

# Structural Considerations for SMR Information Processing System Architecture

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## 1. Introduction

With the expansion of Small Modular Reactor (SMR) development, interest in integrated data processing structures for multi-module operational environments has increased. Unlike conventional single-unit information processing approaches, SMR environments require coordinated management of operational data generated from multiple modules. Accordingly, the structural role of the Information Processing System (IPS) has become an important architectural of consideration. IPS functions as a non-safety digital system that integrates and processes operational data across multiple modules, where architectural stability and consistency of information flow should be considered for long-term operation [1].

Meanwhile, rapid advancements in digital technologies present new challenges for nuclear system design. Compared to long design lifetimes of nuclear facilities, digital equipment lifecycles are relatively short, and vendor-dependent architectures may introduce risks such as component obsolescence and increased maintenance costs. Recent global SMR development trends emphasize interoperability and scalability, including scale-out architectures that allow system expansion without full redesign [2].

In addition, evolving cyber threats have led regulatory bodies to recommend Security-by-Design (SBD) approaches during early design phases [3]. Based on existing information processing system design experience, this study reviews structural characteristics required in SMR environments and summarizes key considerations for IPS architecture design.

## 2. Structural Considerations IPS Architecture

This section summarizes key structural aspects that may be considered in the architectural design of SMR Information Processing Systems (IPS). The elements presented here do not represent a specific design solution but rather focus on representative structural considerations for maintaining stable information flow in multi-module environments.

Rather than defining an exhaustive set of design factors, this study highlights several major structural aspects that are frequently discussed in SMR IPS

architectural considerations. The structural framework considered in this study is summarized in Table I.

Table I. Structural considerations for SMR IPS

Category	Structural Focus	Architectural Intent
Reliability & Availability	Redundancy, fault tolerance	Maintain continuous monitoring capability
Interoperability & Scale-out	Open interfaces, modular nodes	Enable flexible system expansion
Network QoS	Latency, jitter, bandwidth control	Stabilize multi-module information flow
Security-by-Design	Architectural security integration	Balance security and availability

### 2.1 Structural Considerations from Reliability and Availability Perspectives

SMR IPS continuously processes operational data from multiple reactor modules. Although it is a non-safety system, maintaining continuity of information flow is discussed as an important architectural aspect. Based on commonly referenced digital system design principles, structural approaches such as minimizing Single Points of Failure (SPoF) and considering redundancy of major resources may be addressed [4]. Furthermore, architectural consideration of error detection and recovery mechanisms across hardware and software domains may support availability in long-term operation environments.

In multi-module configurations, structural separation concepts may also be discussed to reduce the impact of localized failures on overall information flow, contributing to sustained operational visibility.

### 2.2 Structural Considerations for Interoperability and Scale-Out Capability

Considering rapid technological evolution and phased module deployment in SMRs, architectural flexibility that avoids dependency on specific vendors or technologies is increasingly discussed. International SMR development trends also highlight interoperability-oriented structures supporting platform independence and long-term maintainability [2].

Open interface-based integration may support future connectivity with analysis platforms, while node-based scale-out structures are discussed as an architectural approach to address increasing data processing demand. As data volumes grow in multi-module environments, limitations of centralized processing structures are often discussed, leading to consideration of distributed architectural approaches.

### *2.3 Information Processing Structure from Network QoS Perspective*

In multi-module environments, increasing data traffic makes Quality of Service (QoS) an important architectural consideration. Bandwidth management, latency minimization, and jitter control are commonly discussed elements in industrial communication networks to maintain reliable information processing.

Technologies such as IEEE 1588 PTP time synchronization and redundant network paths (e.g., HSR/PRP) are referenced as approaches for maintaining accurate sequence-of-event data. These QoS elements may be interpreted not only as network performance factors but also as structural considerations for preserving temporal consistency of information flow.

### *2.4 Structural Security Considerations Based on Security-by-Design*

Security-by-Design is increasingly emphasized as cybersecurity requirements evolve [3]. Rather than simply adding security features, this approach reflects architectural discussions on how data protection and access control concepts can be incorporated into system structures.

International standards such as IEC 62443 emphasize the balance between security and availability [5], and similar considerations are discussed in SMR environments to ensure that security mechanisms harmonize with continuous operational data flow. IPS may therefore be viewed as one of the architectural domains where structural cybersecurity considerations are relevant.

## **3. Conclusions**

This study reviewed key structural considerations for SMR IPS architecture in the context of evolving SMR development trends and technological environments. The discussion suggests that long-term reliability, interoperability and scalability, network QoS, and Security-by-Design are important structural considerations in SMR information processing system architecture. Rather than proposing a specific design solution, this paper aims to present technical perspectives that may support ongoing SMR IPS design discussions. The considerations discussed herein mainly reflect representative architectural viewpoints, while additional

design factors may be required depending on operational requirements, regulatory environments, and system configurations. Future work may focus on incorporating these structural considerations as key design elements within evolving SMR information processing system architectures.

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