

# Generation and Management of Data inventory for Critical Sensitive Equipment in Nuclear Power Systems

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**Abstract.** The importance of creating thorough data inventories for critical and sensitive equipment within nuclear power systems is highlighted by the industry's stringent requirements for safety, reliability, and overall integrity. The need for such inventories arises from the significant risks and costs associated with even minor malfunctions, emphasizing the value of a comprehensive management strategy that includes every stage from acquisition to design, manufacturing, and upkeep. The intricate nature of the varied and dissimilar data involved calls for an advanced integration plan to ensure consistent performance in different operational contexts. This paper introduces a novel method designed to boost the quality, protection, and usefulness of data to support decision-making and foster innovation in nuclear power plants. By optimizing the way data is handled, this strategy greatly facilitates operational effectiveness, bolstering nuclear safety, and driving technological progress. This streamlined strategy highlights the essential merging of digital and industrial technologies to create a more secure and productive nuclear energy environment.

**Keywords:** data inventory, nuclear power systems, data resource management, digital transformation

## 1. Introduction

Within the digital evolution tide, data is considered the central component in facilitating business evolution in industries. Within energy sector, this development outlines an increasing demand: the skillful incorporation, detailed analysis, and tactical use of data assets. Namely, for nuclear energy, this shift goes beyond conventional limits, emphasizing the importance of detailed data inventories for equipment that is vital for both functioning and security. These inventories are essential not only for improving performance but also for ingraining a commitment to safety and dependability throughout the entire life cycle of nuclear power plants<sup>[1]</sup>.

The strict reliability demands of the nuclear industry emphasize this necessity: utilization of data in this field is within the scope of fundamental aspect of operational robustness. The industry's exacting criteria for accuracy, safeguarding, and adherence to regulations are shaped by the significant repercussions that can arise from the smallest of mistakes. Consequently, the meticulous oversight of data related to critical and sensitive equipment is established as a key

element, not only for preserving existing operations but also for enhancing the level of safety and dependability in nuclear power installations.<sup>[2]</sup>

Data has played a crucial role in the nuclear power generation industry, influencing various aspects of plant operation, safety, and efficiency, mostly in Operational Monitoring and Control, Predictive Maintenance, Safety and Regulatory Compliance. However, conventional methods for handling metadata limits the costs and effectiveness of data utilization. The nuclear sector requires systems that not only tackle the diversity and complexity of its systems but also conforms to the specific operational schedules and safety requirements that are intrinsic to nuclear operations. This calls for a more advanced strategy for cross-domain and cross-lifecycle data integration, one that integrates the detailed nature of the data with the practical demands of generating nuclear energy<sup>[3]</sup>.

## **2. Background analysis**

Data associated with an industrial equipment's life cycle management is crucial for ensuring efficiency, safety, and longevity of the equipment. This data encompasses a wide range of information that is collected, analyzed, and utilized throughout the various stages of the equipment's life cycle, from design and manufacturing to operation, maintenance, and eventual decommissioning or recycling <sup>[4]</sup>. This requires an effective method for the integration of data across various domain.

Data from different domains often have varying formats, standards, and structures, making it difficult to align and integrate them into a unified system. Different systems and platforms may use incompatible technologies, which can hinder the seamless exchange and integration of data. Such issues render the conventional generalized data management strategy insufficient for environments that require a more advanced treatment due to the heterogeneity and particularities of the data.<sup>[9][10]</sup> This shortfall signifies an immediate need for customized data inventory solutions that can address the intricate aspects of nuclear power systems, ensuring that all essential data is precisely obtained, efficiently administered, and flawlessly incorporated into the operational processes<sup>[5][11]</sup>.

Past safety incidents, such as the Fukushima Daiichi nuclear disaster, demonstrate the profound impact of data management on nuclear safety and crisis response<sup>[6]</sup>. In this scenario, the catastrophe has brought into sharp relief the severe consequences of disorganized and insufficient data systems when confronted with emergency. The event starkly reminds us of the urgency for resilient and all-encompassing data structures that are not only equipped to avert such crises but also to expedite effective emergency responses and recovery initiatives.

Addressing these issues, the development and application of a specialized data inventory tailored for nuclear facilities is essential. This effort seeks to methodically arrange, classify, and amalgamate data, creating a cohesive and structured system that underpins every aspect of nuclear power station management, ranging from standard upkeep to emergency handling. This deliberate shift towards advanced, domain-specific data governance is a vital measure for meeting the dynamic requirements of nuclear energy technology and safety.<sup>[7]</sup>

### 3. Solutions

We introduce an innovative solution centered around the development of a comprehensive data inventory, highlighted by end-to-end implementation methodology. It was created to address the widespread challenges of disjointed data, isolated professional domains, and absence of uniform standards, offering an organized and sequential technique that surpasses traditional data handling procedures.

In the core of this method is the precise integration of the data governance procedure with the full life cycle of nuclear power system elements, from conceptualization, acquisition to utilization and retirement. This life cycle-oriented viewpoint guarantees that data management is not a standalone operation but a crucial component of every phase of the equipment's existence, thus promoting preemptive choice-making, peril evaluation, and tactical planning.

Data inventory provides a consolidated platform that streamlines the gathering, merging, and oversight of information. By instituting uniform guidelines and a centralized regulatory system within this registry, we guarantee the consistency, protection, and dependability of data throughout the entire life cycle. This facilitates the smooth exchange and application of data, breaking down barriers and promoting an environment of cooperation and openness among diverse departments and specialists.

Moreover, the inventory emphasizes the capacity for expansion and flexibility, allowing it to adapt to business evolution, compliance demands, and technological progress. This adaptability ensures that the data management framework remains strong and efficient, supporting ongoing refinement and innovation in the nuclear power sector. By presenting a transparent and thorough overview of data at every phase of the equipment's life cycle, stakeholders can make better-informed choices, react more swiftly to potential incidents, and enhance upkeep and operational tactics. As a result, this strategy not only alleviates the inherent risks in nuclear energy production but also capitalizes on data as a strategic resource, improving the industry's digital evolution and contributing to the sustainable, secure, and efficient management of nuclear installations.

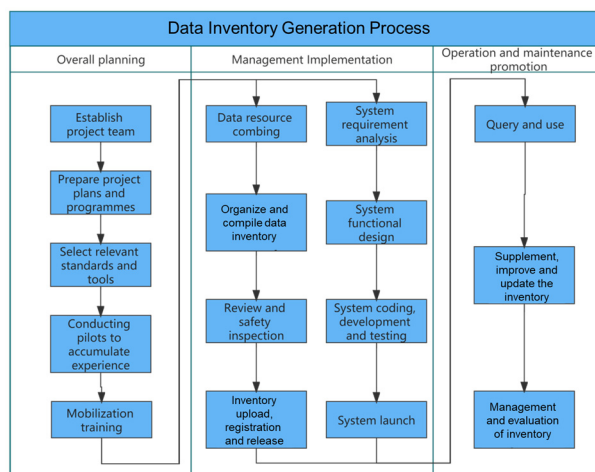


Figure 1 Schematic diagram of the overall workflow of the data inventory

### 3.1 Inventory construction overall process

The development of a data inventory for critical and sensitive equipment within nuclear power facilities is essential for the advancement and security of the energy sector. This section elaborates the methodology to construct a data inventory that encapsulates data integration, streamlined workflow, unified governance, open sharing, and efficient utilization, as shown in Figure 1:

**Overall Planning:** The preliminary step in developing the inventory requires overall planning. This includes grasping the demands of operations, pinpointing key, delicate machinery, and defining explicit goals for data management. Given the complexity of nuclear power structures, with their extensive parts and rigorous safety mandates, it's essential to thoroughly evaluate current data management policy and identify potential deficiency. This lays the groundwork for a solid data inventory by mapping out the breadth, magnitude, and anticipated results of the undertaking.

**Inventory and Classification:** At the heart of this approach is the systematic inventory of data assets. This involves the registration of information systems and operational workflows, the demarcation of operational fields, and the recognition of principal operational elements. In nuclear energy, there is a focus on vital and sensitive equipment like the cooling apparatus and safety controls. The inventory is divided into different layers, beginning with more generic categories, and specialized into sub-domains and coherent data elements, guaranteeing thorough inclusion and systematic arrangement.

**Domain Analysis:** Based on different specialties, data are divided into different domains that organized around pivotal operational spheres, including safety measures, reactor functions, waste disposal, and crisis management procedures, et al. By further analyze and breaking them down, it aids in gaining a profound comprehension of the inner workings of a nuclear power facility, which in turn allows for the pinpointing of essential data elements and their corresponding characteristics.

**Logical Data Entities and Attribute Specification:** A main component of the inventory is logical data element, which corresponds to distinct data points associated with business entities, such as machinery details, operational criteria, and safety criteria. Every element is outlined by a collection of properties, offering in-depth features and assessments crucial for overseeing a nuclear facility. This organized framework guarantees that data is captured with precision and systematically sorted for straightforward access and examination.

**Integration and Governance:** An essential aspect of the suggested approach is the consolidation of data from various systems and divisions. This promotes a cohesive perspective on operations, fostering teamwork and strategic decision-making. Also vital is the formulation of a governance structure that specifies data proprietorship, regulatory access, and quality benchmarks, key for preserving data authenticity and safeguarding it in a critical setting in nuclear power operations.

**Operational Maintenance and Continuous Improvement:** Following its establishment, the data inventory requires frequent upkeep and enhancements to maintain its pertinence and efficacy. This entails persistent oversight, feedback, and repetitive refinements to align with evolving legislative mandates, technological progress, and operational evolution. Moreover, the system

promotes educational and professional initiatives to guarantee that staff make the most of the inventory.

**Adapting to Regulatory Changes and Technological Innovations:** The domain of nuclear energy is governed by rigorous regulatory scrutiny and swift technological transformations. The data inventory must be capable of embracing modifications in safety statutes, assimilate emergent technologies like AI and IoT, and respond to fluctuations in energy legislation and commercial exigencies. This capacity for adaptation maintains the enduring feasibility and pertinence of the registry, bolstering the operational distinction and safety pledges of the nuclear power operations.

To sum up, the development of data inventory for critical and sensitive equipment within nuclear power operations is a complex endeavor that demands thorough preparation, in-depth scrutiny, and solid oversight. In following paragraphs, we describe essential aspects of the process in detail.

## **3.2 Data inventory construction**

### **3.2.1 Integrated planning**

The creation stage of a data inventory, specifically for essential and sensitive components of nuclear power facilities, is fundamental to guaranteeing operational security and productivity. This phase includes the following elements:

**Strategic Formulation:** This initial step establishes the basis for data inventory's development, which includes assembling specialized project teams, defining distinct roles, and devising meticulous, executable project plans. Teams are generally divided into leadership, expertise, and operational units to address the project's governance and implementation facets.

**Project Initiation:** This entails devising a structured plan that pinpoints current challenges in data resource administration, establishes explicit goals, duties, guiding principles, and methodologies for the project, in conjunction with schedules, milestones, and evaluative benchmarks.

**Standardization and Technological Adoption:** The process of recognizing and utilizing pertinent standards and technologies that correspond with the data cataloging prerequisites, such as metadata structures, categorization schemes, and distinct identifiers, is a vital aspect of this phase. This ensures the catalog's interoperability and effectiveness in diverse data contexts and utilizations.

**Prototyping and Feedback:** Executing trial initiatives to examine the cataloging methods and collect valuable information, which aids in honing the overarching strategy and operational blueprint based on empirical feedback.

**Education and Engagement:** Intensive educational and engagement programs are indispensable to provide all participating staff with the requisite understanding and competencies concerning data cataloging principles, technologies, and practices, securing the project's fruition and enduring viability.

### **3.2.2 Management implementation**

The execution phase is vital for the tangible progression and creation of the data inventory, especially in the context of the nuclear energy industry, where the focus is on key and delicate machinery. This stage adheres to the previously devised comprehensive strategy, furthering the construction of the data inventory. The principal activities include the arrangement of data assets, the assembly of the catalog, its scrutiny and validation, and the registration and dissemination.

**Assembly and Specification:** A project team is assembled, consisting of leaders, specialists, and operational personnel, in line with the tasks to be performed. This promotes distinct role allocation and guarantees a synergistic methodology for addressing the project's objectives.

**Strategy and Proposal:** This entails clarifying the project's value, pinpointing current data stewardship challenges, establishing well-defined targets, and mapping out the operational prerequisites. It involves meticulous planning for the project's phases, procedural steps, and timelines, as well as establishing criteria for assessment and endorsement.

**Standardization and Technological Instrumentation:** An essential aspect of this phase is the choice of suitable standards and instruments that meet the project's specifications, such as metadata frameworks and organizational tools. This guarantees that the project adheres to a consistent and sector-appropriate methodology.

**Testing and Feedback:** Prior to large-scale execution, prototype testing is carried out to identify the most efficient methods for organizing data and to adjust the overarching strategy based on practical experience.

**Education and Empowerment:** Thorough training ensures that all participants are proficient in the processes and instruments related to data organization, creating a knowledgeable and prepared team.

**Data Compilation:** Data findings are methodically formatted into organized layouts, such as matrices or diagrams, in accordance with theoretical operational and data frameworks.

**Verification and Security Check:** The data inventory is subjected to an exhaustive examination and security evaluation at multiple stages to guarantee precision and privacy, along with obtaining the required approvals and authorizations.

**Integration and Public Release:** Once the inventory system is complete, the content is uploaded, documented as per protocols, and officially made available.

### **3.2.3 Deployment and maintenance**

**Inquiry for Utilization:** Based on the defined access permissions, users seeking to access shared data can look up the necessary information via the inventory to grasp the fundamental details of the available shared data.

**Maintenance, Enhancement, and Updating:** As the inventory evolves over time, it is essential to continually augment the scope of the data resources it includes. The inventory should be promptly revised to reflect any organizational restructuring or business alterations. Individual departments responsible for the data should consistently refresh and preserve the data inventory disseminated by their unit.

Evaluation: This assessment can be conducted periodically or aligned with the advancement of specific projects or key project milestones; it can be carried out through self-evaluation or by engaging an external third-party for an objective review.

### 3.3 System implementation

In the execution phase, the establishment of a data inventory management system is initiated, guided by specifications identified during the initial steps. This process includes consolidation, streamlining, and mechanization of principal stages, workflows, operational data, and results, thereby creating a suite of complementary management tools. These tools are vital for subsequent large-scale organization and oversight of resources.

The conventional approach to data management by separate systems is facing increasing challenge in the digital transformation, and the demand for swift data retrieval across cohesive business operations. The diversity of database types used in various systems calls for the amalgamation of data from multiple database structures. To tackle these issues, the data inventory framework has introduced a wrapper interface that adheres to the SQL/MED standard<sup>[8][9]</sup>, which automatically translates among different database query languages, allowing for standard SQL syntax to access a variety of data types and metadata. Consequently, it offers a uniform access interface for cross-system data integration applications, facilitating cost-effective and efficient management of integrated data resources.

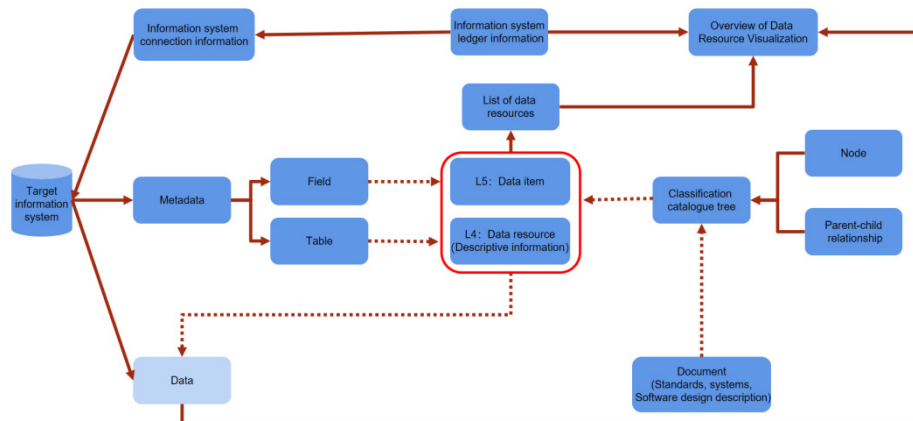


Figure 2 Data flow diagram of the data inventory system

The data inventory framework encompasses six principal modules, as shown in Figure 2, with the reverse analysis of data systems and the management of the data resource directory at its core. This utilizes metadata from target system information to map data ontologies to the data inventory, encompassing the management of information systems, maintaining traceability relationships between systems, the extraction of metadata, the analysis and presentation of metadata, and the binding of data resources. The software system architecture is illustrated in Figure 3. The management of the data resource directory primarily involves the oversight of data resources and the administration of naming directories. The former provides a visual representation of information across the entire lifecycle, while the latter presents the data

inventory results in a categorized tree structure, enabling the management of data resource queries and the mapping of data entities.

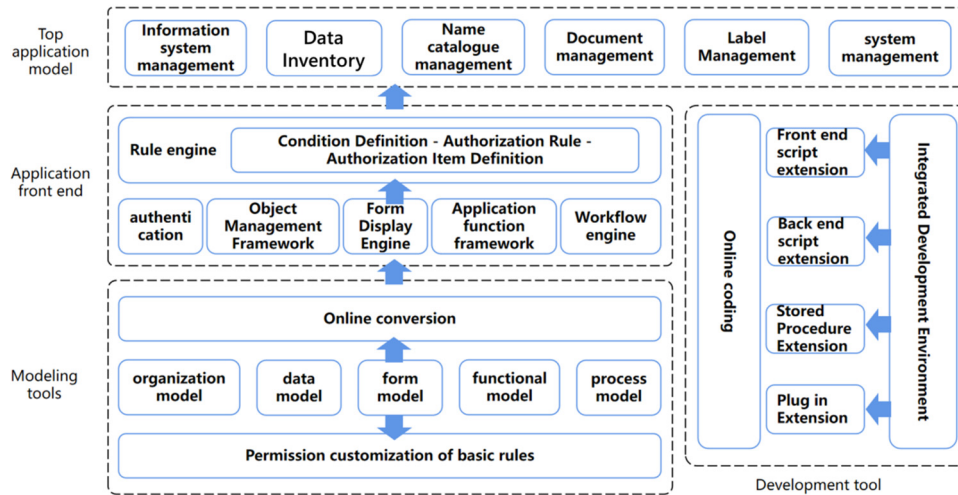


Figure 3 Data inventory system architecture

#### 4. Application Results

With this method, we have efficiently established data inventory for critical sensitive equipment in nuclear power operations. It covers principal fields such as main operations, surveillance, and safety. It includes two top level domains (operation administration and safety oversight), 227 Level 2 operational sectors focusing on key areas like reactors, motor, generator, pump, and cooling systems, 1358 Level 3 operational objects comprising various sensitive apparatus and routine procedures, 8627 Level 4 data elements, and 659,483 Level 5 data items, across over 50 different information systems. By rationally pools data assets dispersed across various information systems, we overcome the fragmentation caused by interdisciplinary and inter-department divides, fostering a cohesive system of logical data taxonomy, establishing a fundamental structure for integrated governance and oversight.

This transformation has replaced the conventional data inquiry models. Data inventory supports online access, empowers users to swiftly detect, pinpoint, and disseminate diverse data assets across different disciplines. This creates a novel model for unified data resource sharing and stewardship across the entire operational continuum.

Moreover, a pragmatic and scalable approach to data inventory generation and governance methodology was suggested, viable across the entire nuclear energy operations, supporting the operational model centered on "integrated presentation, continuous domain observation, and digital direction," promoting multi-dimensional, varied data resource amalgamation and communal utilization that traverses professions, systems, institutions, and hierarchical tiers within the nuclear power business chain. The requisite data encompasses various domains such as operations, safety tracking, environmental oversight, and decision-making analysis,



dispersed across a range of systems including operational management interfaces and digital surveillance platforms.

The utilization of the data inventory has facilitated comprehensive, precise, and punctual data aggregation for system development, boosting construction productivity and the precision of data. It has averted superfluous construction and the squandering of resources, standardizing data portrayal and sorting for straightforward navigation and recovery. Existing data assets can be instantly retrieved through the catalog, simplifying the prompt identification and rectification of any discrepancies or mistakes, thereby enhancing the data's precision, completeness, and the overall quality and efficiency of system development.

## **5. Summary and Conclusion**

In conclusion, this paper presents a method and example of improvement and the practical application of data inventory management solutions in the nuclear energy sector. The creation of a cohesive data service system, anchored by a unified and all-encompassing inventory, is essential for the streamlined registration, sharing, and alignment of data supply and demand. This system is key to promoting integrated data resource sharing and management throughout the nuclear industry, surpassing conventional information isolations and departmental boundaries.

By implementing lifecycle traceability and thorough analysis of data resources across the collection, derivation, and application stages, and utilizing data to connect upstream and downstream processes, this strategy breaks down professional barriers. This comprehensive approach enables an organized, efficient, and secure flow and sharing of internal data, optimizing the extraction of data's inherent value. The holistic management model presented here encompasses data throughout its entire lifecycle, ensuring that every stage, from inception to decommissioning, is meticulously documented, and integrated into the operational framework, enhancing transparency and accountability.

The value of the data inventory extends beyond mere organizational efficiency; it is crucial for unlocking data's potential, improving data quality, and encouraging extensive sharing and collaboration. By refining the quality of backend data analytics and driving the progression of data-informed enterprises, the catalog becomes a cornerstone in the broader narrative of data-driven decision-making and strategic planning.

Furthermore, this methodology lays a solid foundation for the identification of data assets and the transition into assets, signaling a new epoch in data governance and utilization. Specifically, in the context of nuclear power—where high stakes include critical safety and environmental concerns—the systematic cataloging and lifecycle management of data resources are essential strategies. They not only reduce risks and improve operational efficiency but also conform to the sector's stringent regulatory standards and safety protocols, setting a standard for future advancements in data governance and technological integration in nuclear power systems.

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