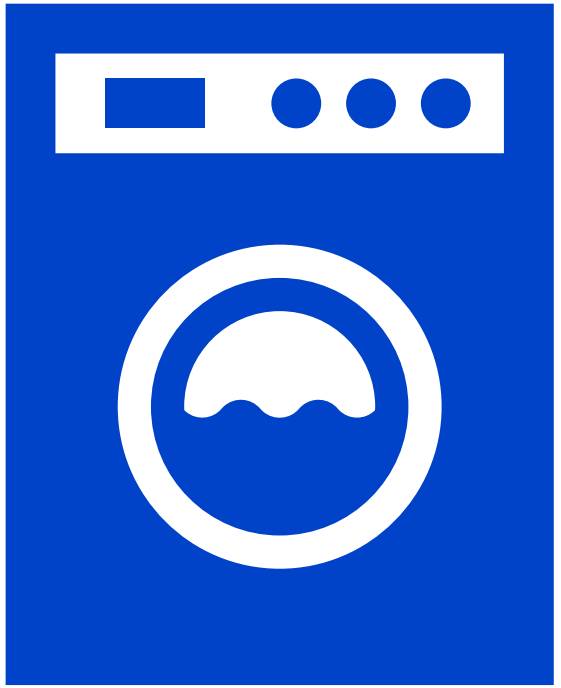
Development of data mining tools and anonymized data set access

Future

Consolidate and grow with other focusses

Expanding categorization (2025 and future)

- Systematic versus random causal factors
- Equipment Under Control (EUC) and plant function impacted
- Failures on demand
- Human errors: expand search, applying a critical eye, errors of cognition vs execution (HFE toolkit), data needed for HRA
- Single Point Vulnerabilities
- Plant condition, activity and events associated to plant evolutions
- Preventable OE
- Types of software faults
- Intervention types: can the fault be
  - DETECTED if it occurs and corrected before the undesired behavior develops
  - MITIGATED should the causal factor occur
  - PREVENTED by a design feature or administrative control
  - ELIMINATED by a design change



Here is a long list of additional insights that we want to work on

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