

TXS COMPACT PLATFORM

ANP-10357NP-A
Revision 0

Topical Report

June 2026

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

June 10, 2026

Ms. Gayle Elliott, Director
Licensing and Regulatory Affairs
Framatome, Inc.
3315 Old Forest Road
Lynchburg, VA 24501

SUBJECT: FINAL SAFETY EVALUATION FOR FRAMATOME ANP-10357P, REVISION 0,
"TXS COMPACT PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)

Dear Ms. Elliott:

By letter dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A2809), and supplemented by letters dated June 30, July 22, July 30, August 14, 2025, and January 16, 2026 (ML25188A148, ML25203A339, ML25212A178, ML25226A233, and ML26020A270) respectively, Framatome, Inc. (Framatome) submitted Topical Report (TR) ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report," for U.S. Nuclear Regulatory Commission (NRC) staff review and approval. By letter dated April 30, 2026 (ML26078A375), an NRC draft safety evaluation (SE) regarding approval of ANP-10357P, Revision 0 (also referred to as "the TR"), was provided to Framatome for proprietary information review. By letter dated May 21, 2026 (ML26141A347), Framatome provided a response on its proprietary information review of the draft SE.

The NRC staff found that ANP-10357P, Revision 0, is acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for NRC acceptance of the TR.

The NRC acceptance applies only to material provided in the subject TR. The NRC does not intend to repeat its review of the acceptable material described in the TR. When the TR appears as a reference in licensing applications, the NRC review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant specific review in accordance with applicable NRC review standards.

NOTICE: The enclosure 1 to this letter contains Proprietary Information. When this letter is separated from the Enclosure 1, this letter is decontrolled.

In accordance with the guidance provided on the NRC website, we request that Framatome publish approved proprietary and non-proprietary versions of ANP-10357P, Revision 0, within two months of receipt of this letter. The approved versions shall incorporate this letter and the enclosed final SE after the title page. For non-proprietary versions, Framatome shall strike the proprietary information markings in this letter and make the appropriate redactions and adjustments to document security classifications to the enclosed SE. Also, they must contain historical review information, including the NRC request for additional information (RAI) questions and Framatome's responses. The approved versions shall include a "-A" (designating approved) following the TR identification symbol.

As an alternative to including the RAI questions and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved of those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAI questions:

1. The RAI questions and RAI responses can be included as an Appendix to the accepted version.
2. The RAI questions and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAI questions and RAI responses which resulted in any changes as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, Framatome will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing.

Sincerely,

/RA/

Damaris Marcano, Chief
Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 99902041
Project No. 728

Enclosure:

1. Final SE (Proprietary)
2. Final SE (Non-Proprietary)

SUBJECT: FINAL SAFETY EVALUATION FOR FRAMATOME ANP-10357P, REVISION 0,
"TXS COMPACT PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)
DATED JUNE 10, 2026

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FINAL SAFETY EVALUATION FOR
FRAMATOME INC. ANP-10357P, REVISION 0
TXS COMPACT PLATFORM TOPICAL REPORT
EPID L-2024-TOP-0029

June 10, 2026

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1.0 INTRODUCTION

By application dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), and supplemented by letters dated June 30, July 22, July 30 and August 14, 2025, and January 16, 2026 (Package ML25188A148, Package ML25203A339, Package ML25212A176, Package ML25226A233, and Package ML26020A269) respectively, Framatome, Inc. (Framatome) submitted Topical Report (TR) ANP-10357P, Revision 0, titled "TXS COMPACT Platform Topical Report" (Ref. 1, also referred to as the TR) for U.S. Nuclear Regulatory Commission (NRC) staff review and approval. Section 1.1 "Objective" of ANP-10357NP Revision 0 states:

This Topical Report describes attributes of the Framatome TELEPERM XS (TXS) COMPACT Field-Programmable Gate Array (FPGA) based Instrumentation and Control (I&C) platform for the purpose to obtain U.S. Nuclear Regulatory Commission (NRC) review and approval for use in nuclear power plant safety-related I&C applications. The generic TXS COMPACT FPGA based platform does not utilize microprocessors or software, but instead relies on a simple hardwired architecture. The safety system logic is implemented using qualified design tools and FPGA technology. The TXS COMPACT platform is designed and qualified by Framatome as a nuclear safety-related product.

The TXS COMPACT Platform was developed as part of the TELEPERM XS (TXS) family, which is designed for nuclear safety-related instrumentation and control (I&C) systems. The TXS COMPACT Platform is based on field-programmable gate array (FPGA) technology and offers some module options for use in safety-related I&C applications in nuclear power plants (NPPs). The original TXS platform is based on microprocessor technology and was reviewed and approved by the NRC staff in 2000 (Ref. 2).

By letter dated October 2, 2024 (ML24256A027), the NRC staff accepted TR ANP-10357P, Revision 0, for review. Additional documentation requested by the NRC staff to conduct its review of the TR was submitted by letters dated June 30, July 22, and August 14, 2025. From March 31 to April 4, 2025, the NRC staff conducted a regulatory audit to support its review of the TXS COMPACT Platform TR (Refs. 3 and 4). The NRC staff also conducted a second audit from January 5 to January 9, 2026 (Refs. 31 and 32).

2.0 REGULATORY EVALUATION

The TR included sections addressing compliance with various standards. For example, Section 8.0 addressed "TXS COMPACT QUALITY ASSURANCE (QA)." Section 11.0 "TXS COMPACT REGULATORY COMPLIANCE" addressed numerous specific standards including: Section 11.1 "TXS COMPACT Compliance to IEEE Std. 603-1991;" Section 11.2 "TXS COMPACT Compliance to NRC Regulatory Guide 1.152, Revision 4-2023 & IEEE Std. 7-4.3.2-2016;" Section 11.3 "TXS COMPACT Compliance to DI&C ISG [Interim Staff Guidance]-04 Revision 1, 2009;" Section 11.4 "TXS COMPACT Compliance to NRC Branch Technical Position (BTP) 7-14 Revision 6, 2016;" Section 11.5 "TXS COMPACT Compliance to NUREG 0800 Table 7-1 Criteria Revision 6, 2016;" Section 11.6 "TXS COMPACT Compliance to DI&C ISG-06 Licensing Process;" and Section 11.7 "Relationship Between TXS COMPACT Program Development in US NRC RG Criteria." As part of its review, the NRC staff assessed the assertions concerning meeting standards. ISG-06, "Digital Instrumentation and Controls

Licensing Process,” includes guidance on what information and documents that the NRC staff should use in the review of a licensee application for a digital upgrade and does not include additional regulatory guidance for a platform TR review. Therefore, the NRC staff used guidance below to perform its review.

NUREG-0800, “*Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*” (SRP), provides guidance for reviewing compliance with applicable sections of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, “Domestic Licensing of Production and Utilization Facilities.” Chapter 7, “Instrumentation and Controls,” of NUREG-0800, Revision 7 (August 2016), was used by the NRC staff to establish acceptance criteria for this review. SRP Chapter 7 addresses requirements for I&C systems in NPPs based on light-water reactor designs. SRP Chapter 7 provides the principal framework for reviewing digital I&C systems and platforms.

SRP Chapter 7, Table 7-1, “Regulatory Requirements, Acceptance Criteria, and Guidelines for I&C Systems Important to Safety,” identifies design criteria and regulations from 10 CFR Part 50 that apply to I&C systems and are relevant to assessing the suitability of a digital I&C platform for safety-related applications. Many SRP review criteria depend on the design of a complete system for a specific application. However, the subject TR addresses only the hardware elements and platform software development processes of the TXS COMPACT Platform, which can be applied in various safety-related I&C applications. Because no plant-specific application of the platform as a safety-related I&C system was provided with the TR, this safety evaluation (SE) is limited to assessing compliance with applicable regulations and guidance to the extent they can be satisfied at the platform level. Consequently, system-level requirements can only be partially evaluated generically based on the platform’s capabilities and characteristics.

The suitability of a digital I&C platform for use in safety-related I&C systems depend on several factors, including component quality, design process quality, equipment qualification (EQ), and system implementation characteristics such as real-time performance, independence, and support for online surveillance requirements. These characteristics must be demonstrated through verification, validation, and qualification activities as required in 10 CFR 50.54(h), GDCs 1, 2, and 4. Because the TXS COMPACT equipment is intended for use in safety-related I&C systems and applications, the TR was evaluated for compliance with the criteria in Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 603-1991, “IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations,” and SRP Chapter 7, Appendix 7.1-C, “Guidance for Evaluation of Conformance to IEEE Std. 603.”

SRP Chapter 7, Table 7-1, identifies Regulatory Guides (RGs), branch technical positions (BTPs), and industry standards that contain information, recommendations, and guidance and, in general, provide an acceptable basis to implement the above regulatory requirements for both hardware and software features of safety-related digital I&C systems. Based on the scope of the TXS COMPACT Platform TR and the limitations of a platform level review, the following guides and positions are determined to be relevant for consideration in this SE:

- RG 1.75, Revision 3, “Criteria for Independence of Electrical Safety Systems,” describes a method acceptable to the NRC staff for satisfying physical independence of the circuits and electrical equipment that comprise or are associated with safety systems.
- RG 1.100, Revision 4, “Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear

Power Plants,” describes a method acceptable to the NRC staff for satisfying the seismic qualification.

- RG 1.152, Revision 4, “Criteria for Programmable Digital Devices in Safety-related Systems of Nuclear Power Plants,” describes an approach that is acceptable to the NRC staff to meet regulatory requirements for promoting high functional reliability, design quality, and a secure development and operational environment (SDOE) for the use of programmable digital devices (PDDs) in the safety-related systems of nuclear power generating stations. This RG endorses, with some exceptions and clarifications, IEEE Std. 7-4.3.2-2016, “IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations.”
- RG 1.180, Revision 2, “Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems,” describes a method acceptable to the NRC staff for design, installation, and testing practices to address the effects of electromagnetic and radio-frequency interference (EMI/RFI) and power surges on safety-related I&C systems.
- RG 1.209, Revision 0, “Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants,” describes a method acceptable to the NRC staff for satisfying the environmental qualification of safety-related computer-based I&C systems for service in mild environments at NPPs.
- Electric Power Research Institute (EPRI) report TR-107330, “Generic Requirements Specification for Qualifying Commercially Available Programmable Logic Controllers (PLC) for Safety-Related Applications in Nuclear Power Plants,” which is endorsed in RG 1.209, Revision 0, and includes guidance on an acceptable method for addressing mild-environment qualification of programmable logic controllers.

The NRC staff also considered applicable portions of the BTPs in accordance with the review guidance established in SRP Chapter 7 and the requirements of 10 CFR 50.34, “Contents of Applications; Technical Information,” as follows:

- Appendix 7.1-C, “Guidance for Evaluation of Conformance to IEEE Std. 603”
- BTP 7-11, Revision 6, “Guidance on Application and Qualification of Isolation Devices”
- BTP 7-14, Revision 6, “Guidance on Software Reviews for Digital Computer-Based Instrumentation and Control Systems”

Determination of compliance with all applicable regulations remains subject to a plant-specific licensing review of a complete system design based on the TXS COMPACT Platform. Plant-Specific Action Items (PSAIs) have been established to identify criteria to be addressed by an applicant or licensee referring to this TR (see Section 6.0, “Limitations and Conditions,” of this SE). These criteria are intended to facilitate an applicant’s or licensee’s demonstration of compliance with the acceptance criteria in SRP Chapter 7, Table 7-1, and the regulations in 10 CFR Part 50 that were applicable at the time of the TXS COMPACT Platform review. The PSAIs identified in Section 6.0 of this SE do not relieve an applicant or licensee of its responsibility to address new or revised acceptance criteria or regulations that may apply in addition to those used in this SE.

At the time of the TR submittal, 10 CFR Part 53 was not issued. Therefore, the NRC staff did not evaluate compliance with Part 53 in this SE.

The following regulations are applicable to the TR (Ref. 1):

- 10 CFR 50.54, "Conditions of licenses," provides, with certain exceptions, conditions in every nuclear power reactor operating license issued under 10 CFR Part 50. Similarly, 10 CFR 50.54 provides, with certain exceptions, conditions in every combined license issued under 10 CFR are only applicable after the Commission makes the finding under 10 CFR 52.103(g). Per 10 CFR 50.54(jj), "Structures, systems, and components subject to the codes and standards in 10 CFR 50.55a must be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed."
- 10 CFR 50.55 "Conditions of construction permits, early site permits, combined licenses, and manufacturing licenses," states in part that each manufacturing license is subject to the terms and conditions in 10 CFR 50.55(i) and the applicable requirements of 10 CFR 50.55a; and each combined license is subject to the terms and conditions in 10 CFR 50.55(i) and the applicable requirements of 10 CFR 50.55a until the date that the Commission makes the finding under 10 CFR 52.103(g). In turn, 10 CFR 50.55(i), states: "Structures, systems, and components subject to the codes and standards in 10 CFR 50.55a must be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed."
- 10 CFR 50.55a(h) provides requirements for protection systems of nuclear power reactors of all types, and conditions for each combined license for a utilization facility. 10 CFR 50.55a(h)(2), "Protection systems," states that, for nuclear power plants with construction permits issued after January 1, 1971, but before May 13, 1999, protection systems must meet the requirements in IEEE Std. 279-1968, "Proposed IEEE Criteria for Nuclear Power Plant Protection Systems," or the requirements in IEEE Std. 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations," or the requirements in IEEE Std. 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995. For nuclear power plants with construction permits issued before January 1, 1971, protection systems must be consistent with their licensing basis or may meet the requirements of IEEE Std. 603-1991, and the correction sheet dated January 30, 1995. 10 CFR 50.55a(h)(3), "Safety systems," requires that applications filed on or after May 13, 1999, for construction permits and operating licenses under this part, and for design approvals, design certifications, and combined licenses under Part 52 of this chapter, must meet the requirements for safety systems in IEEE Std. 603-1991 and the correction sheet dated January 30, 1995.
- 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants"
 - General Design Criterion (GDC) 1, "Quality standards and records"
 - GDC 2, "Design bases for protection against natural phenomena"
 - GDC 4, "Environmental and dynamic effects design bases"

- 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants”

3.0 BACKGROUND AND SYSTEM DESCRIPTION

The following subsections identify and describe the components and features of the TXS COMPACT Platform, which are evaluated along with its development processes in Section 4.0, “Technical Evaluation,” of this SE against the regulatory evaluation criteria identified in Section 2.0 of this SE.

3.1 System Background

Many installed I&C systems for safety-related applications in U.S. NPPs are based on analog technology and face obsolescence challenges. These systems are often not well supported by original equipment manufacturers and suppliers. The TXS COMPACT Platform addresses these challenges by utilizing FPGA-based digital technology.

The TXS COMPACT Platform was developed as part of the TXS family for safety-related I&C applications in NPPs. This FPGA-based platform could be integrated with various modules from the TXS portfolio to implement safety-related I&C systems.

3.2 System Description

Section 2.0, “TXS COMPACT Technical Description,” of the TR, as supplemented, includes the technical description of the TXS COMPACT Platform.

The TXS COMPACT Platform is an FPGA-based system that does not utilize microprocessors during operation. Instead, it relies on a simple design where safety system logic is implemented using qualified design tools and FPGA technology.

The TXS COMPACT Platform-based I&C systems consist of two main elements: generic configware and application-specific logic.

- Generic configware includes prequalified components that provide core functionality.
- Application-specific logic is engineered using graphical tools and function block diagrams to implement project-specific I&C functions.

Using TXS COMPACT engineering tools, I&C functions are developed graphically by selecting and connecting pre-developed function blocks from a pre-developed library. The TXS COMPACT Platform design emphasizes modularity, deterministic execution, and fault tolerance through integrated self-monitoring and error-handling mechanisms.

Since the TXS COMPACT Platform was developed as part of the TXS family, the scope of this SE is limited to the components listed in Table 3.2-1, “TXS COMPACT Platform Components,” which are included in the TR. An applicant or licensee that references the TXS COMPACT TR with different module model and version numbers from those listed in Table 3.2-1 must address PSAI 6.1.1 in Section 6.0 of this SE.

Table 3.2-1: TXS COMPACT Platform Components

Component Name	Model Number	Version	Notes
Processing Module	PM1	V01	Safety-related
Multi-Purpose Input/Output (I/O) Module	MPIOF1	V02	Safety-related
Service, Maintenance, and Diagnosis Module	SMDF1	V01	Not-safety related
Gateway Module	GWF1	V01	Safety-related
Backplane	BPF1	V01	Safety-related

The TXS COMPACT modules - PM1, MPIOF1, SMDF1, and GWF1 - are plug-in modules designed for installation in chassis equipped with the BPF1 backplane. The scope of this SE does not include related cabinets, chassis, power supplies, or other peripheral devices.

The TXS COMPACT Platform-based I&C system consists of one or more automation units (AUs) interconnected via point-to-point optical fibers. Each AU includes a main rack and up to three expansion racks to increase its I/O capacity. The AU executes application functions and handles signal I/O and processing. The main rack is a chassis housing the primary PM1 module along with other modules, and it performs safety I&C functions for the AU. A service unit (SU) is a computer equipped with TXS COMPACT Platform service tools. Although the SU is outside the scope of this TXS COMPACT Platform TR, it is used to configure and monitor the AUs.

The design features and characteristics of the TXS COMPACT Platform components are summarized in Section 3.2.1, “TXS COMPACT Standard Modules,” and its detailed technical evaluation is provided in Section 4.0.

3.2.1 TXS COMPACT Standard Modules

Section 2.2, “TXS COMPACT Standard Modules,” of the TR, as supplemented, includes the technical description of the TXS COMPACT Platform’s standard modules.

The TXS COMPACT Platform consists of four standard modules installed in a 3U/19-inch chassis with an integrated BPF1 backplane for power distribution and internal communication. Each module connects to the BPF1 backplane via a 64-pin male connector, which provides power and enables communication among modules.

- PM1 Processing Module:
The PM1 module is based on an **[[** FPGA and executes logic described in a hardware description language (HDL) program. Its primary functions include reading and executing the I&C application program and performing self-supervision. PM1 provides a fixed library of 87 pre-developed function block types that could be configured to implement safety-related I&C functions. The application executes cyclically, with cycle times configurable between 4 milliseconds (ms) and 2002 ms, depending on project requirements and application size.

- MPIOF1 Multi-Purpose I/O Module:
The MPIOF1 module uses an [[]] FPGA and interfaces the TXS COMPACT Platform with field signals, providing isolation and self-monitoring features. It provides two analog current inputs, two analog current outputs, four binary signal inputs, four binary signal outputs, one input for counting transistor-to-transistor logic (TTL) pulse signals, and two 24 volts (V) sensor power supply outputs. They are organized into four independent I/O channel groups where the counter input is incorporated in analog channel group. During STARTUP mode, PM1 configures MPIOF1. The module acquires binary and analog input signals, digitizes them, and receives output values from PM1 to convert into electrical signals for transmission to output pins.
- GWF1 Gateway Module:
The GWF1 module, based on an [[]] FPGA, provides communication between a TXS COMPACT Platform-based AU and the TXS Ethernet network. During start-up, PM1 transfers module-specific parameterization data to GWF1, which stores it in internal FPGA memory. This ensures GWF1 exchanges only those signals required for the engineered functionality of the AU.
- SMDF1 Service Module:
The SMDF1 module, also based on an [[]] FPGA, connects the AU to the SU for system configuration and maintenance. Its functions include loading new application programs or parameters under controlled conditions, monitoring AU status, forwarding signal values to the SU, and retrieving system event logs.
[[]]. SMDF1 does not process safety-related I&C functions and is classified as non-safety-related.
- BPF1 Backplane:
The BPF1 backplane provides internal communication between modules within the AU and distributes the 24 volts direct-current (VDC) power supply.

3.2.2 TXS COMPACT Operation Principles

Section 2.3, “TXS COMPACT Operation Principles,” of the TR, as supplemented, includes the technical description of the TXS COMPACT Platform’s operating principles.

The TXS COMPACT Platform does not include a central processing unit or microcontroller in its processing path. Instead, it relies on dedicated logic implemented within the FPGA, enabling execution of any developed application program. The FPGA configware is generically predeveloped for safety applications as part of the TXS COMPACT product development process.

The platform operates on FPGA logic without interrupts or real-time clocks, ensuring predictable performance. Processing is executed in a fixed cyclic sequence with defined acquisition and output phases, guaranteeing consistent input data for each cycle. Memory allocation is static, and execution times are constant, allowing precise calculation of response times. Safety principles include strict separation of system and application logic, use of predeveloped configware, and comprehensive self-monitoring.

3.2.3 TXS COMPACT Internal Communications

Section 2.4 of the TR, “TXS COMPACT Internal Communications,” as supplemented (ML25212A176), describes in detail the internal communications of the TXS COMPACT Platform.

The TXS COMPACT Platform employs dedicated internal communication networks for specific functions:

- Service Network: Using the SMDF1 module, the platform can receive service commands and transmit monitoring and diagnostic information to/from the SU via a dedicated service network. This connection uses a copper RJ45 Ethernet link or optical fiber when electrical isolation is required.
- Processing Network: Through PM1 modules, the AU exchanges data with other AUs over point-to-point optical links. Each frame within this network includes signal validity information, ensuring integrity of transmitted data.
- I/O Synchronization: [[

]].
- Gateway Network: The GWF1 module enables Ethernet-based data exchange between the TXS COMPACT Platform and external systems or devices.

3.2.4 TXS COMPACT Modes of Operation

Section 2.5, “TXS COMPACT Modes of Operation,” of the TR, as supplemented, includes the technical description of the TXS COMPACT Platform’s modes of operation.

The TXS COMPACT Platform ensures undisturbed operation of the AU by protecting the chassis from external influences and failures of interfacing components during the processing of I&C safety functions. This is achieved through predefined operating modes implemented in the processing module.

The platform supports multiple operating modes to maintain safety during normal operation and maintenance. These modes include:

- STARTUP: The initial mode after the main PM1 configware has been successfully deserialized into the FPGA’s internal memory and taken control.
- FACTORY: Activated when no valid application program is available. The AU automatically returns to STARTUP mode once a new application program is received from the SU and successfully loaded.
- OPERATION: The normal operating mode in which the AU can access I/O modules, exchange signal data with other AUs, and execute I&C safety functions.

- WAITSTATE: Entered `[[ ]]` from OPERATION mode when `[[ ]]`. The AU remains in WAITSTATE until a valid service command instructs a transition to service mode.
- MAINTENANCE: Accessible only from WAITSTATE upon receiving a MAINTENANCE service command. Used for maintenance activities.
- DIAGNOSIS: Allows modification of input signal values in function blocks. The AU can switch to DIAGNOSIS mode only from WAITSTATE upon receiving a DIAGNOSIS service command.
- COMMISSIONING: Similar to DIAGNOSIS mode but outputs are not inhibited. Intended for electrical continuity testing or periodic testing of signal conditioning modules, provided actuation paths are secured.
- ERRORSTOP: Entered from any mode if a fatal error occurs. In ERRORSTOP, the main PM1 halts application program processing and stops sending network messages.

The operating modes described above are organized into the following three distinct categories:

- Normal Mode: OPERATION ensures safe execution of I&C functions.
- Service Modes: MAINTENANCE, DIAGNOSIS, and COMMISSIONING allow controlled operator interaction via the SU.
- Transitional Modes: STARTUP, FACTORY, WAITSTATE, and ERRORSTOP ensure safe state changes.

Transitions between modes occur automatically based on system conditions or manually via SU commands. Manual transitions are restricted `[[ ]]` to maintain safety integrity.

3.2.5 TXS COMPACT Cabinet and Peripherals

Section 2.6, “TXS COMPACT Cabinet and Peripherals,” of the TR, as supplemented, includes the technical description of the TXS COMPACT Platform’s cabinet and peripherals.

The TXS COMPACT Platform AUs can be deployed in various scenarios: as a partial upgrade to an existing I&C installation, a full replacement of an existing I&C system, or a part of a new I&C installation.

This review does not cover specific cabinets or peripherals which are outside the scope of this TR. The application strategy for a TXS COMPACT-based solution will determine whether existing cabinets can be reused or if new cabinets are required.

Typically, I&C applications require the AUs to be housed in a cabinet along with supporting peripherals. The selection and arrangement of these peripherals within the cabinet are application-specific and depend on the overall system design.

3.2.6 TXS COMPACT Response Time and Accuracy

Section 2.7, “TXS COMPACT Response Time,” and Section 2.8, “TXS COMPACT Accuracy,” of the TR, as supplemented, includes the technical description of the TXS COMPACT Platform’s subject information.

The TXS COMPACT AU is designed based on fully deterministic static response time without any interrupts. The total response time for TXS COMPACT Platform-based applications can be calculated in advance as the sum of the following three components: input acquisition, automatic processing, and output propagation. The contribution of signal conditioning, decoupling, and routing modules to the overall response time depends on the specific configuration of each I&C system.

As described in PSAI 6.1.4 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must perform a system level evaluation of the response time to demonstrate that response time performance satisfies application specific requirements established in the plant specific safety analysis report.

The accuracy of the TXS COMPACT Platform AU is primarily influenced by the analog channels in the I/O modules, which perform conversion between analog and digital signals. These channels use [[]] to ensure high resolution. Additionally, the PM1 module employs double-precision floating-point calculations to minimize computational errors. Uncertainties introduced by the computation inside the logic of the function blocks are uncorrelated with each other, independent from uncertainties in the signal acquisition chain, and independent from environmental factors. These design features deliver high accuracy for safety-critical applications.

3.2.7 TXS COMPACT Human Factors Considerations

Section 2.9, “TXS COMPACT Human Factors Considerations,” of the TR, as supplemented, includes the technical description of the TXS COMPACT Platform’s human factors considerations.

Human factors are considered throughout the development process of the TXS COMPACT Platform, including features such as a simplified system architecture, standardized I&C design, intuitive system interface, self-supervision with alarming, and ease of maintenance.

TXS COMPACT Platform human factors related to defining manual functions and associated control room indications to support operator tasks are not addressed in the TR. Such human factors engineering considerations for the TXS COMPACT Platform-based safety-related I&C system are application-specific and therefore outside the scope of this review.

4.0 TECHNICAL EVALUATION

The following subsections evaluate the TXS COMPACT Platform and its development processes against the regulatory evaluation criteria identified in Section 2.0 of this SE.

4.1 Equipment Qualification

The objective of EQ for safety-related equipment is to minimize the potential for common cause failures (CCF) due to environmental conditions, electromagnetic compatibility (EMC), seismic events, and Class 1E (safety-related) to non-Class 1E (non-safety related) isolation effects. EQ also demonstrates that safety-related equipment can perform its designated safety functions during and after a design basis event.

This section addresses hardware qualification for the TXS COMPACT Platform. Software quality and qualification for the TXS COMPACT Platform are evaluated in Sections 4.3, "Life Cycle Management," and 4.6, "Quality Assurance and Training," of this SE.

The EQ evaluation in this section covers environmental (climatic), EMC, seismic, and Class 1E to non-Class 1E isolation qualifications for the TXS COMPACT Platform components listed in Table 3.2-1 of this SE. Applicants or licensees that reference the TXS COMPACT Platform TR for plant-specific safety-related applications must verify whether these evaluated components are used. Any revised or newly developed components for plant-specific applications must undergo qualification (see Section 6.0 of this SE).

EQ ensures that the TXS COMPACT-based safety I&C system meets design and performance requirements under normal and adverse environmental conditions at its installation location. The EQ presented in the TR and supplemental documents was performed for generic conditions. Therefore, applicants or licensees must confirm that site-specific conditions are enveloped by these generic conditions. If not, project-specific qualification is required for the TXS COMPACT components evaluated in this SE (see PSAI 6.1.3 in Section 6.1 of this SE).

The TXS COMPACT Platform is intended for safety I&C systems in NPPs with various reactor technologies and in many countries with different regulatory requirements. So, generic EQs were initially performed primarily through type testing, supplemented by analysis per relevant International Electrotechnical Commission (IEC) and other international nuclear standards on qualification.

To meet NRC regulatory requirements, [[

]] (Refs. 6 and 7).

The NRC staff reviewed both the generic and supplemental EQ for the TXS COMPACT Platform components as listed in Table 3.2-1 against NRC regulatory requirements in Clause 4, "Safety System Designation," Subclauses 4.7 and 4.8, and Clause 5.4, "Equipment Qualification," of IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," the associated guidance of IEEE Std. 7-4.3.2-2016. The NRC staff also evaluated whether the TXS COMPACT Platform EQ meets NRC regulatory requirements in GDCs 2 and 4. The regulatory guidance the NRC staff used for the evaluation on EQ includes RG 1.75, RG 1.100, RG 1.180, RG 1.209, and EPRI TR-107330.

The regulation at 10 CFR 50.49, "Environmental qualification of electric equipment important to safety for nuclear power plants," addresses environmental qualification of electric equipment

important to safety. However, per 10 CFR 50.49(c), requirements for seismic qualification, protection against natural phenomena, and qualification in mild environments are excluded. The TXS COMPACT Platform is intended for mild environments - conditions are no more severe than normal plant operation, including anticipated operational occurrences. Therefore, 10 CFR 50.49 does not apply to the EQ of the TXS COMPACT equipment.

TXS COMPACT equipment is designed for normal operating conditions with radiation dose rate [

]. EPRI TR-107330 requires I&C equipment to operate within 10^3 RADS. Since TXS COMPACT equipment meets these criteria, radiation qualification was deemed unnecessary for mild environments. For installations outside mild environments (see PSAI 6.1.3 in Section 6.1 of this SE).

Although the SMDF1 module listed in Table 3.2-1 is non-safety-related, its hardware is classified for use in safety-related systems. To confirm no impact on safety functions, SMDF1 was integrated into the EQ tests (environmental, EMC, seismic). Class 1E to non-Class 1E isolation for SMDF1 is specifically evaluated in Section 4.1.4, "Class 1E to Non-Class 1E Isolation Capability," of this SE.

The NRC staff found that the applicant performed its generic EQ for the TXS COMPACT equipment according to its test plan and specification (Refs. 8-13) via type testing with additional analysis. Framatome's qualification testing plan links to its specifications and details test cases for TXS COMPACT modules. Supplemental EQ followed a separate test plan and specifications to meet NRC regulatory guidance (Refs. 6 and 7). The NRC staff reviewed these plans and specifications and found adequate documentation of test specimens, setup, and procedures for performing the TXS COMPACT equipment hardware qualification. Specific evaluations of environmental, EMC, seismic, and Class 1E to non-Class 1E isolation qualifications are provided below.

4.1.1 Environmental Qualification

To demonstrate fault-free operation under generic environmental conditions, the TXS COMPACT Platform equipment underwent environmental qualification testing in accordance with IEC 60068 and other international standards. These standards require multiple test cases to verify equipment performance under specified conditions. The NRC staff evaluated both the generic and supplemental environmental qualifications using regulatory guidance in RG 1.209, Revision 0, and EPRI TR-107330, which was accepted by the NRC in a safety evaluation report (SER) by letter dated July 30, 1998.

The NRC staff reviewed the generic environmental qualification summary results, audited detailed test records, and confirmed that all required test cases were successfully completed without incorrect or unintended states for the equipment under test (EUT). Initial and final functional tests were performed at the minimum and maximum permissible ambient temperatures of [, respectively. No loss of monitoring function occurred during environmental qualification testing.

For the generic environmental qualification test cases for both long term and cyclic operations, which are used to demonstrate long-term stability over 1000 hours while applying thermal stress into the electronic and mechanical components of the TXS COMPACT equipment, the NRC staff noted that the TXS COMPACT modules were tested at [

operation.]] to demonstrate its

However, these testing profiles differ from those illustrated in Figure 4-4 of EPRI TR-107330, which specifies the testing at 60°C (140 degrees-Fahrenheit (°F)) for at least 48 hours at 90 percent relative humidity (RH) and then followed by +4°C (39.2°F) for a minimum of 8 hours at 5 percent RH. EPRI TR-107330, endorsed with clarifications in RG 1.209, Revision 0, establishes these conditions for environmental qualification of safety-related I&C equipment.

The generic TXS COMPACT EQ program did not include any test for ambient temperature below 5°C (41°F) for at least 8 hours and RH of 90 percent at 60°C (140°F) for at least 8 hours. To address these gaps and comply with NRC regulatory guidance, Framatome developed a supplemental test plan and specification and conducted additional testing on the same setup (Refs. 6 and 7). The NRC staff reviewed and audited these supplemental test results which show no incorrect/unintended states and no occurrence of faults (Ref. 23). Therefore, the NRC staff confirms that the supplemental environmental qualification tests meet the criteria in RG 1.209 and EPRI TR-107330 for environmental qualifications.

4.1.2 EMC Qualification

The generic EMC qualification for the TXS COMPACT Platform was performed in accordance with IEC 62003:2020, "Nuclear power plants – Instrumentation, control and electrical power systems – Requirements for electromagnetic compatibility testing," which references the IEC 61000 series standards for EMC testing.

During EMC qualification testing, modules were installed inside the chassis, and no credit was taken for electromagnetic attenuation provided by the TXS cabinet or other enclosures. The EMC qualification performed includes:

- EMI/RFI conducted and radiated emissions
- EMI/RFI conducted and radiated susceptibility
- Power surge susceptibility
- Electrical fast transient/burst susceptibility
- Electrostatic discharge (ESD) withstand capability

The NRC staff used relevant regulatory guidance in RG 1.180, Revision 2, to evaluate both the generic and supplemental EMC qualification for the TXS COMPACT equipment listed in Table 3.2-1 of this SE.

EMI/RFI Emissions – Conducted and Radiated

For the generic qualification on conducted emissions, the TXS COMPACT equipment was tested for compliance with permissible limits on I/O DC power ports across the following required frequency ranges:

Frequency Range	Test Level (decibels (db) $\mu\text{V/m}$)
150 kHz to 500 kHz	≤ 79 quasi-peak
500 kHz to 30 MHz	≤ 73 quasi-peak

[[

]].

For the generic qualification on radiated emissions, the TXS COMPACT equipment was tested for the frequency ranges and at the test levels listed below:

Frequency Range	Test Level (db $\mu\text{V/m}$)
30 MHz to 230 MHz	40 quasi-peak @10 m
230 MHz to 1 GHz	47 quasi-peak @10 m
1 GHz to 3 GHz	76 peak @ 3 m
3 GHz to 6 GHz	80 peak @ 3 m

The NRC staff reviewed these testing results which show compliance with acceptance criteria and hence confirmed compliance with relevant regulatory guidance in RG 1.180 for EMI/RFI conducted and radiated emissions.

EMI/RFI Susceptibility – Conducted

Framatome performed the following generic susceptibility qualification tests:

- Susceptibility conducted from DC power leads at low frequency of 0 hertz (Hz) to 150 kilo(k)Hz to show immunity of the TXS COMPACT equipment against conducted common mode disturbances on the I/O DC power port, and immunity against conducted common mode disturbances at main frequencies on the I/O DC power port.
- Susceptibility conducted from disturbances induced by radio frequency (RF) fields of 150 kHz to 80 mega (M)Hz at power leads to demonstrate immunity of the TXS COMPACT equipment against conducted disturbances induced by RF fields on the I/O DC power port.
- Susceptibility conducted from electrically fast transients/bursts on signal leads to show immunity of the TXS COMPACT equipment against electrical fast transients (burst) on the signal ports, and immunity against electrical fast transients (burst) on the I/O DC power ports.
- Susceptibility conducted from surges on signal leads to demonstrate immunity of the TXS COMPACT equipment against surge disturbances on the signal ports.
- Susceptibility conducted from disturbances induced by RF fields of 150 kHz to 80 MHz at signal leads to show immunity of the TXS COMPACT equipment against conducted disturbances induced by RF fields on the signal ports.

- Susceptibility conducted from 100 kHz ring wave to demonstrate immunity of the TXS COMPACT equipment against ring wave disturbances on the I/O DC power port, and immunity against ring wave disturbances on the signal ports.
- Susceptibility conducted from signal leads at low frequency of 0 Hz to 150 kHz to show immunity of the TXS COMPACT equipment against conducted common mode disturbances on the signal ports, and immunity against conducted common mode disturbances at mains frequencies on the signal ports.

The NRC staff reviewed and audited these testing results (Refs. 14-24) and confirmed that all tests were successfully completed and the TXS COMPACT equipment continued to operate as intended during and after testing. The NRC staff confirmed those tests met regulatory guidance in RG 1.180, Revision 2, for conducted susceptibility qualification tests for safety-related I&C equipment.

However, the NRC staff found that the generic susceptibility qualification for the TXS COMPACT equipment did not include the test for the AC power lead susceptibility as required in RG 1.180, Revision 2. The NRC staff determined that this deviation is acceptable because this test is only applicable to AC power ports, and the TXS COMPACT equipment uses 24 VDC power.

The NRC staff also found that the qualification test for the surge susceptibility on signal leads was tested at 1 kV instead of the required 2 kV per RG 1.180 because the TXS COMPACT equipment was designed to withstand a surge level of 1kV on the signal leads. So, project-specific applications requiring 2 kV immunity must implement substitute measures (see PSAI 6.1.3 in Section 6.1 of this SE).

EMI/RFI Susceptibility – Radiated

RG 1.180 requires radiated susceptibility tests for electric field (26 MHz – 6 GHz), magnetic field at 60 Hz, 60 Hz – 50 kHz, and 100 kHz – 1 MHz.

For the generic EQ for the TXS COMPACT equipment, Framatome performed the electric field susceptibility test and met acceptance criteria. [[

]]. To demonstrate compliance, Framatome planned and conducted supplemental magnetic field tests after TR submission. The NRC staff reviewed and audited these testing results which show immunity to magnetic field effects for the TXS COMPACT equipment.

Electrostatic Discharge Susceptibility

For EMC qualification, RG 1.180, Revision 2, requires performing qualification tests on susceptibility to ESD with test levels at 8 kV for direct contact discharge and 15 kV for indirect air discharge.

The generic EQ tests for the TXS COMPACT equipment were performed at [[

]]. The NRC staff reviewed and audited the supplemental testing results and confirmed compliance with criteria in RG 1.180 for the ESD withstand capability.

Surge Withstand Capability

RG 1.180 requires surge withstand tests for ring wave at 100 kHz and electrical fast transients on AC power lines. These tests were not performed for the generic EQ for the TXS COMPACT equipment. The NRC staff found this acceptable because the required tests are applicable for the AC power ports, but the TXS COMPACT equipment uses 24 VDC power.

The NRC staff reviewed and audited generic and supplemental EMC qualification results (Refs. 14-24) and determined that the TXS COMPACT Platform meets regulatory guidance in RG 1.180, Revision 2, for EMC qualification. Deviations identified in the generic qualification testing were addressed through supplemental tests.

4.1.3 Seismic Qualification

The generic seismic qualification approach for the TXS COMPACT Platform was based on IEC/IEEE Std. 60980-344:2020, "Nuclear Facilities – Equipment Important to Safety – Seismic Qualification," and other international standards. The previous version, IEEE Std. 344-2013, "IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations," is endorsed with clarifications and regulatory positions in RG 1.100, Revision 4, which the NRC staff used along with EPRI TR-107330 to evaluate both generic and supplemental seismic qualification for the TXS COMPACT components listed in Table 3.2-1 of this SE.

[[

]].

The NRC staff reviewed and audited the results of these generic seismic qualification tests. All test cases were successfully completed without incorrect or unintended states of the TXS COMPACT Platform equipment. There was no occurrence of faults during the generic seismic qualification testing.

However, EPRI TR-107330 specifies that seismic qualification must be conducted according to the frequency and acceleration profiles identified in Figure 4-5, "Required Response Spectrum," of EPRI TR-107330 for one safe shutdown earthquake (SSE) test and five operating base earthquake (OBE) tests. [[

These requirements ensure that the response spectra used for the seismic qualification envelope the seismic conditions for most U.S. NPPs. The NRC staff found that the generic seismic qualification for the TXS COMPACT equipment **[[** **]]**, which does not meet the qualification testing methodology requirements in EPRI TR-107330.

To address this gap and comply with NRC regulatory guidance, Framatome developed a supplemental seismic test plan and specification (Refs. 6 and 7) and performed additional testing on the same setup of the TXS COMPACT EQ. The NRC staff reviewed and audited the supplemental test results (Ref. 23) and confirmed that they meet the requirements in EPRI TR-107330 and RG 1.100 for seismic qualification of safety-related I&C equipment.

The NRC staff determined that, after supplemental testing, the TXS COMPACT Platform equipment meets NRC regulatory guidance for seismic qualifications. The supplemental tests addressed gaps in the seismic qualification methodology and demonstrated compliance with relevant guidance in RG 1.100, Revision 4, and EPRI TR-107330.

4.1.4 Class 1E to non-Class 1E Isolation Capability

As required by Clauses 4.7, 4.8, and 5.4 of IEEE Std. 603-1991, safety-related I&C systems must provide isolation between Class 1E and non-Class 1E systems to prevent faults in non-Class 1E systems from propagating into safety systems. Regulatory guidance for isolation qualification is provided in RG 1.75 and Section 6.3.6 of EPRI TR-107330, which is endorsed in RG 1.209.

The NRC staff reviewed the TXS COMPACT Platform TR and supplemental documents and determined that Class 1E to non-Class 1E isolation qualification was not addressed in the submitted materials. Consequently, the NRC staff issued a Request for Additional Information (RAI) 10637 (Ref. 30) requesting evidence of compliance with the relevant regulatory guidance in RG 1.75 and EPRI TR-107330 regarding Class 1E to non-Class 1E isolation qualification.

In the RAI response (Ref. 30), Framatome provided detailed information demonstrating Class 1E to non-Class 1E isolation for the TXS COMPACT Platform. **[[** **]]**.

For this interface, the NRC staff found in the RAI response that Framatome used a combination of hardware qualification and architectural design measures to achieve the required Class 1E to non-Class 1E isolation. **[[**

]].

For interfaces between the TXS COMPACT-based safety system and other non-safety I&C equipment, the Ethernet connector on SMDF1 is **[[** **]]** isolated from the safety-related digital processing area. Isolation tests were documented in the electrical test report and referenced in the SMDF1 summary qualification report.

The NRC staff determined that Framatome provided adequate information to demonstrate adequate compliance with RG 1.75 and Section 6.3.6, "Class 1E to non-1E Isolation Testing," of EPRI TR-107330 for Class 1E to non-Class 1E isolation qualification.

4.2 Platform Communications

Platform communications between systems, structures, and components (SSCs) that are required to be independent per Clause 5.6, "Independence," of IEEE 603-1991 are of particular regulatory interest. That is, communication between redundant portions of a safety system and communications between safety systems and other systems are of particular regulatory interest, as depicted in TXS COMPACT TR Figure 5-1, "Recommended Architecture for a TXS COMPACT-based I&C System." Section 11, "TXS COMPACT REGULATORY COMPLIANCE," of the TXS COMPACT TR describes the regulatory compliance of TXS COMPACT with respect to platform communications.

RG 1.152, Revision 4, Section C.1.b.(2), includes clarification regarding the endorsement of guidance in Clauses 5.6, 5.8.1, and 5.8.2 of IEEE Std. 7-4.3.2-2016. Section 11.2.2.6, "Independence," of the TXS COMPACT TR describes the degree of conformance with IEEE 7-4.3.2 Clause 5.6, as augmented by RG 1.152, Revision 4, Section C.1.b.(2).

RG 1.152, Revision 4, Clauses 5.8.1 and 5.8.2 provide criteria that apply to multidivisional control and display stations for control of safety-related equipment. Specifically, Section C.1.b.(2.2) states that the criteria for the interface between information displays and safety-related systems in Clause 5.8.2 should be supplemented with the following: "2.2.1 The control processor and its associated communication processor should only process the commands that pass the error checking." However, since information displays are not included in the scope of the TXS COMPACT TR and may be included in the scope of an application, conformance with these criteria must be evaluated at the application level (see PSAI 6.1.11, in Section 6.1 of this SE)

Section 2.4, "TXS COMPACT Internal Communications," of the TR, describes the communication networks, interfaces, and characteristics of the TXS COMPACT internal communications. Section 5.0, "TXS COMPACT Platform Communications," of the TR, as supplemented (Response to RAI 10638, Ref. 30), describes the TXS COMPACT Platform communications:

"Communication within network architecture (intra-Divisional or inter-Divisional safety-to-safety communication) is operated through the PM1 (via front optical fiber interface implementing MODBUS protocol) or a TXS COMPACT Gateway Module (GWF1) (via Ethernet port for connection to a TXS-Ethernet network).... TXS COMPACT physically segregates safety and non-safety communications; that is to say, non-safety communications use a dedicated medium which is independent from the one used for safety-related communications."

There are two specific TXS COMPACT modules primarily used for communications that are described in Section 2.2.2.3, "TXS COMPACT Gateway Module (GWF1)," and Section 2.2.2.4, "TXS COMPACT Service, Maintenance, and Diagnosis Module (SMDF1)." The safety communication principles are described in TXS COMPACT Platform TR Table 5-1, "Safety Communication Principles."

IEEE 7-4-3-2 Clause 5.6, Independence

RG 1.152, Section C.1.b.(2), includes clarification regarding the endorsement of guidance in Clauses 5.6, "Independence," and Clause 5.6.4, "Detailed criteria" (and associated subclauses, i.e., 5.6.4.1, 5.6.4.2, and 5.6.4.3), of IEEE Std. 7-4.3.2-2016, "IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations." Clause 5.6 includes normative criteria that are applicable to the application and are therefore not reviewed in this SE that are supported by TXS COMPACT Platform features that meet the detailed criteria in Clause 5.6.4, and associated subclauses, which also include some application specific criteria that were not evaluated in this SE.

IEEE 7-4-3-2 Clause 5.6.4, Detailed Criteria

Section 11.2.2.6.4, "Detailed Criteria," of the TXS COMPACT TR summarizes the description of the degree of conformance with IEEE 7-4.3.2 Clause 5.6.4, as augmented by RG 1.152, Revision 4, Section C.1.b.(2), and references Section 11.3 of the TR for additional information. All of the criteria under Clause 5.6.4, which are contained in the three subclauses, are addressed individually below.

IEEE 7-4-3-2 Clause 5.6.4.1, Buffering function/circuit

IEEE 7-4.3.2 Clause 5.6.4.1 states:

"A buffering function provides an interface between the communications link and the safety function. The primary function of the buffering function is to prevent faults and failures on the communication originating outside the safety division from propagating to the safety function within the division, maintaining the integrity of the safety function..."

Buffer handling is described in TR Section 5.1.2. TR Figure 5-2, PM1 Optical Fiber Memory Implementation, depicts communication controllers that are separate from the application logic processing. TR Figure 5-3, "PM1 Module Buffer Management," depicts the buffering of separate messages in accordance with the description in the TR. The regulatory evaluation with respect to buffering criteria is documented in TR Section 11.3.2, "Interdivisional Communications." This evaluation was written against the criteria in DI&C ISG-04, Revision 1; however, the NRC staff evaluation used this information to evaluate the compliance with IEEE Std. 7-4.3.2-2016 Clause 5.6.4.1.

Generally, the problem introduced by using two separate communications processors (with one writing to and the other reading from a shared memory location) is that one may be writing while the other is reading, resulting in a corrupted message. This concern is described as being addressed in the TR by 1) using two shared memory locations (i.e., the buffer implementation) for each value transferred, and 2) reading from a locked memory location while writing to an unlocked one.

Based on comparing the descriptions identified in the paragraphs above, the NRC staff concluded that the implementation of the buffering provides an adequate interface between the communications link and the safety function and will prevent faults and failures on the communication originating outside the safety division from propagating to the safety function within the division, maintaining the integrity of the safety function. Therefore, the NRC staff

concluded that the implementation of the buffering conforms to the guidance in IEEE Std. 7-4.3.2-2016, Clause 5.6.4.1, and, therefore, the independence criteria of IEEE Std. 603-1991, Clause 5.6.

IEEE 7-4.3.2 Clause 5.6.4.2 Communications independence

Clause 5.6.4.2 contains criteria applicable to the TXS COMPACT communication mechanisms and application specific configurations, such as “A safety channel shall not receive any communication from outside its own safety division unless that communication supports the performance of the safety function. Receipt of information that does not support the safety function would involve the performance of functions that are not directly related to the safety function.”

Communications independence is described in TR Sections 2.4.5, “TXS COMPACT Communication Interfaces Characteristics,” 5.1, “TXS COMPACT Intra-Divisional / Inter-Divisional Safety-to-Safety Communication,” 11.2.2.6.4, “Detailed Criteria,” and 11.3.1, “Interdivisional Communications,” and depicted in Figure 2-8, “MPIOF1 Mechanical Design.”

A description of the regulatory evaluation with respect to communication independence is documented in TR Section 11.3.1. This evaluation was performed against the criteria in DI&C ISG-04, Revision 1; however, the NRC staff evaluation used the information provided to evaluate the compliance with IEEE Std. 7-4.3.2-2016, Clause 5.6.4.2.

Generally, communication independence is achieved by using a separate point-to-point physical communication pathway between each independent redundancy (which is incorporated into a plant specific application during application specific design and development) that complies with IEEE 603-1991 independence criteria (e.g., TXS COMPACT is also depicted as using fiber optic communications to achieve electrical independence). Some IEEE Std. 7-4.3.2-2016 Clause 5.6.4.2 criteria, to address the particular failure modes of digital communications, are incorporated into the buffering features of the TXS COMPACT components (e.g., see buffering above) while other criteria that are included in Clause 5.6.4.2 are addressed by individual features that must be used in the specific applications in a manner that conforms to the guidance (see PSAI 6.1.11 in Section 6.1 of this SE).

Therefore, as described in PSAI 6.1.11 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must identify the approach taken to satisfy the communication independence criteria of IEEE Std. 7-4.3.2-2016.

IEEE 7-4-3-2 Clause 5.6.4.3 Data independence

The TR regulatory evaluation with respect to data independence was written against the criteria in DI&C ISG-04, Revision 1 (see TR Section 11.3.1, see item 1.1); however, the NRC staff evaluation used this information (and the other information identified in the TR) to evaluate the compliance with IEEE Std. 7-4.3.2-2016, Clause 5.6.4.3.

Data independence is described in TR Sections 5.1, 11.2.2.6.4, and 11.3.1. In effect, data independence is an architectural concern addressed in the plant specific application; therefore, as described in PSAI 6.1.11 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must identify the approach taken to satisfy the data independence criteria of IEEE Std. 7-4.3.2-2016.

IEEE 7-4-3-2 Clause, 5.8.1, Independence and isolation requirements for multidivisional control and display stations

RG 1.152, Revision 4, Section C.1.b.(2.2), includes clarification regarding the endorsement of guidance in Clauses 5.6 and 5.8.1 of IEEE Std. 7-4.3.2-2016. Clause 5.8.1 provides criteria that apply to multidivisional control and display stations for control of safety-related equipment. Specifically, Section C.1.b.(2.2) states that the criteria for the interface between information displays and safety-related systems in Clause 5.8.2 should be supplemented with the following: “2.2.1 The control processor and its associated communication processor should only process the commands that pass the error checking.”

Independence and isolation requirements for multidivisional control and display stations is described in Section 5.3, “TXS COMPACT Multidivisional Control in Multiple Safety Divisions,” of the TR. In effect, the concerns relating to multidivisional control and display stations are an architectural concern that must be addressed in the plant specific application; therefore, as described in PSAI 6.1.11 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must identify the approach taken to satisfy the independence and isolation requirements for multidivisional control and display stations of IEEE Std. 7-4.3.2-2016.

IEEE 7-4-3-2 Clause 5.8.2, Malfunctions and spurious actuations

RG 1.152, Revision 4 Section C.1.b.(2.2) includes clarification regarding the endorsement of guidance in Clauses 5.6, and Clauses 5.8.2 of IEEE Std. 7-4.3.2-2016. Clause 5.8.2 provides criteria that apply to malfunctions and spurious actuations of information displays interfacing to safety systems. Specifically, Section C.1.b.(2.2) states that the criteria for malfunctions and spurious actuations in Clause 5.8.2 should be supplemented with the following: “2.2.1 The control processor and its associated communication processor should only process the commands that pass the error checking.”

Malfunctions and spurious actuations requirements on information displays interfacing to safety systems are described in Sections 3.2, “TXS COMPACT Diagnostics and Fault Indications,” and 11.2.2.8.2, “Malfunctions and Spurious Actuations,” of the TR. In effect, the concerns relating to malfunctions and spurious actuations are mostly an architectural concern that must be addressed in the plant specific application; however, the TXS COMPACT equipment associated with communications does address the RG 1.152 criterion that specifies “The control processor and its associated communication processor should only process the commands that pass the error checking.” Table 3-2, “PM1 Self-monitoring / Self-test,” of the TR describes the communications related to the self-monitoring and self-test performed by the TXS COMPACT modules or performed at the system application level (grouped by the type of error detected and the associated self-monitoring and self-testing for each error type).

Based on the above evaluation, the NRC staff concluded that the implementation of the malfunctions and spurious actuations requirements for information displays interfacing to safety systems is application specific but can conform to the guidance in IEEE 7-4.3.2 Clause 5.8.2. As described in PSAI 6.1.11 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must identify the approach taken to satisfy the malfunctions and spurious actuations criteria of IEEE Std. 7-4.3.2-2016.

4.3 Platform Development

The NRC staff review guidance for evaluating digital I&C systems software development activities is in NUREG-0800, and BTP 7-14. Furthermore, GDC 1 also states: "Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function." Implementation of an acceptable software life cycle provides the necessary software quality. The development of safety system software should progress according to a formally defined life cycle. Many life cycles have been defined in the technical literature and in national and international standards. These differ in the definitions of life cycle activity groups and in the order in which life cycle activities are performed. The software developer should select and document the software life cycle, and specify the products that will be produced by that life cycle. All software development life cycles share certain characteristics. The activities that should be performed can be grouped into a number of categories listed below, which are common to all life cycles.

- **Planning** of software life cycle process
- **Implementation** of software life cycle process
- **Design Outputs** of software life cycle process

For each of the activity groups, one or more sets of the following reports should be available:

- Requirements
- Design
- Implementation
- Integration
- Validation
- Installation
- Operations and maintenance

BTP 7-14 references RGs related to software development activities that endorse various IEEE standards. Since the TXS COMPACT Platform components are being developed in accordance with the IEC standards, appropriate consideration is given to the acceptance criteria outlined in Section B.3, "Acceptance Criteria," of BTP 7-14.

The NRC staff's review of the TXS COMPACT development life cycle activities is limited to evaluating activities related to safety-related modules described in Section 1.2 of the TR (i.e., PM1, "TXS COMPACT Processing Module," MPIOF1, "TXS COMPACT Multi-Purpose I/O Module, and GWF1, "TXS COMPACT Gateway Module," and BPF1, "TXS COMPACT Backplane.") Section 6.0, "TXS COMPACT Life Cycle Management," of the TR describes the safety-related TXS COMPACT Platform modules life cycle management process including planning, requirements, design, manufacture, integration, assembly, and test phases that follow guidelines from the following international standards and national regulations:

- IEC 60987:2021, "Nuclear power plants – Instrumentation and control systems important to safety – Hardware requirements"
- IEC 61513:2011, "Nuclear power plants – Instrumentation and control systems important to safety – General requirements for systems"

- IEC/IEEE 60780-323:2016, “Nuclear facilities – Electrical equipment important to safety – Qualification”
- IEC 60880:2006, “Nuclear power plants – Instrumentation and control systems important to safety – Software aspects for computer-based systems performing category A functions”
- IEC 62138:2018, Nuclear power plants – Instrumentation and control systems important to safety – Software aspects for computer-based systems performing category B or C functions”
- IEC 62566:2012, Nuclear power plants – Instrumentation and control systems important to safety – Development of HDL-programmed integrated circuits for systems performing category A functions
- ISO/IEC/IEEE 24748-1:2018-11, “Systems and software engineering – Life cycle management – Part 1: Guidelines for life cycle management”
- RCC-E:2019, “Design and construction rules for electrical and I&C systems and equipment”
- KTA 3503:2015, “Type Testing of Electrical Modules for the Instrumentation and Control System Important to Safety”

Section 6.1, “TXS COMPACT Life Cycle Model,” of the TR describes the TXS COMPACT life cycle model based on ISO/IEC/IEEE 24748-1. Figure 6-2, “Product Life Cycle Overview Including Corresponding Work Instructions,” of the TR shows an overview of product life cycle stages including corresponding work instructions ([

],”)

The TXS product breakdown structure, as shown in Figure 6-3, “Product Breakdown Structure,” of the TR, places the [

].”

The TXS COMPACT engineering and service tools and commercial off-the-shelf (COTS) tools qualification and assessment are described in Section 6.2.2.2, “TXS COMPACT Engineering & Service Tools and Commercial Off-the-Shelf (COTS) Tools Qualification,” of the TR.

Tools used for development, operation, maintenance, and diagnosis of TXS COMPACT I&C systems are separated into two sets: 1) pre-developed tools (COTS); and 2) in-house developed (IHD) tools. [

11.

TXS COMPACT Engineering and Service Tools support design, generation, verification, validation, and operation of a TXS COMPACT based safety-related I&C system. TXS COMPACT Engineering and Service Tools that consist of software components are:

- Engineering Unit used to develop TXS COMPACT based systems
- Testing Unit used to test TXS COMPACT based systems
- Service Unit connected to TXS COMPACT based system via a network to perform local diagnosis and service task

11

11.

The TXS COMPACT Platform is developed under an iterative V shape life cycle process as shown in Figures 6-4, “Development Life Cycle Overview Including Corresponding Work Instructions,” and 6-5, “TXS COMPACT Platform Development Process,” of the TR. Each phase is terminated only if the preceding phases have been completed, and if its outputs were consistent with the inputs provided by these preceding activities. V&V is performed at each Level to ensure integrity of the V&V life cycle.

Planning phase is described in Section 6.2.1.1, “Planning Phase,” of the TR, which produces the following planning documents:

- QA plan: TXS COMPACT Platform Quality Assurance plan; and TXS COMPACT Engineering and Service Tools Quality Assurance plan
- V&V plan: TXS COMPACT Platform V&V plan; and TXS COMPACT Engineering and Service Tools V&V plan
- CCM plan: TXS COMPACT Platform Configuration and Change Management plan (CCMP) applicable to hardware, software, and configware components.

These plans constitute quality references for the development process of the TXS COMPACT Platform and the TXS COMPACT Engineering and Service Toolchain.

Requirement phase is described in Section 6.2.1.2, “Requirements Phase,” of the TR. In this phase, the components requirements specifications are derived from the system specifications according to the system breakdown structure. The TXS COMPACT requirements engineering activity includes identification and analysis of external interface requirements, functional requirements, performance requirements, and constraints, as well as quantitative and qualitative measures related to these requirements. These technical requirements are recorded in a requirements specification, which is the output of this phase. Definition of the TXS COMPACT modules is further refined by providing new requirements consistent with parent design decisions. This task is the starting point of the formal engineering work of designing the hardware, software, and configware components. This phase is performed in accordance with the Framatome procedure [1]

[1],” to assure that the requirements are documented in a way that is understandable, traceable, unambiguous, and concise.

Requirements traceability process is described in Section 6.2.1.2.1, “Requirements Traceability,” of the TR. [1]

[1].

Design phase is described in Section 6.2.1.3, “Design Phase,” of the TR. A design activity is executed upon completion of the requirement phase. Using outputs of the requirement phase as inputs, the design phase establishes traceability between the requirements and design decisions. Design documents rely on drawings and text documents to clarify the design. [1]

]]. In accordance with the applicable Framatome procedure, design decisions are documented in an understandable, traceable, and concise way.

Verification and Validation activities of the TXS COMPACT AU are discussed in Section 6.2.2, “TXS COMPACT Verification and Validation,” of the TR. The TXS COMPACT Platform is verified and validated according to a set of procedures and V&V instructions embedded in the Framatome QA system, which include the safety I&C platform development V&V plan. This IEC 61513, IEC 60880, IEC 62138, IEC 60987, and IEC 62566 compliant work instruction specifies a common framework of V&V processes, activities, and tasks necessary for development of hardware and software components and system integration for a safety I&C platform. It also defines the necessary V&V tasks, required inputs, and required outputs for each development phase. This work instruction follows the recommendations of IEEE Std. 1012-2016. The organization of the TXS COMPACT IV&V team ensures the required technical and managerial level of independence. [[

]].

For validation of TXS COMPACT HPD towards IEC 62566, V&V activities are performed following a bottom-up approach for each module developed within HPD development. Qualification strategy of the HPD of the TXS COMPACT modules is established and documented. In accordance with recommendations from IEC 62566, following methods and procedures are implemented for TXS COMPACT V&V:
[[

11.

System Integration and Test Phase. In its supplemental response to RAI 10688, Question 2(c) (Ref. 27), Framatome states that it has revised the TR to remove Sections 6.3.2, "System Integration Testing" and 6.3.3, "Installation and Commissioning," because these activities are determined to be application-level activities outside the intended scope of the TR.

A sample of V&V, safety analysis, and configuration management documentation for various life cycle activities were audited to confirm that the life cycle activities stated in Section 6.0 of the TR are being properly implemented. A sample of software design outputs was audited to confirm that they address the functional requirements allocated to the software, and that the expected software development process characteristics are evident in the design outputs.

Based on the NRC staff's evaluation described above, the NRC staff finds that the TXS Compact Platform lifecycle development meets the planning, implementation, and design output criteria in BTP 7-14. Because a TXS Compact Platform application development software program was not submitted as part of this TR, the NRC staff's evaluation of this TR does not include the development of application software. Therefore, as stated in PSAI 6.1.2 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT Platform must ensure that the development of application software is performed in accordance with a defined and controlled software development process consistent with applicable regulations, NRC guidance, and consensus industry standards, or an NRC-approved application software program manual.

4.4 Secure Development Environment

RG 1.152, Revision 4, Section C.1.b.(3), includes clarification regarding the endorsement of guidance in Clause 5.9, "Control of access" (and associated subclauses) of IEEE Std. 7-4.3.2-2016, "IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations." Clause 5.9 includes normative criteria that are applicable to the application (and are therefore not reviewed in this SE) that are supported by TXS COMPACT Platform features that meet the detailed criteria in Clause 5.9, and associated subclauses (which also include some application specific criteria that were not evaluated in this SE).

The TXS COMPACT secure development environment (SDE) is described in Section 9.0, "TXS Compact Security," of the TR. Specifically, Section 9.3 of the TR describes provisions taken to ensure security of design, development, testing, and manufacturing of the TXS COMPACT

Platform. Both technical and process-based measures are applied to the SDE. Development and validation activities of the safety I&C platform life cycle are carried out using two separate environments:

- Activities which do not require specific IT items of equipment, environment, and infrastructures, such as: project management activities and authoring and storage of platform technical documentation. These activities are carried out using the Framatome IT environment.
- Activities which do require specific IT items of equipment, infrastructures, tools, or technical environments, such as detailed design and implementation and execution of test cases. These activities are carried out using the TXS Development Environment.

Both environments together constitute the SDE for the TXS COMPACT Platform.

Activities carried out on the Framatome IT environment are described in Section 9.3.1, “Activities Carried Out on the Framatome IT Environment,” of the TR. These activities are those which require office automation, requirements management, project management, and communication software. Such features are provided through the Framatome corporate IT infrastructure, which is documented and managed by Framatome’s IT entities. The corresponding infrastructure, equipment, and procedures are shared amongst all Framatome activities (i.e., not limited to I&C). It is continuously maintained by Framatome corporate IT entities. Related documentation is generally confidential and stored in a secured location.

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Activities carried out using the TXS development environment are described in Section 9.3.2, “Activities Carried Out Using the TXS Development Environment,” of the TR. These activities lead to creation of the following binary assets of the platform:

- The generic bitstream files running on the hardware module’s FPGAs.
- The software tool’s executable files.

[[

]].

Controls and vulnerability analysis for the TXS Development network are documented in a Security Plan, which is under responsibility of the Security Officer.

The NRC staff audited the TXS COMPACT Platform development environment and found it to be consistent with security description provided in Section 9.0 of the TR. Therefore, the NRC staff finds that the TXS COMPACT Platform development environment meets the SDE criteria of IEEE Std. 7-4.3.2-2016 as endorsed by RG 1.152. As described in PSAI 6.1.12 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR for a safety related plant specific application must ensure that a secure development and operational environment have been established for its plant specific application, and that it satisfies the applicable regulatory evaluation criteria of RG 1.152, Revision 4.

4.5 Reliability and FMEA

Section 7, "TXS Compact Reliability and FMEA," of the TR describes the reliability and Failure Modes and Effects Analysis (FMEA) methods. The reliability analysis [

]]. This analysis includes stress factors such as operating temperature and electrical conditions. [

]].

A functional FMEA analysis is conducted for each module by following IEC 60812:2018. These analyses include self-monitoring and failure detection functionalities. Such analyses examine detailed failure effects, and such results could be used as inputs to the self-monitoring and periodic test functional requirements as well as the application specific demonstration of meeting the single failure criterion.

As described in PSAI 6.1.5 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must perform a system level FMEA to demonstrate that plant specific use of the TXS COMPACT Platform identifies each potential failure mode and determines the effects of each.

In addition, as described in PSAI 6.1.6 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must perform a system-level evaluation of the degree of redundancy, diversity, testability, and quality provided in a TXS COMPACT Platform-based safety system to determine if the degrees provided are commensurate with the safety functions being performed. An applicant or licensee must confirm that a resultant TXS COMPACT Platform-based system continues to satisfy any applicable reliability goals that the plant has established for the system. This plant specific action must consider the effect of possible

failures, system-level design features provided to prevent or limit the failures' effects, and any plant specific inclusion of a maintenance bypass to support plant operations.

4.6 Quality Assurance and Training

Section 8.1, Regulatory Basis," of the TXS COMPACT TR states, in part, that the TXS COMPACT Platform is designed and qualified by Framatome as nuclear safety-related products. The TXS COMPACT Platform is designed, developed, verified, and validated (V&V) by Framatome SAS¹. In its supplemental response (Ref. 27) to RAI 10688, Question 1 (Ref. 28), Framatome revised the TR, Section 8.1, to clarify that, "For the TXS COMPACT Platform TR, design engineering was completed by the Framatome SAS organization in accordance with European Standards. The decision to apply for the NRC approval to use the TXS COMPACT Platform for safety-related applications in the U.S. NPPs was made after the design was fully complete. The TXS COMPACT Platform TR is being submitted by Framatome in accordance with the Framatome Quality Assurance Program (QAP)" (Ref. 25).

In its supplemental response (Ref. 27) to RAI 10688, Question 2, Framatome revised the TR, Section 8.2, "Framatome Quality Assurance Program," to clarify that Framatome QAP "applicability is based on the elements of the program applicable to product development in Framatome SAS. TXS COMPACT Platform components will be provided by Framatome SAS to Framatome as basic components design and manufactured under the applicable elements of the Framatome Integrated Management System Manual (IMS) (Ref. 26). Therefore, regarding the TXS COMPACT Platform and implementing procedures, as defined in the TXS COMPACT Quality Management Plan (Ref. 29), Framatome SAS is considered a "supplier" to Framatome Inc., subject to the controls imposed under the Framatome QAP. Applicable elements of the Framatome QAP are as follows:

- "Quality Assurance Program" – 10 CFR Part 50, Appendix B, Criterion II.
- "Control of Purchased Materials, Items, and Services" – 10 CFR Part 50, Appendix B, Criterion VII.
- "Control of Nonconforming Items" – 10 CFR Part 50, Appendix B, Criterion XV.
- "Corrective Action" – 10 CFR Part 50, Appendix B, Criterion XVI.
- "Audits" – 10 CFR Part 50, Appendix B, Criterion XVIII.

The following elements of the Framatome QAP are applicable to Framatome's procurement of TXS COMPACT Platform basic components:

- "Design Control" – 10 CFR Part 50, Appendix B, Criterion III.
- "Procurement Document Control" – 10 CFR Part 50, Appendix B, Criterion IV
- "Quality Assurance Records" – 10 CFR Part 50, Appendix B, Criterion XVII

The NRC staff evaluated the proposed changes to the TR identified in Framatome's supplemental response to RAI 10688, Questions 1 and 2, and determined that the revisions are acceptable for describing applicable elements of the Framatome QAP for the procurement of the platform from Framatome SAS. Specifically, the NRC staff found that these aspects of the Framatome QAP are appropriate to:

¹ Framatome SAS (Société par actions simplifiée) based in France is owned by Électricité de France (EDF) Group (80.5 percent) and Mitsubishi Heavy Industries (MHI - 19.5 percent)

- establish the scope, technical requirements, safety classification, and the applicability of the QAP to the TXS COMPACT Platform, as required by Criterion II of Appendix B to 10 CFR Part 50.
- establish training requirements for Framatome personnel performing activities affecting quality related to the procurement of the platform, as required by Criterion II of Appendix B to 10 CFR Part 50.
- establish design control measures that will establish technical and quality requirements to be imposed in specifications, as required by Criterion III of Appendix B to 10 CFR Part 50.
- establish procurement document controls for procurement of the TXS COMPACT Platform, as required by Criterion IV of Appendix B to 10 CFR Part 50.
- qualify Framatome SAS as a safety-related supplier on Framatome's approved supplier list, as required by Criterion VII of Appendix B to 10 CFR Part 50.
- establish measures to ensure that procurement of the TXS COMPACT Platform conforms to the procurement documents, as required by Criterion VII of Appendix B to 10 CFR Part 50.
- establish measures to ensure that nonconforming items are adequately identified, documented, segregated, and dispositioned, as required by Criterion XV of Appendix B to 10 CFR Part 50.
- establish measures to ensure that conditions adverse to quality are promptly identified and corrected, as required by Criterion XVI of Appendix B to 10 CFR Part 50.
- establish measures to ensure sufficient records are maintained to furnish evidence of activities affecting quality, as required by Criterion XVII of Appendix B to 10 CFR Part 50.

The NRC staff's evaluation for each of the above aspects is documented in Sections 4.6.1, "Criterion II, Quality Assurance Programs," through 4.6.7, "Criterion XVII, Quality Assurance Records," of this SE and is only applicable for the TXS COMPACT Platform design, development, and manufacturing activities. An applicant or licensee that references the TXS COMPACT TR for a safety-related plant specific application must ensure that the system design, development, and testing activities are performed under an Appendix B to 10 CFR Part 50 compliant QAP. See PSAI 6.1.13 in Section 6.1 of the SE.

4.6.1 Criterion II, "Quality Assurance Program"

In its supplemental response to (Ref. 27) to RAI 10688, Question 3(a), Framatome revised the TR, Section 1.1 to state "This Topical Report describes attributes of the Framatome TELEPERM XS (TXS) COMPACT Field Programmable Gate Array (FPGA) based instrumentation and Control (I&C) platform (herein identified as TXS COMPACT Platform) for the purpose to obtain U.S. [NRC] review and approval for use in nuclear power plant safety-related I&C applications....The TXS COMPACT Platform and associated module and Backplane are designed and qualified by Framatome as nuclear safety-related products."

In its supplemental response (Ref. 27) to RAI 10688, Question 3(b), Framatome revised the TR, Section 8.2.1, "Quality Assurance Program," to state "The Framatome Inc. (QAP) complies with Criterion II of Appendix B to 10 CFR Part 50, and Requirement 2, Quality Assurance Program, American Society of Mechanical Engineers (ASME) NQA-1, 2015 "Quality Assurance Requirements for Nuclear Facility Applications." This section defines the QAP implemented for nuclear safety-related activities.

The QAP establishes prerequisites for achieving quality, such as the need for specialized equipment and skills; use of suitable administrative, process, and environmental controls; training and indoctrination of personnel performing activities affecting quality; and the need for verification of quality by reviews, inspection, examination, and test.

The Framatome Inc. QAP is established through written policies, procedures, and instructions. Indoctrination and training are provided for personnel performing quality-related activities. Control of activities affecting quality is achieved through supplier qualification audits, source surveillance, and receipt inspection, performed by trained and qualified personnel in accordance with the Framatome QAP.

The NRC staff reviewed Framatome's supplemental response to RAI 10688, Question 3(a) and 3(b) and found that the proposed changes to the TR, Sections 1.1 and 8.2.1 are acceptable in:

- identifying the TXS COMPACT Platform as "safety-related" and thus covered by the Framatome's QAP, for activities associated with procuring the platform from Framatome SAS.
- describing the training requirements for Framatome personnel performing quality-related activities associated with procuring the platform from Framatome SAS.
- specifying that activities affecting quality are performed in accordance with written policies, procedures, and instructions.

As such, the NRC staff determined that these proposed changes conform to the requirements of Criterion II of Appendix B to 10 CFR Part 50.

4.6.2 Criterion III, "Design Control"

Section 6.0 of the TXS COMPACT TR describes the TXS COMPACT Platform lifecycle, including the verification and validation process. Section 6.1 of the TR states that the TXS COMPACT life cycle is regulated by a work instruction that describes the missions and tasks of the product manager, and the procedure applied during the lifecycle of Framatome I&C products. It provides overall guidance for product managers' interactions with the main contributors to product activities along the various stages of the product lifecycle.

The TXS COMPACT Quality Management Plan (QMP) (Ref. 26) defines the [I]

II.

In its supplemental response to RAI 10688, Question 2(c) (Ref. 27), Framatome states that it has revised the TR to remove Sections 6.3.2, "System Integration Testing" and 6.3.3, "Installation and Commissioning," because these activities are determined to be application-level activities outside the intended scope of the TR.

In its supplemental response to the RAI 10688, Question 3(c) (Ref. 27), Framatome clarified that it is not imposing Framatome's QAP, Section 3 with respect to the development, control,

and use of computer programs for the procurement of the Framatome COMPACT platform. In addition, in this supplemental response, Framatome stated the discussion on computer programs from the Framatome QAP will be removed from the TR. Instead, in response to the RAI 10688, Question 4 (Ref. 27), Framatome revised Section 8.2.2, "Control of Purchased Materials, Items, and Services," of the TR to state "Acceptability of suppliers of safety-related materials, items, or services are based on the following items:

- An evaluation of their QA Program to 10 CFR Part 50, Appendix B and ASME NQA-1 to determine the capability to supply materials, items, or services meeting the procurement document requirements.
- A survey/audit of the supplier's facility."

In addition, in this supplemental response, Framatome revised the TR to include information regarding its audit of Framatome SAS's TXS COMPACT Platform project implementation and lifecycle processes, as described in Section 6.0 of this TR.

The NRC staff reviewed Framatome's responses to RAI 10688, Questions 2(c), 3(c), and 4(a) and determined that these responses adequately describe Framatome's (1) reviews of Framatome SAS and GmbH's QA program, and (2) audits of Framatome SAS's and GmbH's implementation of its QA program to verify compliance with Criterion III of Appendix B to 10 CFR Part 50 for the design, development, and manufacturing activities related to the TXS COMPACT Platform. Based on the acceptable results of Framatome's review and audit activities, as documented in the revised Section 8.3, "Audit of the TXS COMPACT Platform," of the TR, and the applicability of Criterion III of Appendix B to 10 CFR Part 50, as stated in the revised Section 8.2 of the TR, the NRC staff determined that the information presented in Section 8 of the TR conforms to the requirements of Criterion III of Appendix B to 10 CFR Part 50, for Framatome's procurement of the TXS COMPACT Platform.

4.6.3 Criterion IV, "Procurement Document Control"

As stated in the supplemental response to RAI 10688, Question 2(b) (Ref. 27), Framatome revised Section 8.2 of the TR to state that Criterion IV of Appendix B to 10 CFR Part 50 applies to Framatome's procurement of the TXS COMPACT Platform basic components.

Section 4 of the Framatome QAP states that this [I].

I].

² Framatome GmbH, based in Erlangen, Germany is a wholly owned subsidiary of Framatome SAS in France.

Based on the procurement controls described in Section 4 of the Framatome QAP and the proposed revisions to the TR to include applicability of Criterion IV of Appendix B to 10 CFR Part 50 for the procurement of TXS COMPACT basic components, as described in RAI 10688, Question 2(b), the NRC staff determined that these descriptions conforms to the requirements of Criterion IV of Appendix B to 10 CFR Part 50 for the procurement of TXS COMPACT Platform basic components.

4.6.4 Criterion VII, "Control of Purchased Material, Equipment, and Services"

Section 8.2.2 of the TR states, in part, that "the Framatome Inc. QAP, Section 7 governs control of purchased safety-related materials, items, and services including source evaluation and selection, source inspection, and receiving inspection in accordance with regulatory and contract requirements...Acceptability of suppliers of safety-related materials, items, or services are based on" an evaluation of their QA Program to Appendix B to 10 CFR Part 50 and ASME NQA-1 and a survey/audit of the supplier's facility. In its supplemental response to RAI 10688, Question 4(a) (Ref. 27), Framatome Inc. revised Section 8.2.2 to state "Framatome Inc. QAP controls, such as supplier audits, source surveillance, receipt inspection and testing, are relied upon for product acceptance. These activities ensure procured items satisfy procurement document requirements and provide verification of the effectiveness of supplier quality controls."

Section 7 of the Framatome QAP identifies controls of purchased safety-related materials, items, and services, including [[

]].

The following sections within the Framatome QAP address control of purchased materials, equipment, and items that the NRC staff determined are applicable for Framatome's procurement of the TXS COMPACT Platform from Framatome SAS and GmbH:

[[

]]

Section 8.2.5 of the TR states that Framatome's QAP, Section 18, describes the elements of quality auditing that are applicable to the procurement of the TXS COMPACT Platform components. This section of the TR also states, in part, that "procedures are established to provide program definition, as well as direction, for performance of audits and supporting activities. Audits are performed in accordance with pre-established written procedures or checklists and conducted by personnel who have no direct responsibilities in the areas being audited. Audits for suppliers' safety-related items and services are performed to ensure only qualified suppliers are used. Qualified suppliers are audited on a triennial basis... Additional evaluations of supplier performance are performed periodically or when issues warrant additional oversight."

In its supplemental response to RAI 10688, Question 4(a) (Ref. 27), Framatome stated that “[[

]].” Section 8.3 of the TR to state “The Framatome Inc. QA organization performed an independent audit of the Quality Assurance Program and TXS COMPACT Platform activities in the following locations:

- Erlangen, GmbH...
- Paris, France...
- Lyon, France...

The audit purpose was to evaluate program compliance and effectiveness of activities supporting the TXS COMPACT Platform project implementation in accordance with the Framatome Integrated Management System, 10 CFR Part 50 Appendix B, and applicable references in Erlangen, Paris, and Lyon in support of submittal of the TR.

The audit concluded that Framatome Inc. has completed a 10 CFR 50, Appendix B assessment and documented issues as appropriate in the applicable Corrective Action Program. These issues will be managed in accordance with the Framatome Inc. QAP through resolution.”

In its supplemental response to RAI 10688, Question 4(b) (Ref. 27), Framatome revised Section 8.3 TR to state “[[

]].”

In its supplemental response to RAI 10688, Question 2(d) (Ref. 27), Framatome revised the TR to add Section 8.4 to describe [[

]]. The NRC staff reviewed this response and determined that the response adequately describes how [[

]].

The NRC staff reviewed the responses to RAI 10688, Questions 4(a) and 4(b) and determined that these responses adequately describe Framatome’s implementation of controls for procurement of the TXS COMPACT Platform from Framatome SAS. [[

]]. Based on these descriptions, the

NRC staff determined that Framatome's implementation of controls for the procurement of the TXS COMPACT Platform and the applicability of Section 7 of the Framatome QAP to the procurement of the platform components conform to the requirements of Criterion VII of Appendix B to 10 CFR Part 50.

4.6.5 Criterion XV, "Nonconforming Material and Equipment"

Section 8.2.3, "Control of Nonconforming Items," of the TR states that Framatome QAP, Section 15, "Control of Nonconforming Items," applies to safety-related materials and items and their supporting documentation. It addresses characteristics, documentation, or procedure deficiencies that render an item or activity unacceptable or indeterminate. Procedures are established to control documentation and items that do not conform to specified requirements in order to prevent their inadvertent use of installation. Nonconforming items are reviewed and deemed accepted, rejected, or reworked in accordance with documented procedures. The NRC staff reviewed Framatome QAP, Section 15. For Framatome's procurement of the TXS COMPACT Platform from Framatome SAS and GmbH, the NRC staff determined that the description in Section 15.3 of the Framatome QAP regarding the [[

]] is adequate to ensure Framatome SAS and GmbH nonconformances for the TXS COMPACT Platform are adequately identified, reviewed, and dispositioned by Framatome.

Based on the above evaluation, the NRC staff determined that the description of Framatome's nonconformance program in Section 8.2.3 of the TR and in Framatome QAP, Section 15 conforms to Criterion XV of Appendix B to 10 CFR Part 50 for Framatome's procurement of the TXS COMPACT Platform.

4.6.6 Criterion XVI, "Corrective Action"

Section 8.2.4, "Corrective Action," of the TR states that Framatome QAP, Section 16, defines the elements of the corrective action generation, implementation, and verification system for safety-related items or services. Procedures are established to ensure prompt identification and correction of conditions adverse to quality, such as failures, malfunctions deficiencies, deviations, defective material and equipment, nonconformances during design, procurement, fabrication, inspection, and testing of items. [[

]]. The NRC staff reviewed Framatome QAP, Section 16, which describes the procedures established by Framatome to [[

]].

The NRC staff determined that the above measures are adequate to ensure that (1) potential conditions adverse to quality are promptly identified and corrected, and (2) the cause of any significant conditions adverse to quality and the corrective action to preclude repetition are

identified for Framatome's procurement of TXS COMPACT Platform components. As such, the NRC staff determined that the measures described in Section 16 of the Framatome's QAP and Section 8.2.4 conform to the requirements in Criterion XVI of Appendix B to 10 CFR Part 50 for Framatome's procurement of the TXS COMPACT Platform.

4.6.7 Criterion XVII, "Quality Assurance Records"

As stated in the supplemental response to RAI 10688, Question 2(b) (Ref. 27), Framatome revised Section 8.2 of the TR to state that Criterion XVII of Appendix B to 10 CFR Part 50 applies to Framatome's procurement of the TXS COMPACT Platform basic components.

Section 17.1 of the Framatome QAP (Ref. 25) states that "[[

]].

The NRC staff reviewed the response to RAI 10688, Question 2(b) and Section 17 of the Framatome QAP and determined that the applicability of Criterion XVII of Appendix B to 10 CFR Part 50 to the procurement of the TXS COMPACT Platform basic components, and the QA record controls in Section 17.1 of the Framatome QAP conform to the requirements of Criterion XVII of Appendix B to 10 CFR Part 50 for the procurement's of TXS COMPACT Platform basic components. Specifically, the NRC staff determined that, as required by Criterion XVII of Appendix B to 10 CFR Part 50, (1) sufficient records will be maintained to furnish evidence of activities affecting quality, (2) [[

]] records will be included as QA records, (3) records will be identifiable and retrievable, and (4) record retention policies are established and will apply to the procurement of the TXS COMPACT Platform basic components.

4.7 Diagnostics and Monitoring

RG 1.152, Revision 4, which endorses, with some exceptions and clarifications, IEEE Std. 7-4.3.2-2016, describes an approach that is acceptable to the NRC staff to meet regulatory criteria for high functional reliability, design quality, and a SDOE for using PDDs in the safety-related systems of NPPs. Clause 5.5.3 of IEEE Std. 7-4.3.2-2016 states, in part, that self-diagnostics are a means to provide timely detection of failures. Self-diagnostics are not required for systems in which failures can be detected by alternate means in a timely manner. If self-diagnostic functions are integrated into the safety system, these functions shall be subject to the same V&V processes as the safety functions.

The purpose of self-diagnostic, testing, and monitoring features in safety-related I&C systems is to detect as many errors as possible during system operation and ensure the integrity of safety functions. The NRC staff evaluated the self-diagnostic, testing, and monitoring features of the TXS COMPACT Platform and found that each hardware module in the TXS COMPACT Platform as listed in Table 3.2-1 of this SE has built-in self-diagnostic, testing, and self-monitoring features. The self-diagnostic and testing features are implemented to ensure that safety-related aspects of the AU operate appropriately. The self-testing tasks in the TXS

COMPACT Platform perform verifications on each safety-related module in AUs when their FPGAs are not actively processing the engineered I&C functions, while self-monitoring is always active during normal operation of the AUs.

On the module level, automation unit level, and system level, the self-diagnostic and self-testing functions for the modules in the TXS COMPACT Platform cover various areas, such as network communication, memories, power supply, clock, analog and digital I/O's.

Self-diagnostic and self-testing results in the TXS COMPACT Platform are pushed cyclically by each module to the main PM1 module in each AU for monitoring. For the self-detection and management of faulty input signals, the NRC staff found that the TXS COMPACT Platform provides a generic, embedded way to manage invalidity of signals. **[[**

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Depending on specific I&C system specification, reporting of fault conditions from self-diagnostics and testing can be achieved in multiple ways and can be combined, which include LED indicators on the front plates of modules, on the SU computer connected to the AU through the SMDF1 module, and other application specific reporting features.

The NRC staff identified that self-diagnostics, tests, and monitoring are part of the TXS COMPACT Platform and are also designed and tested with the same high level of quality as the processing part of the platform, including independent verification and validation (IV&V).

In Section 1.2.2 of RG 1.152, Revision 4, it states, in part, that the design of self-diagnostic features maintains channel independence and system integrity and meets the single-failure criterion. The NRC staff found that the self-diagnostic and self-testing features of the TXS COMPACT Platform may be able to support a plant specific application based on the TXS COMPACT Platform to meet this criterion. But, the compliance with this criterion is dependent on the plant-specific I&C system design and configuration and therefore is application specific.

Therefore, the NRC staff concludes that the TXS COMPACT Platform implements means to detect erroneous behavior of the hardware and FPGA HDL program through self-diagnostics with permanently running self-monitoring and for-purpose self-tests. However, the NRC staff finds that the TXS COMPACT Platform complies with the regulatory guidance in RG 1.152 and Clause 5.5.3 of its endorsed IEEE Std. 7-4.3.2-2016 for self-diagnostic and testing features in safety-related I&C systems (see PSAI 6.1.11 in Section 6.1 of this SE).

Although self-testing and self-diagnostics capabilities of the TXS COMPACT Platform could be used for reduction in surveillance intervals and requirements, the TR does not include information to demonstrate reduction or replacement of any specific surveillance requirements by the TXS COMPACT Platform's self-testing and self-diagnostic functions. The TXS COMPACT Platform-level self-diagnostic and self-testing features could be complemented by engineered self-diagnostic functions in application specific programs. An applicant or licensee referring the TXS COMPACT Platform TR must provide adequate justifications if platform self-testing and self-diagnostic capabilities of the TXS COMPACT Platform are used to reduce or replace any specific surveillance requirements (see PSAI 6.1.8 in Section 6.1 of this SE).

The regulation at 10 CFR 50.55a(h) incorporates by reference IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations." Clause 5.7 of IEEE Std. 603-1991, "Capability for Testing and Calibration," contains testing and calibration requirements.

IEEE 7-4.3.2-2016 provides additional criteria to be considered for capability for test and calibration. Clause 5.7 of IEEE Std. 7-4.3.2-2016 states that safety system configuration shall not require change or modification to support periodic automated or manual surveillance testing. It also states that measurement and test equipment (M&TE) used for safety systems shall not adversely affect the safety system functionality. SRP Chapter 7, Appendix 7.1-D, Section 5.7, "Capability for Test and Calibration," provides guidance for evaluating and determining acceptability of test and diagnostic software.

The NRC staff also reviewed the calibration capability of the TXS COMPACT Platform and identified that for the applicable MPIOF1 module a calibration sequence of the MPIOF1's analog channels is performed during manufacturing to get the right accuracy. This concerns the analog to digital converter of the analog input channels and the digital to analog converters of the analog output channels. A very precise value can be injected on one given channel and read back by the FPGA. A gain and/or an offset can then be added to compensate for the deviation in the electronic device. Once calibrated, the calibration coefficients are written in a non-volatile memory and are used by the module's final configware. So, the calibration does not need to be adjusted later during commissioning and operation.

The analog inputs are self-tested through dedicated circuitry to ensure that the precision remains in specified ranges. [[

]]. Hence, the NRC staff finds that the applicable MPIOF1 module of the TXS COMPACT Platform has the capability of calibration.

Because the modules for the TXS COMPACT Platform are developed as part of the TXS family system, for the TXS COMPACT Platform-based portions of a safety-related I&C system, the NRC staff found that the periodic surveillance testing can be performed from the SU. However, a TXS COMPACT Platform-based safety system also includes field devices such as sensors, actuators, and control room devices. These devices are interfaced to TXS COMPACT-based AUs using hardwired connections. [[

]]. Also, application programs must be set up for the SU to control test signals and test execution.

Therefore, determination of the test and calibration requirements that must be fulfilled depends upon the plant specific safety requirements that apply. In addition, the establishment of the types of surveillance testing requirements necessary for the TXS COMPACT Platform based I&C safety system is a plant specific activity. Since the TXS COMPACT Platform TR does not address a specific application or establish a definitive safety system design, the above evaluation against the requirement for capacity of test and calibration is limited to consideration of the means provided within the modules of the TXS COMPACT Platform to enable testing and calibration. The TXS COMPACT Platform's self-diagnostic, testing, and monitoring capabilities evaluated above in this section could be used to support compliance with criteria in Clause 5.7,

“Capability for Test and Calibration,” of IEEE Std. 603-1991 and Std. 7-4.3.2-2016. But, full compliance with the criteria of capability of test and calibration for a TXS COMPACT Platform based I&C safety system is application specific.

4.8 Compliance to IEEE Std. 603-1991

The TXS COMPACT Compliance to IEEE Std. 603-1991 is assessed by going through requirements one by one. As described in PSAI 6.1.10 in Section 6.1 of this SE, an applicant or licensee must demonstrate that the plant specific use of the TXS COMPACT Platform satisfies the applicable IEEE Std. 603-1991 clauses in accordance with the plant specific design basis and safety system application. The NRC staff developed the table below that summarizes the compliance analysis results.

IEEE Std. 603 Clause	Title	TR Section	Compliance ³
4.1	Safety System Design Basis	11.1.2	
4.2			
4.3			
4.4			
4.5			
4.6			
4.7			
4.8			
4.9			
4.10			
4.11			
4.12			
5.1	Single Failure Criterion	2.1.2, 11.1.2, 11.1.3.1	
5.2	Completion of Protective Action	11.1.3.2	
5.3	Quality	4.2.2, 4.2.3, 11.1.3.3	
5.4	Equipment Qualification	4.1, 4.10, 11.1.3.4	

³ An applicant or licensee that reference the TXS COMPACT TR must identify how each applicable clause of IEEE Std. 603-1991 is addressed, taking into account the plant-specific design basis. See Section 6.2.10 of this SE for further discussion.

5.5	System Integrity	4.0, 4.6, 4.7, 4.8, 11.1.3.5	
5.6	Independence	11.1.3.6	
5.6.1	Between Redundant Portions of a Safety System	4.7, 11.1.3.6.1	
5.6.2	Between Safety Systems and Effects of Design-Basis Event	4.7, 11.1.3.6.2	
5.6.3	Between Safety Systems and Other Systems	11.1.3.6.3	

5.6.4	Detailed Criteria	11.1.3.6.4	
5.7	Capability for Testing and Calibration	3.24.2.4, 7.0, 11.1.3.7	
5.8	Information Displays	11.1.3.8	
5.8.1	Displays for Manually Controlled Actions		
5.8.2	System Status Indication		
5.8.3	Indication of Bypasses		
5.8.4	Location		
5.9	Control of Access	2.6.3, 2.6.6, 11.1.3.9	
5.10	Repair	11.1.3.10	
5.11	Identification	11.1.3.11	

5.12	Auxiliary Features	11.1.3.6, 11.1.3.12	
5.13	Multi-Unit Stations	11.1.3.13	
5.14	Human Factors Considerations	11.1.3.14	
5.15	Reliability	11.1.3.15	
6.1	Automatic Control	11.1.4.1	
6.2	Manual Control	11.1.4.2	
6.3	Interaction Between Sense and Command Features and Other Systems	11.1.4.3	
6.4	Derivation of System Inputs	11.1.4.4	
6.5	Capacity for Testing and Calibration	11.1.4.5	
6.6	Operating Bypasses	11.1.4.6	
6.7	Maintenance Bypass	11.1.4.7	

6.8	Setpoints	2.8, 11.1.4.8	
7.1	Automatic Control	11.1.5	
7.2	Manual Control		
7.3	Completion of Protective Action		
7.4	Operating Bypass		
7.5	Maintenance Bypass		
8.1	Electrical Power Sources	11.1.6	
8.2	Non-Electrical Power Sources		
8.3	Maintenance Bypass		

As described in the table above, the NRC staff determined that the TXS COMPACT Platform can satisfy various sections and clauses of IEEE Std. 603-1991. However, this SE does not address a specific application, establish a definitive safety system or protective action, or identify and analyze the impact of credible events including direct and indirect consequences. Therefore, as described in PSAI 6.1.10 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT TR must identify the approach taken to satisfy each applicable clause of IEEE Std. 603-1991 with consideration of the plant specific design basis.

4.9 Conformance with RG 1.152 and IEEE 7-4.3.2

RG 1.152, Revision 4, describes an approach that is acceptable to the NRC staff to meet regulatory requirements for promoting high functional reliability, design quality, and a SDOE for the use of programmable digital devices (PDDs) in the safety-related systems of nuclear power generating stations. This RG endorses, with some exceptions and clarifications, IEEE Std. 7-4.3.2-2016, "IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations."

Section 11.2, "TXS COMPACT Compliance to NRC Regulatory Guide 1.152, Revision 4, 2023 & IEEE Std. 7-4.3.2-2016," of the TXS COMPACT TR, as supplemented, describes the approach to complying with NRC regulatory requirements for safety systems in NPPs by conforming to applicable clauses of IEEE 7-4.3.2 as endorsed by RG 1.152. Section 11.2 of the TR includes a complete quotation of each IEEE clause and a fully proprietary description of the manner of conformance. Some criteria are characterized as being in "Compliance: Full" and these include a detail description of the manner of conformance; however, even these clauses need to be re-evaluated by the application implementer because the application (as opposed to the platform and associated application framework described in the TR) also must address each clause. There are some criteria in the IEEE standard that are only applicable to the final application, and these are described in the TR and the evaluation below.

As described in TR Sections 2.1.1, 2.1.2, 2.1.3, and 2.1.4, compliance is partitioned into two steps: (1) module or component features or properties, and (2) how those modules are used in an application to achieve compliance with regulatory requirements by conforming to endorsed

guidance. Only modules or component features or properties are evaluated in this section. As a PSAI, an applicant must demonstrate the modules and components are configured and arranged in a manner consistent with RG 1.152, Rev. 4, IEEE Std 7-4.3.2-2016 (see PSAI 6.1.11), and the NRC approved TR, as augmented and supplemented by limitations and condition listed in the SE.

IEEE Std. 7-4.3.2-2016 specifies additional digital system normative criteria to supplement the requirements of IEEE Std. 603 and should be used in conjunction with IEEE Std. 603 for completeness of the safety system design when a programmable digital device is to be used for a safety system function. The TXS COMPACT compliance with IEEE Std. 603 is assessed separately in Section 4.8 above. The TXS COMPACT conformance with IEEE Std. 7-4.3.2-2016 is assessed by going through requirements one by one. The NRC staff developed the table below that summarizes the conformance analysis results.

IEEE Std. 7-4.3.2 Clause	Title	TR Section	Conformance
4	Safety System Design Basis	11.2.1	
5	Safety System Criteria	11.2.2	
5.1	Single Failure Criterion	11.2.2.1	
5.2	Completion of Protective Action	11.2.2.2	
5.3	Quality	6.0, 6.2.2.2, 8.0, 11.2.2.3	
5.3.1	Software development	Figs. 6-2 & 6-4, 6.2.1, 11.2.2.3.1	
5.3.2	Software tools	3.1.2.1, 3.1.3, 3.1.4, 6.2.2.2, 11.2.2.3.2	
5.3.3	Verification and validation	3.1.4, 6.2.2, 11.2.2.3.3	

5.3.4	V&V independence requirements	6.2.2, 11.2.2.3.4	
5.3.5	Configuration management	3.1.1, 9.4.1, 11.2.2.3.5	
5.3.6	Project risk management	11.2.2.3.6	
5.4	Equipment Qualification	4.0, 4.1.2, 4.10.5, 11.2.2.4	
5.5	System Integrity	9.4.1, 9.4.2, 11.2.2.5	
5.5.1	Design for PDD integrity	11.2.2.5.1	
5.5.2	Design for test and calibration	3.2, 3.4, 11.2.2.5.2	
5.5.3	Fault detection and self-diagnostics	3.2.2.2, 3.2.2.3, 11.2.2.5.3	
5.5.4	Prioritization of functions	1.2, 11.2.2.5.4	

5.6	Independence	2.5.1, 5.0, 7.0, 11.2.2.6, RAI 10638 Question 1 Response (ML25212A176)	
5.6.1	Between Redundant Portions of a Safety System	2.4, 5.1, 11.2.2.6.1	
5.6.2	Between Safety Systems and Effects of Design-Basis Event	11.2.2.6.2	
5.6.3	Between Safety Systems and Other Systems	2.2.2.3, 2.2.2.4, 2.4.1, 5.2, 11.2.2.6.3	
5.6.4	Detailed Criteria	11.2.2.6.4	
5.6.4.1	Buffering function/circuit	Figure 5-3, 5.1.2, 11.2.2.6.4, 11.3.1	
5.6.4.2	Communications independence	Figure 2-8, 2.4.5, 5.1, 11.2.2.6.4, 11.3.1	
5.6.4.3	Data independence	5.1, 11.2.2.6.4, 11.3.1	
5.7	Capability for Testing and Calibration	3.2, 11.2.2.7	
5.8	Information Displays	5.3, 11.2.2.8	
5.8.1	Independence and isolation requirements for multidivisional control and display stations	5.3, 11.2.2.8.1	
5.8.2	Malfunctions and spurious actuations	3.2, 11.2.2.8.2	
5.9	Control of Access	2.5, 2.6.3, 2.6.13, 3.6, 5.3, 6.1, 9.0, 11.2.2.9, Figure 5-1, Figure 6-2	
5.9.1	Physical security	9.0	
5.9.2	Access controls	2.6.6	

5.9.3	Interaction between cyber security features and safety functions	Figure 5-1, 11.2.2.9.3	
5.9.3.1	Non-safety engineering workstations		
5.9.4	Life cycle approach	6.1 Figs. 6-2 & 6-4, 11.6.8	
5.9.5	Maintenance	1.2, 2.5.2.5	
5.10	Repair	11.2.2.10	
5.11	Identification	2.6.7, 11.1.3.11, 11.2.2.11	
5.12	Auxiliary Features	11.2.2.12	
5.13	Multi-Unit Stations	11.2.2.13	
5.14	Human Factors Considerations	2.9, 11.2.2.14	
5.15	Reliability	3.2, 7.0, 11.2.2.15	
5.16	Common cause failure criteria	1.2, 11.2.2.16	
5.17	Use of commercial digital equipment	1.2, 11.2.2.17	
5.18	Simplicity	2.9, 11.2.2.18	
6	Sense and command features—functional and design requirements	11.2.3	
7	Execute features—functional and design requirements	11.2.4	
8	Power source requirements	11.2.5	

4.10 Compliance to DI&C ISG-04 Revision 1, 2009

Section 11.3, "TXS COMPACT Compliance to DI&C ISG-04 Revision 1, 2009," of the TXS COMPACT TR, as supplemented, describes the approach to complying with NRC regulatory requirements for safety systems in NPPs by conforming to applicable clauses of DI&C ISG-04.

The NRC public web page states that the guidance from DI&C-ISG-04 Revision 1, "Highly Integrated Control Rooms & Digital Communication Systems," was incorporated into RG 1.152, Rev. 4 (88 FR 47754), July 2023. The NRC staff evaluation against RG 1.152 is found in Section 4.9 of this SE. Therefore, no separate evaluation of the TXS COMPACT TR was performed for conformance with DI&C ISG-04, Revision 1, 2009.

5.0 SUMMARY AND CONCLUSION

The NRC staff determined the TXS COMPACT Platform, consisting of modules described in both the TXS COMPACT Platform TR and Section 3.2 of this SE, their design features and the development processes used to produce them, are sufficient to support compliance with the applicable regulatory requirements for plant specific use. This determination is applicable for use of the TXS COMPACT Platform in safety related applications for NPPs provided that each applicable plant specific application items satisfies the limitations and conditions delineated in Section 6.0 of this SE and the system is properly installed and used as indicated by Framatome. The NRC staff further concludes that the TXS COMPACT Platform can be used in safety related systems to provide reasonable assurance of adequate protection of public health, safety and security based on the technical evaluation provided in Section 4.0 of this SE. On this basis, the NRC staff determined the TXS COMPACT Platform is acceptable for use in safety related I&C systems after addressing the limitations and conditions in Section 6.0 of this SE.

6.0 LIMITATIONS AND CONDITIONS

For each PSAI that applies to the applicant's or licensee's use of the TXS COMPACT Platform, an applicant or licensee that reference the TXS COMPACT TR (Ref. 1) must demonstrate that applicable items have been satisfactorily addressed. The applicable items provide limitations and conditions for the use of the TXS COMPACT Platform, as reviewed by the NRC staff and documented within this SE. This SE is limited to the TXS COMPACT Platform components listed in Table 3.2-1 in Section 3.2 of this SE.

6.1 Plant Specific Action Items

For use of this TR as approved by the NRC, the following PSAIs must be addressed by an applicant or licensee that references the TXS COMPACT Platform TR (Ref. 1) for a safety-related system based on the TXS COMPACT Platform.

- 6.1.1 TXS COMPACT Platform Changes – An applicant that references the TXS COMPACT Platform must demonstrate that the TXS COMPACT Platform used to implement the plant specific system is unchanged from the generic platform addressed in this SE. Otherwise, the licensee must clearly and completely identify any modification or addition to the generic TXS COMPACT Platform as it is employed and provide evidence of compliance by the modified platform with all applicable regulations that are affected by the changes. In addition, the applicant must verify that modules, features, and/or functions that require configuration are properly configured and tested to meet application specific system requirements.
- 6.1.2 Application Software Development Process – An applicant or licensee that references the TXS COMPACT Platform must ensure that the development of application software is performed in accordance with a defined and controlled software development process consistent with applicable regulations, NRC guidance, and consensus industry standards, or an NRC-approved Application Software Program Manual.
- 6.1.3 Plant Specific Equipment Qualification – The licensee must demonstrate that the EQ envelope established for the TXS COMPACT Platform bounds the corresponding plant specific environmental conditions (i.e., temperature, humidity, radiation, and EMC) for the location(s) of the equipment. The licensee must ensure that specific equipment

configuration of TXS COMPACT components to be installed is consistent with that of the TXS COMPACT equipment used for the EQ tests. The licensee must ensure any deviations of surge susceptibility testing levels from RG 1.180 Revision 2 are identified and justified.

- 6.1.4 Response Time – The licensee must perform timing analyses and functional testing of the application implementation and system configuration to demonstrate that response time performance satisfies application specific requirements established in the plant specific safety analysis report.
- 6.1.5 Failure Modes and Effects Analysis – An applicant or licensee that references the TXS COMPACT TR must perform a system level failure modes and effects (FMEA) to demonstrate that plant specific use of the TXS COMPACT Platform identifies each potential failure mode and determines the effects of each. The FMEA must demonstrate that single failures, including those with the potential to cause a non-safety-related system action (i.e., a control function), that result in a condition requiring protective action (i.e., a protection function), cannot adversely affect the protection functions, as applicable. The applicant or licensee must ensure system failure states identified in the FMEA are consistent with system requirements and must review how errors and failures are indicated and managed upon being detected.
- 6.1.6 Application Specific System Reliability – An applicant or licensee that references the TXS COMPACT TR must perform a system-level evaluation of the degree of redundancy, diversity, testability, and quality provided in a TXS COMPACT Platform-based safety system to determine if the degrees provided are commensurate with the safety functions being performed. An applicant or licensee must confirm that a resultant TXS COMPACT Platform -based system continues to satisfy any applicable reliability goals that the plant has established for the system. This plant specific action must consider the effect of possible failures, system-level design features provided to prevent or limit the failures' effects, and any plant specific inclusion of a maintenance bypass to support plant operations.
- 6.1.7 Setpoint Methodology – An applicant or licensee that references the TXS COMPACT TR must perform an analysis of accuracy, repeatability, thermal effects, and other necessary data for use in determining the contribution of the TXS COMPACT Platform to instrumentation uncertainty in support of setpoint calculations for plant specific applications.
- 6.1.8 System Testing and Surveillance – The applicant or licensee that references the TXS COMPACT Platform TR must establish periodic surveillance testing necessary to detect system failures for which automatic detection and indication are not provided. The applicant must also define appropriate surveillance requirements and intervals to provide acceptable comprehensive coverage of identifiable system failure modes.
- 6.1.9 Diversity and Defense-InDepth Analysis – Since a diversity and defense-in-depth (D3) analysis was not provided as part of the TR, a D3 analysis must be performed by the applicant or licensee consistent with regulatory criteria at the time of applications.
- 6.1.10 IEEE Std. 603 – Although the NRC staff determined that the TXS COMPACT Platform can satisfy various sections and clauses of IEEE Std. 603-1991, an applicant or licensee

that references the TXS COMPACT TR must identify the approach taken to satisfy each applicable clause of IEEE Std. 603-1991 with consideration of the plant specific design basis. This SE does not address a specific application, establish a definitive safety system or protective action, or identify and analyze the impact of credible events including direct and indirect consequences. Therefore, an applicant or licensee must demonstrate that the plant specific use of the TXS COMPACT Platform satisfies the applicable IEEE Std. 603-1991 clauses in accordance with the plant specific design basis and safety system application.

- 6.1.11 IEEE Std. 7-4.3.2 – Even though the NRC staff determined that the TXS COMPACT Platform is capable of satisfying various sections and clauses of IEEE Std. 7-4.3.2-2016, an applicant or licensee that references the TXS COMPACT TR must identify the approach taken to satisfy each applicable clause of IEEE Std. 7-4.3.2-2016 with consideration of the plant specific design basis. This SE does not address a specific application, establish a definitive safety system or protective action, or identify and analyze the impact of credible events including direct and indirect consequences. Therefore, the applicant or licensee must demonstrate that plant specific use of the TXS COMPACT Platform satisfies the applicable IEEE Std. 7-4.3.2-2016 clauses in accordance with the plant specific design basis and safety system application.
- 6.1.12 Secure Development and Operational Environment – An applicant or licensee that references the TXS COMPACT TR for a safety-related plant specific application must ensure that a secure development and operational environment have been established for its plant specific application, and that it satisfies the applicable regulatory evaluation criteria of RG 1.152, Revision 4.
- 6.1.13 System Development Quality Assurance – An applicant or licensee that references the TXS COMPACT TR for a safety-related plant specific application must ensure that the system design, development, and testing activities are performed under an Appendix B to 10 CFR Part 50 compliant QA program.

7.0 REFERENCES

- [1] Framatome ANP-10357P, Revision 0, TXS COMPACT Platform Topical Report, August 2024 (Package Accession No. ML24218A279).
- [2] TR EMF-2110(NP)(A), Revision 1, “TELEPERM XS: A Digital Reactor Protection System,” Siemens Power Corporation, July 2000 (Package Accession No. ML003732665).
- [3] Regulatory Audit Plan for March 31-April 4, 2025, TXS COMPACT Platform Topical Report, Revision 0, dated March 2025 (Package Accession No. ML24352A156).
- [4] Regulatory Audit Report for March 31-April 4, 2025, TXS COMPACT Platform Topical Report, Revision 0, dated June 2025 (Package Accession No. ML25154A657).
- [5] 51-9389344-000, TXS COMPACT Gap Analysis.
- [6] D02-ARV-01-236-646, TXS COMPACT: Supplementary Equipment Qualification Plan (Supplementary EPRI Testing for TXS COMPACT Phase 1 Modules).

- [7] D02-ARV-01-238-128, Test Specification for Supplementary US Qualification of TELEPERM XS Modules.
- [8] D02-ARV-01-160-510, TXS COMPACT - Qualification Plan.
- [9] D02-ARV-01-174-276, TXS COMPACT - Test Set-Up for System Integration.
- [10] D02-ARV-01-176-856, TXS COMPACT - PM1 Functional Test Specification.
- [11] D02-ARV-01-173-512, TXS COMPACT: MPIOF1 - Functional Test Specification.
- [12] D02-ARV-01-173-640, TXS COMPACT - GWF1 Functional Test Specification.
- [13] D02-ARV-01-178-612, TXS COMPACT - SMDF1 Functional Test Specification.
- [14] D02-ARV-01-236-054, TXS COMPACT - PM1 Summary Qualification Report.
- [15] D02-ARV-01-236-056, TXS COMPACT - MPIOF1 Summary Qualification Report.
- [16] D02-ARV-01-236-060, TXS COMPACT - GWF1 Summary Qualification Report.
- [17] D02-ARV-01-236-061, TXS COMPACT - SMDF1 Summary Qualification Report.
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- [26] D02-ARV-01-101-817, "Framatome Integrated Management System Manual," Revision F (Package Accession No. ML25203A339).
- [27] Supplemental Responses to RAI-10688, January 16, 2026 (Package Accession No. ML26020A269).
- [28] RAI-10688 for Framatome TXS Compact Topical Report, ANP-10357, Revision 0, July 2, 2025 (Package Accession No. ML25178A329).

- [29] 38-9394823-000, "Quality Plan – TXS COMPACT Quality Management Plan," Revision A, May 7, 2024 (Package Accession No. ML25203A339).
- [30] Response to First Set of Requests for Additional Information Regarding Framatome ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report," RAls 10636, 10637, 10638, and 10688, July 30, 2025 (ML25212A178).
- [31] January 5-9, 2026, Audit Plan for Framatome ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report" (Package Accession No. ML25344A019)
- [32] Report for January 5-9, 2026, Framatome ANP-10357P, Revision 0, TXS COMPACT Platform Topical Report Audit (Package Accession No. ML26064A008)

**Summary Table for Response to Framatome Comments on ANP-10357P, Revision 0,
“TXS Compact Platform Topical Report,” Draft Safety Evaluation**

#	Page/Section	Framatome’s Proposed Revision to SE	Framatome Comment	NRC Staff Response
1		See draft SE markups in Enclosure 2 for proprietary markups by Framatome.		The NRC staff accepts the additional proposed proprietary markings and has incorporated into the final SE.
2	Page 54 / PSAI 6.1.5	“6.1.5 Failure Modes and Effects Analysis – An applicant or licensee that references the TXS COMPACT TR must perform a system level failure modes and effects (FMEA) to demonstrate that plant specific use of the TXS COMPACT Platform identifies each potential failure mode and determines the effects of each. The FMEA must demonstrate that single failures, including those with the potential to cause a non-safety-related system action (i.e., a control function), that result in a condition requiring protective action (i.e., a protection function), cannot adversely affect the protection functions, as applicable. The applicant or licensee must ensure system failure states identified in the FMEA are consistent with system requirements and must review how errors and failures are indicated and managed upon being detected. ~~The applicant or licensee must also demonstrate that watchdog timer functions that are credited for initiating fail safe states upon a given failure are not susceptible to the same cause for the failure.~~”	The watchdog timer was not included in the discussions about potential PSAs. [[]]	The NRC staff accepts the proposed deletions regarding PSAI 6.1.5 and have incorporated those changes into the final SE.

#	Page/Section	Framatome's Proposed Revision to SE	Framatome Comment	NRC Staff Response
3	Page 22 / IEEE 7-4.3.2 Clause 5.6.4.2	Add the following suggested wording to Page 22 / IEEE 7-4.3.2 Clause 5.6.4.2: <u>"The NRC staff concluded that data communications between safety channels of a TXS Compact based system or communications between safety and external non-safety systems would not inhibit the performance of the systems safety functions."</u>	The draft SE does not include the conclusion reached by staff like other sections. Recommend adding a conclusion and then referring to PSAI for application specific action.	The proposed change is not accepted by the NRC staff since these are PSAIs and therefore no conclusion can be provided at this time.
4	Page 22 / IEEE 7-4.3.2 Clause 5.6.4.3	Add the following suggested wording to Page 22 / IEEE 7-4.3.2 Clause 5.6.4.3: <u>"The NRC staff concluded that platform data independence meets the IEEE 7-4.3.2 Clause 5.6.4.3."</u>	The draft SE for these IEEE Clauses does not include the conclusion reached by staff like other sections. Recommend adding a conclusion and then referring to PSAI for application specific action.	The proposed change is not accepted by the NRC staff since these are PSAIs and therefore no conclusion can be provided at this time.
5	Page 29 / Section 4.3	"Therefore, as stated in PSAI 6.1.2 in Section 6.1 of this SE, an applicant or licensee that references the TXS COMPACT Platform must ~~provide oversight to ensure the development of its application software is performed in accordance with a process that must be included in a TXS COMPACT Platform application software program manual~~ <u>ensure that the development of application software is performed in accordance with a defined and controlled software development process consistent with applicable regulations, NRC guidance, and consensus industry standards, or an NRC-approved Software Program Manual</u> "	The change provides consistency with the PSAI 6.1.2 wording.	The NRC staff accepts the proposed revisions to Section 4.3 and have incorporated those changes in the final SE. In addition, the NRC staff has added the word, "Application," before "Software Program Manual," in Section 6.1 of the final SE regarding the discussion on PSAI 6.1.2 for consistency with the Section 4.3 changes.
6	Page 11 / Section 3.2.4	"WAITSTATE: Entered <u> </u>] from OPERATION mode when <u> </u>]. The AU remains in WAITSTATE until a valid service command instructs a transition to service mode."	Additional word is needed to describe design correctly and provides consistency with TR Section 2.5.2 and Figure 2-24.	The NRC staff accepts the proposed changes and has incorporated into the final SE.

#	Page/Section	Framatome's Proposed Revision to SE	Framatome Comment	NRC Staff Response
7	Page 24 / Section 4.3	"The NRC staff's review of the TXS COMPACT development life cycle activities is limited to evaluating activities related to safety-related modules described in Section 1.2 of the TR (i.e., PM1, "TXS COMPACT Processing Module," MPIOF1, "TXS COMPACT Multi-Purpose I/O Module, and GWF1, "TXS COMPACT Gateway Module," <u>and BPF1, "TXS COMPACT Backplane."</u>)	Include BPF1 in the list of safety-related modules described in Section 1.2.	The NRC staff accepts the proposed changes and has incorporated into the final SE.
8	Page 8 / Section 3.2.1	"PM1 provides a fixed library of 87 ~~pre-developed~~ <u>prequalified</u> function block types that could be configured to implement safety-related I&C functions."	Match the TR characterization of the function blocks as prequalified.	The proposed change is not accepted by the NRC staff. No changes made to the final SE.
9	Page 9 / Section 3.2.1	"The SMDF1 module ... functions include loading new application programs or parameters under controlled conditions, monitoring AU status, forwarding signal values to the SU, and retrieving system event logs. <u>II</u> <u>II</u> SMDF1 does not safety-related I&C functions and is classified as non-safety-related.	This is a key safety feature of SDMF1, consistent with TR Section 6.2.1.	The NRC staff accepts the proposed changes and has incorporated into the final SE.
10	Page 9 / Section 3.2.1	The MPIOF1 module ... ~~It includes four independent I/O channel groups, one input for counting transistor to transistor logic (TTL) pulse signals, and two 24 volts (V) sensor power supply outputs. It provides two analog current inputs, two analog current outputs, four binary signal inputs, four binary signal outputs, one input for counting TTL pulse signals, and two 24 volts (V) sensor power supply outputs. They are organized into four independent I/O channel groups where the counter input is incorporated in analog channel group.~~ During STARTUP mode, ..."	Description of I/O signal types does not match TR and can lead to confusion.	The NRC staff accepts the proposed changes and has incorporated into the final SE.

Note: The page and section numbers in this table refer to the original draft SE. The strikethrough text denotes Framatome's proposed deletions. The italicized and underlined text denotes Framatome's proposed additions.

TXS COMPACT PLATFORM

ANP-10357NP
Revision 0

Topical Report

July 2024

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

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Nomenclature

Acronym	Definition
AC	Alternating Current
ACI	Analog Channel - Input
ACO	Analog Channel - Output
AGT	Application Generation Toolkit The software tool which transforms the specification of the engineered safety I&C application function expressed as function block diagrams and architecture diagrams into an application program.
AI	Analog Input
AM	Amplitude Modulation
AO	Analog Output
API	Application Programming Interface
ARM	Advanced RISC Machines Family of computer processors
ASD	Acceleration Spectral Density
AU	Automation Unit
AVT	Application Verification Toolkit The software tool that allows systematic and automatic verification of the outcomes of AGT software.
BI	Binary Input
BO	Binary Output
BPF1	TXS COMPACT Backplane
BTP	Branch Technical Position
BU	Business Unit Framatome Business entity
CCF	Common Cause Failure
CCM	Configuration and Change Management
CCMP	Configuration and Change Management Plan
CFR	Code of Federal Regulations
CGD	Commercial Grade Dedication
CGF1	Cable Gland Frame TXS COMPACT peripheral for I&C and power supply cables.
CGS	Commercial Grade Surveys
CISPR	International Special Committee on Radio Interference
CMM1	Cabinet Monitoring Module
CMU1	Cabinet Monitoring Unit

Acronym	Definition
CONGEN	CONstant GENerator Function Block provided by the TXS COMPACT engineering toolchain
COTS	Commercial Off-the-Shelf
CRC	Cyclic Redundancy Check
CST	COMPACT Service Tools The graphical software tool running on Service Unit which allows to configure and monitor the Automation Units of a system.
CS ²	COMPACT System Simulator The tool that is used to simulate I&C systems implemented with TXS COMPACT technology.
CW	Configware
DC	Direct Current
DDR	Double Data Rate
DMT	Data Management Toolkit
ECB	Electronic Circuit Breaker
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
EUT	Equipment Under Test
FAN1	Fan Cassette
FAW	Fachanweisungen German word for work instruction
FB	Function Block
FMEA	Failure Modes and Effects Analysis
FNU1	Fan Unit
FPGA	Field-Programmable Gate Array
FPU	Floating Point Unit
GDC	General Design Criteria
GHz	Gigahertz
GUI	Graphical User Interface
GWF1	TXS COMPACT Gateway Module
HDL	Hardware Description Language
HMI	Human-Machine Interface
HP	Horizontal Pitch
HPD	HDL-Programmed Device
HPS	Hardware Processor System
HW	Hardware
IAEA	International Atomic Energy Agency

Acronym	Definition
ID	Identifier
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IHD	In-House Developed
IK	International Mechanical Protection IK code represents a coding system to indicate the degree of protection provided by an enclosure against harmful external mechanical impacts. <i>Source: IEC 62262:2002 §3.3 IK code</i>
IP	International Protection IP code represents a coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water, and to give additional information in connection with such protection. <i>Source: IEC 60529:2013 §3.3 IP code</i>
IPC	Institute for Printed Circuits Trade association whose aim is to standardize the assembly and production requirements of electronic equipment and assemblies.
IPC-A-610	IPC standard for Acceptability of Electronic Assemblies
ISG	Interim Staff Guidance
ISO	International Organization for Standardization
IT	Information Technology
IV&V	Independent Verification and Validation
I&C	Instrumentation and Control
I/O	Input/Output
KSA	Knowledge, Skills, and Attitudes
KTA	Kerntechnischer Ausschuss German Nuclear Safety Standards Commission.
LC	Lucent Connector Optical connector compliant with IEC 61754-20 standard.
LED	Light-Emitting Diode
MHz	Megahertz
MILA	Maximum Installation Location Acceleration
MLVDS	Multipoint Low-Voltage Differential Signaling
MPIOF1	TXS COMPACT Multi-Purpose I/O Module
MRAM	Magnetic Random Access Memory
MRC	Function block used for Measuring Range Conversion of analog signals
NIS	Named Interface Signal

Acronym	Definition
NOK	Not OK
NPP	Nuclear Power Plant
NRC	U.S. Nuclear Regulatory Commission
NUREG	U.S. Nuclear Regulatory Commission Regulation
NVM	Non-Volatile Memory
OPU	Operating Unit
PCB	Printed Circuit Board
PDD	Programmable Digital Device
PM1	TXS COMPACT Processing Module
PSD1	Power Supply Diode
PSU1	Power Supply Unit
QA	Quality Assurance
QDS	Qualified Display System
RAM	Random Access Memory
RCC-E	French standard: Design and construction rules for electrical equipment of nuclear islands
RF	Radio Frequency
RFI	Radio Frequency Interference
RG	Regulatory Guide
RJ45	Ethernet connector type
RMS	Root Mean Square
RPS	Reactor Protection System
SAT	Systematic Approach to Training
SCMx	Connection Module
SDOE	Secure Development and Operational Environment
SEU	Single Event Upset
SFP	Small Form-Factor Pluggable
SHA256	Secure Hash Algorithm 256 Bits
SMC1	Media Converter Module
SMDF1	TXS COMPACT Service, Maintenance, and Diagnosis Module
SN	SIEMENS Standard
SPDL	Safety Program Description Language
SPDL/FB	Safety Program Description Language/Function Blocks
SPDL/NA	Safety Program Description Language/Network Architecture
SPS1	Power Supply Module
SR-	Subrack
SRACKCR	TXS COMPACT chassis including BPF1

Acronym	Definition
SSH	Secure Socket Shell
SU	Service Unit
SW	Software
TCP	Transmission Control Protocol
TDL	Tool Development Level
TTL	Transistor-Transistor Logic
UDP	User Datagram Protocol
UMP1	Universal Mounting Plate
VHDL	Very high-speed integrated circuits Hardware Description Language
V&V	Verification and Validation

1.0 INTRODUCTION

1.1 *Objective*

This Topical Report describes attributes of the Framatome TELEPERM XS (TXS) COMPACT Field-Programmable Gate Array (FPGA) based Instrumentation and Control (I&C) platform (herein identified as TXS Compact platform) for the purpose to obtain U.S. Nuclear Regulatory Commission (NRC) review and approval for use in nuclear power plant safety-related I&C applications.

The generic TXS COMPACT platform does not utilize microprocessors or software, but instead relies on simple hardwired architecture. Its safety system logic is implemented using qualified design tools and FPGA technology. The TXS COMPACT platform and associated Modules and Backplane are designed and qualified by Framatome as nuclear safety-related products.

1.2 *Scope*

The scope of this topical report includes the TXS COMPACT platform, which consists of the following Modules and Backplane:

- TXS COMPACT Processing Module – PM1
- TXS COMPACT Multi-Purpose Input/Output (I/O) Module – MPIOF1
- TXS COMPACT Service, Maintenance, and Diagnosis Module – SMDF1
- TXS COMPACT Gateway Module – GWF1
- TXS COMPACT Backplane – BPF1

The TXS COMPACT modules: PM1, MPIOF1, SMDF1, and GWF1 are plug-in modules intended for installation in chassis which are equipped with the BPF1. The TXS COMPACT chassis enables the installation of modules with the dimensions of a 3U/19" format.

The TXS COMPACT platform does not include the cabinet, power supply, or peripheral devices. These components are part of a complete TXS COMPACT safety system and are discussed in Section 2.6 to the extent necessary to ensure compatibility with the TXS COMPACT platform. Included in this TXS COMPACT topical report is a detailed discussion of the TXS COMPACT platform (including hardware, development tools and associated processes, design qualification, communications, reliability, configuration management, and Independent Verification and Validation (IV&V)).

This Topical Report is organized in the following sections:

- Section 2.0: TXS COMPACT Technical Description – describes the TXS COMPACT platform, architecture, Processing Module (PM1), Multi-Purpose I/O Module, Service, Maintenance, and Diagnosis Module (SMDF1), Gateway Module, and TXS COMPACT Backplane (BPF1). This section also describes the cabinet and peripheral components required to support the TXS COMPACT platform in a typical safety system application.
- Section 3.0: TXS COMPACT Configuration, Diagnostics, and Monitoring – describes TXS COMPACT design configuration tools, diagnostic and fault detection features, platform maintenance features, calibration, test capabilities, and access control.
- Section 4.0: TXS COMPACT Equipment Qualification – describes environmental (temperature and humidity), seismic, and electromagnetic compatibility (EMC) qualifications.
- Section 5.0: TXS COMPACT Platform Communications – describes TXS COMPACT intra-division communication, inter-division safety-to-safety communication, safety-to-non-safety communication, and multidivisional control.

- Section 6.0: TXS COMPACT Life Cycle Management Process – describes the TXS COMPACT Life Cycle including planning, requirements, design, manufacture, integration, assembly, and test phases.
- Section 7.0: TXS COMPACT Reliability and Failure Modes and Effects Analysis (FMEA) – summaries the use of failure rate calculations and module-level FMEAs as the basis for failure analyses and reliability studies.
- Section 8.0: TXS COMPACT Quality Assurance (QA) – describes compliance to Code of Federal Regulations (CFR) 10 CFR Part 50 Appendix B requirements for TXS COMPACT development and delivery.
- Section 9.0: TXS COMPACT Security – describes TXS COMPACT Security life cycle measures and features.
- Section 10.0: TXS COMPACT Training – describes TXS COMPACT Training with respect to development, application, and customer personnel.
- Section 11.0: TXS COMPACT Regulatory Compliance – describes compliance to IEEE 603 [1], IEEE 7-4.3.2 [9], NUREG-0800 [20] (U.S. Nuclear Regulatory Commission Regulation) Criteria, and Interim Staff Guidance (ISG) documents.

1.3 *Background*

Many of the installed instrumentation and control safety systems in the United States and international nuclear power plants have obsolescence challenges and are not always well-supported by original equipment manufacturers. Framatome has developed a “state-of-the-art” safety system addition to the TXS solution portfolio identified as TXS COMPACT. TXS COMPACT is an FPGA technology-based solution built upon decades of Framatome operational experience acquired from a global fleet of installed I&C systems. The TXS COMPACT design is based on the experience in design, manufacturing, installation, and commissioning of safety I&C systems in 88 nuclear power plants in 17 countries. The TXS COMPACT technology offers the following benefits:

- Fully deterministic Automation Units based on static response time without any interruptions.
- Unique and modern set of automated user-friendly design tools allowing for application development and maintenance without detailed FPGA training.
- Resistance to cybersecurity issues.
- Resilience to hardware obsolescence.
- Self-testing and diagnostics capabilities allowing for reduction in surveillance intervals.
- Reliability and availability improvements.
- Small form factor (3U/19") – easily fits into existing system cabinets.

TXS COMPACT has been developed as platform based on FPGA technology that can be integrated with different modules from the TXS portfolio to implement safety I&C systems in accordance with applicable regulatory requirements for safety-related I&C systems in nuclear power plants (NPPs).

We consider that NRC review and approval of this newly developed “state-of-the-art” safety system platform would provide significant benefit to the commercial nuclear industry.

1.4 ***Abbreviations and Terminology***

Application I&C function	Function to control, operate, and/or monitor a defined
also called	part of a process. Application I&C functions are specified
Engineered I&C function	by a collection of function block (FB) diagrams.

Application Program	A set of binary configuration files generated from the technical specification of the system which can be loaded into TXS COMPACT Automation Units to configure them to process specified application functions.
Architecture Diagram	Specification of the physical architecture of the system represented as an assembly of equipment such as racks, modules, and network links.
Automation Unit	A TXS COMPACT subsystem which executes application functions. It performs signal input/output and signal processing. Each Automation Unit consists of one main rack and up to three expansion racks. A system is composed of one or several Automation Units connected through point-to-point optical fibers. The occurrences of “TXS COMPACT Automation Unit” or “AU” in this document refer to “Automation Unit.”
Configware	The program written in Hardware Description Language (HDL) that describes the hardware logic executed within the FPGA chips. In the context of TXS COMPACT, it represents the generic system platform part and is generically qualified. It cannot be modified by I&C system users or design engineers.
Engineering Unit	The computer on which the engineering tools for TXS COMPACT are installed and design of the application I&C functions and generation of the application program take place.

Expansion Rack	One of up to three additional chassis connected to the main rack through fiber optic links (daisy chain topology) for expanding I/O capability of the Automation Unit.
Fatal Error	A fatal error is a defect in hardware or software which, either directly or via self-monitoring, leads to the end of operation of a component. Fatal Errors are classified as either transient or permanent.
Function Block	A reusable, closed, and pre-qualified operation which applies a specified mathematical function on input signals to compute output signals. Function blocks are the building blocks for application I&C Functions.
Function Block Diagram	Specification of the implementation of an application I&C function, or part of it, in terms of function blocks which are mutually interconnected by wires and with the diagram's input and output signals.
HP	Board widths are specified in horizontal pitch (HP) units, with 1 HP being 0.20 inch (5.08 mm).
I&C Project repository also called Project database	A directory tree containing I&C project data: the technical specification of the application I&C functions along with project configuration data (expressed as function block diagrams, architecture diagrams, and miscellaneous configuration data), metadata to ensure traceability, configuration management, and, optionally, a generated Application Program.

Main Rack	The chassis which contains the main PM1 and hence executes the safety I&C functions for the entire Automation Unit.
Parameter Set	A parameter set comprises a consistent set of binary files containing the value of the parameters in binary format, hashes over values, and means to verify that they correspond to the Application Program in use on the target Automation Units.
Slot	Identified location of modules in the chassis. There are 21 slots numbered from 0 to 20 as shown in Figure 2-2.
Service Unit	The computer on which the service tools for TXS COMPACT are installed. This computer is then used to configure and monitor the Automation Units.
Technical specification	Schematic design of the functions and system architecture of an I&C system. Collection of function block diagrams organized into an I&C project repository.
U	Height of the chassis is measured in rack units, "U," with 1 U being 1.75 inches (44.45 mm). This dimension refers to the chassis in which the board is to be mounted, rather than the board itself.

2.0 TXS COMPACT TECHNICAL DESCRIPTION

2.1 *TXS Family Overview*

The TXS system platform is intended for the design of safety Instrumentation and Control (I&C) systems for nuclear power plants (NPPs) of different reactor technologies and, in many countries, subject to various licensing requirements. Therefore, hardware and configware/application qualification of the TXS system platform components is performed based on the requirements from international standards, namely International Atomic Energy Agency (IAEA) and International Electrotechnical Commission (IEC) standards. In addition, nuclear Institute of Electrical and Electronics Engineers (IEEE) standards, such as IEEE 603 [1], are considered, being representative for applications in many countries with influence from the USA.

This report presents design features and characteristics and explains how the qualification of TXS COMPACT is performed. Also discussed are the structured development and Verification and Validation (V&V) processes involving independent assessor organizations.

This section provides an overview of the principles of the configware architecture of TXS COMPACT with its separation into generic components, generic qualification principles, and discussion of how this generic qualification is credited for the overall qualification of safety I&C systems.

Section 4.0 and Section 6.0 explain the approach taken for the qualification of TXS COMPACT and its basis for the development of a new generic configware for nuclear safety I&C systems, relying on a rigorously structured development process and the involvement of independent assessors.

2.1.1 Architecture of TXS COMPACT

The function running on the TXS COMPACT-based I&C systems is subdivided into:

- A common qualified generic configware.

- An individual application.

The TXS generic configware consists of a set of qualified components, which are part of all implemented TXS COMPACT-based I&C systems. It enables the application to run on the distributed I&C system and provides a TXS-specific and application-oriented function block library.

The application implements the project specific I&C functions. With the support of TXS engineering tools, the I&C functions are engineered in a graphical manner as function block diagrams by selecting and connecting pre-developed function blocks from the library. The application is stored in a specification database.

A qualified application generator automatically generates the entire application data (function block diagrams and their generic interfaces) for each Automation Unit from this specification database. Manual modifications or additions to this data are neither possible nor necessary.

The result is an interconnection of preexisting, qualified configware components with defined interfaces to each other. This minimizes risk of errors.

To meet the stringent reliability and quality demands for configware in safety I&C systems of nuclear power plants, the TXS configware:

- Avoids errors through a modular system with simple, thoroughly tested components,
- Avoids design errors by enforcing a clear design process with a phased structure including verification and validation steps,
- Operates the application functions in a deterministic way, and
- Copes with component and system failures using self-monitoring and fault handling routines.

A description of the operation principles and safety features of the TXS system platform can be found in Section 2.3, a summary of the self-monitoring and self-test features in Section 3.2.1.

2.1.2 Basic Approach for Qualification of Programmable Logic Items

The use of programmable logic technology in safety I&C systems has associated regulatory criteria. With respect to the design, qualification, and assessment of hardware, proven methodologies are available. Requirements from IEC 61226 [26], IEC 61513 [27], and IEEE 603 [1] result in a system design that meets the single failure criterion, using adequate redundancy of separated channels, and relies on qualified and proven hardware components.

Adequate assessment of programmable logic reliability for safety-related I&C systems is more complex. An accepted methodology for the qualification of programmable logic for digital safety I&C focuses on:

- A design which addresses the technical requirements for safety systems, especially deterministic behavior, fail-safe characteristics, and adequate fault propagation barriers.
- High-quality processes for configware development in addition to verification and validation with independent assessment.

For TXS COMPACT, I&C system qualification is further split into a generic and an application-dependent portion, both of which include preparation of evidence for implementation of adequate technical characteristics and quality:

- Generic qualification of the platform's hardware components, reusable configware components, and generic system properties.
- Project-specific (application-dependent) qualification of the architecture and of the I&C functions of the safety system.

To support this approach, the hardware and configware components have been developed as generic components, in a plant-independent framework, and have undergone a qualification program based on an approach enveloping the requirements of the anticipated licensing criteria. Resulting from this, generic qualification evidence is available for the platform, and the plant-specific licensing procedure can focus on the application system's functional requirements.

2.1.3 Generic Qualification

TXS COMPACT was developed in accordance with IEC 62566 [28] as the configware standard, IEC 60987 [31] as the hardware standard, and IEC/IEEE 60780-323 [46] and German Nuclear Safety Standards Commission (Kerntechnischer Ausschuss (KTA)) standard KTA 3503 [52] as the hardware qualification standards. Essential tools used for development and/or V&V are accessed in accordance with §15 of IEC 62566 [28], which refers to §14 of IEC 60880 [42].

The system platform has undergone a generic qualification based on type testing.

The objective of generic qualification by type testing is to demonstrate that equipment performance meets or exceeds requirements of the equipment specifications for the intended nuclear power plant deployment.

Type tests consist of a planned sequence of test conditions that meet or exceed expected or specified operational conditions and account for normal, abnormal, and accident conditions.

Although generic qualification by type testing was developed for hardware components, the basic idea of component-related qualification has also been applied to reusable configware components: If there is a clearly structured configware architecture of well-defined modules with proper interfaces, each of these modules can be tested as a generic component independent of a specific application.

Configware qualification focuses on aspects critical to assure configware quality; e.g., code review, static timing analysis, equivalence checking, constraint analysis, and Hardware Description Language (HDL)-Programmed Device (HPD) simulation, in addition to a structured and reviewable development process based on a phase model including verification and validation. Details about TXS COMPACT configware type testing are described in Section 6.2.2.1.

Based on the requirements of §14 of IEC 60880 [42], a graded approach of quality measures is applied to development of the software tools used for development, operation, maintenance, or diagnosis of TXS COMPACT-based I&C systems. Through this approach, a defined and documented qualification strategy for software tools is established. Thus, the software tools are qualified in accordance with the appropriate requirements, which is demonstrated through validation testing activities.

For each type of safety-related component belonging to the system platform, the IV&V checks that all properties have correctly implemented on both a theoretical and practical basis.

After verification, a type tested component can be assumed to fulfill those qualified properties when used in the application of a safety system.

All safety-related, generic configware components of the TXS system platform have been qualified in this manner.

This approach is particularly suited to the TXS concept since the complete application data is generated as an execution sequence of function blocks from the designed logic diagram. This is analogous to the wiring of predefined standardized hardware modules in hardwired systems.

The same process requirements apply for modifications to components and for any new developments. Details including a description of the development process, in addition to change and release procedures, are a fixed part of the TXS COMPACT Quality Assurance (QA) program.

In this way, qualification of the system platform is consistent over the entire service life of TXS.

The department that performed the initial development of TXS COMPACT is also responsible for maintaining the qualified status of the platform.

2.1.4 Application-Dependent Qualification

Qualification of an I&C system is the “process of determining whether a system or component is suitable for operational use, performed in the context of a specific class of the I&C system and a specific set of qualification requirements” – IEC 61513 §3.38 [27].

This implies demonstrating that:

- Technical requirements are fulfilled and
- Quality requirements are fulfilled.

For safety I&C systems, demonstrations of technical characteristics comprise evidence typically in the following areas:

- Proper implementation of the assigned I&C functions.
- Design compliant with the safety concept of the plant:
 - ◆ Redundancy,
 - ◆ Diversity,
 - ◆ Physical separation, including electrical isolation,
 - ◆ Failure behavior,
 - ◆ System availability,
 - ◆ Maintainability and testability,
 - ◆ Handling of Information Technology (IT) security requirements.
- Qualification of the hardware in accordance with applicable environmental conditions (seismic, climatic, electromagnetic compatibility (EMC)).

Demonstration of adequate quality typically comprises:

- Checks that adequate processes including V&V are implemented.
- Checks that processes are adhered to through audits and inspections.

Evidence to be submitted comprises a combination of material from several areas:

- Design documentation that presents mapping of the design to the requirements.
- Testing (manufacturing tests, simulation, test bay testing, installation, and commissioning testing).
- Analyses such as Failure Modes and Effects Analysis (FMEA), reliability analysis, accuracy, and response time analyses.
- Inspections and audits of engineering, manufacturing, and testing activities.

TXS COMPACT, together with other parts of the TXS family, forms a “generic system platform,” which simplifies preparation of the various evidence for I&C system qualification.

In the area of hardware qualification, generic evidence for the properties of hardware components is available from type testing under climatic, EMC, and seismic conditions. With this, the suitability demonstration can be limited to checking that plant-specific environmental requirements are enveloped by the technical data of the TXS platform, including seismic loads and power supply characteristics.

Also, in the area of Automation Units and application design, preparation of application-specific evidence takes credit from generic evidence for the system properties. This evidence covers:

- Self-monitoring and fail-safe characteristics including effectiveness of fault propagation barriers.
- Independence of the operation of individual Automation Units.

- Independence of Automation Units from the service and maintenance units and from external systems.
- Deterministic behavior.

Deterministic behavior, strict separation between system and application, and automated generation of application data allow for simplification of many other application-specific demonstrations, such as response time calculation, test coverage justification, and validation of the application, which includes modifications through a combination of tests in a simulation environment and in a test bay. Application-specific configuration of the TXS COMPACT Automation Units is generated by fully automated and qualified toolchain from the system's technical specification. This technical specification is comparable to application software written in application-specific language, as defined by IEC 60880 [42].

In brief, the standard design process of TXS COMPACT, which is based on use of the platform's generic system properties, reusable hardware and configware components, and a dedicated engineering tool set, significantly reduces the need to address configware-related safety questions in the application-dependent qualification phase.

2.2 TXS COMPACT Standard Modules

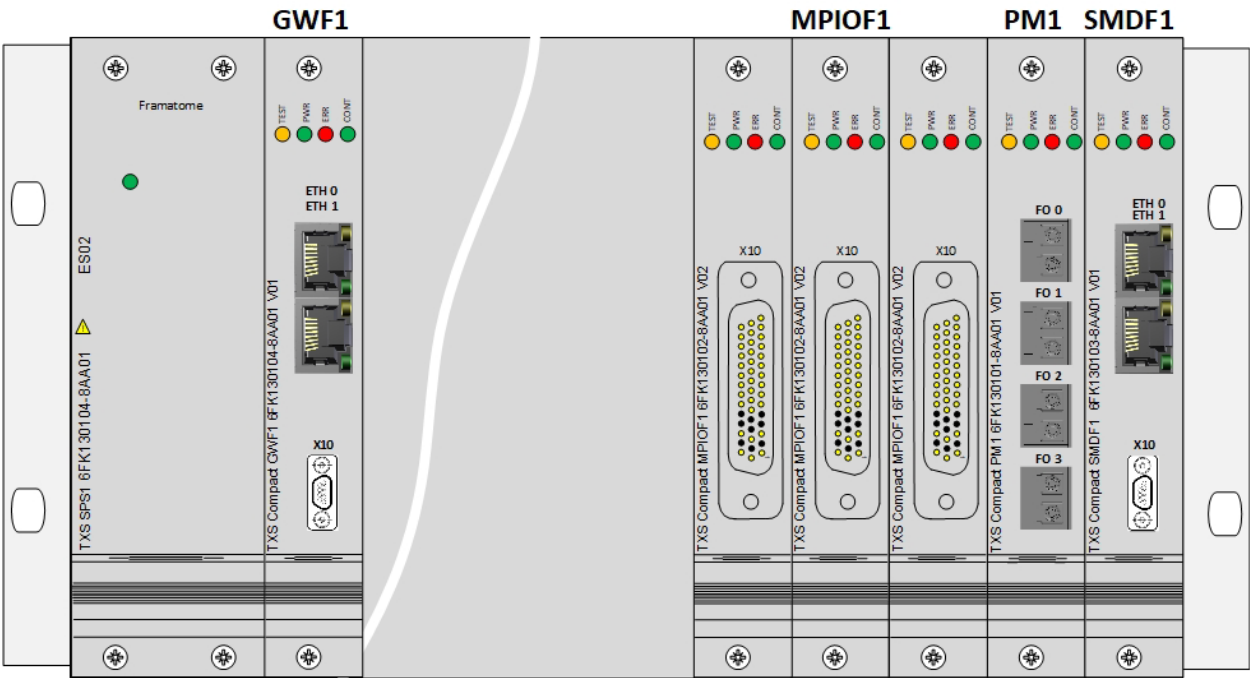
2.2.1 TXS COMPACT Mechanical Aspect

2.2.1.1 TXS COMPACT Chassis

The TXS COMPACT chassis is designed for installation of modules with a height of 3U (1 U being 1.75 in (44.45 mm)) and a mounting depth of 160 mm (single Eurocard format). It complies with the standard 19" packaging system and is made of aluminum.

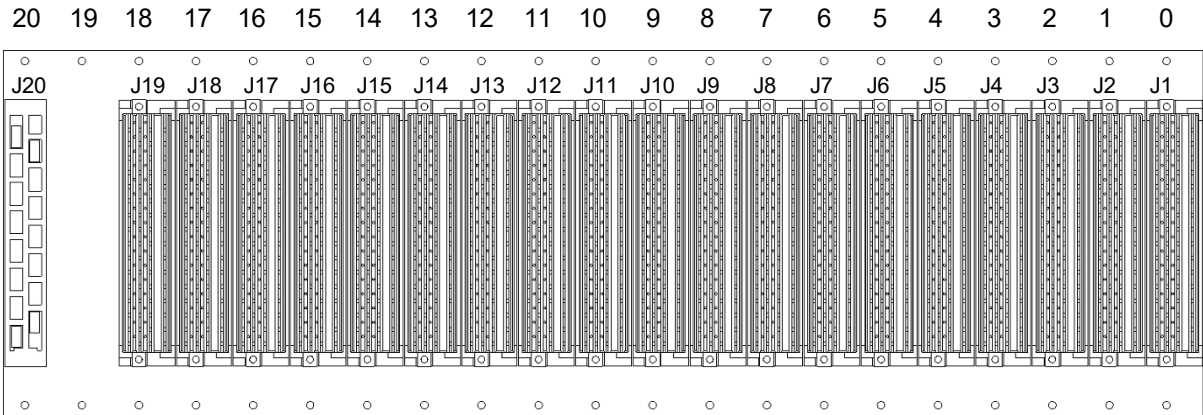
The bottom and top covering plates of the chassis are perforated throughout to enable inlet and outlet air flow. The chassis is attached to the cabinet frame using four fixing brackets.

Figure 2-1
TXS COMPACT Chassis with Modules



The TXS COMPACT Backplane inside the chassis allows internal communication between the inserted modules and distribution of the 24 V_{DC} power supply.

Figure 2-2
TXS COMPACT Backplane (BPF1)



2.2.2 Modules

The TXS COMPACT modules: Processing Module (PM1), Multi-Purpose Input/Output (I/O) module (MPIOF1), Service, Maintenance, and Diagnosis Module (SMDF1), and Gateway Module (GWF1) are plug-in modules implemented on a printed circuit board in 160 x 100 mm Eurocard format intended for installation in chassis equipped with a BPF1 (see Figure 2-2).

In the chassis, a module is secured in place by means of guide rails and individual screw-in fixing. It requires a mounting space of 3U and 4 HP.

The front plate of a module is made of anodized aluminum and fitted with an EMC gasket.

A TXS COMPACT module is connected to the BPF1 using a 64-pin male connector type G in accordance with EN 60603-2, which is mounted on the rear of the printed circuit board (PCB). It receives its power supply and performs internal communication through the backplane. To ensure that a module is inserted into the correct slot, the backplane indicates a 5-bit slot address, which is checked on module startup.

The status light-emitting diodes (LEDs) on the front plate indicate errors and operating states by means of flashing or static light (see Figure 2-4, Figure 2-8, Figure 2-11, Figure 2-14).

2.2.2.1 TXS COMPACT Processing Module (PM1)

The PM1 is a Field-Programmable Gate Array (FPGA)-based module running an HDL-made program describing the hardware logic executed within the FPGA chips. This program is called configware and is developed and prequalified in a generic way, which means it always remains the same from one I&C application to another. Its main purposes are to read and execute the I&C application program (describing the I&C functions) while performing self-supervision.

Figure 2-3
PM1 Board



The PM1 provides a fixed library of 87 prequalified function block types that are configured to implement I&C safety functions. The application is cyclically executed, and one cycle can be configured to last between 4ms and 2002ms depending on project needs and size of the application.

The I&C application is developed using the engineering software tools and represents system-specific engineered I&C functions in a form recognized by the processing hardware. It cannot be considered executable code but is rather similar to configuration data. The application program, along with functional parameters, is stored in the Magnetic Random Access Memory (MRAM) memory.

The PM1 performs one of three different roles depending on the slot it is plugged into:

- The **main PM1** is plugged into slot 1 of the main chassis. It operates as an application function controller executing the engineered I&C functions. It manages data exchange inside the Automation Unit and with remote Automation Units. Its optical interfaces can be used to establish point-to-point network connections with other TXS COMPACT AUs or with the expansion racks.

- When plugged into slot 2, 3, or 4, it only establishes point-to-point network connections with up to four PM1s in other TXS COMPACT Automation Units (AUs). In this role, it is called **communication PM1**.
- When plugged into slot 0, it operates as **expansion PM1**. It enables the exchange of data frames between the main PM1 and the I/O modules in the expansion racks.

Each module can perform one role at a time, which is determined by the module identifier (ID) derived from the slot identification.

Figure 2-4 PM1 Mechanical Design

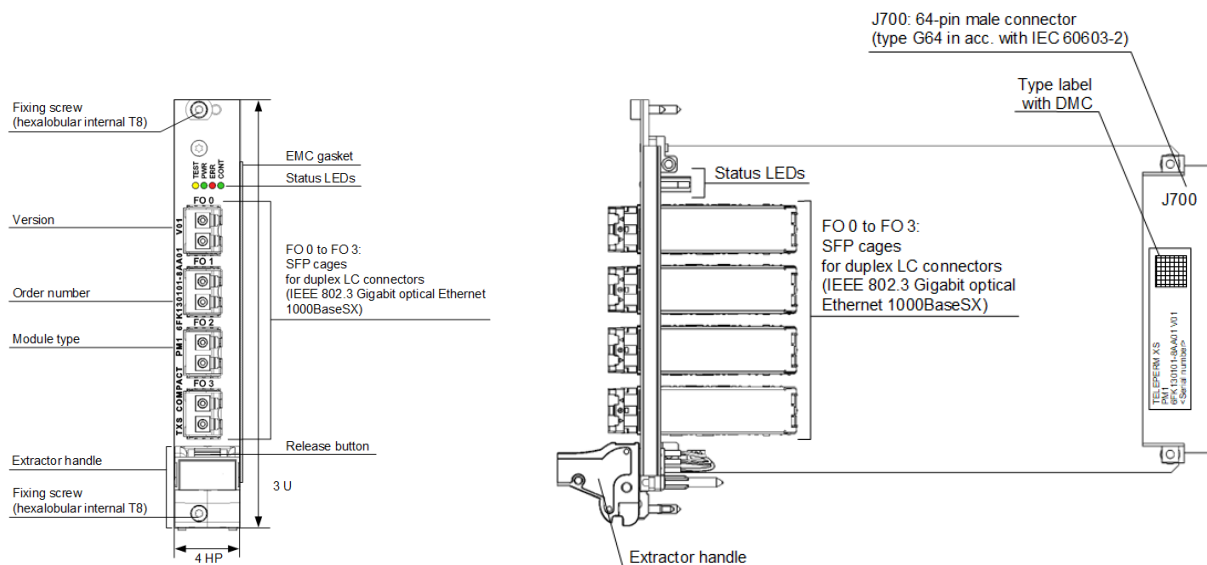


Figure 2-5
PM1 Hardware Block Diagram

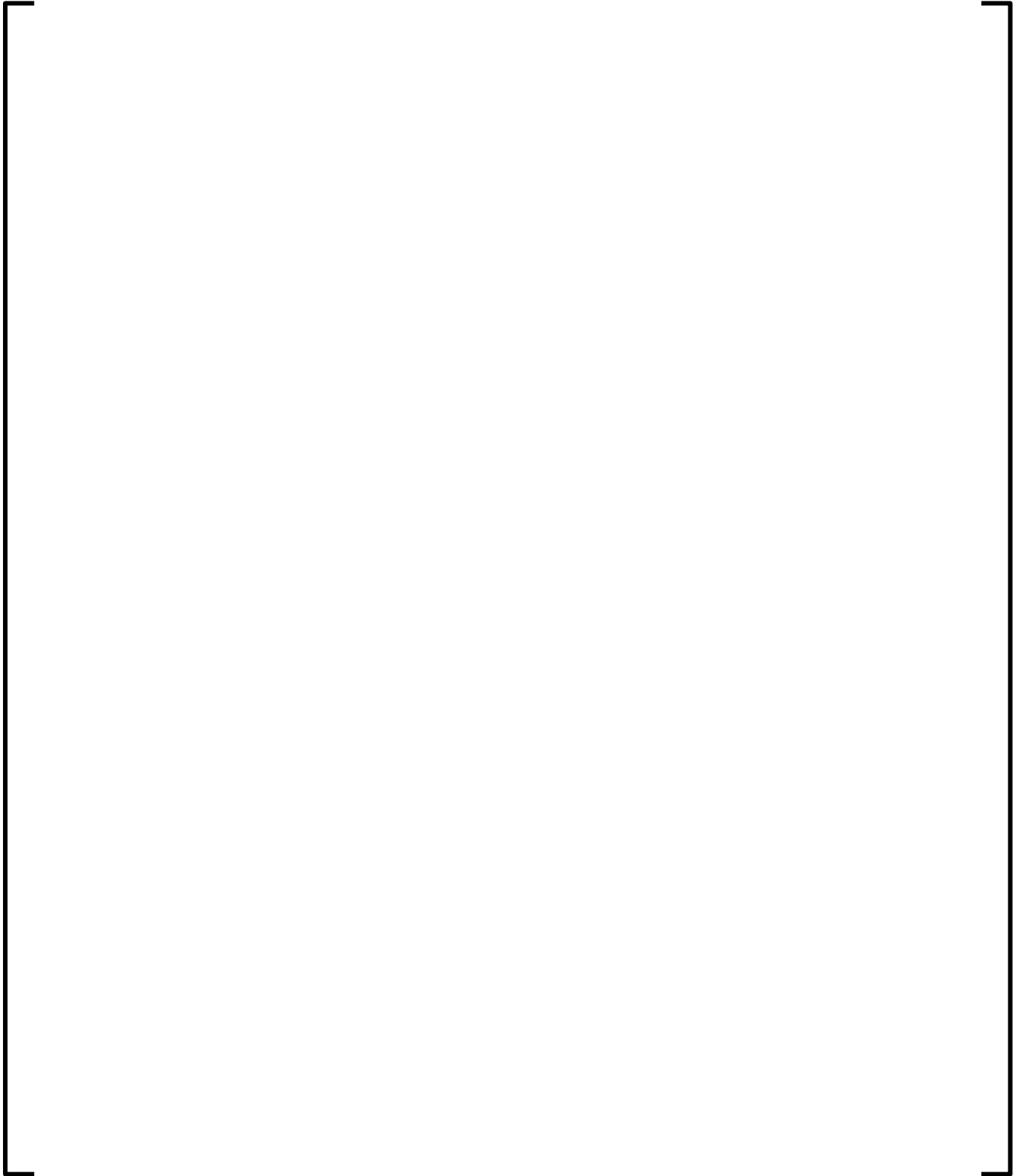


Table 2-1
PM1 Block Diagram Description



Table 2-2
PM1 Physical Interfaces

2.2.2.2 TXS COMPACT Multi-Purpose I/O Module (MPIOF1)

The MPIOF1 is an FPGA-based board used to interface the TXS COMPACT with field signals. It interfaces with the following standard I&C input and output signal types:

- Two analog current inputs (0...20 mA, 4...20 mA);
- Two analog current outputs (0...20 mA, 4...20 mA);
- Four binary signal inputs (0...24 V);
- Four binary signal outputs (0...24 V);
- One input for counting Transistor-Transistor Logic (TTL) pulse signals [

]

In addition, the MPIOF1 is equipped with two 24 V sensor power supply outputs.

Figure 2-6
MPIOF1 Board



The MPIOF1 is configured by the PM1 during STARTUP operating mode (see Section 2.5.2.1). Configuration data is used by the MPIOF1 to set:

- A fallback position for outputs in case of failure which would prevent the module from retrieving setpoints from the main PM1.
- The test period, the range of analog channels, and the pulse input period.

The MPIOF1 module acquires signals present at its binary and analog inputs and digitalizes them. Signal values and their validity statuses are transmitted to the PM1 upon request via the BPF1.

The MPIOF1 receives analog and binary output values from the PM1 and converts them into electrical signals which are transmitted to the module's output pins.

The MPIOF1 provides one channel for counting pulse signal TTL []

The MPIOF1 ensures a high detection rate for internal and external errors based on extensive cyclic self-monitoring functions of its own operation and the input data, self-test of the analog or binary input channels, and read back of the analog or binary outputs. This status data can be read out by the PM1 via the TXS COMPACT backplane buses.

Errors are also signaled on the ERROR output and indicated on the “ERR” LED on the front plate (see Figure 2-8).

The MPIOF1 provides four I/O channel groups which are independent. [

]

Figure 2-7
MPIOF1 Channel Groups



Figure 2-8
MPIOF1 Mechanical Design

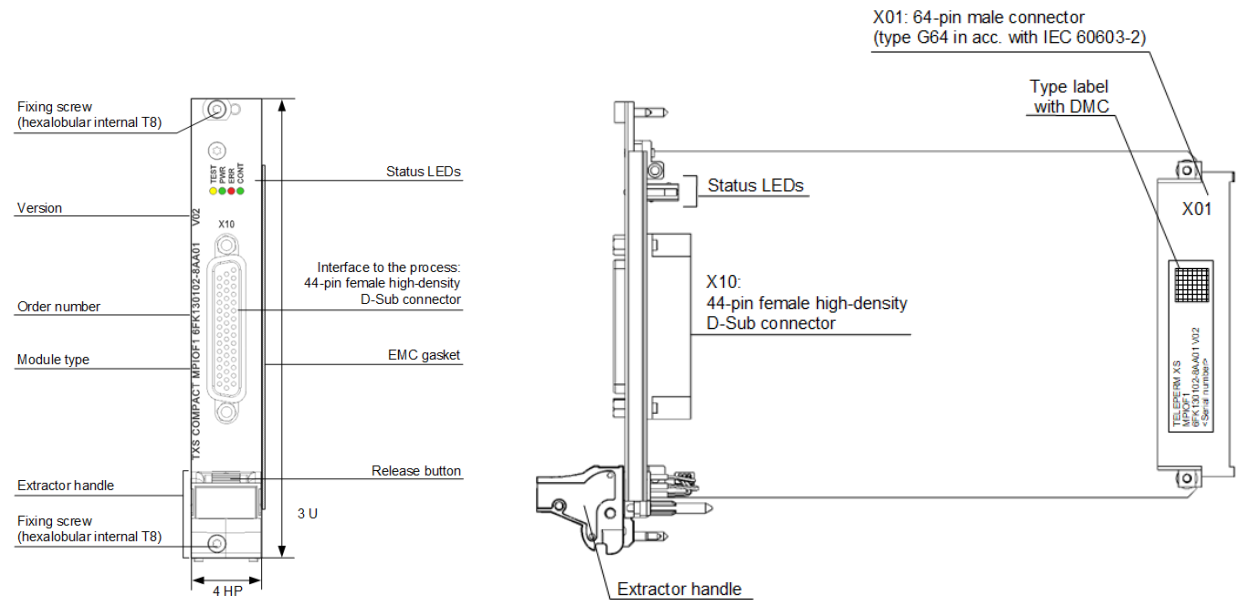


Figure 2-9
MPIOF1 Hardware Block Diagram

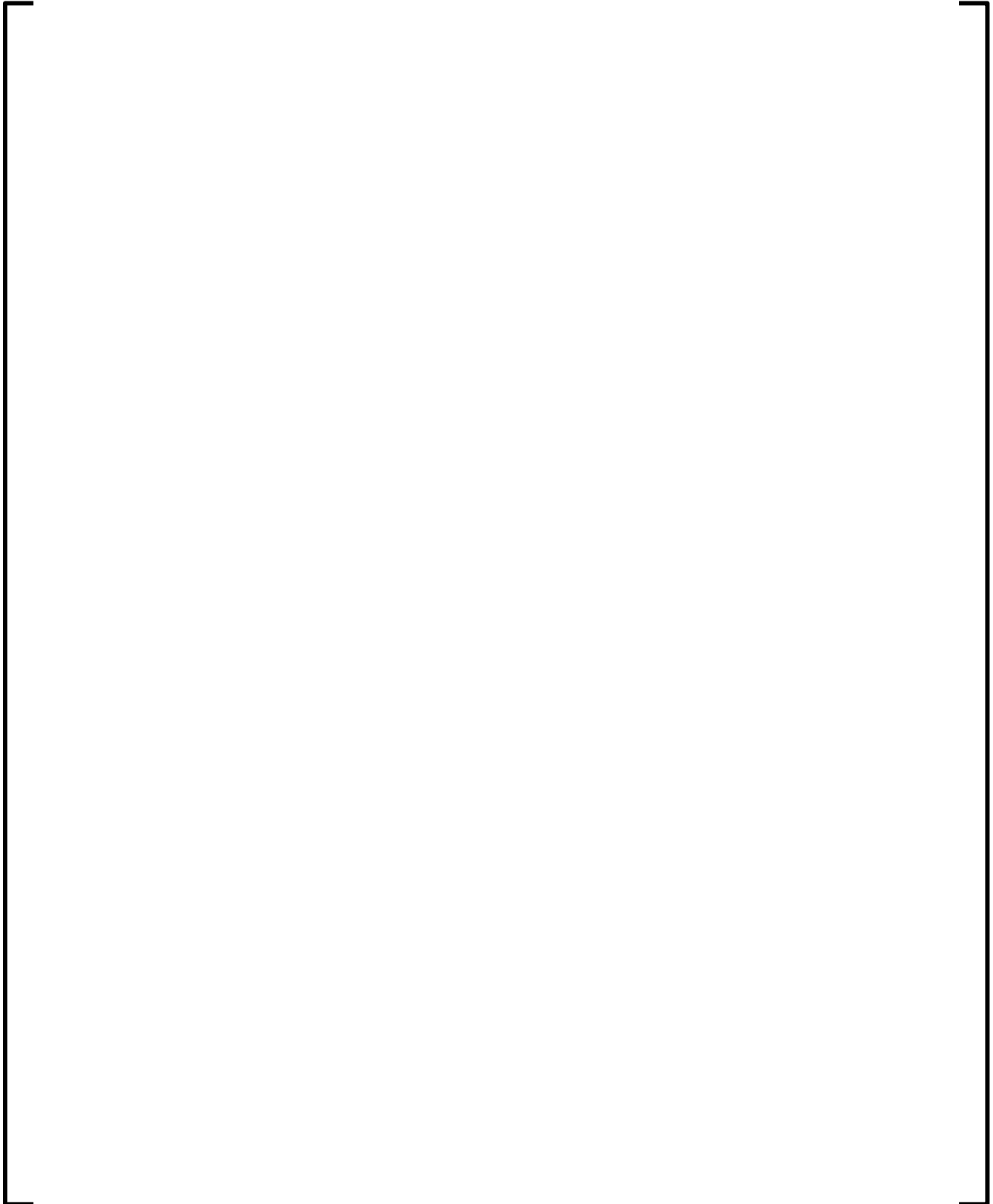
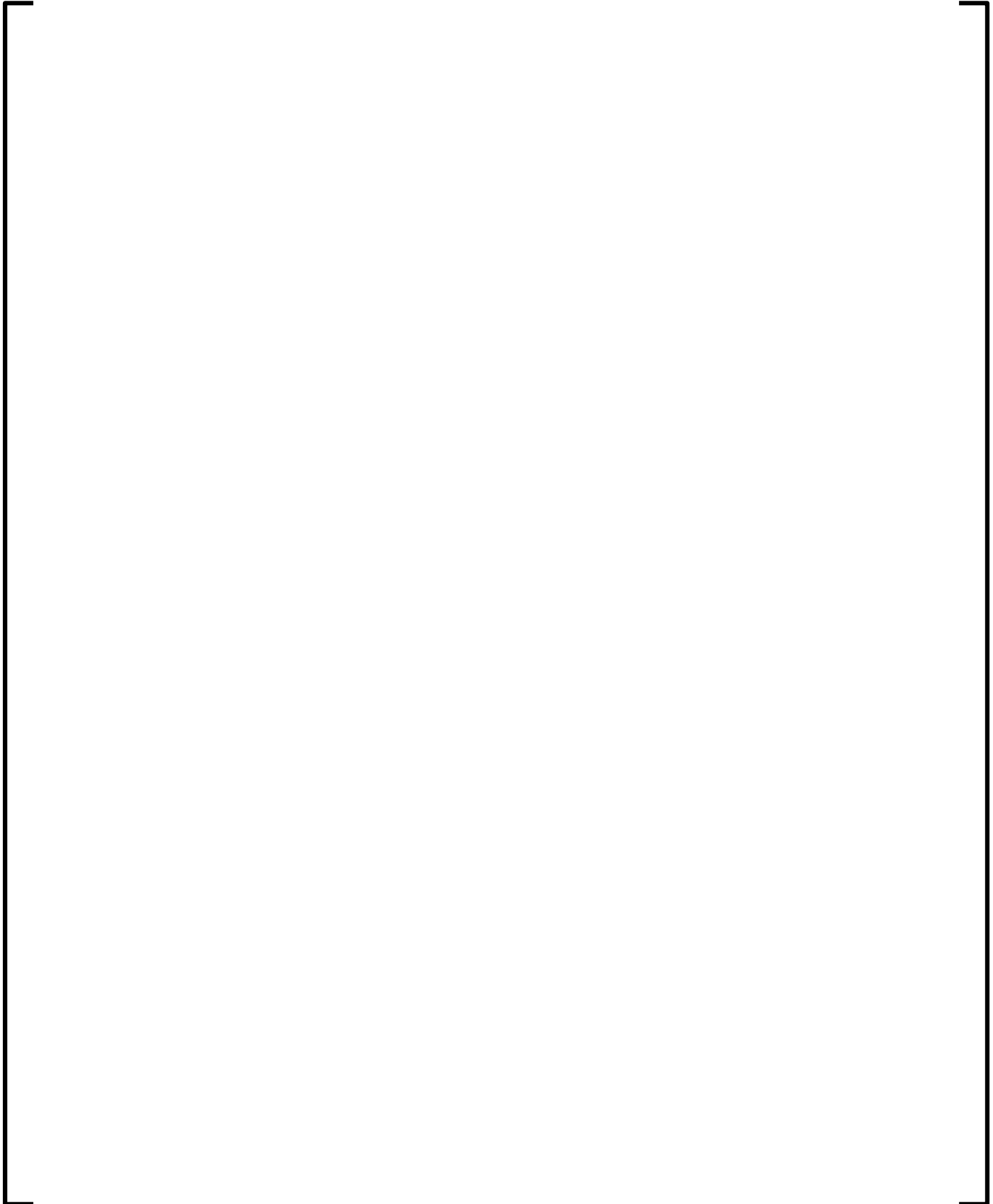


Table 2-3
MPIOF1 Block Diagram Description



1



2.2.2.3 TXS COMPACT Gateway Module (GWF1)

The Gateway Module (GWF1) is used to interface a TXS COMPACT AU to the TXS Ethernet network. In this way, it becomes possible to exchange analog and binary signals between a TXS COMPACT AU and a TXS Core Automation Computer, a TXS Gateway Unit, or a Qualified Display System (QDS) Unit.

**Figure 2-10
GWF1 Board**



The GWF1 module is an FPGA-based module. It provides [] (Ethernet connector type) network ports; however, only one is used in practice. The active port can be connected to a Media Converter Module (SMC1 – part of TXS Family) which converts copper-based Ethernet to optical fiber and provides electrical isolation.

The GWF1 module receives module-specific parameterization data from the PM1 during start-up that are stored in an internal FPGA memory. This parameterization ensures that the GWF1 module can only exchange those signals which are required for engineered functionality of the TXS COMPACT AU.

The GWF1 HPD maps analog and binary signals correctly received from the PM1 via MLVDS interfaces according to the configuration and transmits them using the Ethernet Media Access Control layer to the external Ethernet Physical Layer (PHY) transceiver and conversely.

Figure 2-11
GWF1 Mechanical Design

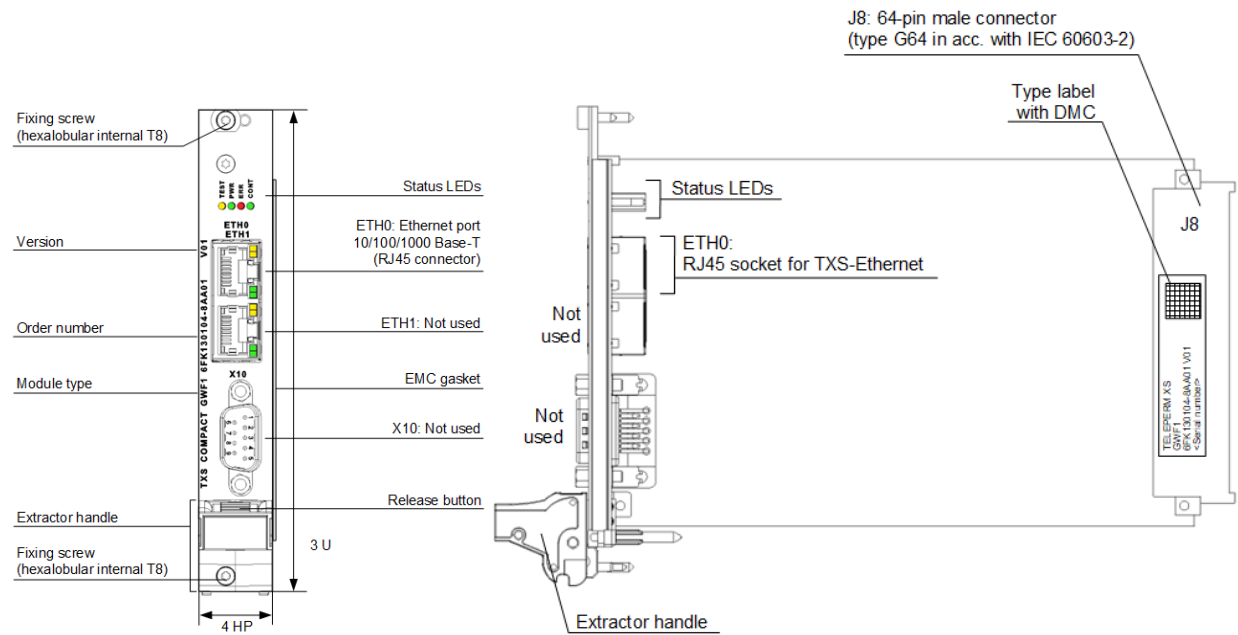


Figure 2-12
GWF1 Hardware Block Diagram

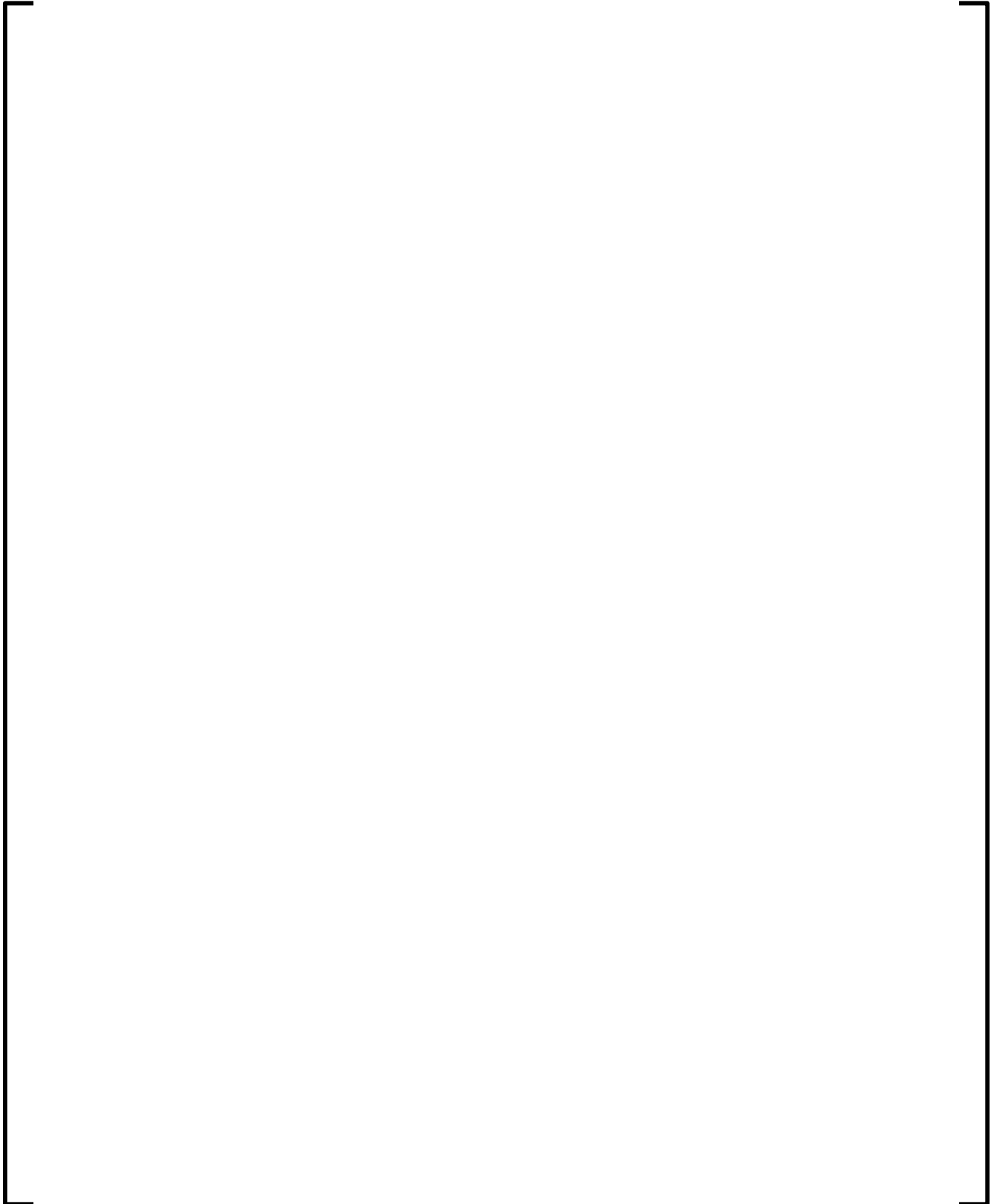


Table 2-6
GWF1 Physical Interfaces

2.2.2.4 TXS COMPACT Service, Maintenance, and Diagnosis Module (SMDF1)

The SMDF1 is used to connect the TXS COMPACT AU to the Service Unit (SU). The SMDF1 is an FPGA-based module. The FPGA contains an ARM-based Central Processing Unit which executes non-safety software on an embedded Linux operating system. The SMDF1 embeds a Modbus server to communicate with external non-safety systems.

Each Automation Unit must contain exactly one SMDF1 which provides features to:

- Configure the Automation Unit by loading a new application program or new parameters under certain conditions (see Section 2.5).
- Monitor the Automation Unit by forwarding statuses of the modules and the value of signals processed by the Automation Unit to the Service Units.
- Retrieve the system event logging journal.

As opposed to PM1, MPIOF1, and GWF1 modules, the SMDF1 is not safety-related. It is not involved in processing the safety I&C functions.

Figure 2-13
SMDF1 Board



Tests and maintenance activities are separated from the essential functions to avoid jeopardizing execution of the application program by test activities. The processing network (between main PM1s) and the service network (SMDF1 and Service Unit) are physically separated, and isolation barriers are used for internal communication between the SMDF1 and the PM1 (see Section 2.5.1).

Figure 2-14
SMDF1 Mechanical Design

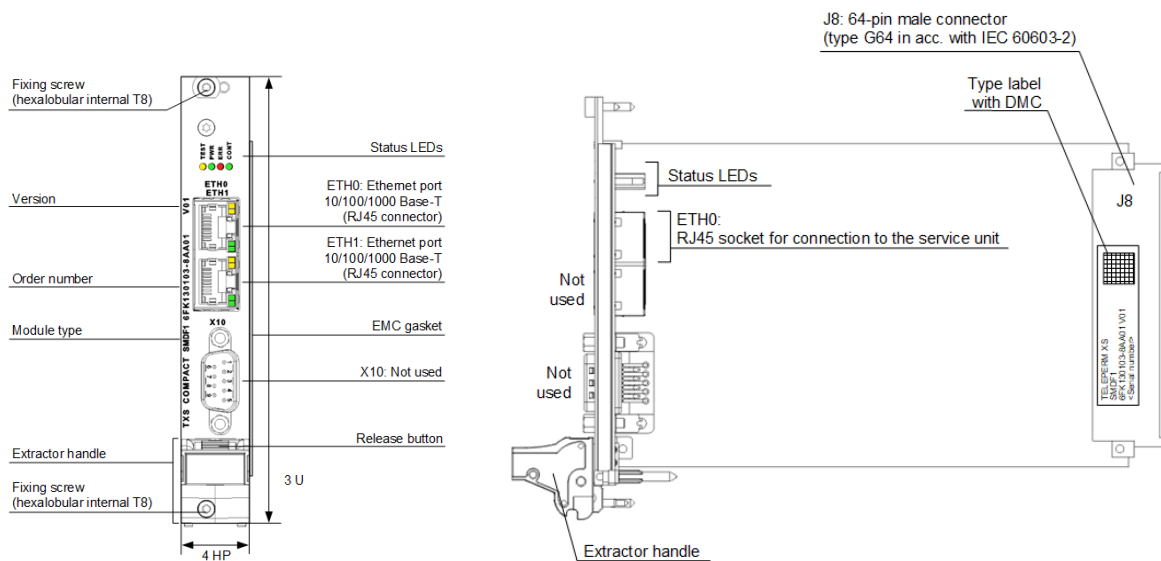
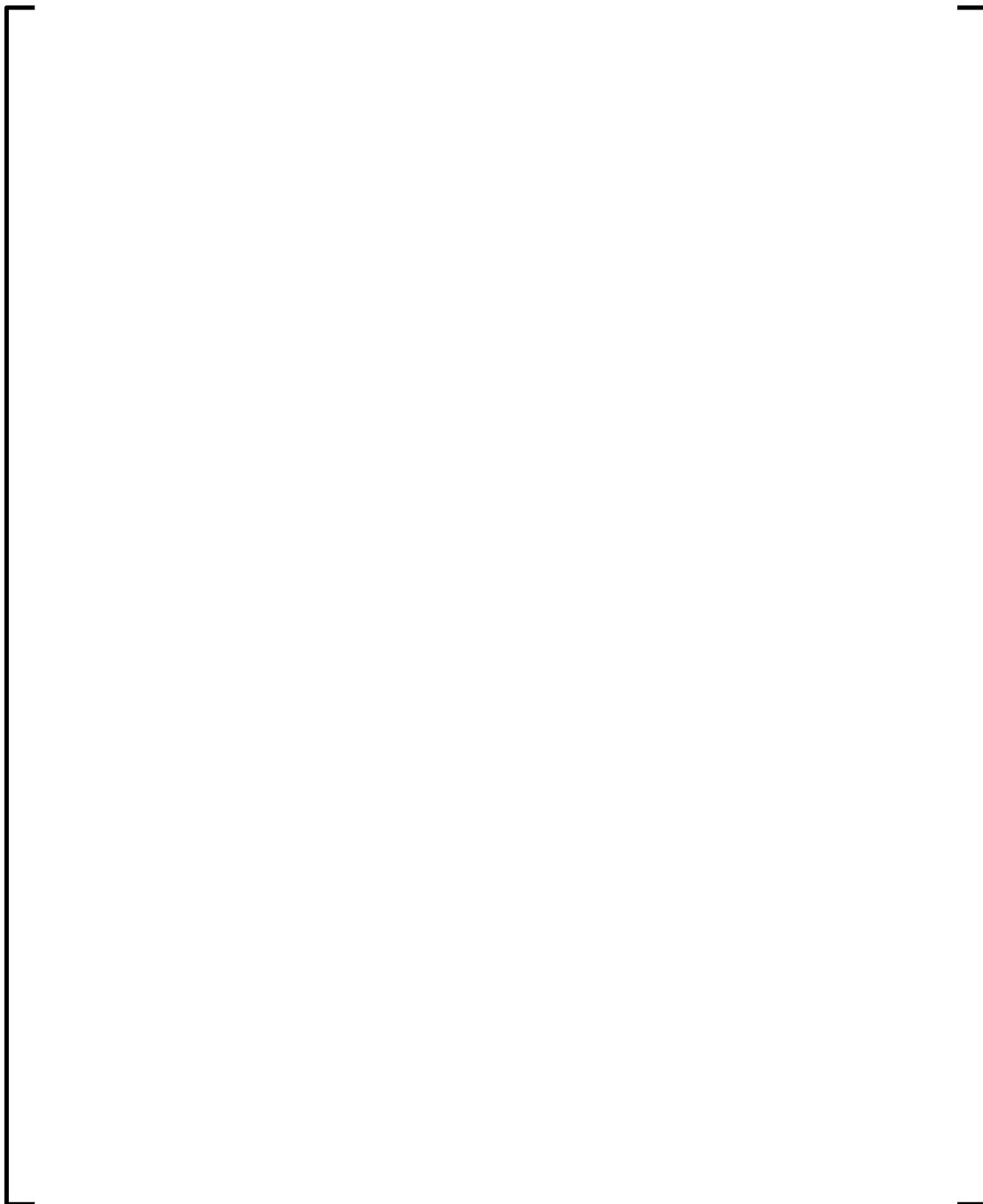


Figure 2-15
SMDF1 Hardware Block Diagram



[illegible]

Table 2-8
SMDF1 Physical Interfaces

2.3 TXS COMPACT Operation Principles

2.3.1 Overall Description

The TXS COMPACT safety I&C platform uses dedicated hardware logic implemented in the silicon structure of an FPGA which allows execution of any developed application program. It does not contain any Central Processing Unit or microcontroller in the processing path.

TXS COMPACT processing modules are composed of a restricted set of logic elements:

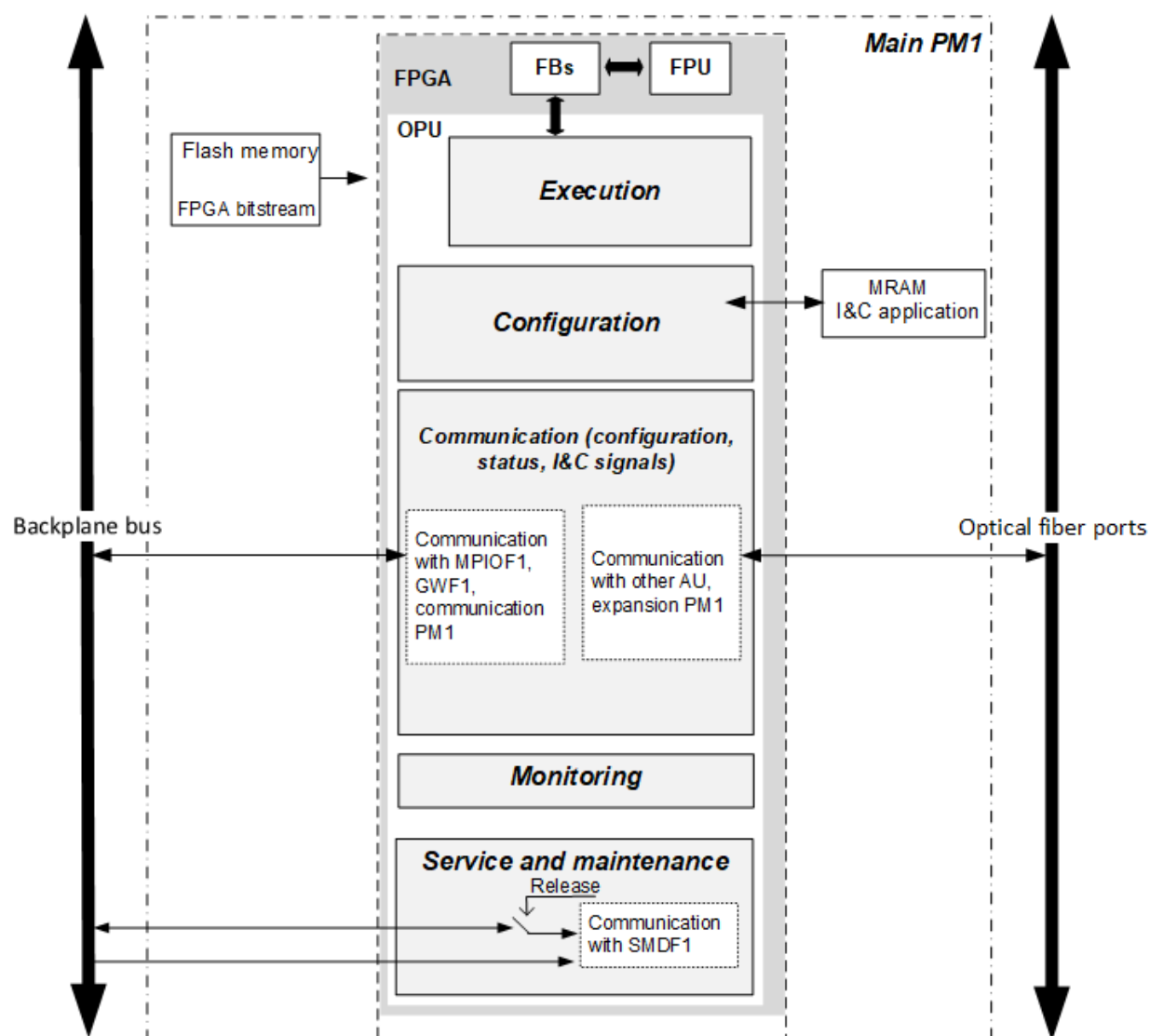
- An Operating Unit (OPU) managing:
 - ◆ Execution of the application program.
 - ◆ Configuration given by the application program.
 - ◆ Communication (protocol, serializer/deserializer).
 - ◆ Self-supervision of the FPGA.

- A library of function blocks providing the required elementary functions.
- A mathematical solving unit (Floating Point Unit (FPU)).

Automation Unit internal and external communications are managed by the FPGA containing hardwired logic for serial point-to-point data transmission [

]

Figure 2-16
Main PM1 Functional Block Diagram



Within the FPGA, dedicated logic elements are allocated for the OPU, FBLIB, and FPU. Configware of the FPGA is generically prequalified for use in safety applications in the frame of the TXS COMPACT product development process.

Only the main PM1 module executes the application program; communication PM1, expansion PM1, I/O modules, and GWF1 gateway modules are pass-through, which only allow forwarding of signals and self-supervision information from/to the main PM1. These modules are not configured by the SMDF1 but receive their configuration at startup from the PM1 through the appropriate communication controller.

A service and maintenance HPD is in charge of forwarding monitoring information to the SMDF1 and also updating configuration when the state of the system authorizes it.

Application specific functionality of the individual FPGAs in an I&C system is determined using a set of configuration data files called the Application Program which are not part of the configware. TXS COMPACT is designed to be used for projects as a generic and fully pre-qualified Automation Unit. It is provided with released, generic, and certified HPD programs for the different module types, and only the required application program and functional parameters are configured from one I&C system to another.

The application program is used on each individual main PM1 as the execution plan for the FPGA to perform the I&C overall function composed of elementary functions. Elementary functions are operators dedicated to performing operations commonly observed in safety I&C systems: Boolean logic, arithmetic, voting, etc. The required nuclear power plant specific I&C functions are implemented using function block diagrams.

To create such diagrams and configuration data files, TXS Design Studio (a dedicated Computer-Aided Design diagram editor specifically designed by Framatome for that purpose) is used to provide state-of-the-art look and feel and authoring functionalities.

TXS COMPACT can be configured:

- At a single location using single chassis architecture. It is the most basic and simplest configuration that can be used.

- For distributed installation with cabinets possibly at multiple locations. TXS COMPACT AUs can be arranged in a variety of configurations, for example 1/2, 2/3, or 2/4 coincidence applications.

Each TXS COMPACT AU is configured from base modules assembled in a chassis in line with the I&C system's requirements: binary and analog input/output; data processing; gateway; and service, maintenance, and diagnosis (see details of the TXS COMPACT modules in Section 2.2). These modules installed in a chassis are to be combined with other TXS modules (such as mechanical enclosures, signal conditioning modules, etc.) to cover the complete scope of system requirements.

2.3.2 Main Safety Principles

2.3.2.1 Use of Released Configware Version

TXS COMPACT is provided with generic and prequalified configware (FPGA HPD programs) for the different modules released as a product for application with the platform equipment. Only the safety I&C application program (configuration data generated via the engineering tools) changes from one I&C system or project to another.

2.3.2.2 Cyclic Processing

TXS COMPACT follows strict cyclic processing. When in OPERATION mode (see Section 2.5.2.3), operations are performed sequentially in a pre-defined order, and the sequence is repeated over and over again until power is suspended or the Automation Unit receives a maintenance order to switch to a different mode.

The execution sequence consists of (in this order):

- A service part of fixed duration where the acquisition of input signals and the development of output signals are performed.

- A variable part corresponding to the processing of engineered I&C functions, which is determined in advance by the engineering tools (Application Generation Toolkit).

Duration of the sequence is specified by automation engineers during engineering in a range between 4ms and 2002ms. Tools are provided to determine the free margin (difference between the specified processing time and the actual time needed to process the engineered I&C functions).

2.3.2.3 One Single Cycle Time Per Automation Unit

Within each Automation Unit, only one cycle time is possible. This cycle time is predefined according to the application. This contributes to keeping the design of the platform simple.

2.3.2.4 Consistent Input Data for Every Processing Cycle

Every processing cycle operates using consistent input data; i.e., acquired during the same exact time period.



This assures time-dependent processing such as filters will be calculated based on data that are always coherent. Therefore, there is no need for additional synchronization mechanisms.

2.3.2.5 Static Memory Allocation

TXS COMPACT is based on FPGA technology where resources are allocated inherently in a static way, including internal Random Access Memory (RAM) used during processing.

[

]

2.3.2.6 Constant Execution Time

TXS COMPACT is based on FPGA technology. For any implemented function, hardware resources are exclusively allocated. Therefore, execution time is constant and can be precisely known in advance as a factor of the clock cycle, with negligible variability.

As a result, computing time of the I&C application can be calculated accurately by the engineering tools and identified early before any simulation or target tests are performed.

2.3.2.7 No Real-Time Clock

To exclude any interference of the cyclic processing with any calendar dates or clock-based events, no real-time clock is implemented in the PM1. A cycle counter is individually handled by each Automation Unit and incremented at start of the processing cycle.

[

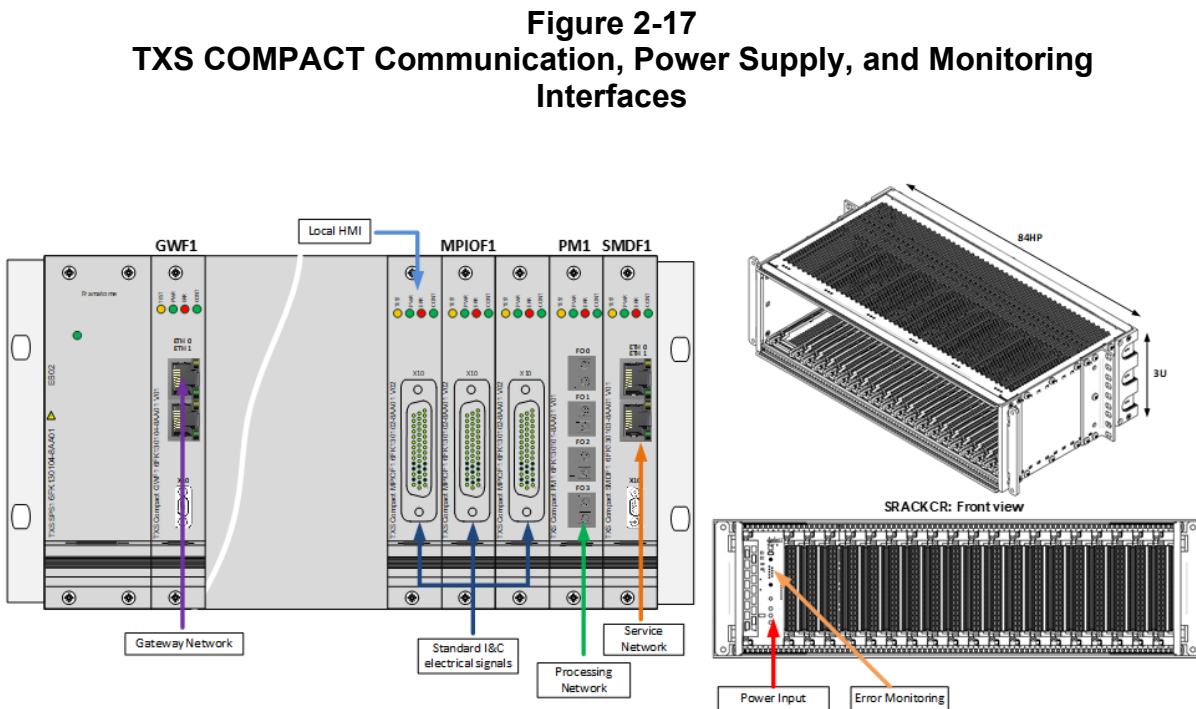
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2.3.2.8 No Process-Dependent Interrupts

The TXS COMPACT is designed in a way where interrupts are not used.

2.4 TXS COMPACT Internal Communications

Figure 2-17 shows the TXS COMPACT communication, power supply, and monitoring interfaces.

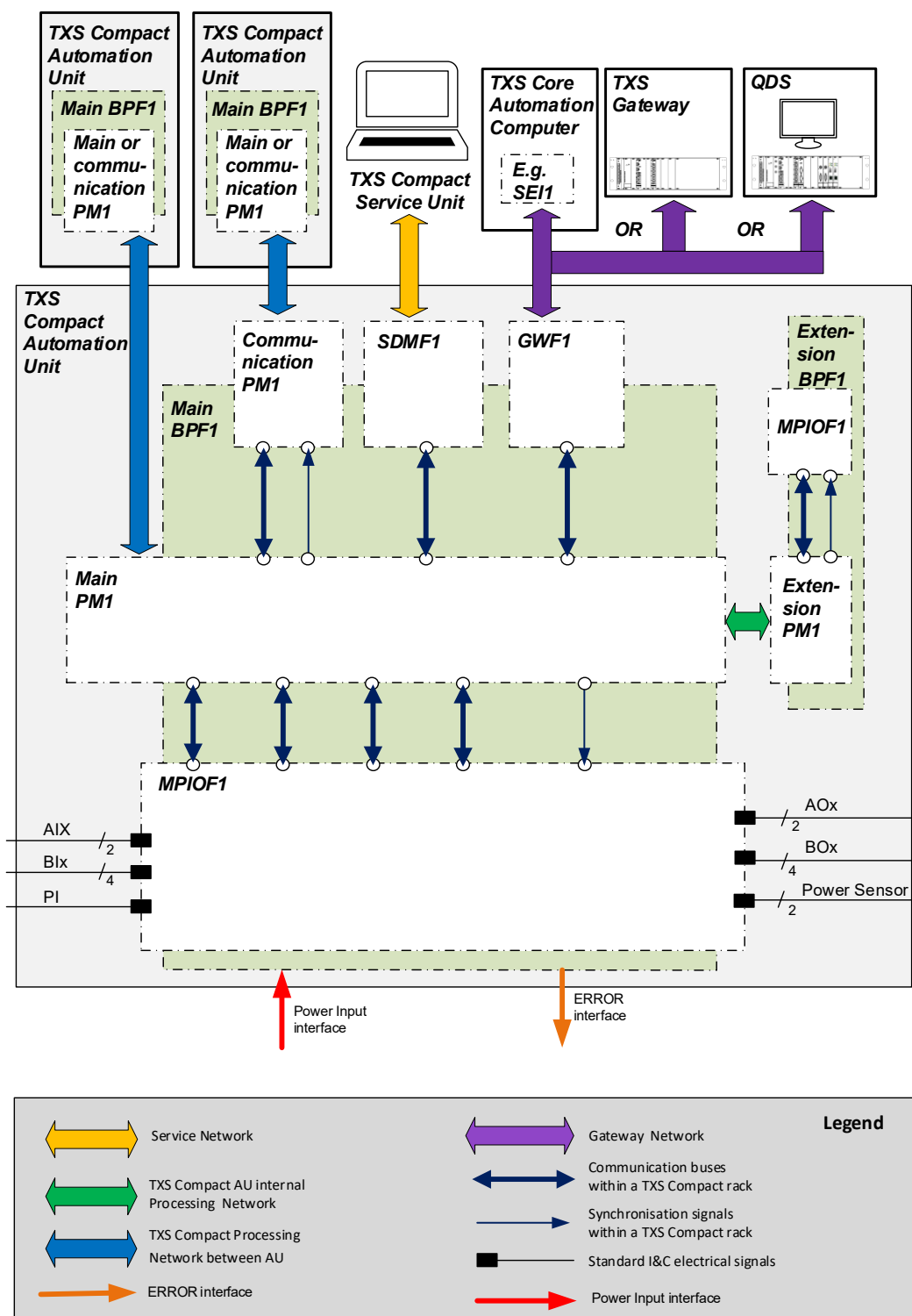


TXS COMPACT is electrically powered with a nominal voltage value of +24 V_{DC} and an accepted range of +19.5 V_{DC} ... +30.5 V_{DC}. From this input power supply, the Power Supply Module (SPS1), which is a switched-mode direct current (DC)/DC converter, generates a stabilized voltage of +24 V_{DC} distributed to all modules via the backplane.

A dry contact +24 V_{DC} error monitoring interface is provided for the Cabinet Monitoring Unit (CMU1) and gives visual information of module operating mode. If one of the modules inside the chassis identifies an error (switches to ERRORSTOP mode, see Section 2.5.2.8) or in case power is lost, then the dry contact opens. The dry contact can be configured to provide status information to the operator.

Internal and external communication of a TXS COMPACT AU and their different senders or receivers are shown in Figure 2-18:

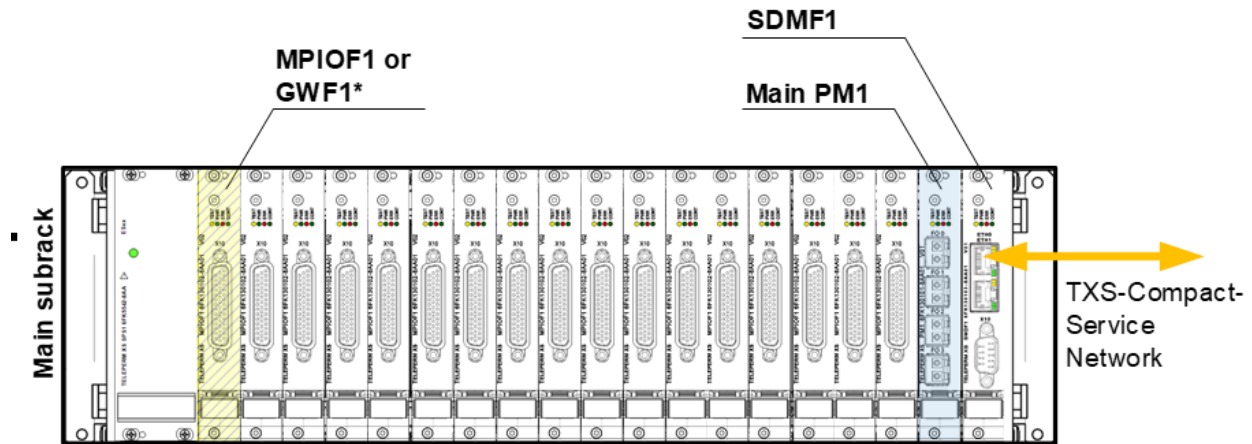
Figure 2-18
TXS COMPACT Automation Unit Internal and External Communications



2.4.1 TXS COMPACT Service Network

Using the SDMF1, the TXS COMPACT can receive service commands and send monitoring and diagnosis information from/to the Service Unit (SU) through a dedicated service network using a copper RJ45 Ethernet link, or optical fiber when electrical isolation is required (using a TXS SMC1). Section 5.2 provides detailed discussion on safety-to-non-safety communication process.

Figure 2-19
TXS COMPACT Service Network

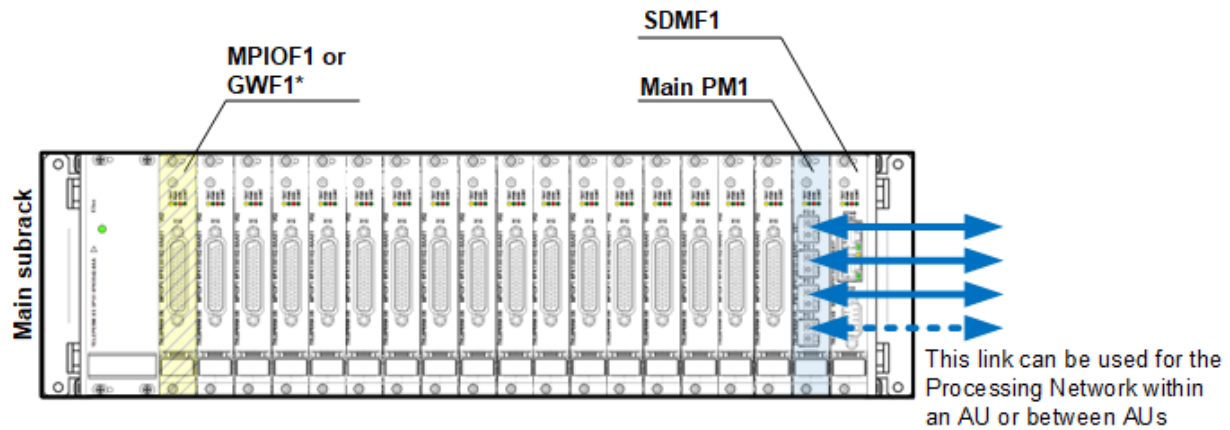


2.4.2 TXS COMPACT Processing Network

Using the PM1s, the Automation Unit manages data exchange with other Automation Units via point-to-point optical links. Within the processing network, every frame contains the validity of each signal.

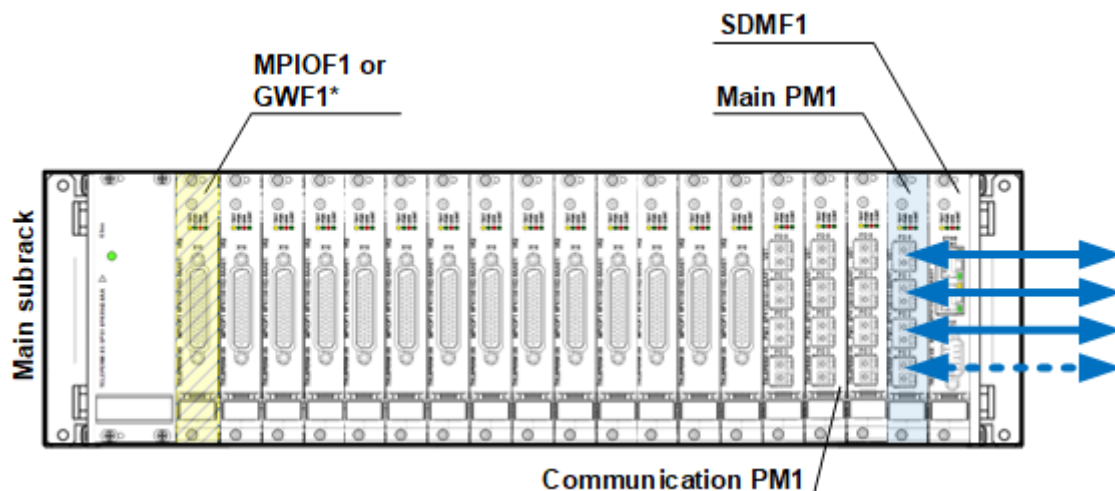
The main PM1 in the Automation Unit can be connected to four PM1s in other Automation Units. The fourth optical port can also be configured to implement the connection to the expansion racks within the Automation Unit.

Figure 2-20
TXS COMPACT Processing Network



To extend the number of processing network interfaces, up to three communication PM1s can be added in the main chassis. Then the main PM1 executes the application program and configures communication PM1s via the PM1-PM1 backplane bus to transfer input or output data to/from other Automation Units.

Figure 2-21
PM1 Communication Expansion

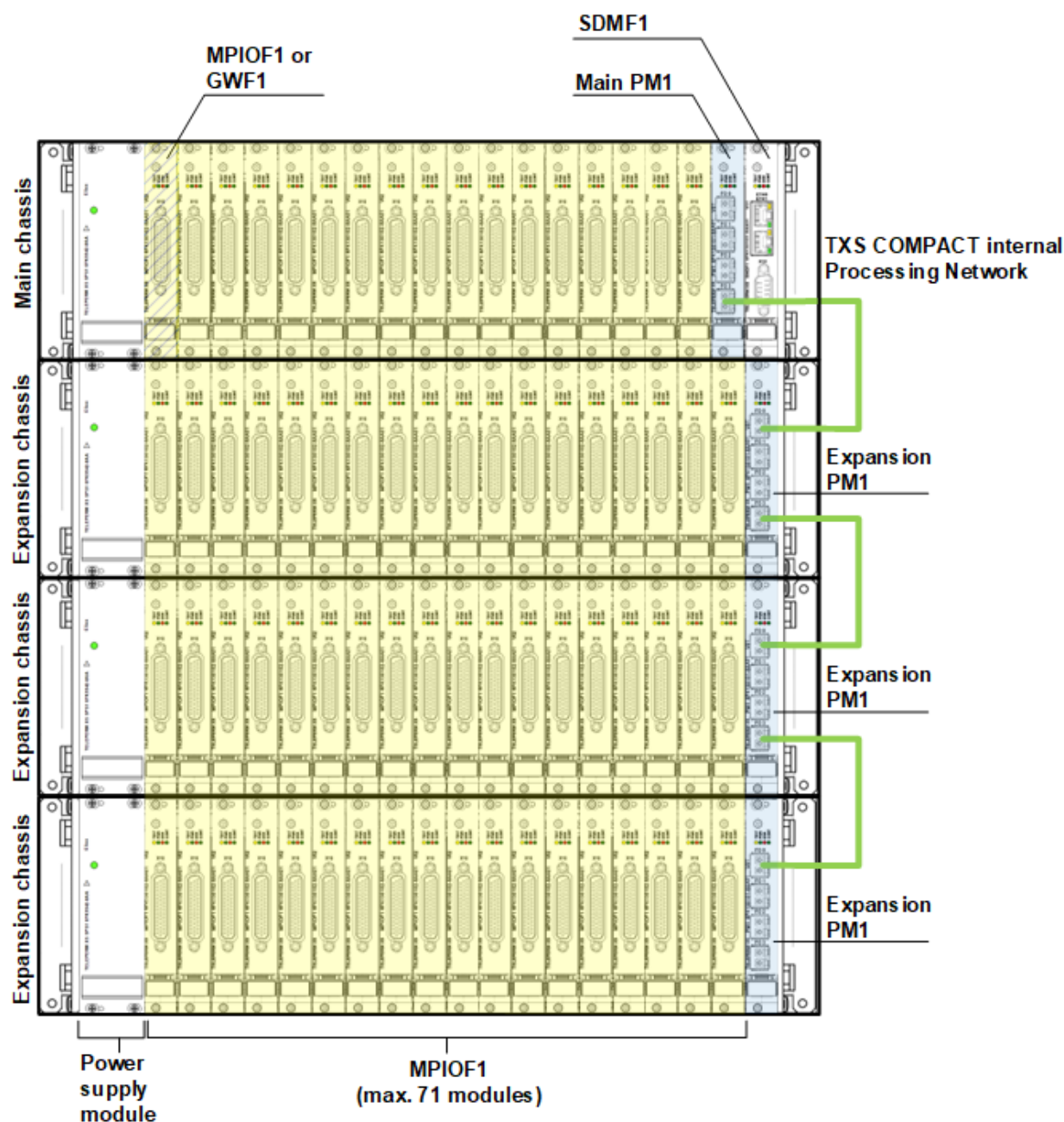


Network communications between Automation Units are immune to fault propagation: the network controller on each Automation Unit verifies that communication behaves as intended. When a communication issue is detected, signals are flagged as invalid but processing of the logic continues.

In case extending the number of I/Os is required, up to three expansion racks can be added in an Automation Unit working synchronously with the main PM1. Then the main PM1 executes the I&C application and configures the expansion PM1s via the processing network to transfer input or output requests to/from the remote I/O modules.

A detailed discussion on communication processes between AUs is provided in Section 5.1.2.

Figure 2-22
TXS COMPACT Processing Network for I/O Expansion



In the system presented by Figure 2-22, expansion racks may be seen as one bigger chassis by the application I&C functions running on the main PM1.

2.4.3 TXS COMPACT I/O Interface

The MPIOF1 provides analog and binary channels organized with four channel groups with specific functionality (See Figure 2-7):

- ACI0 and ACI1: two channels for analog current inputs 0/4...20 mA.
- ACO0 and ACO1: two channels for analog outputs 0/4...20mA.
- BI0, BI1, BI2, and BI3: four channels for binary inputs 0-24V; and PI1: one channel for pulse input 5V TTL / up to []
- BO0, BO1, BO2, and BO3: four channels for binary outputs 0-24V; and Sensor power: a channel for providing supply power to a transducer.

[

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[

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2.4.4 TXS COMPACT Gateway Network

The TXS COMPACT chassis has the ability to interface with other safety-related devices such as a QDS through an Ethernet connection using GWF1 module.

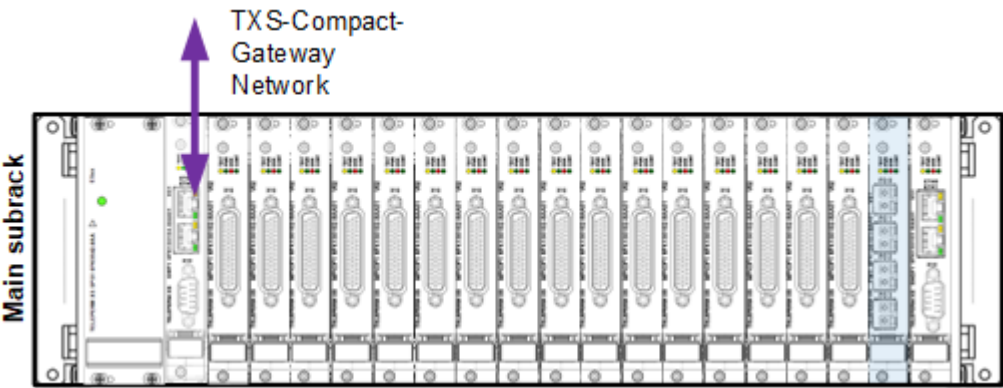
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Figure 2-23
TXS COMPACT Gateway Network



A detailed discussion on the communication process between an AU and equipment over TXS-Ethernet network is provided in Section 5.1.1.

2.4.5 TXS COMPACT Communication Interfaces Characteristics

[
]

Table 2-9
PM1 Communication Interfaces Characteristics

Table 2-10
SMDF1 Communication Interfaces Characteristics

Table 2-11
GWFI Communication Interfaces Characteristics

Table 2-12
Backplane Communication Interfaces Characteristics

2.4.6 TXS COMPACT I/O Characteristics

[]

Table 2-13
MPIOF1 – Binary Input Characteristics

Table 2-14
MPIOF1 – Binary Output Characteristics

Table 2-15
MPIOF1 – Analog Input Characteristics

Table 2-16
MPIOF1 – Analog Output Characteristics

Table 2-17
MPIOF1 – Pulse Input Characteristics

Table 2-18
MPIOF1 – Sensor Power Characteristics

2.5 *TXS COMPACT Modes of Operation*

Undisturbed operation of the Automation Unit is ensured by protecting the TXS COMPACT chassis from the influence of external events (such as service commands) or failures of interfacing components (such as network failures) when processing I&C safety functions. To achieve that behavior, the processing module implements pre-determined modes.

The operating modes of the TXS COMPACT Automation Unit (AU) are identical to the modes of the main PM1 from a functional perspective. In addition, each module has independent status that impacts only the functions assigned to this module.

Each operating mode has different capabilities with respect to maintenance and diagnosis, but only one mode at a time is allowed to ensure safe operation. Switchover between these different modes is performed by sending service commands to the Automation Unit (i.e., to the main processing module through the SMDF1) but must be previously authorized by positioning releases which allow or deny transitions between the modes. The operating mode of each automation unit is independently set (from the other AUs of an I&C system) according to the principles defined in Figure 2-24.

2.5.1 Releases and Isolation Barriers

TXS COMPACT guarantees safety of the Automation Unit using a hardware isolation barrier (see Section 5.2.2.2). This design:

- Allows communication from the PM1 (processing I&C safety functions) to the SMDF1 (communicating with the Service Unit) at any time.
- During normal operation, physically blocks communication from the non-safety-related SMDF1 to the safety-related PM1.

By doing so, events on the Service Unit cannot propagate to nor influence processing of I&C safety functions.

Sending service and maintenance requests (commands, configuration, I&C application, parameters, etc.) to an AU requires access across this barrier. This is done by means of a special signal called a release. [

]

[

]

[

]

[

]

[

] This condition is verified by

the automatic application configuration checker. The I&C system designer can implement any kind of Boolean logic to [

] trigger releases to appropriately comply with the I&C system's requirements.

[

]

Figure 2-24
TXS COMPACT Operating Modes

2.5.2 Operating Modes

Transitions between modes are triggered either automatically (due to conditions or events) or manually by the maintenance operator using the Service Unit. Such manual actions are restricted from the perspective of the AU by special signals called releases, as explained in Section 2.5.1.

While OPERATION is the normal mode where the AU operates safely, modes MAINTENANCE, DIAGNOSIS, and COMMISSIONING are service modes where the operator is permitted to interact with the AU from the Service Unit. The other modes are built-in transitional modes needed to ensure safe behavior of the I&C system.

2.5.2.1 Operating Mode STARTUP

STARTUP is the initial mode of an automation unit after the main PM1 configware has been successfully deserialized in the main FPGA internal memory and has taken control. Then each hardware module performs built-in self-tests and reports its status to the main PM1:



Initialization of each AU does not depend on availability of the SMDF1 of this AU or availability of other AUs or the Service Unit. [

]

[

]

After successfully completing the startup phase, the AU will automatically switch to:

- FACTORY mode when no Application Program has been previously loaded (i.e., brand new module from the warehouse).
- OPERATION mode when an Application Program is found and successfully loaded.

2.5.2.2 Operating Mode FACTORY

The AU enters FACTORY mode when no valid Application Program is available; i.e., MRAM application program memory is empty or application program is corrupted.

In this mode, [] hence bidirectional communication between the AU and the Service Unit is enabled and new application program can be loaded. Status of this mode is indicated by the front panel LEDs.

The AU exits FACTORY mode and switches automatically back to STARTUP mode once a new Application Program has been received from the Service Unit and successfully loaded.

2.5.2.3 Operating Mode OPERATION

OPERATION is the regular mode in which an AU is only allowed to access I/O modules, to send and receive signal data to and from other AUs, and to perform I&C safety functions. The latter actions are cyclically performed by the AU.

The AU will leave OPERATION mode in two cases:

- If a fatal error occurs, the AU switches to ERRORSTOP mode.
- [] the AU switches to WAITSTATE mode.

2.5.2.4 Operating Mode WAITSTATE

The AU switches from OPERATION to WAITSTATE mode [] and stays in this mode until it receives a valid service command ordering it to switch to one of the service modes such as DIAGNOSIS, MAINTENANCE, or COMMISSIONING. There is no service command to explicitly enter WAITSTATE mode.

When in WAITSTATE mode, the AU sets its outputs (electrical channels and outgoing network messages) to failsafe values. As mentioned above, the AU will accept commands from the Service Unit (a non-safety-related system), hence the impact on the plant process is suspended. However, inputs continue to be acquired and the application continues to process so that integrative algorithms (for instance, using filters) are still being continuously updated.

The AU will leave WAITSTATE mode [] At this point in time, behavior of the AU will differ depending on the service commands issued during WAITSTATE mode:

- []

the AU immediately switches back to OPERATION mode. That means the process will continue with no interruption, including integrative algorithms.

- [] the AU restarts by entering STARTUP mode.

2.5.2.5 Operating Mode MAINTENANCE

The AU is only allowed to switch to MAINTENANCE mode when it is in WAITSTATE mode and receives a MAINTENANCE service command.

Even though inputs continue to be acquired and the application continues to process, the AU sets its outputs (electrical channels and outgoing network messages) to failsafe values.

When in MAINTENANCE mode, the AU offers specific capabilities to the maintenance operator from the Service Unit:

- []
 - ◆ A new Application Program can be downloaded from the Service Unit to the AU.
 - ◆ A new set of initial conditions memory values can be downloaded from the Service Unit to the AU.
- [] a new set of Application Parameters can be downloaded from the Service Unit to the AU.

These new files will be used by the AU:

- As the new set of Application Parameters for the next processing cycle.

- As Application Program and new set of initial conditions memory values when the AU restarts after leaving WAITSTATE mode.

The AU will leave MAINTENANCE mode if one of the two following conditions is met:

- []
- [] the AU will automatically transition to WAITSTATE, where the exit condition will be immediately evaluated, leading to reset or to switch to OPERATION.

2.5.2.6 Operating Mode DIAGNOSIS

DIAGNOSIS mode allows modification of input signal values of the function blocks (simulated inputs).

The AU is only allowed to switch to DIAGNOSIS mode when it is in WAITSTATE mode and receives a DIAGNOSIS service command.

Even though inputs continue to be acquired and the application continues to process, the AU sets its outputs (electrical channels and outgoing network messages) to failsafe values.

When in DIAGNOSIS mode, the AU offers the maintenance operator the ability to download a set of predetermined (test) values from the Service Unit to the AU. The new files are used immediately and will then interact with the signal trajectories of the Application Program. When the AU leaves DIAGNOSIS mode, memory banks relative to set of predetermined (test) values are automatically and immediately reset in a way that the AU operates again as specified in the Application Program.

The AU will leave this mode if one of the two following conditions is met:

- It receives a service command asking the AU to switch back to operation; in this case it will switch back to WAITSTATE, []
- [] in this case the AU will automatically transition to WAITSTATE, where the exit condition will be immediately evaluated (see corresponding section), leading to reset or to switch to OPERATION.

2.5.2.7 Operating Mode COMMISSIONING

COMMISSIONING mode is analogue to DIAGNOSIS mode except that outputs are not inhibited:

- Electrical output channels will output the calculated values.
- []

This mode is intended for electrical continuity testing or for periodic testing of signal conditioning modules, provided the corresponding actuation paths have been previously secured.

2.5.2.8 Operating Mode ERRORSTOP

The AU enters ERRORSTOP mode from any other state if a fatal error occurs [] If possible (no unrecoverable hardware fault), the AU then automatically resets to STARTUP mode.

The main PM1 of the AU stops processing the Application Program and will not send any network messages. MPIOF1s channels output their failsafe values.

2.6 TXS COMPACT Cabinet and Peripherals

The TXS COMPACT Automation Unit (AU) can be deployed as a partial upgrade for an existing installation, as a replacement for an existing installation, or as a new installation. The project strategy will determine whether an existing cabinet is to be used or a new cabinet is to be provided.

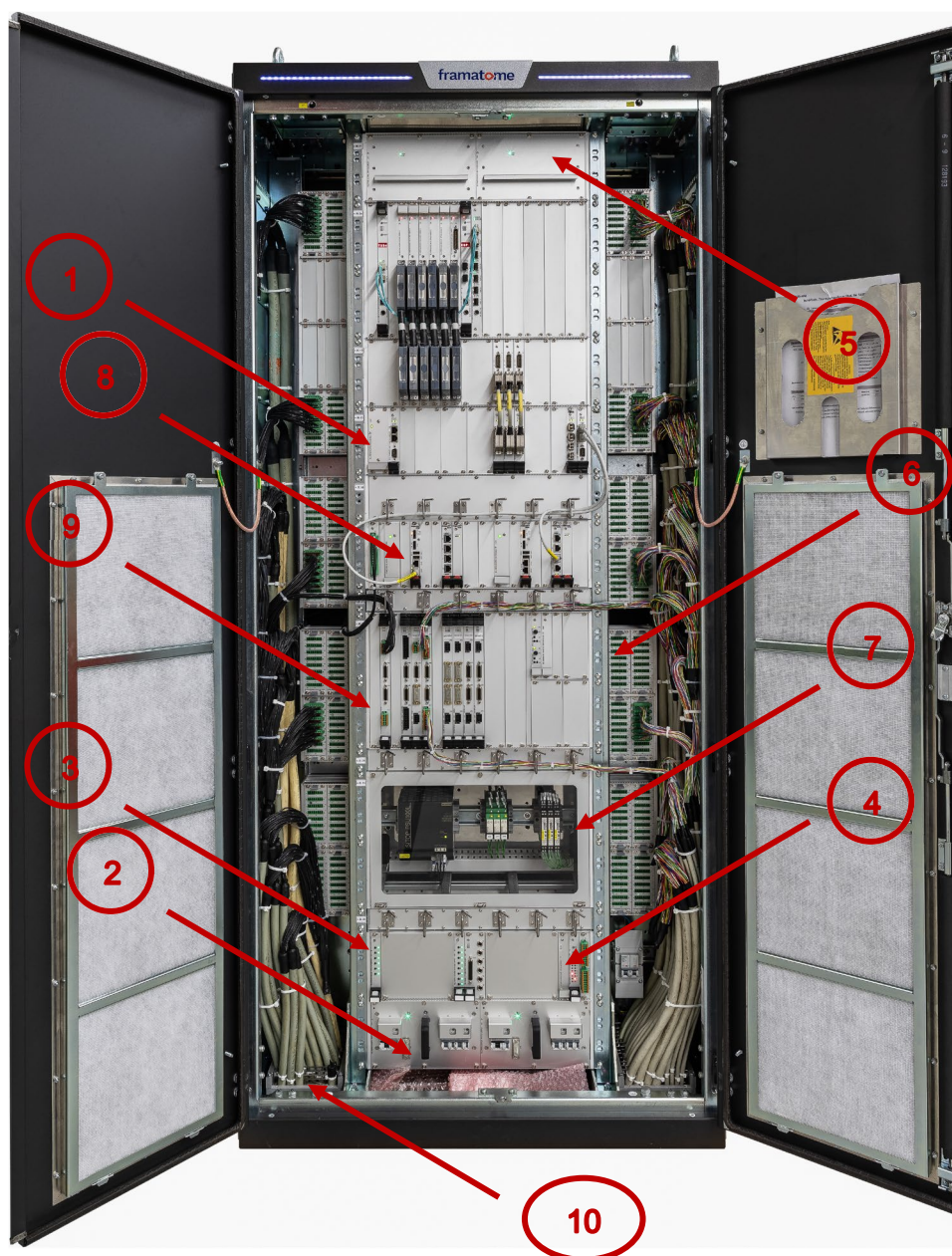
If an existing cabinet or housing and its peripherals are used, these are assessed for compliance with the specific requirements of the site and of the TXS COMPACT AU. The assessment can be performed by analysis or actual testing. As required, the cabinet or housing is upgraded. If a new cabinet is required, the TXS COMPACT AU is delivered in a cabinet fully qualified for nuclear safety system applications with respect to mechanical and seismic loads, electro-magnetic compatibility, and environment.

Typically, the I&C application requires the TXS COMPACT AU to be supported by a cabinet and peripherals. Peripherals used and arrangement of peripherals within the cabinet is application-specific. There is no standardized arrangement; however, Table 2-19 lists the peripherals typically used together with a TXS COMPACT AU. For illustration, Figure 2-25 shows a TXS COMPACT AU integrated into the CAB-S 9/4/20 standard TXS cabinet and supported by typical peripherals.

Table 2-19
Typical Peripherals of the TXS COMPACT Automation Unit

Equipment	Short Name	Figure 2-25
TXS COMPACT chassis		
Logic signal processing	SRACKCR (rear mounting)	1
Logic signal processing	SRACKCF (front mounting)	---
Standard TXS cabinet	CAB-S 9/4/20	---
Cabinet Power Supply Unit	PSU1	
Decoupling diode	PSD1	2
Electronic circuit breakers	ECB1, ECB2	3
Cabinet Monitoring Module	CMM1	4
Fan Unit	FNU1	
Fan cassette	FAN1	5
Module frames (only for the side sections)	SF-6U	6
I&C cable connection		
Connector hardware (HW) modules		
Plug HW modules		
Potential distribution HW modules		
Universal mounting plate	UMP1	7
Communication		
Housing of non-TXS equipment		
Additional racks		
Communication		8
Secondary logic		
Signal conditioning		9
Decoupling and protection		
Cable gland frame	CGF1	10
I&C cables		
Power supply cables		

Figure 2-25
Assembled CAB-S 9/4/20 Standard TXS Cabinet



The cabinet houses the chassis of the TXS COMPACT AU and all peripherals. The cabinet physically separates I&C system parts and provides protection against intrusion, dust, accidental contact, water, external mechanical impacts, and electromagnetic interference. It contributes to cooling of installed electronic equipment and ensures that seismic and EMC requirements are met.

The chassis of the TXS COMPACT AU hosts all HW modules of the TXS COMPACT AU. Different types of HW modules can be configured in the chassis depending on application-specific requirements.

The cabinet power supply filters incoming alternating current (AC) or direct current (DC) power. It converts or decouples incoming power to the DC power required by the TXS COMPACT AU and other peripherals. Power is distributed within the cabinet via electronic circuit breakers (ECBs). The monitoring unit acquires cabinet internal status signals of the TXS COMPACT AU and peripherals and reports any detected errors to the outside.

The cooling fan unit provides for heat dissipation from the cabinet.

Module frames are mounted in the side sections and hold the connector HW modules. These connector HW modules provide the specific field interconnects needed for the I&C application. From here, field signals are distributed inside the cabinet.

Additional chassis house other application-specific HW modules used; e.g., for communication, signal conditioning, signal duplication, protection, or decoupling.

Mounting plates house application-specific devices such as terminal blocks, interposing optocouplers or relays, switches, and other equipment.

Cable gland frames (CGF1s) feed input and output field signals and cabinet power supply. Field signals are transmitted via shielded cables. The cable shield is typically connected to the local reference potential of the cabinet at the cable entry point.

A TXS COMPACT AU-based safety I&C system is typically implemented using one or more TXS COMPACT AUs together with none, one, or more of the peripherals previously described. Although peripherals are specific to the application, usage and assembly methods within the safety system are standardized.

2.6.1 Cabinet Arrangement

2.6.1.1 Basic Cabinet Arrangement

The TXS Platform offers great flexibility regarding the arrangement of equipment within cabinets. However, arrangement of equipment within CAB-S 9/4/20 standard TXS cabinets follows basic guidelines as shown in Figure 2-26.

Two vertical mounting bars extend over the entire cabinet height. These separate the cabinet into three mounting sections: a central section of 84 HP width and two side sections of 18 HP width. The front and rear flanges of the vertical mounting bars allow for attachment of 19" equipment. It is possible to mount equipment from the rear; however, it is also possible from the front if installation from the rear is not practical due to conditions in the plant.

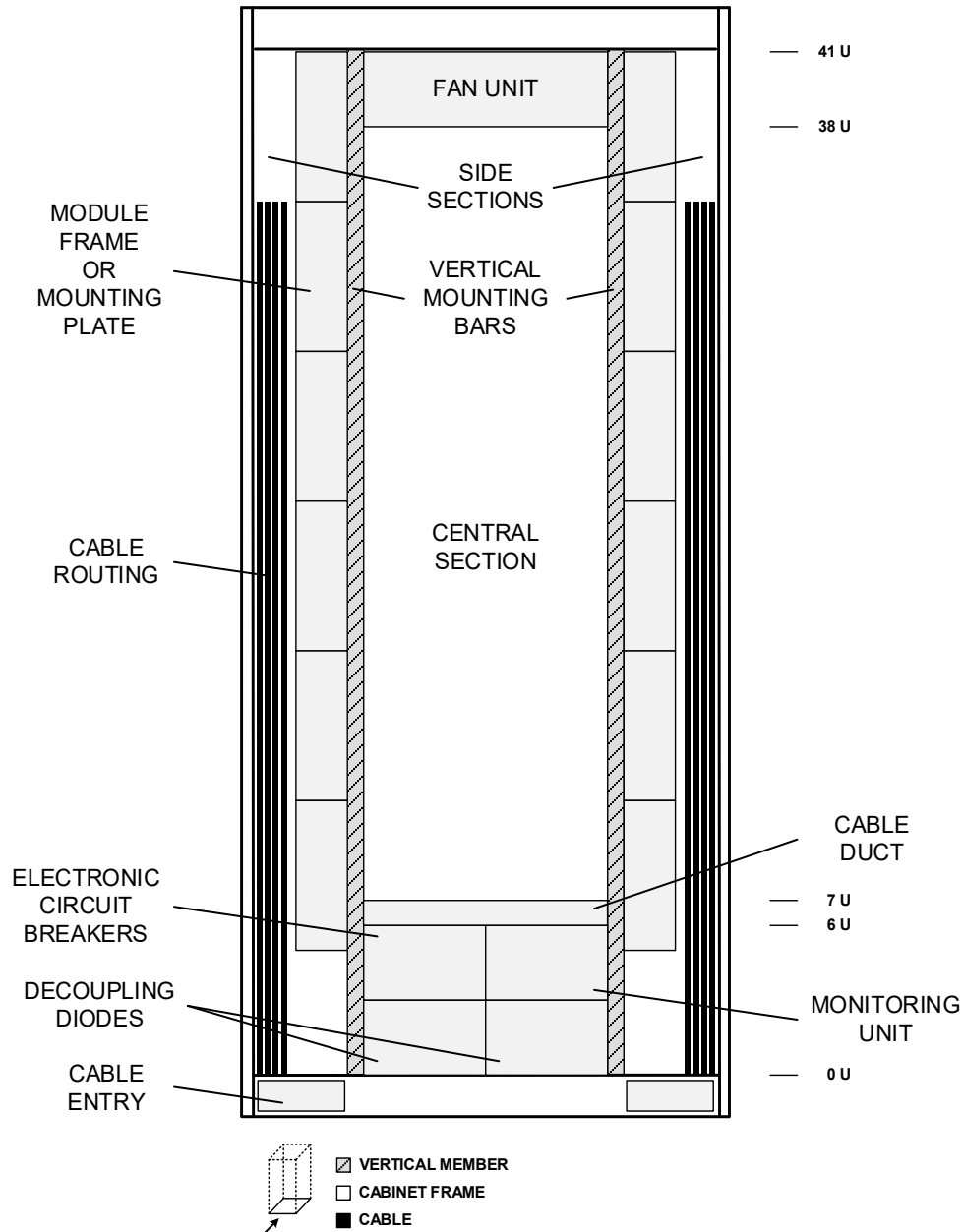
The entire mounting height in the central section of the cabinet is 41 U. Cabinet power supply, ECBs, and the CMU1 are installed in the bottommost 6 U of the central section, and the fan unit for cabinet cooling in the topmost 3 U. In case of front only access, an additional cable duct of 1 U above the Power Supply Unit (PSU1) is required. 31 U then remain free in the central section for other 19" equipment such as chassis, large mounting plates, and cable trays.

In the side section, module frames with connector or plug HW modules and small mounting plates are installed within a maximum of 36 U. The remaining bottommost 5 U in the side sections are reserved for cabinet cable entry.

Across the entire height of the cabinet, areas are reserved in the side sections for routing I&C cables from the cable entry of the cabinet to the module frames.

The cabinet has two front doors with frames for mounting air filters. The cabinet has a stiffening plate on the rear by default. In this case, no cross stays are required. Rear doors are optional. Rear doors may require rear and/or front cross stays, depending on the seismic requirements of the power plant.

Figure 2-26
Basic Arrangement of CAB-S 9/4/20 Standard TXS Cabinet
(Front Access Only to Cabinet)



2.6.1.2 TXS COMPACT Automation Unit

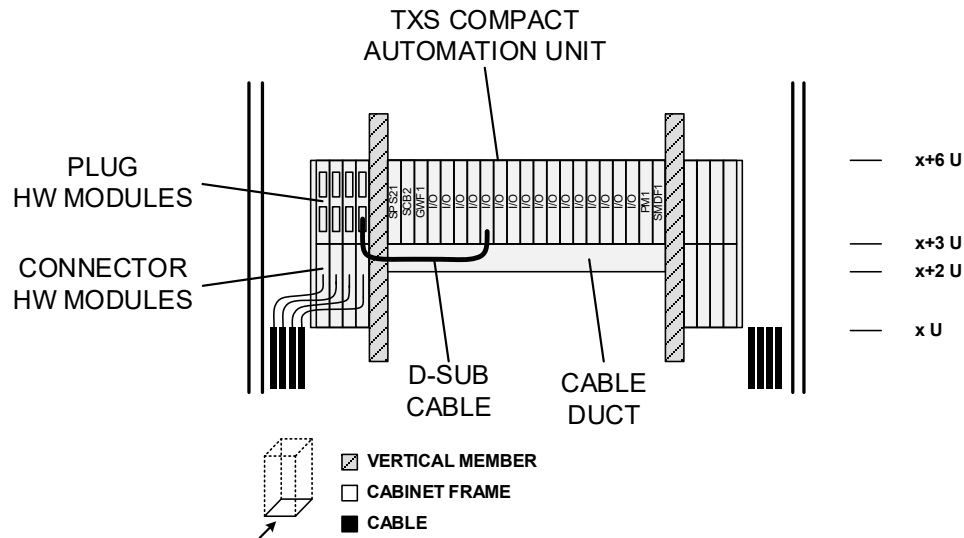
A TXS COMPACT Automation Unit (AU) is an industry standard 19" chassis. The chassis can be front mounted in all types of existing 19" compatible cabinets and wall-mounted enclosures; however, rear mounting is only possible in the CAB-S 9/4/20 standard TXS cabinet. Configuration of the chassis depends on the I&C functions to be implemented for the specific application.

I&C cables are connected to the connector HW modules. If the TXS COMPACT AU can process I&C signals directly, I&C signals are forwarded to the plug HW modules. If no signal marshaling is required, a simple feedthrough PCB, which mounts on the back of the module frame, is used. Otherwise, signals are arranged using single-wire cabling. This enables application-specific signal routing from the field to the TXS COMPACT AU.

From the plug HW modules, signals are routed to the I/O HW modules in the TXS COMPACT AU installed in the central section via D-sub/D-sub cables. A cable duct with a height of 1 U is required for these cables.

D-SUB connecting cables are manufactured in different lengths. To lay the cables optimally with regard to the bending radii, a fixed assignment of the slots of the I/O HW modules placed in the TXS COMPACT AU and the plug HW modules placed in the module frames can be defined. If this assignment is consistently applied, connecting cables can be pre-assembled in standard lengths. Figure 2-27 shows a typical main rack of a TXS COMPACT AU populated with HW modules.

Figure 2-27
Main Rack of a TXS COMPACT Automation Unit

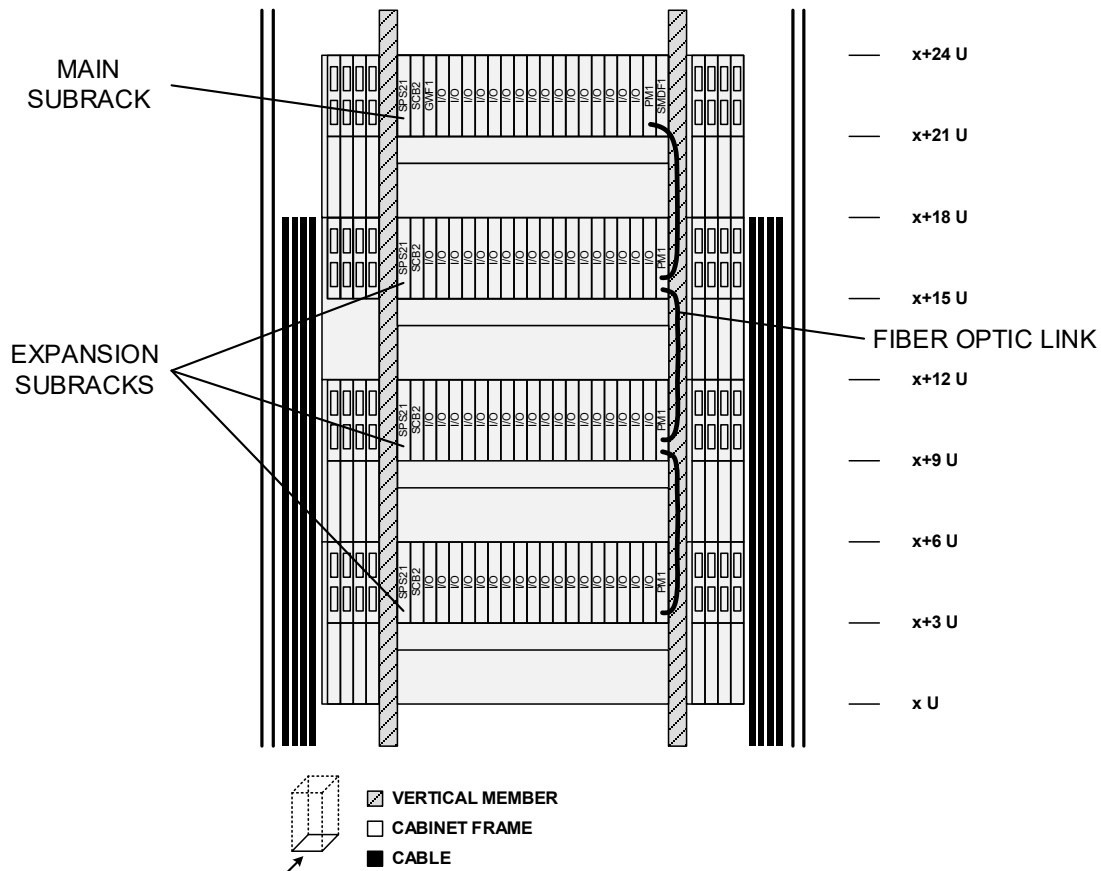


A TXS COMPACT AU consists of at least one main rack. Additional expansion racks can be daisy-chained to the main rack to provide I/O expansion or remote I/O capabilities, see Figure 2-28. Only one main PM1 HW in the main rack runs the I&C application. Additional PM1 HW in the main rack are only used to increase the number of network connections.

PM1 HW in the expansion racks are only used to expand I/O capacity. The network connection between the main rack and the expansion racks is based on point-to-point fiber optic links between PM1 HW.

Architecture of a TXS COMPACT AU allows for one main rack and up to three expansion racks located within the same or different cabinets. These chassis allow for up to 72 I/O HW modules per TXS COMPACT AU.

Figure 2-28
Main and Expansion Racks of a TXS COMPACT Automation Unit

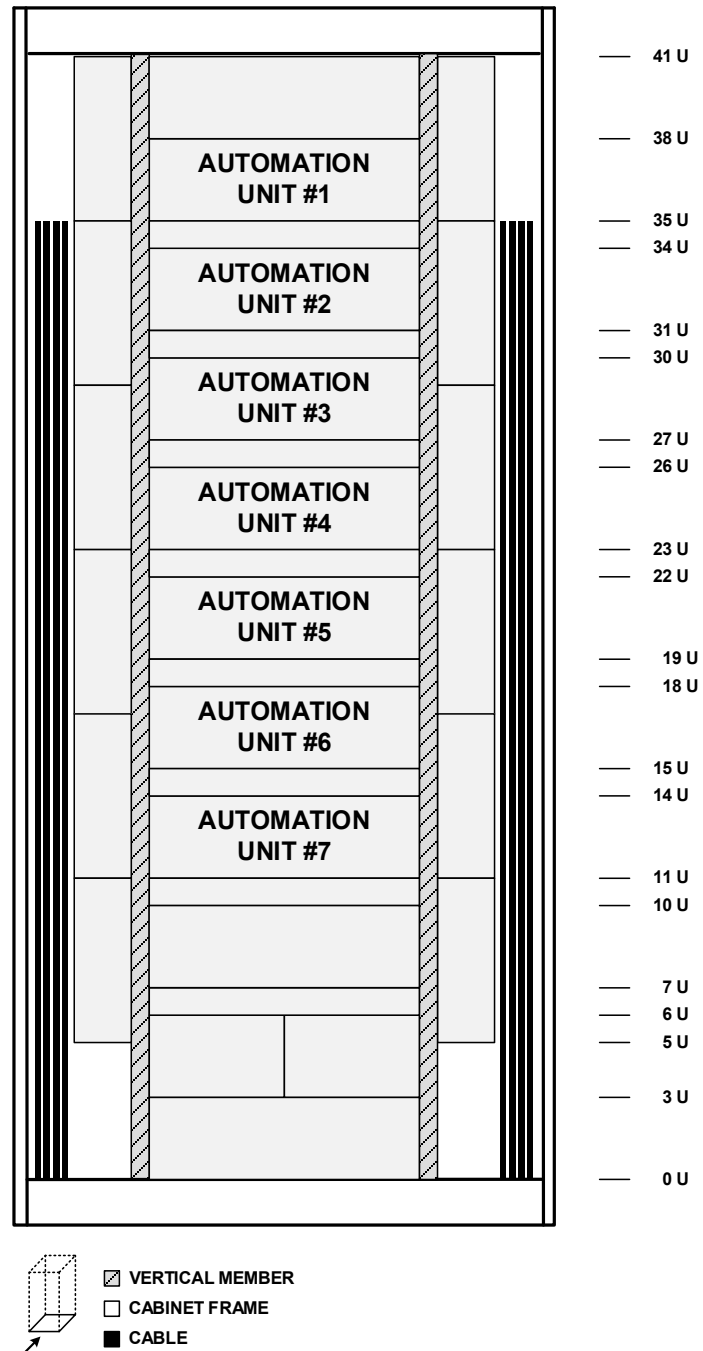


Slots on the backplane of the TXS COMPACT AU are pre-assigned. The SPS1 DC/DC converter HW module is placed in the leftmost slot (slot 20). If present, the GWF1 gateway HW module is placed in slot 18 (to the right of the SPS1 HW). If required, the SMDF1 is placed in the slot on the far right (slot 0). The chassis can contain up to four PM1 processing and interface HW modules. A main rack has a main PM1 HW in slot 1. If the number of optical interfaces is not sufficient, up to three additional PM1 HW can be plugged into slots 2 to 4. Similarly, if the number of I/O channels in the main rack is not sufficient, the TXS COMPACT AU can be expanded by a maximum of three expansion racks. In each of these expansion racks, exactly one PM1 HW is in slot 0 and is only used for communication with the main PM1 in the main rack. Different types of I/O HW modules are placed in the remaining slots (slots 1 to 18) depending on the number of GWF1, PM1, and SMDF1 HW present.

Table 2-20
Chassis Slot Assignment of TXS COMPACT Automation Unit

The maximum number of chassis of TXS COMPACT AU that can be mounted in a CAB-S 9/4/20 standard TXS cabinet with front only access is seven, whether the chassis are main or expansion racks. In case of rear access, the number is eight. Figure 2-29 shows an example of a standard TXS cabinet fully fitted with main racks of TXS COMPACT AUs for front only access.

Figure 2-29
CAB-S 9/4/20 Standard TXS Cabinet Fully Fitted
with TXS COMPACT Automation Units
(Front Access Only to Cabinet)



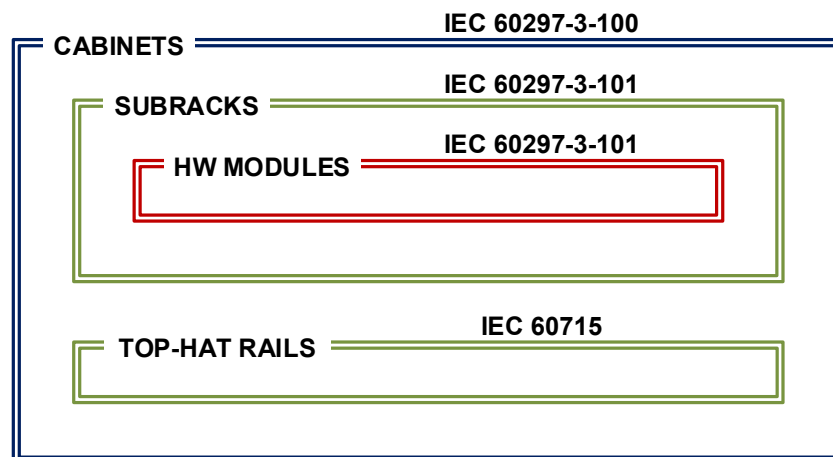
2.6.2 Standards

The mechanical dimensions and properties of the TXS platform conform to the

- 19" industry standard
(see IEC 60297-3 [33]; mechanical structures of the 19"-series), and
- Top-hat rail industry standard
(IEC 60715 [34]; standardized mounting on rails).

Chassis can be front-mounted in all types of existing 19" compatible cabinets and wall-mounted enclosures; however, rear-mounting is only possible in the CAB-S 9/4/20 standard TXS cabinet. Mechanical board dimensions and properties of the HW modules correspond to those of front-mounted 3 U or 6 U HW modules with a depth of 160 mm.

Figure 2-30
Standards Met by
Mechanical Equipment of TXS Platform

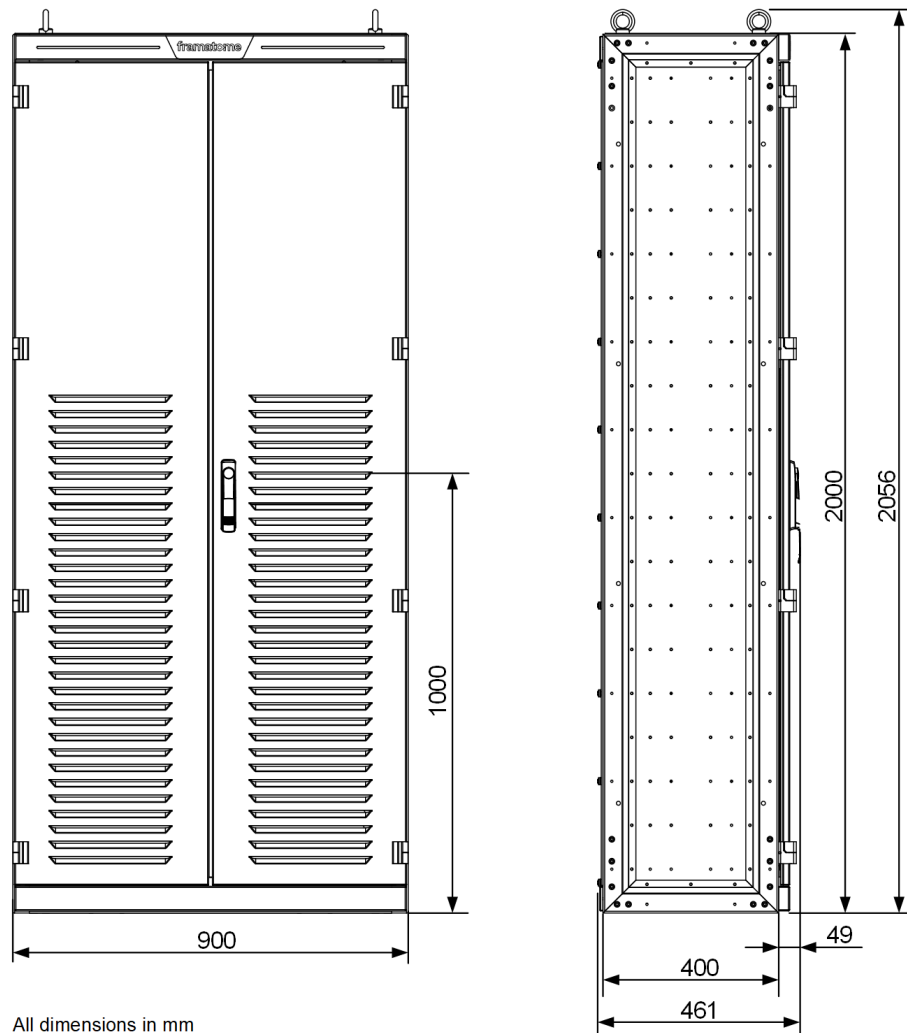


2.6.3 Cabinet

The outer frame dimensions of the CAB-S 9/4/20 standard TXS cabinet are 900 mm x 400 mm x 2000 mm (width x depth x height). The front doors including the handle, stiffening plate, and mounting bolts increase the total depth to 461 mm. If the cabinet is fitted with rear doors instead of the stiffening panel, total depth of the cabinet is 498 mm. Side panels that can be fitted to the left and right of a cabinet add 7 mm to the width per side panel. The roof increases the overall height of the cabinet by 56 mm.

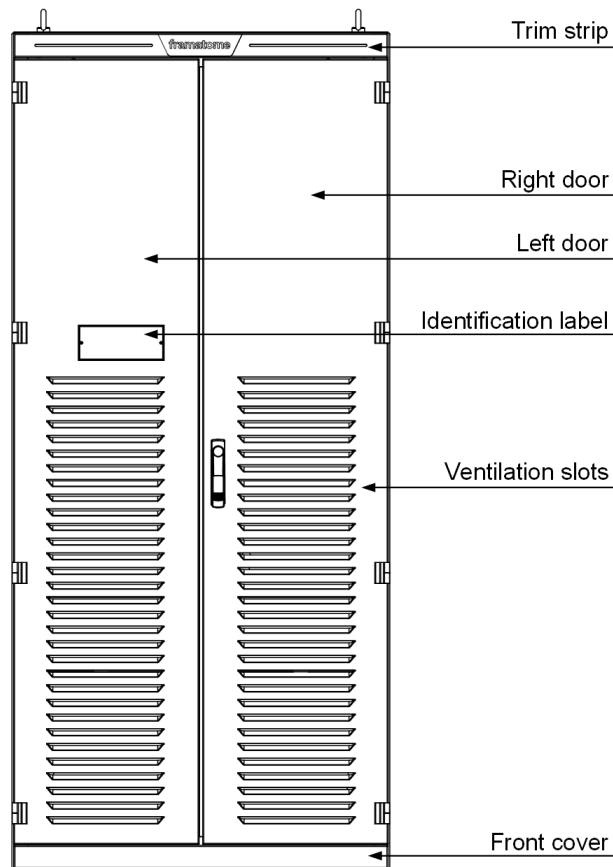
Side panels can be used to cover the outer cabinet frame and partition panels of stand-alone cabinets or the visible sides of the first and the last cabinet in a row.

Figure 2-31
Outer Dimensions of CAB-S 9/4/20 Standard TXS Cabinet



The CAB-S 9/4/20 standard TXS cabinet is accessed from the front via two symmetrical side-swinging doors. Instead of the stiffening plate, the cabinet can also be equipped with such doors on the back. The right-hand door features a counterbored turning handle with or without a cylinder lock to limit access.

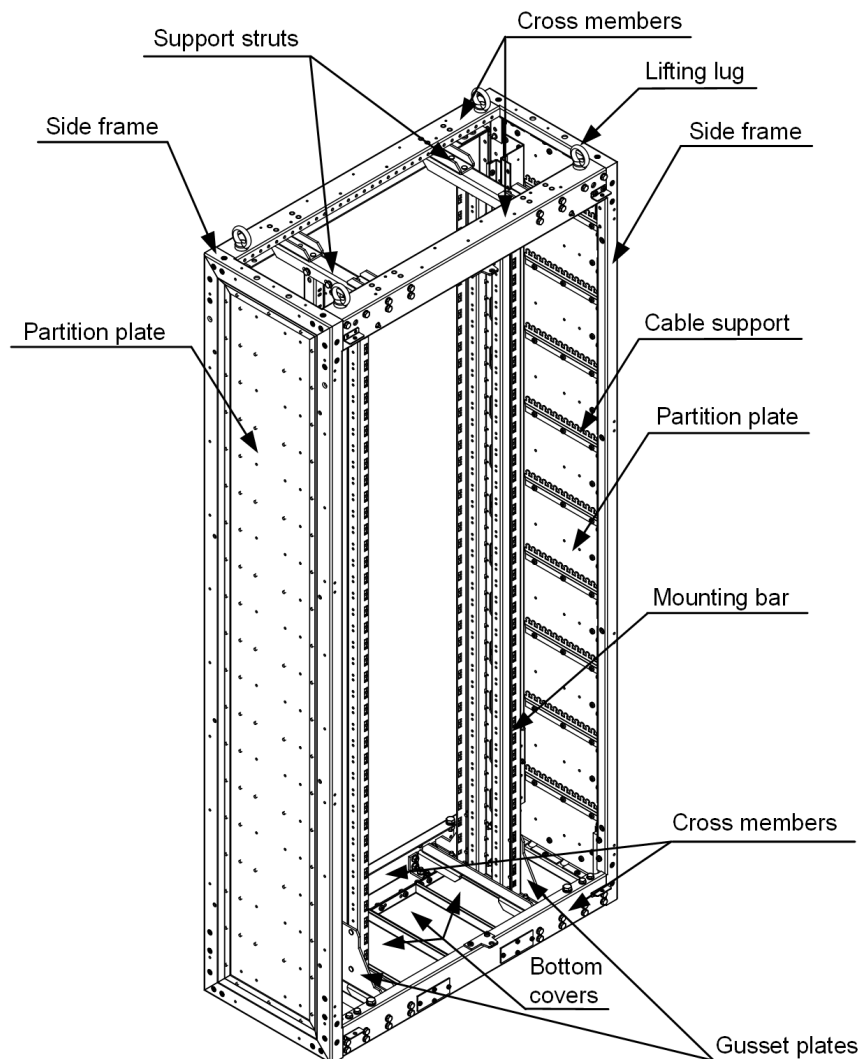
Figure 2-32
Front of CAB-S 9/4/20 Standard TXS Cabinet



The rear of the cabinet is equipped with a stiffening plate that is bolted to the cabinet frame and contributes significantly to the structural stiffness of the cabinet. The stiffening plate can be mounted and dismounted. If the stiffening plate is dismounted, this is indicated by two door contacts. Optionally, the stiffening plate can be exchanged for two doors of the same design as those on the front if access to the cabinet from the rear is required. This, however, reduces the seismic resistance of the cabinet.

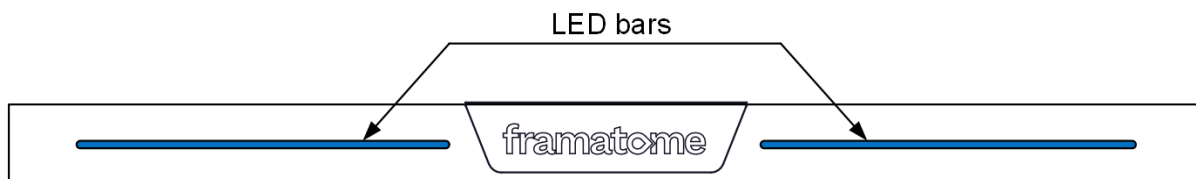
[] the CAB-S 9/4/20 standard TXS cabinet is equipped with partition plates on both sides. The partition plates are integral parts of the side frames. If multiple cabinets are placed in a row, they separate each cabinet from its neighboring cabinets. The partition plates are equipped with cable holders for I&C cables. The cable supports provide mushroom-shaped means to attach I&C cables with cable ties []

Figure 2-33
Mechanical Structure of CAB-S 9/4/20 Standard TXS Cabinet



The upper front edge of the CAB-S 9/4/20 standard TXS cabinet is equipped with a trim strip which features LED bars for error indication.

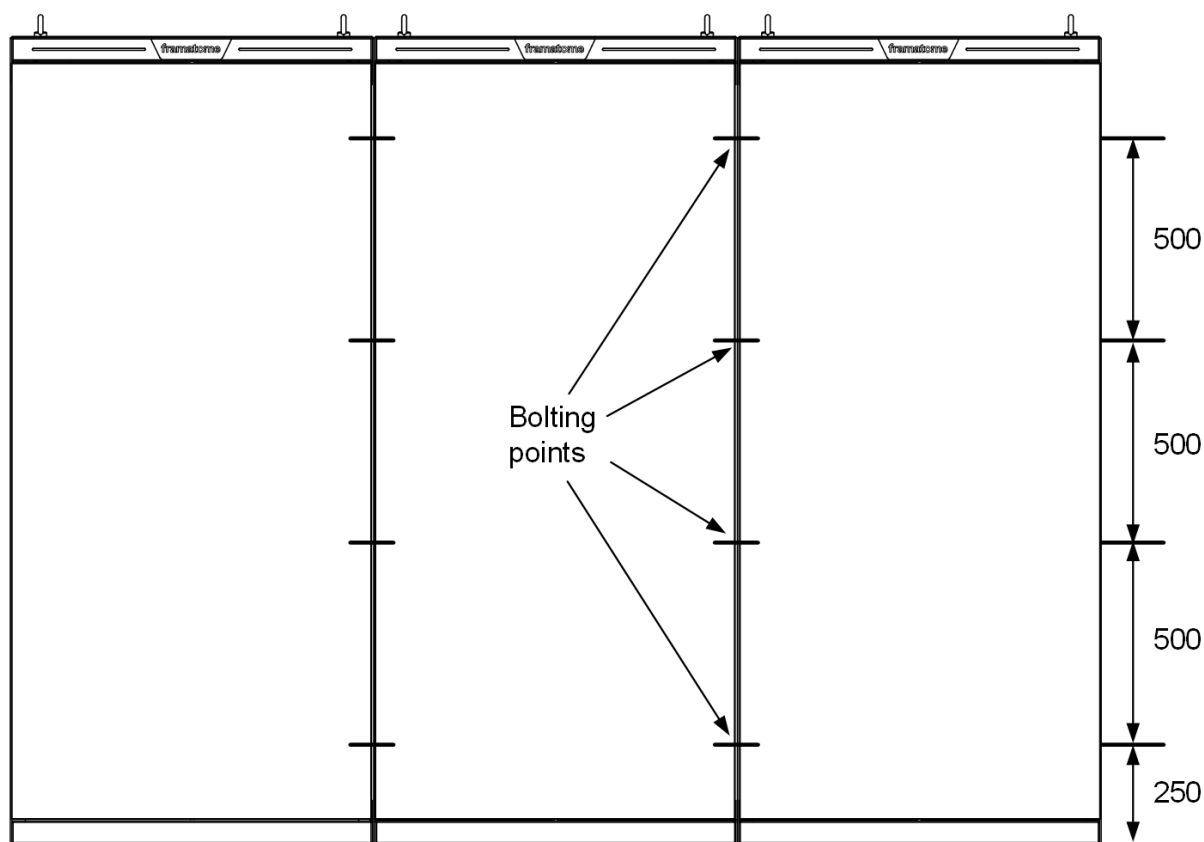
Figure 2-34
Trim Strip



The CAB-S 9/4/20 standard TXS cabinet is installed in the plant by bolting it through four holes by default. The cabinet may also be welded to a supporting structure at the installation location in the plant; e.g., a steel base frame. In this case, it is not required to additionally bolt the cabinet.

Typically, TXS cabinets are lined up in rows and must be fastened to each other and to the floor. For this purpose, the cabinets are bolted together at their adjoining side frames at eight points. In addition, the cabinet is standalone erectable.

Figure 2-35
Cabinet-to-Cabinet Bolting



All dimensions in mm

The CAB-S 9/4/20 standard TXS cabinet is designed for use under tough mechanical and seismic load conditions (rugged environments). It is maintenance-free and has an unlimited service life.

The total mass of the CAB-S 9/4/20 standard TXS cabinet if fully equipped with I&C cables, chassis, HW modules, etc., and is only limited by its own structural integrity. Stability depends on the project-specific configuration of the cabinet, mass distribution, and mechanical and seismic load requirements of the nuclear power plant.

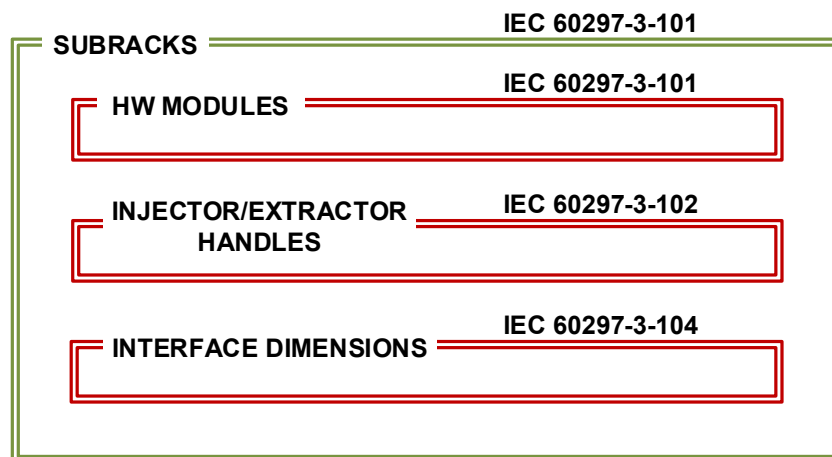
Table 2-21 gives the typical mass distribution of a free-standing, fully assembled CAB-S 9/4/20 standard TXS cabinet.

Table 2-21
Typical Mass of Fully Assembled CAB-S 9/4/20 Standard TXS
Cabinet

2.6.4 Chassis

The TXS chassis complies with the standard 19" packaging system.

Figure 2-36
Standards Met by
the Chassis and HW Modules of TXS Platform



The TXS chassis allows installation of HW modules according to EMC, mechanical, and seismic requirements. Chassis are suitable for HW modules with a height of 3 U or 6 U and a mounting depth of 160 mm (i.e., single or double Eurocard format). The chassis offers a total width of 84 HP for HW modules. To facilitate installation and replacement of HW modules, the TXS chassis supports HW modules with injector/ejector handles on the front plates and hot plug functions. The TXS chassis can be rear-mounted in the CAB-S 9/4/20 standard TXS cabinet and front-mounted in any other 19" industry standard compliant packaging system.

The TXS chassis has a 19" compatible width of 443.8 mm (distance rear angle to rear angle) and 482.60 mm (distance mounting bracket to mounting bracket) as shown in Figure 2-37 and Figure 2-38. The distance of the mounting points on the vertical bars is 465.0 mm. The depth is 251.0 mm, as can be seen in Figure 2-39.

Figure 2-37
Width of Subrack (SR-)3U Chassis (Rear-Mounting)



Figure 2-38
Distance of Mounting Points of SR-3U Chassis

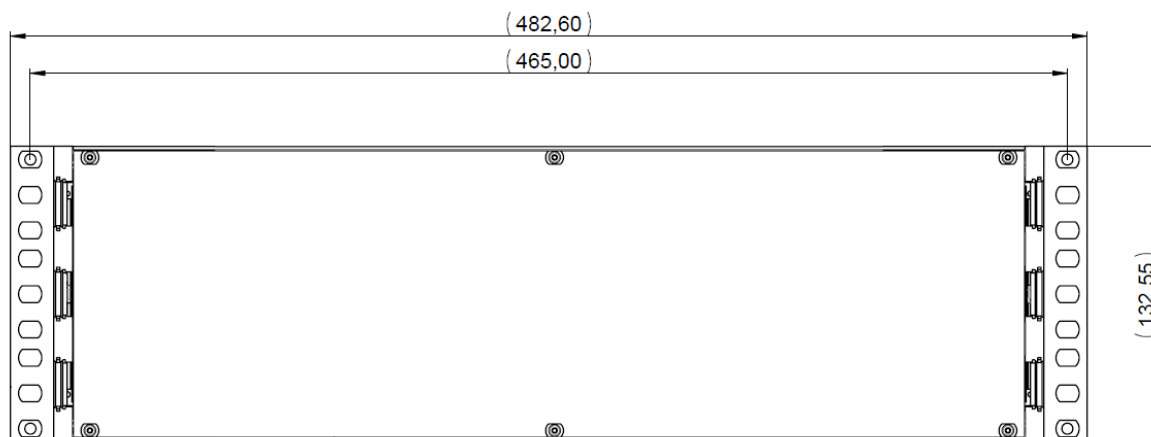
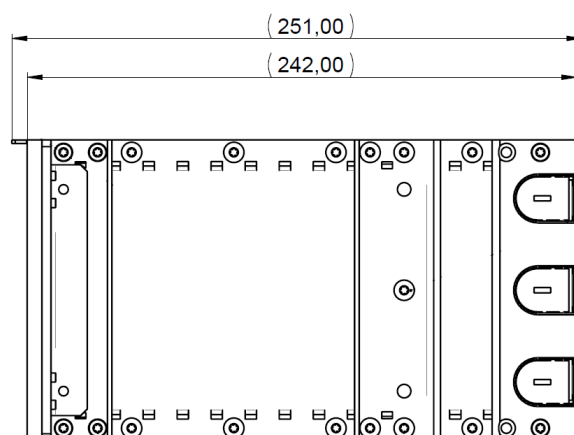


Figure 2-39
Depth of SR-3U Chassis

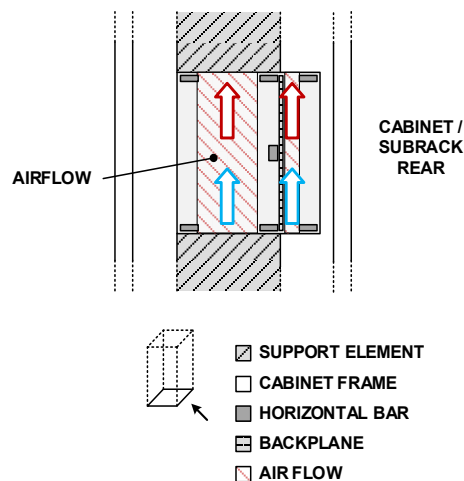


Chassis height depends on the chassis type, see Table 2-22. Total mass of the TXS chassis when fully equipped with HW modules is limited. Table 2-22 gives maximum mass. Maximum mass considers the chassis, backplanes, rear connectors, internal wiring, and HW modules.

Table 2-22
Maximum Mass of Fully Assembled TXS Chassis

The TXS chassis features a lightweight construction of aluminum panels and bars. Mounting brackets are attached over the full height on both sides. The mounting brackets have holes on each side, through which the chassis are screwed to the vertical members of the cabinet. The rear of the chassis is closed by a rear panel. The top and bottom of the chassis and the EMC cover plates are perforated throughout to allow vertical ventilation, as shown in Figure 2-37 and Figure 2-40. TXS chassis are EMC-proven enclosures with a defined shielding effectiveness. TXS chassis support both natural convection cooling and forced convection cooling.

Figure 2-40
Vertical Airflow on Chassis Level



TXS chassis are equipped with backplanes or rear connectors and guide rails as required for HW modules to be installed. HW modules are inserted into the guide rails and attached to the chassis by means of individual screw-in mounting. Internal cabling of the chassis may be required depending on the installed HW modules.

TXS chassis are usually delivered to the customer preassembled. Each chassis is configured individually according to application-specific requirements. The configuration and cabling of each chassis is documented in a detailed hardware arrangement diagram.

TXS chassis are bolted to the cabinet using mounting brackets. The bolts are evenly distributed on the front and rear mounting brackets. The number of bolts depends on the type of chassis. Normally eight bolts are used per 3 U height.

The design of TXS chassis and the way they are mounted within the CAB-S 9/4/20 standard TXS cabinet result in a robustness that enables use under harsh mechanical and seismic loading conditions.

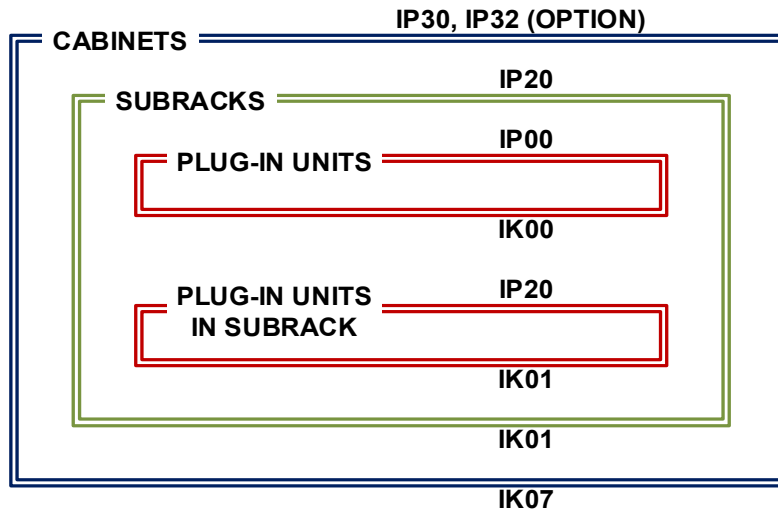
To ensure compliance with EMC, mechanical, protection, and seismic requirements, chassis are completely closed during normal operation. This means:

- The back of the chassis is closed with the supplied rear panel.
- Unused cable entries are closed with blanking plugs.
- Unused slots are closed with blanking plates.

2.6.5 IK/International Protection (IP)

TXS mechanical equipment provides protection against intrusion, dust, accidental contact, water, and external mechanical impacts. The design conforms to IEC 60529:2013 [38] and to IEC 62262:2002 [39]. An overview is given by Figure 2-41.

Figure 2-41
Protection Classes Met by
the Mechanical Equipment of the TXS Platform



The IK07 and IP30 degree of protection of the CAB-S 9/4/20 standard TXS cabinet is achieved without a roof cover and with or without air filters. Typically, I&C cabinets are installed in clean and dry areas like electrical and electronics rooms. By default, no protection against exposure to water is required. To ensure minimum protection against the presence of water, protection against dripping water (vertically falling drops of water) and dripping water at an angle of 15° is provided as an option. This optional IP protection class IP32 is implemented with a different type of roof cover.

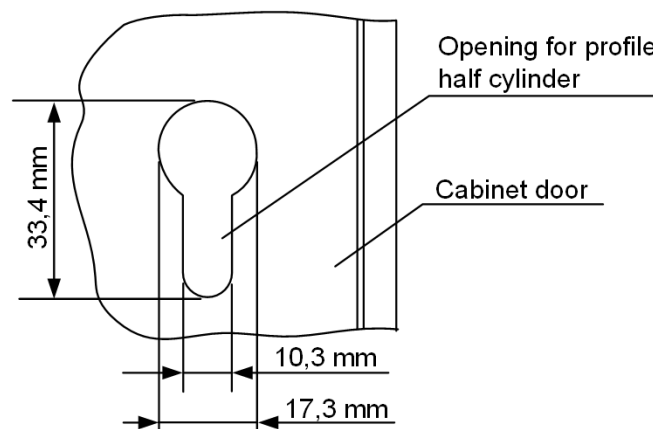
TXS HW modules for installation in chassis do not offer protection against the presence of water. However, chassis with mounted HW modules offer protection of IK01 and IP20. This feature applies to comparable HW modules (e.g., rail-mounted and chassis-mounted HW modules).

2.6.6 Physical Access Control

The CAB-S 9/4/20 standard TXS cabinet is accessible from the front via symmetrical doors. Optionally, the cabinet can also be equipped with such doors on the rear. The right door of the two symmetrical doors is equipped with a counterbored turning handle, as shown in Figure 2-32. A cylinder lock can be fitted in this turning handle to physically control access if cabinet doors are locked and to trigger an alarm when opened.

Cabinet doors have an opening for the cylinder lock. If a cylinder lock is not installed, the opening is covered with a blanking cover (plug). The opening in the cabinet door is designed for a profile half cylinder.

Figure 2-42
Opening for Cylinder Lock in Cabinet Door

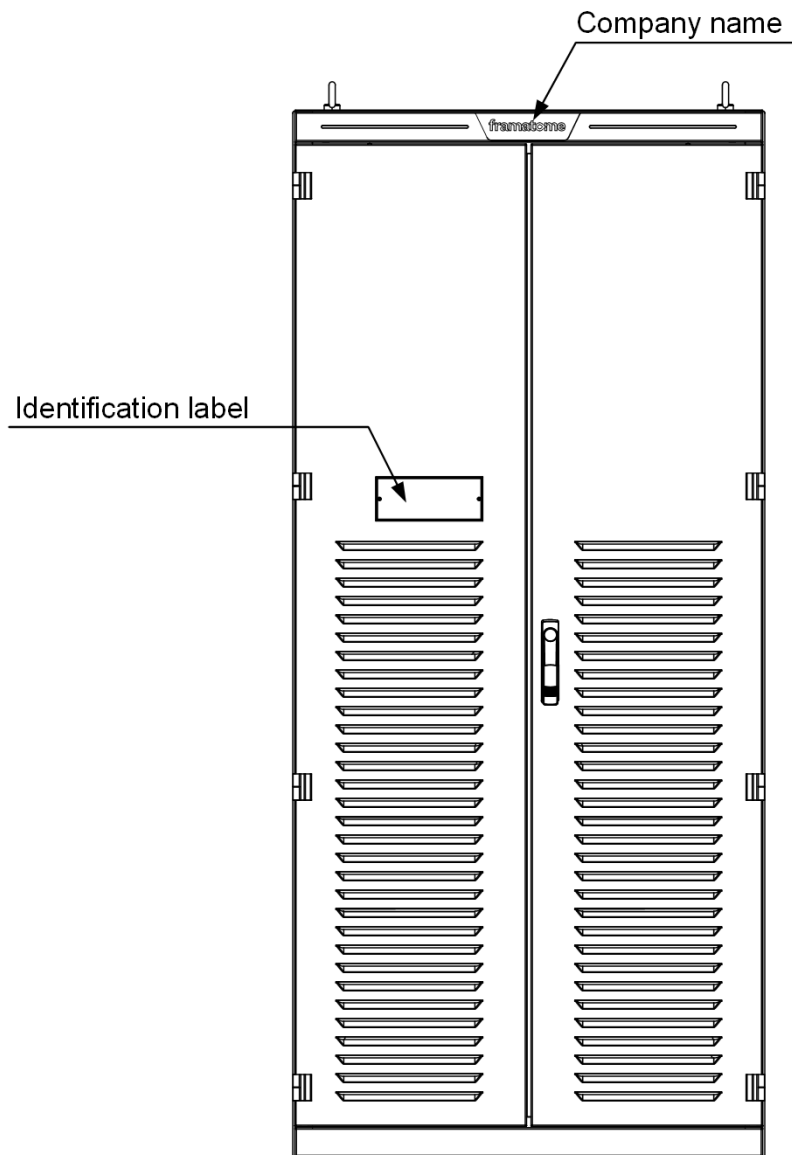


Whether a cylinder lock is used in the cabinet door is determined individually for the application. However, a typical cabinet installation includes an integrated cylinder lock on the turning handle to limit access to the interior of the cabinet.

2.6.7 Identification

If required for the specific application, an identification label can be attached to the left cabinet door, as shown in Figure 2-43. The identification label contains six fields for inscriptions; for example, the name of the I&C system platform and the cabinet identifier.

Figure 2-43
Cabinet Identification Label

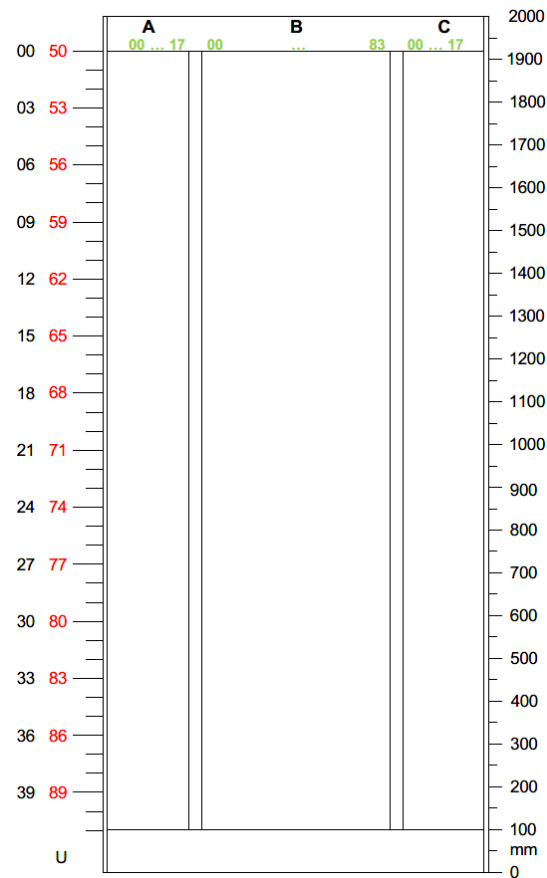


The identification system for the CAB-S 9/4/20 standard TXS cabinet complies with IEC 81346-1 [40]. Inside the cabinet, the mounting space for HW modules, chassis, etc., is divided into different mounting areas as shown in Figure 2-44 and identified by the following letter codes:

- A Inside cabinet – Left side section
- B Inside cabinet – Central section

- C Inside cabinet – Right side section
- D Outside cabinet – Outer side of door
- E Inside cabinet – Inner side of door

Figure 2-44
Identification System within Cabinet



Mounting areas D (door outside) and E (door inside) are usually not applicable for the CAB-S 9/4/20 standard TXS cabinet. If equipment such as panels or Human-Machine Interfaces (HMIs) is to be mounted in the cabinet door, mounting sections D and E are also applicable.

The starting point for designating the horizontal and vertical mounting positions is the upper left corner of the mounting area. Numbering is from left to right and top to bottom. Based on the numbering of the 19" system, each step in the horizontal direction corresponds to a horizontal pitch (HP), which is 5.08 mm, and each step in the vertical direction corresponds to a height unit (U), which is 44.45 mm.

Available mounting space in the CAB-S 9/4/20 standard TXS cabinet is shown in Figure 2-44. The cabinet offers a mounting height of 41 U, numbered from 00 to 40 from top to bottom. From left to right, mounting sections A and C each offer a mounting width of 18 HP, numbered from 00 to 17. And mounting section B in the center offers a mounting width of 84 HP, numbered from 00 to 83. To distinguish between front and rear mounting spaces in the center section B of the cabinet, numbering of height units on the rear ranges from 50 to 91 (shown in red in Figure 2-44).

Within a chassis, horizontal mounting positions are numbered from 00 to 83. Mounting position of a module is the horizontal pitch (HP) where the module's upper left fixing screw is located. The full location designation of a HW module in a mounting area is defined as the combination of

- [mounting area]+[vertical position]+[horizontal position].

Labels for the following items are included in the front plates of the HW modules as shown in Figure 2-45.

- Identification of the HW module using the following format:
 - ◆ TELEPERM XS – name of HW module – order number – version number
- Reference designators of front plate elements:
 - ◆ Front connectors.
 - ◆ Service and diagnostic connectors.
 - ◆ LED and/or push buttons.

Figure 2-45
Label on Front Plate Example



HW module identification labels can be attached to the injector/ejector handle of HW modules as shown in Figure 2-46.

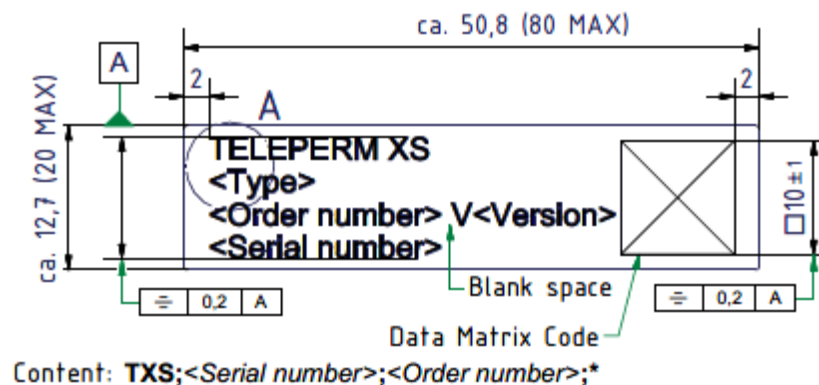
Figure 2-46
Identification Label on Handle

In addition, a type label is attached to the HW module, as depicted in Figure 2-47. It consists of human-readable text and a data matrix code. The data matrix code is entirely visible when the PCB is fully populated and all subcomponents are mounted. Label placement depends on the HW module itself. Usually, the label is placed on the rear connector.

Content of the label is as follows:

- Name of HW module – order number – version number – serial number

Figure 2-47
Label of HW Modules

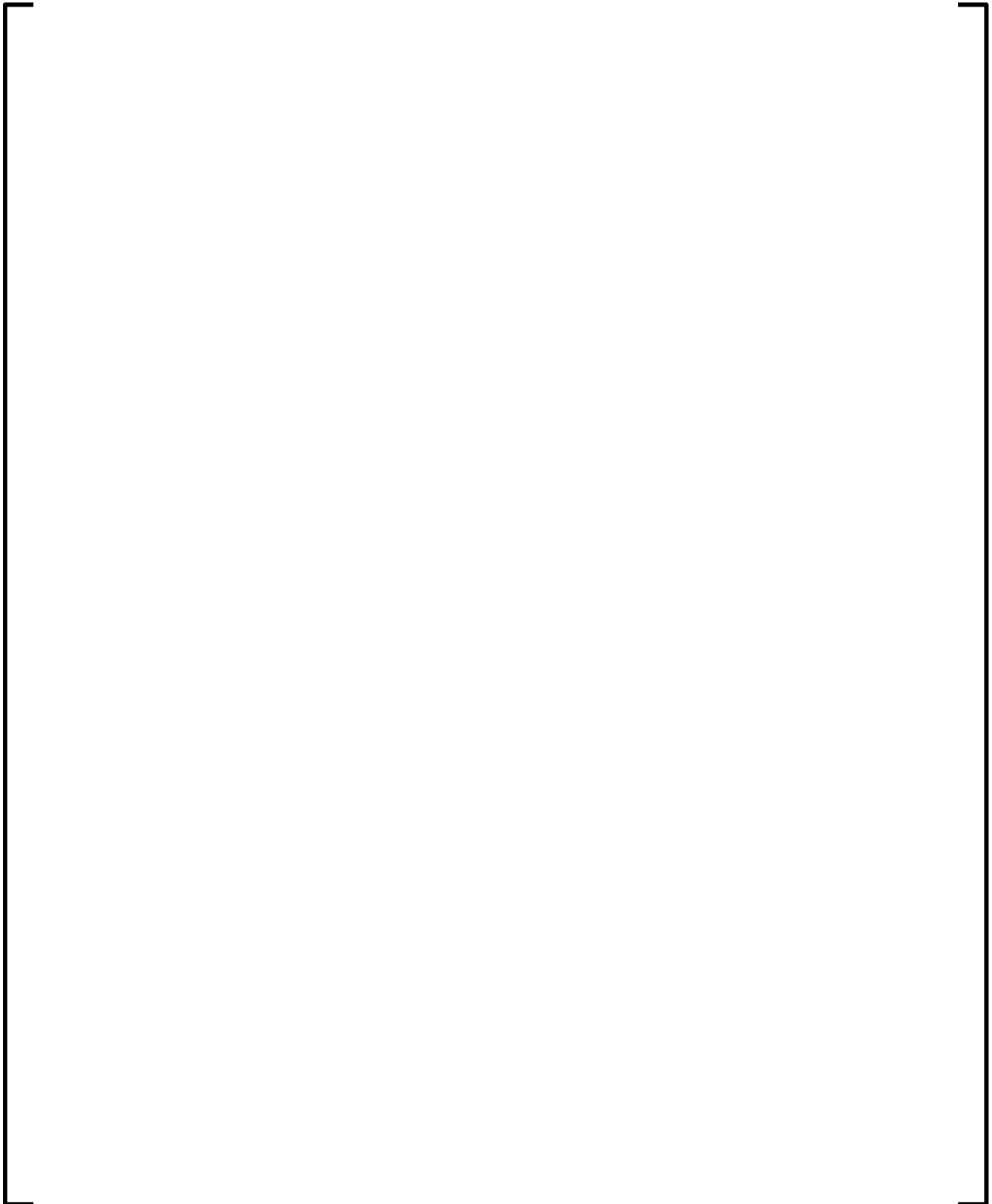


The identification system of the TXS Platform allows for maximum flexibility. In case of retrofit projects, identification of cabinets, chassis, and HW modules can be fully adapted to the existing approach in the nuclear power plant.

2.6.8 Cooling

The TXS Platform is designed for vertical cooling airflow from the bottom to the top of the cabinet as shown in Figure 2-48. Cooling air enters the CAB-S 9/4/20 standard TXS cabinet through louvers in the front doors and exits the cabinet through perforations in the cabinet roof. Inside the cabinet, cooling air enters the chassis through perforations in the EMC covering plate on the bottom and leaves the chassis through perforations in the EMC covering plate on the top (see Figure 2-37 and Figure 2-40).

Figure 2-48
Vertical Airflow on Cabinet Level



TXS equipment is designed for low heat dissipation. I&C systems based on the TXS Platform do not require forced convection cooling. This allows them to operate with natural convection cooling. Permissible heat dissipation with natural convection cooling of the CAB-S 9/4/20 standard TXS cabinet is sufficient to operate a full-scale TXS COMPACT AU and the required peripherals.

However, heat extraction from a cabinet with natural convection cooling is limited, which means that possible packing density in the cabinet is limited by the heat extraction. To achieve maximum packing density of a cabinet, forced convection cooling is required. Forced convection cooling maintains a minimum ambient temperature of the HW modules, which extends the service life and increases availability.

For forced convection cooling, an FNU1 is installed in the top 3 U mounting space in the central section as shown in Figure 2-48 and Figure 2-49. Other chassis of the TXS COMPACT AU and the peripherals are arranged below the FNU1.

Figure 2-49
Fan Unit (FNU1)



[

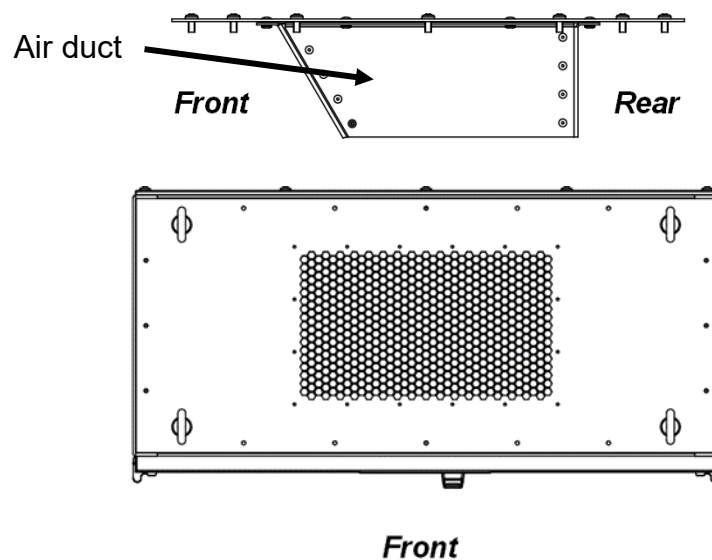
]

Figure 2-50
Fan Cassette (FAN1)



The top of the cabinet is covered by the cabinet roof and a roof plate with hexagonal openings in a central field, see Figure 2-51. The air duct with a trapezoid cross section is mounted below the hexagonal openings in the roof plate. This air duct with a nozzle type character draws exhaust air from the chassis out of the cabinet. The chassis, fan unit, air duct, and cabinet roof create a cooling air duct without thermal bypasses. This prevents hot air from flowing from the upper chassis into the lower installation cabinet areas, thus preventing any air recirculation.

Figure 2-51
Roof of CAB-S 9/4/20 Standard TXS Cabinet



Ventilation slots in the cabinet doors allow entry of cooling air from the outside. Long filter boxes are located on the inside of the doors directly behind the ventilation slots as shown in Figure 2-52 and Figure 2-53. If the cabinet is equipped with fans for forced convection cooling, air filter mats are added to protect HW modules from windblown dust, sediment dust, and suspended dust.

Figure 2-52
Ventilation Slots in Cabinet Doors

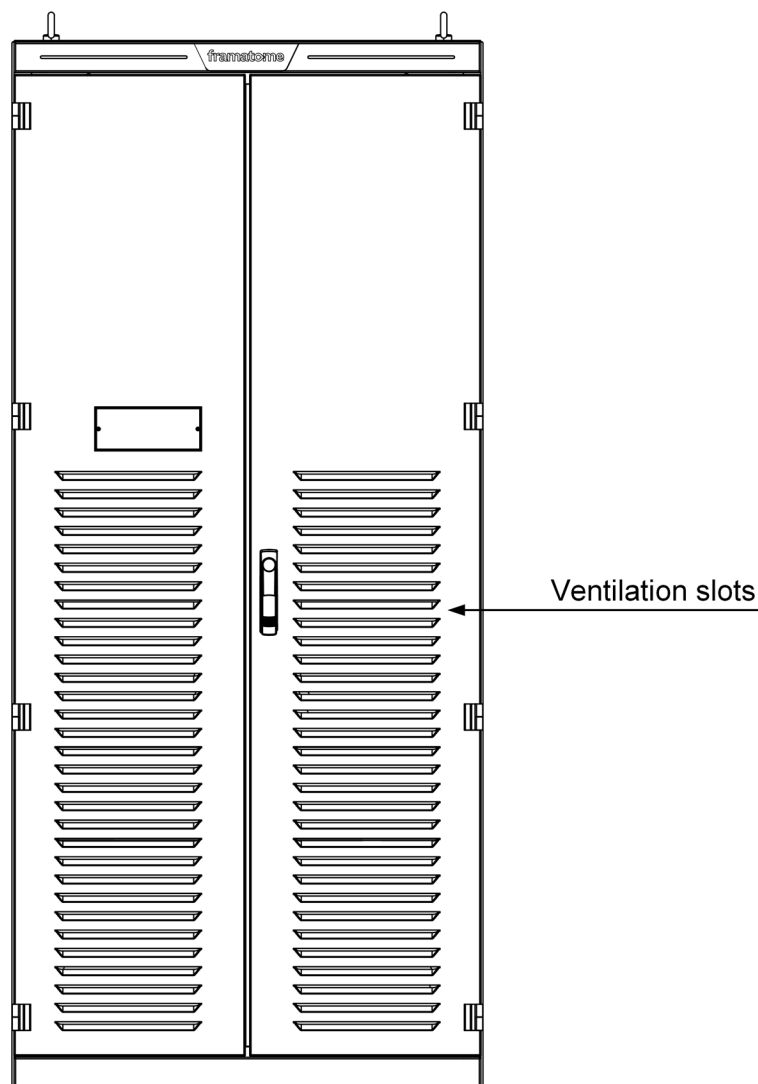


Figure 2-53
Interior Side of Doors



The fan ensures that temperature rise between the air inlet and air outlet of the cooling air duct is limited to a maximum of 10 °K. For this purpose, two PT100 sensors which measure inlet air temperature are mounted below the bottom chassis of the cooling air duct. Two more PT100 sensors measuring outlet air temperature are placed on top of the fan unit, as shown in Figure 2-48. The sensors are distributed across the width of the central section so the temperature can be measured and temperature difference can be determined on both the left half and right half of the central section.

Forced convection cooling of the cabinet is designed in such a way that hotspots in the chassis are reliably avoided up to total cabinet heat dissipation of 750 W. Cabinet heat extraction up to 1500 W is possible; however, this requires detailed analysis of the specific cabinet arrangement in order to identify and avoid hotspots in the chassis. For this purpose, the fully assembled cabinet is thermally modeled using computational fluid dynamics software, see Figure 2-54. The model is used to carry out heat dissipation simulations and to optimize cabinet arrangement.

Figure 2-54
Thermal Cabinet Model Example



2.6.9 Power Supply

Power supply is usually implemented in a redundant current-sharing arrangement. Each cabinet is supplied from two independent external sources. This ensures that power supply is continuously available in the event a power source or power supply cable fails. A single power supply failure does not lead to failure of the cabinet.

In general, the CAB-S 9/4/20 standard TXS cabinet is supplied with 24 V_{DC} voltage via:

- A central DC switchgear with rectifiers and buffer batteries; or
- External AC/DC or DC/DC converters assigned to a cabinet; or
- Internal AC/DC or DC/DC converters of the TXS system.

Output of the cabinet power supply is always 24 V_{DC}.

Typically, TXS cabinets are supplied with a nominal voltage of 24 V_{DC}, see Figure 2-55.

If present, technical measures must be taken such that circuits with nominal voltages > 25 V_{AC} / 60 V_{DC} or > 115 V_{AC} / 230 V_{AC} are separated from 24 V_{DC} circuits.

Figure 2-55
Standard 24 V_{DC} Cabinet Power Supply



The way the power supply voltage is filtered depends on:

- Worst-case disturbances assumed by the plant; and
- Supply characteristics required by the HW modules.

With the standard 24 V_{DC} plant power supply, current from two independent external power sources (1L+ and 2L+) is conducted via supply filters and overvoltage protection with the aid of decoupling diodes to the redundant potential L+ inside the cabinet. This diverts conducted emissions to the outside of the cabinet and reduces incoming noise to an acceptable level for the HW modules.

The filtering and protection function is implemented within the PSU1 of the cabinet as follows (see also Figure 2-56 and Figure 2-57):

- Suppressor diodes and supply filters in the Power Supply Diode (PSD1).
- Filters in ECB1 and ECB2.

Figure 2-56
Power Supply Unit (PSU1)

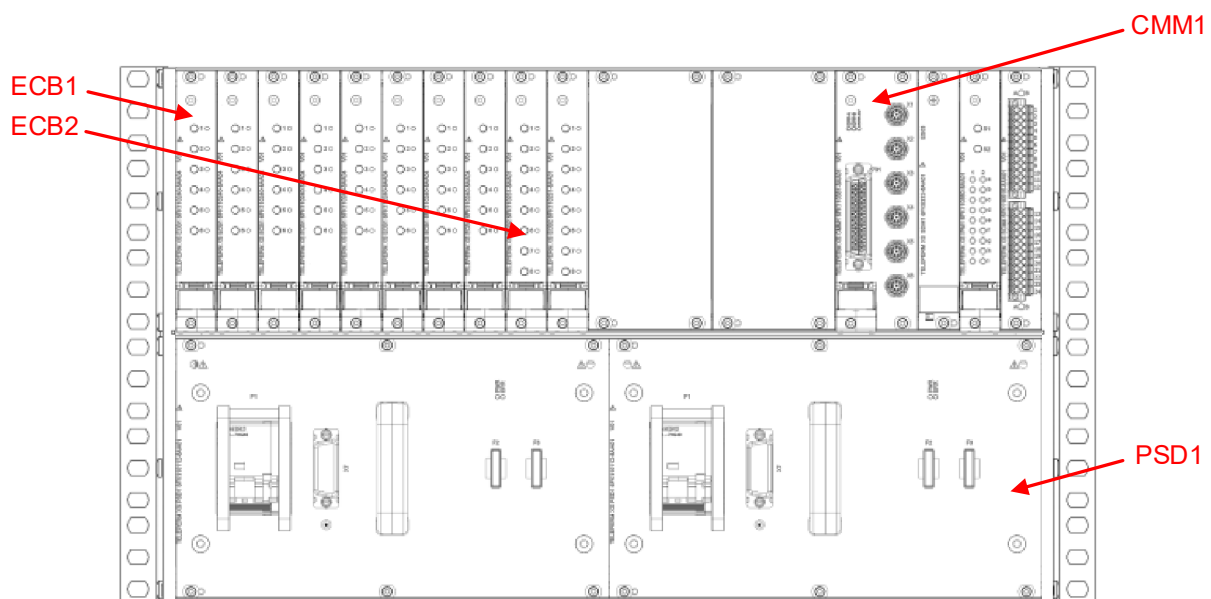


Figure 2-57
Block Diagram Power Supply



The PSD1s and ECB1 and ECB2 are monitored by CMM1 cabinet monitoring such that power supply failures and opening of circuit breakers are annunciated.

The current-sharing PSD1s are redundant. Each PSD1 can provide more than 100% of cabinet load, whereby cabinet load includes the TXS COMPACT AUs and all peripherals. A single defective PSD1, therefore, never jeopardizes cabinet operation. PSD1s are hot swappable, which means that one PSD1 can be switched off and replaced while the cabinet is operational without interruption of the external power supply. The same applies if a PSD1 is switched off during maintenance.

Power supply inside the cabinet is provided via electronic circuit breakers (ECBs). Up to 64 breaker channels are available within the PSU1 for this purpose. ECBs are assigned to the I&C functions implemented in the cabinet based on the criteria of electrical separation. ECBs distribute power over individual wires and terminal blocks according to the needs of the application. The approach ensures that a defective device in the cabinet does not affect the rest of the devices.

The digital FPGA-based processing part of the TXS COMPACT AUs provides 1 ms supply buffering on the chassis level. The I/O part (front-end) handles issues in the event of a power interruption. The power supply of large-scale I&C systems ensures freedom from interruptions, ensuring that TXS COMPACT AUs in combination with the plant power supply fulfill buffering requirements []

2.6.10 Grounding

The different reference potentials that can exist in a nuclear power plant are taken into account by the power supply architecture of the TXS COMPACT AU.

The architecture respects the need for a defined galvanic isolation between these reference potentials. The part of a TXS COMPACT AU that handles digital logic signal processing is completely galvanically isolated, as shown in Figure 2-58. Galvanic isolation is provided from the following parts of the plant:

- Plant power supply.
- Plant process.
- Plant switchgear.
- Secondary logic.

Isolation from the following parts of the NPP is provided by using fiber-optic cables:

- Other TXS COMPACT AUs.
- Other I&C systems used for logic signal processing (optional).

- The monitoring and service level (Service Unit) (optional).

The TXS COMPACT AU chassis and peripherals in the cabinet are attached directly to the cabinet frame (bars, rails, etc.) so their housing is bonded to the local ground A.

Figure 2-58
Galvanic Isolation of TXS COMPACT Automation Unit

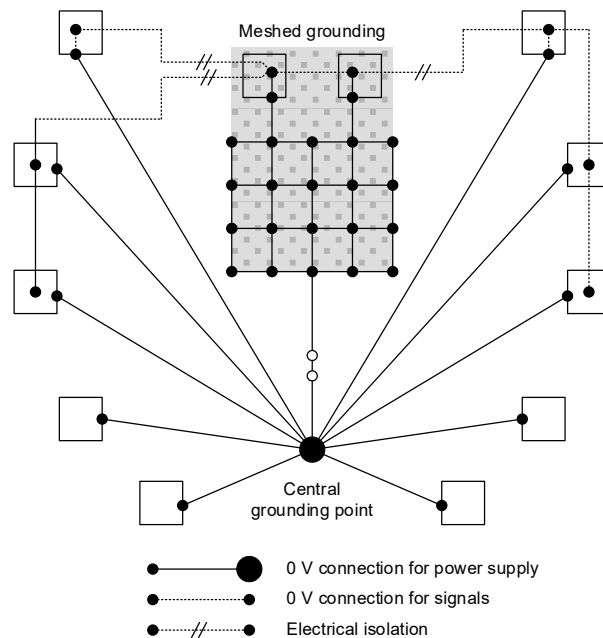


The HW modules of the TXS COMPACT AU provide galvanic isolation by default, with the exception of the MPIOF1. Galvanic isolation of the MPIOF1 front end depends on the respective application. If required, an additional DC/DC converter can be used for galvanic isolation of the front end.

GWF1 and SMDF1 HW have galvanically isolated network ports. With regard to possible differences in reference potentials, this is usually sufficient; however, to eliminate potential signal interference, use of media converters for network communication with other I&C systems and the NPP monitoring and service network is recommended.

Due to the measures described above, the TXS platform is suitable, by default, for both power plants with meshed grounding and with central-point grounding, as depicted in Figure 2-59. In particular, if the TXS COMPACT AU is used as a replacement for an existing installation or as an upgrade to an existing installation, the power plant's grounding system does not need to be modified to minimize potential differences.

Figure 2-59
Combination of Meshed and Central-Point Grounding



2.6.11 Shielding

Shielding measures are used to prevent the introduction of interference into HW modules and propagation of interference to other electronic equipment.

In plants with meshed grounding and in plants with central-point grounding, the cable shield is always connected to the TXS cabinets and, therefore, to the local cabinet ground. This ensures that the shield of cables between TXS cabinets maintains a connection to ground on both sides.

This is particularly important for retrofits in older or third-party plants where shielding concepts with one-sided shield contact still apply. This ensures that interference is diverted at the cable's point of entry to the CAB-S 9/4/20 standard TXS cabinet.

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Figure 2-60
Stay Plate, EMC Gasket Strips and Cable Gland Frame



2.6.12 Overvoltage

The TXS platform meets requirements regarding clearances and creepage distances of IEC 60664-1:2007 [41] and IEC 61131-2:2017 [29]. The 24 V_{DC} circuits of the HW modules are designed for a rated insulation voltage of 50 V x $\sqrt{2}$, overvoltage category II, and pollution degree 2. Terminals, cabling, wiring, and HW modules for higher voltages are designed to meet the higher requirements.

The TXS platform protects the downstream I&C system against static overvoltage (i.e., voltages higher than nominal voltages). This overvoltage can be present constantly at the unprotected side as seen in Figure 2-61. By default, terminals, cabling, wiring, connector HW modules, and overvoltage barrier HW modules are designed to handle overvoltage from the 220 V_{DC} grid or the 230/400 V_{AC} three-phase grid on the analog/binary inputs/outputs and the transducer supply outputs. In addition, special solutions of the TXS platform are available for maximum overvoltage from the 400/690 V_{AC} three-phase grid.

Figure 2-61
Assumed Voltages in Case of External Overvoltage



Overvoltage barrier HW modules limit overvoltage at the field side to a harmless value for downstream HW modules in the protected area. Analog and binary inputs and outputs for signals intended to be routed to the outside of a CAB-S 9/4/20 standard TXS cabinet are designed for compatibility with the overvoltage barrier HW modules of the TXS platform.

Whether an input signal, output signal, or transducer supply output is equipped with an overvoltage barrier HW module is clarified on a project-specific basis.

2.6.13 Monitoring

The Cabinet Monitoring Unit (CMU1) is integrated into the PSU1 as shown in Figure 2-56. CMU1 consists of a standardized part covering the basic monitoring concepts of I&C projects. In addition, it includes 22 HP of free space for additional and/or project-specific HW modules. There is no standard configuration regarding HW modules to be installed and their wiring. CMU1 is configured in accordance with application-specific and plant-specific requirements.

CMU1 typically hosts the following HW modules:

- CMM1 – Cabinet Monitoring HW Module.
- IPM1 – Indication and push-button HW module.
- SCM4 Connection HW Module.

CMU1 is intended for alarm and annunciation signal gating. It monitors the TXS COMPACT AU, cabinet infrastructure, mechanical equipment, and other peripherals (see Figure 2-62).

Figure 2-62
Cabinet Monitoring Unit (CMU1)



CMU1 generates the following static and dynamic signals:

- TXS Automation Unit alarm.
- Simulation/test/peripheral alarm.
- Communication alarm.
- Insertion monitoring alarm (static only).
- Cabinet filter alarm (static only).
- Cabinet door alarm (static only).
- Cabinet power supply alarm.

In addition, CMU1 generates signals for actuating the cabinet lamp.

As outputs depend on inputs, alarms are not permanently signaled. An alarm is only output if the cause of the alarm is present on the inputs.

CMU1 includes an indicator and pushbutton HW module. LEDs are intended for optical alarm and status indication. The HW module indicates static alarms:

- TXS Automation Unit.
- Simulation/test/peripheral.
- Insertion monitoring alarm (static only).
- Cabinet power supply alarm.

Function of the remaining LEDs is to be defined in the process of project engineering.

CMU1 indicates status on LED bars in the trim strip of the CAB-S 9/4/20 standard TXS cabinet by means of a combination of light color and state:

- Normal operation is indicated by steady blue light.
- Unacknowledged errors are indicated by red flashing light.
- Acknowledged errors are indicated by constant red light.

2.6.14 Coating

Most parts of the CAB-S 9/4/20 standard TXS cabinet are made of sheet steel and are protected from corrosion by a galvanic zinc coating. In addition, doors, stiffening plate, roof cover, rear and front covers, trim strip, and side panels are powder coated. Chassis surfaces are made of anodized or passivated aluminum. Only contact surfaces between the different parts are uncoated to ensure good electrical contact after chassis assembly. All fastening material, for example bolts, screws, safety washers, etc., are corrosion-protected. These measures ensure long equipment lifetime.

2.6.15 Conditioning

Interfaces of the TXS COMPACT AU are designed to comply with international standards IEC 60381-1 [35], IEC 60381-2 [36], and IEC 60946 [37].

The following interface types are used:

- Binary interfaces (24 V, 48 V tolerant).
- Analog interfaces (0 ... 20 mA).
- Serial electrical interfaces (TXS Ethernet).
- Serial optical interfaces.
- Bus interfaces.

Above interfaces can be managed directly by the TXS COMPACT AU. Many other input/output signal types are supported by the TXS Platform through dedicated HW modules that convert these signal types into those required by the TXS COMPACT AU. Similarly, other functions important for I&C systems like decoupling and protection are supported by the TXS platform.

Signal types and functions supported by the TXS Platform include but are not limited to:

- Signal range conversion.
- Speed signal sensors.
- Thermocouples, PT100, and resistive sensors.
- Signal duplication.
- Overvoltage protection.
- Priority and actuator control.
- Decoupling by:
 - ◆ Galvanic isolation;
 - ◆ Open collector output, diode, or solid state relay;

- ◆ Optocoupler or mechanical relay (including high fan out).

HW modules supporting the aforementioned signal types and functions are placed in the central section of the CAB-S 9/4/20 standard TXS cabinet. Figure 2-63 shows a typical chassis populated with connector and signal conditioning HW modules.

Figure 2-63
Conditioning Chassis (Front Access Only to Cabinet)

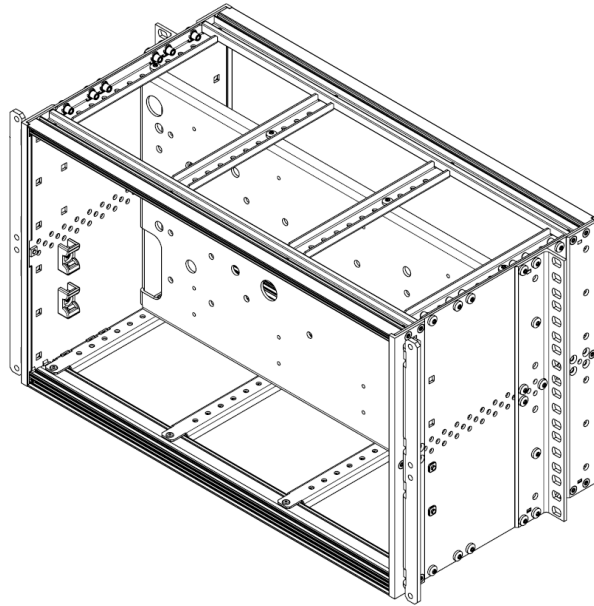


2.6.16 Mounting Plate

Typically, I&C application requires the TXS COMPACT AU to be supported by peripherals. Some peripherals are installed in the TXS chassis, while others require installation on special rails. The Universal Mounting Plate (UMP1) is used for rail-mounting TXS and non-TXS equipment.

In principle, the UMP1 is similar to the SR-6U chassis. The UMP1, with a space requirement of 6 U, is intended for the center section of the CAB-S 9/4/20. The UMP1 is attached to the vertical bars in the same way as the chassis.

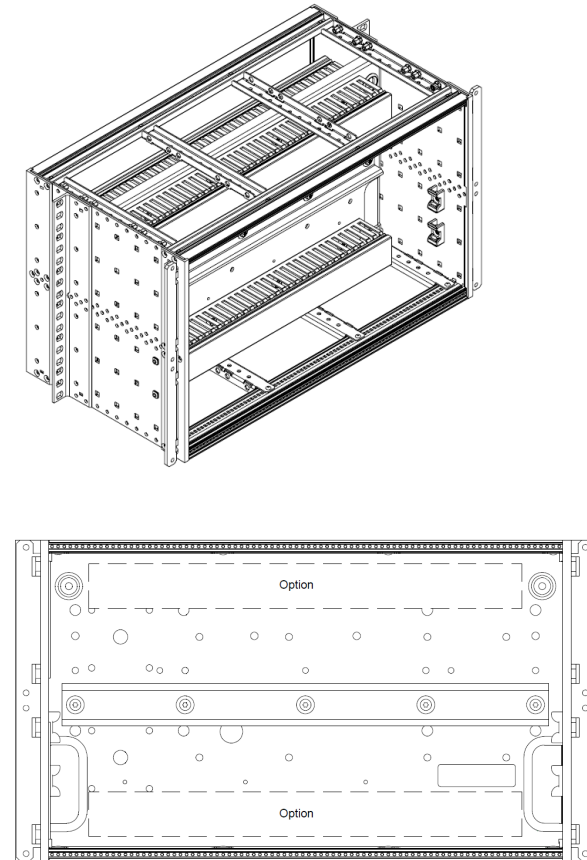
Figure 2-64
Universal Mounting Plate



The basic model of the UMP1 accommodates flexible installation of TXS equipment; however, the most common mounting option is the “top-hat rail.”

Network systems can be implemented and rail-mounted components can be installed using the UMP1 with the “top-hat rail” option. It is fitted with top-hat rails across the entire width at the front and rear. Top-hat rails are screwed to the UMP1. Top-hat type H rails have the profile 35/15 and correspond to IEC 60715 [34]. Clamping profiles for edge protection are clipped onto the cut-outs.

Figure 2-65
Top-Hat Rail Option of UMP1



If required, the configuration “top-hat rail” can be equipped with cable ducts. Cable ducts are screwed to the UMP1 on front and rear at top and bottom.

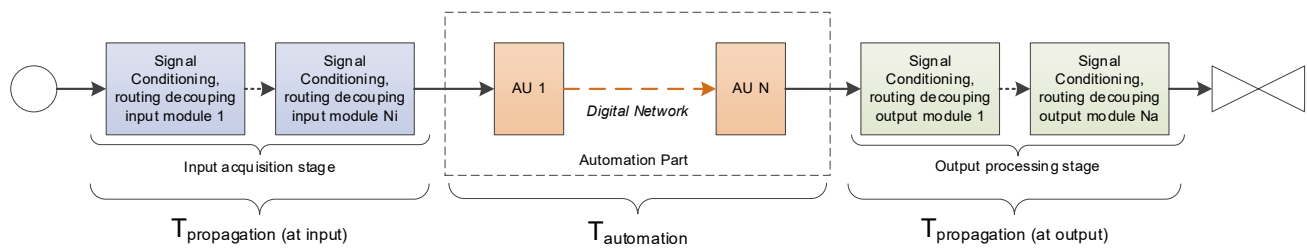
Terminal blocks, fuse holders, relays, optocoupler, network components, fiber optic converters, isolator modules, and all types of field interfacing hardware can be mounted on the top-hat rails of the UMP1. Depending on the application, none, one, or more UMP1s are installed within a CAB-S 9/4/20 standard TXS cabinet.

2.7 TXS COMPACT Response Time

The TXS COMPACT is a deterministic platform: execution time of the engineered I&C functions is constant and can be calculated in advance.

When considering the complete signal path for a given signal (from sensor to actuator), the signal can be acquired using signal conditioning, routing, or decoupling input modules, then processed by one of several Automation Units (possibly including network exchanges), and ultimately sent to the actuator through signal conditioning, routing, or decoupling output modules.

**Figure 2-66
Signal Path**



In other words, the total response time for a given signal path can be obtained with the following formula:

$$T_{path} = \left(\sum_{\text{Input conditioning stages}} T_{propagation} \right) + T_{automation} + \left(\sum_{\text{Output conditioning stages}} T_{propagation} \right)$$

Response time for each type of input and output signal conditioning, decoupling, and routing module is provided in the user documentation of the hardware module.

Contribution of signal conditioning, decoupling, and routing modules to T_{path} depends on the configuration of each I&C system and evaluating it does not present any complexity. Further details are provided in a dedicated report (see [156]).

2.8 ***TXS COMPACT Accuracy***

Accuracy of numeric processing in the AU is determined by accuracy of analog channels in the I/O modules. These channels convert analog measurement data to digital data or vice versa. Accuracy of the analog channels is $\pm 0.35\%$ of the 0/4...20mA range(s) over the 0...70°C operating temperature range and [

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The PM1 implements a double-precision floating point calculation unit, as defined in IEEE 754:1985 [17], used for the function blocks for computation of analog signals, which minimizes contribution of the PM1 to the uncertainties introduced by numerical calculations. In practice, uncertainties depend on specific implementation of function blocks and are kept sufficiently low to not impact the global accuracy of the calculation. Between function blocks, signals are exchanged using single precision floating point values; hence, accuracy of the individual calculations always exceeds accuracy of the interfaces.

Figure 2-67
Computation Flow of Analog Signals by FPU of the PM1 Module



Uncertainties introduced by the computation inside the logic of the function blocks are uncorrelated with each other, independent from uncertainties in the signal acquisition chain, and independent from environmental factors.

2.9 TXS COMPACT Human Factors Considerations

The following human factors concepts are considered at the initial stages and throughout the design process during development of the TXS platform:

- Simple system architecture: The TXS COMPACT architecture can be easily designed using a few simple modules.
- Standard I&C design: The TXS Platform consists of prequalified and predesigned modules, such as standard cabinets, power supply, and conditioning modules.
- Standard Product: Each TXS module is described in a user manual and no manual configuration on the module itself is provided. Configuration is accomplished using graphical software tools.

- Intuitive system design: The application can be configured by interconnecting function blocks from the software toolset. Similarly, application testing is simplified by means of graphical visualization and tracing of internal process values.
- Self-supervision and alarming: The TXS COMPACT provides extensive self-supervision and monitoring including a predefined alarming system. Failures are clearly indicated at the cabinet (cabinet lamp) and at the module level (module failure indication).
- Ease of Maintenance: TXS COMPACT modules can be easily swapped by the NPP engineer given that each module is clearly labeled and, except for the PM1, do not require custom configuration.
- Electrostatic discharge (ESD): The TXS COMPACT platform is extremely resistant to ESD as demonstrated during module qualification (see Section 4.6.2 of this report).

3.0 TXS COMPACT CONFIGURATION, DIAGNOSTICS, AND MONITORING

3.1 *TXS COMPACT Application Configuration*

TXS COMPACT is a generic safety Instrumentation and Control (I&C) platform and, therefore, is not dedicated to one specific application but provides pre-qualified building blocks which can be assembled to realize virtually any kind of safety I&C function.

This goal is achieved by configuring the platform in a way which fits the requirements of the system to be realized.

In practice, it means the design engineer must perform the following operations:

- Create an I&C project repository as a support for further project data.
- Specify the physical architecture which fulfills the system's specification.
- Specify the logic of the system (the application I&C functions) so it corresponds to the system's specification, including but not limited to functional and failsafe behavior, monitoring, annunciation, and bypass.
- Specify the assignment of each function block (FB) diagram to an Automation Unit and the associated calculation cycle time.
- Configure the system interfaces, namely the assignment of digital input and output signals to appropriate electrical inputs and outputs and/or to digital interfaces such as the Qualified Display System (QDS).
- Convert the system specification into an application program suitable for loading onto the Automation Units.

The TXS COMPACT System Simulator (CS²) tool provides the capability to support testing activities. Its intended use is verify the application program compared to input requirements. Hence, the TXS COMPACT simulator tool can reproduce the behavior of the application program appropriately for testing. It also allows testing partial implementation of an application program (for instance, when the design is not completed).

3.1.1 Configuration Management for I&C Project Repositories

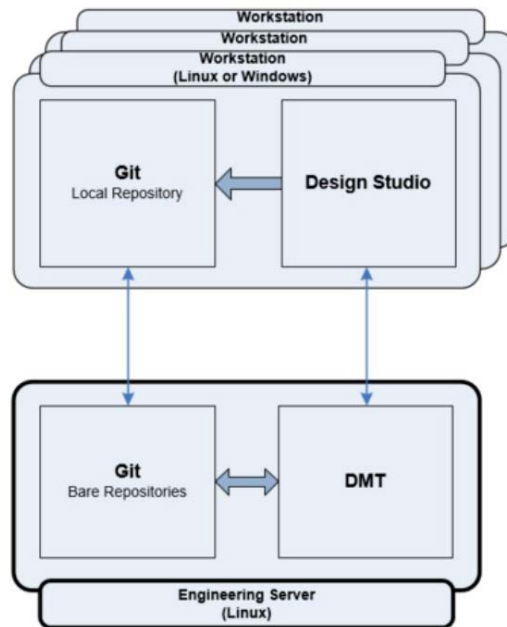
The TXS COMPACT engineering environment provides an integrated I&C system's data management system called Data Management Toolkit (DMT). This software tool physically hosts the data on an engineering server in a safe and secure manner.

DMT manages a collection of repositories, each of which contains the technical specification of an I&C system or I&C system variant, which is called the I&C project repository.

When starting a new customer project, the server administrator must first create a new I&C project repository using the DMT graphical interface and then proceed with configuration.

The I&C project repository contains a collection of configuration items. For the sake of simplicity, configuration items match files stored on the disk. DMT is independent of actual format project data: it considers each file as a close piece of data and its behavior is generic (does not depend on these project data). By design, DMT is not capable of unintentional modification of the configuration items it manipulates.

Figure 3-1
DMT Repositories



Repository management is powered by the version control tool, Git; therefore, a typical Git workflow is implemented. Once an I&C project repository has been created:

- Each user can clone it to a personal working copy on its local workspace.
- Modifications can be made using authoring tools such as TXS Design Studio.
- Modifications are packaged into a signed commit.
- The commit is pushed back to the DMT server, where it becomes available to other system designers.

Git software provides a SHA-1-based blockchain which guarantees the integrity of configuration items when they are exchanged with TXS Design Studio.

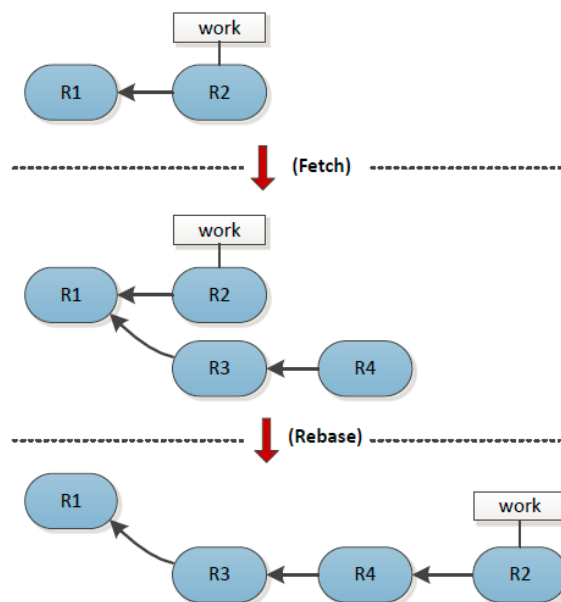
The tool allows multiple users to simultaneously access project data while preventing concurrent modifications that could threaten the quality of the data.

To achieve that, DMT manages and maintains a collection of “locks”: any user who intends to modify, create, or delete a configuration item first needs to acquire a lock on that item. Each lock is exclusive and prevents other users from modifying the same configuration item at the same time.

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**Figure 3-2
Safe Update**



DMT also allows for configuration of permissions that control access to the project repository:

- Read/Write access: the user can read, modify, create, and delete configuration items.

- Read Only: the user can only read existing configuration items but cannot push modifications.
- Review: the user can only perform reviews of configuration items which support this mode (such as function block diagrams).

Permissions are set by groups (knowing that each group can contain one to many users) and directory. The principle of least privilege is applied: default permission is Read Only until permission is explicitly granted to a given directory.

Configuration of users and permissions is specific to each I&C project repository and must be carried out by the administrator to satisfy the rules defined in both the project's Quality Assurance (QA) and Security Plan.

The next step consists of configuring project parameters, [] The following parameters can be adjusted to satisfy requirements of the project:

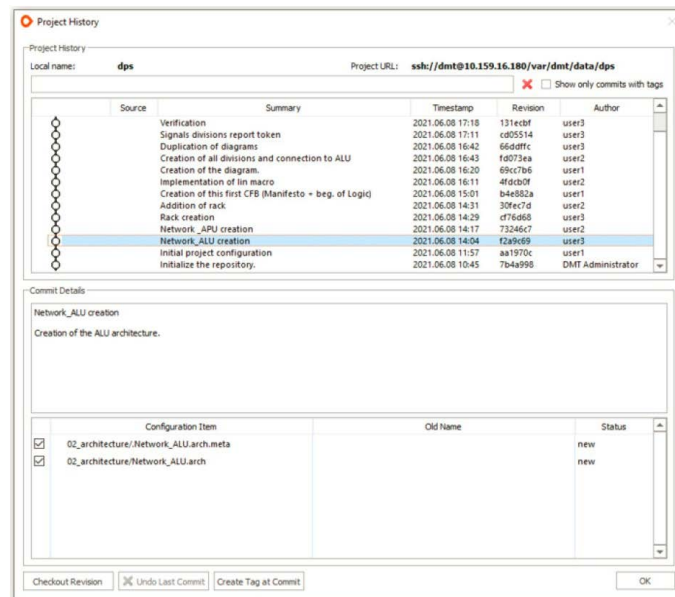
- Name of the project, starting date, project descriptions, and identification of stakeholders (vendor and customer).
- Names of subdirectories that must be used by the tool.
- Version of the hardware and function block libraries that must be used (which must align with the version of TXS COMPACT HDL-Programmed Device (HPD)).
- Optional naming rule enforcement for function block diagram names, named interface signals (NISs), etc.

Upon completion of configuration, changes must be submitted to the DMT server using commit/push, same as any other configuration item.

Once submitted to the DMT server, the I&C project repository is ready and can be used by design engineers.

Additional configuration management features continue to accompany design and validation engineers during the lifetime of the project.

Figure 3-3
Navigation in Project History



TXS Design Studio allows navigating through history of the project: any commit can be displayed and analyzed. Furthermore, different versions of function block diagrams can be compared together, which eases the impact analysis of changes from one version to another.

3.1.2 Design of the System Technical Specification

The functional and safety behavior of the I&C system is driven by configuring it to implement and realize safety I&C functions that match the I&C system's requirements.

3.1.2.1 Creation of the System's Technical Specification

TXS COMPACT provides an authoring tool called TXS Design Studio to specify engineered I&C functions into the I&C project repository. By using graphical user interface (GUI) and function-oriented blocks-based programming language, the likelihood of introducing programming errors is minimized.

Figure 3-4
Various Examples of Function Blocks from the Platform Base
Library: Comparator, Absolute Value, XOR, Integrator



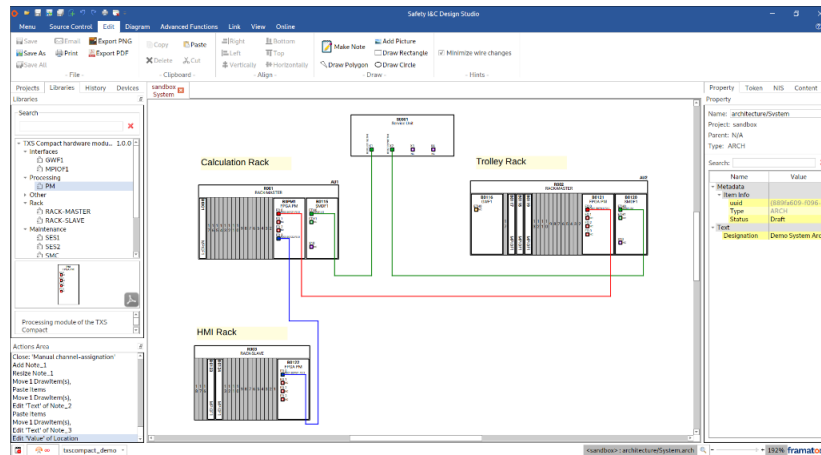
Creating the system technical specification relies on construction of function block diagrams by assembling basic function blocks and populating the data tables of each with configuration information. Function blocks are available in the tool as part of the platform pre-qualified libraries, and it is impossible for the system designer to write any low-level code. Function blocks can easily be installed by dragging and dropping them from the library panel to the diagram layout. Objects, such as function blocks, can be connected by drawing lines between them. Properties and parameters can be modified by selecting the parent object.

In practice, creating the technical specification means achieving each of the four following steps, in any order:

1. Specify the physical architecture.

This step consists of assembling blocks representing the hardware modules and linking them together to model network connections within and between the Automation Units. Informational data (such as location, designation, etc.) and some configuration parameters for modules can also be modified.

Figure 3-5
Edition of an Architecture Diagram



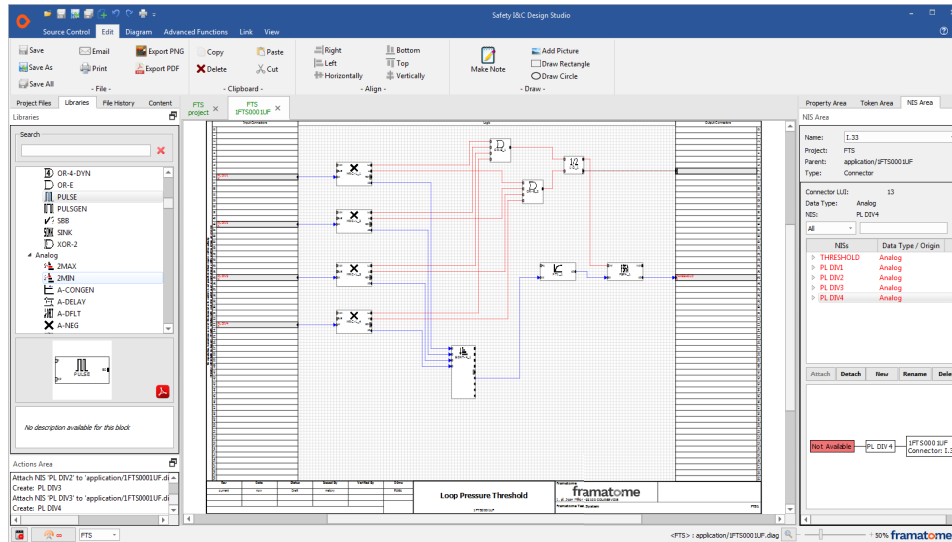
The format of such a diagram follows the rules of a descriptive language called SPDL/NA (Safety Program Description Language/Network Architecture).

The Application Generation Toolkit (AGT) will use such data to automatically generate signal routing over the networks.

2. Specify the logic of the system.

Application I&C function specifications (including but not limited to functional and failsafe behavior, monitoring, annunciation, and bypass) must correspond to the system's specification. This is achieved by creating a collection of function block diagrams using the proprietary language SPDL/FB (Safety Program Description Language/Function Blocks), which is further detailed in Section 3.1.2.2 of this report.

Figure 3-6
Edition of a Function Blocks Diagram



Initial values for block parameters can be modified and made online-addressable, if necessary.

Composite function blocks (also called macro blocks), which are assemblies of basic blocks to realize more complex functions, can be created and used.

Diagrams can exchange signals by means of connectors. Connectors can be linked together by creating signals called NIS. Each NIS has a given signal type and can distribute a signal from a single source to multiple destinations.

3. Allocate logic to hardware.

Once the architecture and logic have been at least partly specified, the system design engineer uses TXS Design Studio to allocate each diagram to an automation unit, which must process it. Calculation cycle time is also specified for each function block diagram. This can be done either diagram-per-diagram or through a global table listing the available Automation Units and diagrams.

4. Allocate Inputs/Outputs (I/Os) to hardware.

Once the architecture and logic have been at least partly specified, the system design engineer can allocate each signal that must get into or out of the system to the appropriate electrical inputs and outputs and/or to digital interfaces such as the QDS.

The TXS Design Studio tool provides an allocation table where each NIS with a free input or output can be linked to either:

- ◆ A digital input/output when the Automation Unit that generated the logical signal contains at least a TXS COMPACT Gateway Module (GWF1); or
- ◆ An electrical input/output when the Automation Unit that generated the signal contains at least an I/O module such as the Multi-Purpose I/O Module (MPIOF1). In such cases, properties of the I/O channel, such as failsafe behavior (de-energized, set point, or freeze), can be modified.

As previously explained, after these steps are completed and at any intermediate step, the user can push modifications to the central repository, in addition to saving the modification to the local hard drive.

3.1.2.2 SPDL Language

The application program is created by specifying the application using a proprietary blocks-based language called SPDL (Safety Program Definition Language).

This language has two variants:

- SPDL/NA language [150]: a purely descriptive language for specifying the arrangement of hardware modules, which constitute the digital part of the I&C system.
- SPDL/FB language [151]: a declarative, graphical function block-based, language used for specifying application-specific I&C functions.

The two variants comply with strict explicit rules and well-defined semantics and are comprehensively documented. In both cases, information is represented by interconnected standardized symbols. They both support annotations, which are solely for documentation purposes and not considered when generating the application program.

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This programming language is comprehensive and fully documented. It has been created to foster explicit and non-ambiguous syntax. Even though many SPDL/FB concepts are compliant with IEC 61131-3 [30], SPDL/FB does not fully comply with this standard. Indeed, constructs and features that could negatively impact nuclear safety principles (like deterministic behavior) have been deliberately removed or simplified.

Furthermore, SPDL/FB is not Turing-complete for purpose, as it does not provide any kind of conditional branching operator, thus strictly limiting the propagation of potential application design faults to the specific mis-implemented function.

As a result, the combination of the SPDL/NA and SPDL/FB variants provides an inherently safe programming language to specify TXS COMPACT-based safety I&C systems.

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3.1.2.3 Review of the Technical Specification

When the technical specification is created or modified, each diagram has the status “draft,” indicating the modification has not been formally reviewed.

Once diagrams have been pushed to the central repository, other users with “review” role can download the changes, review them, and mark the diagram as “reviewed.” This information is explicitly visible on the diagram layout, including status, git commit identifier, and name of the reviewer, which allows identifying whether the quality process for system design and verification has been followed appropriately.

The “reviewed” status is automatically reset to “draft” when a modification is introduced.

3.1.2.4 Traceability Features

TXS Design Studio can be used by the I&C system designer to implement and verify traceability of system requirements to implementation. Traceability tokens can be attached to either a function block diagram or to one or several blocks of diagrams, or both. Traceability tokens are text-based tags used to link requirements of application functions defined in the I&C system's requirements database.

Details regarding how the requirements database is established and implementation of traceability are specific to the I&C system design.

Once traceability tokens have been assigned to diagrams and blocks, the tool allows navigating through the logic related to this token by traversing function block diagrams. Token assignments are also available in reports and can be highlighted on diagrams to support impact analysis.

3.1.2.5 Library of Function Blocks

A library of pre-qualified I&C function blocks is supplied along with the TXS COMPACT platform; therefore, the application program is entirely implemented within the TXS Design Studio tool using elementary function blocks (assembled together using wires within function block diagrams) and by defining the hardware architecture from hardware blocks. This results in fully automatic generation of the application program to be executed by the main PM1 of each automation unit. Section 3.1.2.1 describes the steps for creating a technical specification of an I&C system.

Function blocks are organized in the TXS Design Studio tool according to type. They are characterized by functionality, including error handling, and by interface. The interface consists of input signals, output signals, parameters, internal memories, and an additional name used for identifying the function block on a function diagram.

Figure 3-7
Organization of the Function Blocks in the Library
(with Lists Collapsed)

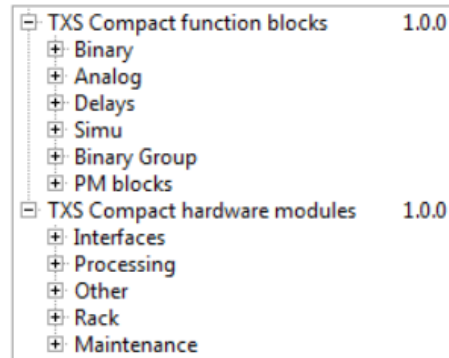
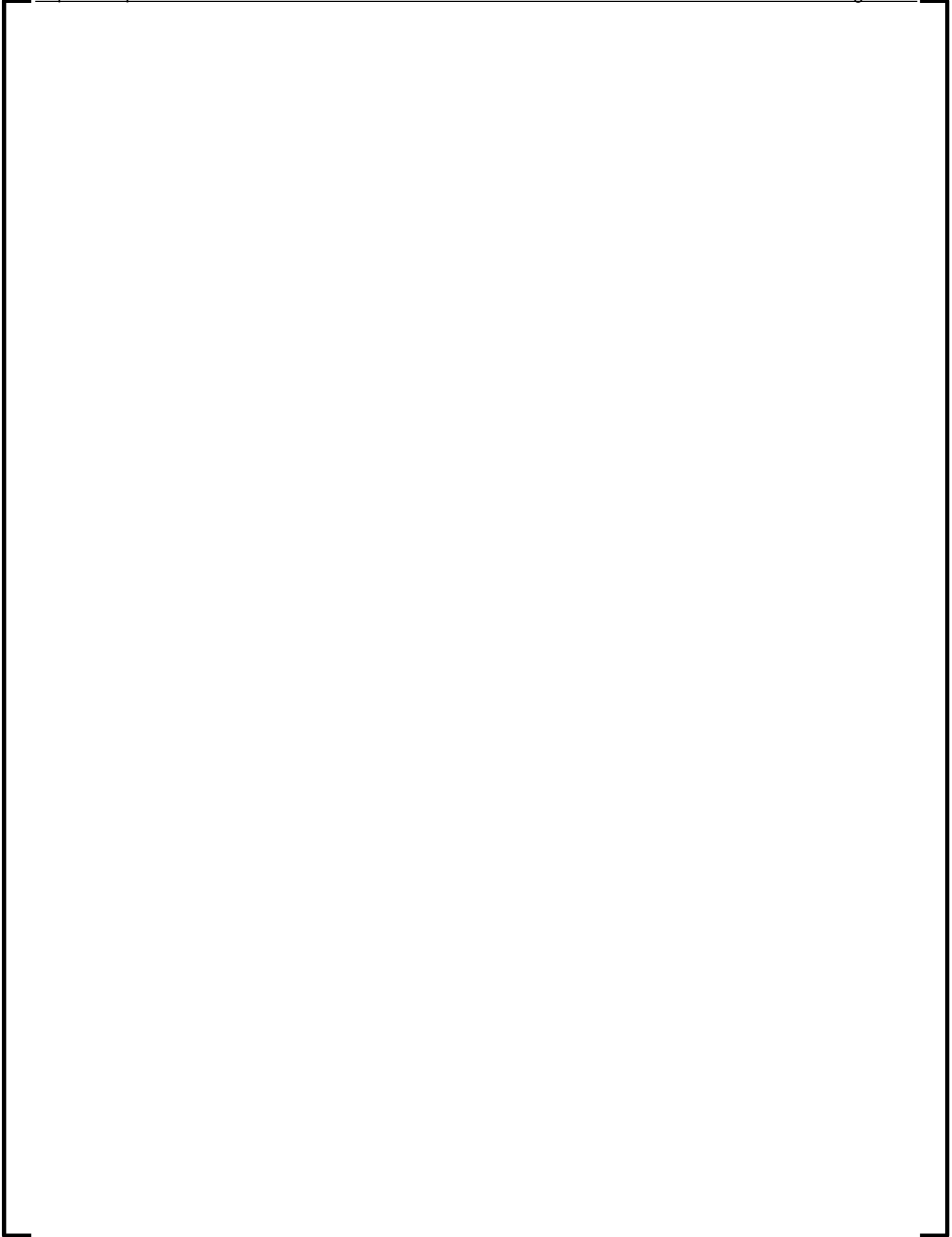
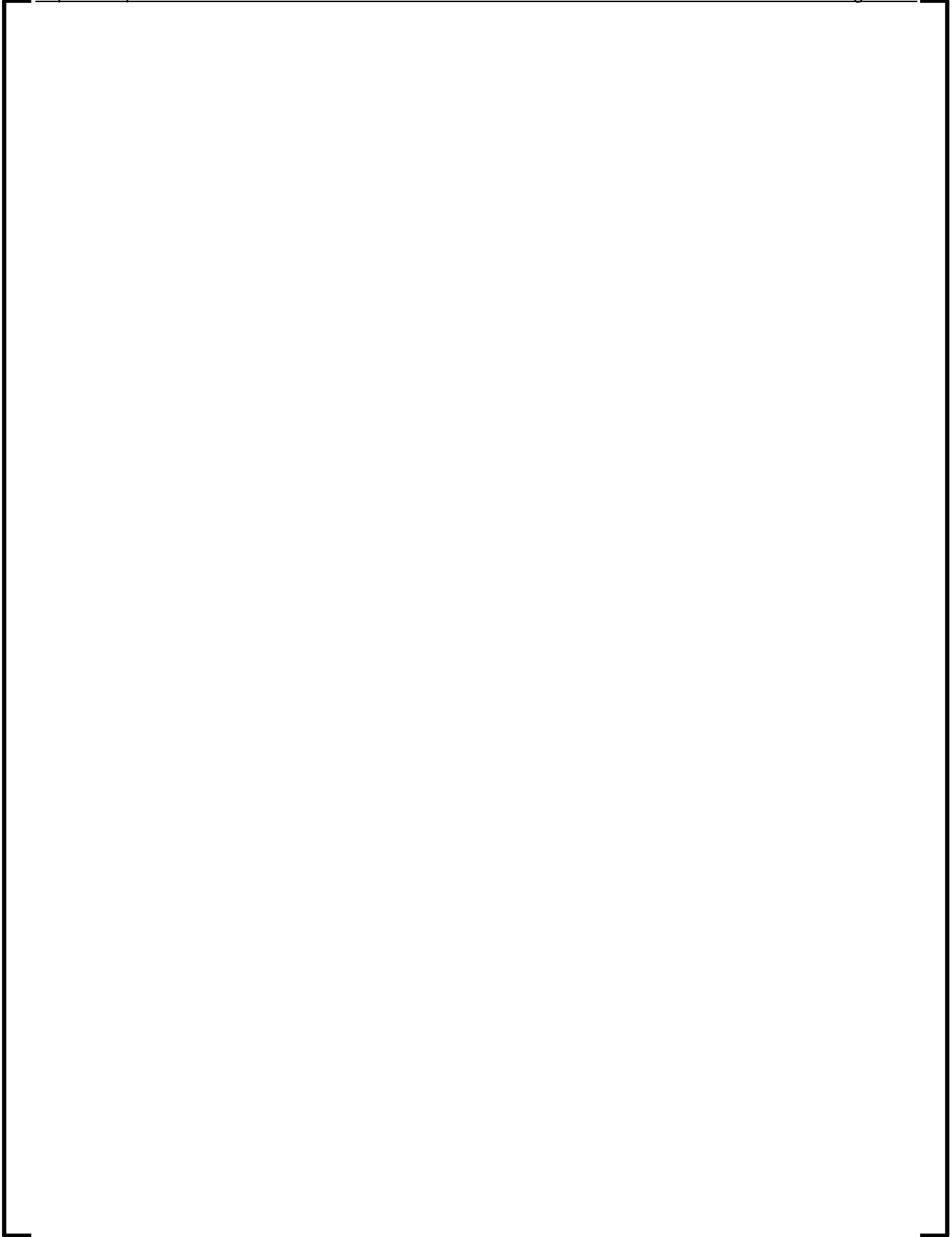


Figure 3-8
Organization of the Function Blocks in the Library
(with an Expanded List)

Table 3-1 provides a list of available function blocks in the TXS COMPACT platform which can be executed by the PM1. Characteristics and capabilities of the function blocks are documented in the TXS COMPACT Engineering Unit User manual [155].

Table 3-1
List of Available Function Blocks in the Library





For instance, 1-out-of-2, 2-out-of-3, 2-out-of-4, and other redundant architecture schemes are supported at the application level by dedicated function block types and spatial separation (see Section 5.0). Included are function blocks supporting validation of redundant signals by majority voting (e.g., 2/4, 2MAX) to exclude incorrect signals (due to undetected failures) from further processing.

Also included are dedicated function blocks providing status information concerning malfunctions detected by self-monitoring (communication failures, I/O failures, etc.).

3.1.3 Generation of the Application Program

Once a stable version of the technical specification is finished and has been pushed to the configuration management server, the software tool AGT (Application Generation Toolkit) can be invoked to generate the Application Program.

The list of the files, organization of the directory, and encoding and content of each file is specified in detail in the platform technical documentation.

Each version of the application program is sealed using a cryptographic signature, which is created when invoking AGT. This signature is then verified automatically when the Application Program is loaded onto the Service Unit for installation on the Automation Units. In the event of a verification failure, the Service Unit refuses to download the Application Program to the Automation Units.

The Application Program also contains verification mechanisms which guarantee that it cannot be loaded on an incompatible version of the TXS COMPACT HPD. When an Automation Unit receives a new Application Program, the PM1 compares its own HPD serial number with the serial number expected by the Application Program. Should a verification failure occur, the Automation Unit refuses to further read the Application Program and remains unaltered.

The engineering toolchain has a mechanism to detect when local modifications are present (i.e., have not been pushed to the project's central repository) by comparing the actual version of the file with the information stored in the last known Git commit. Any difference indicates an unpublished modification. In this situation the AGT would not block the application generation process, but this information is then stored in the generated report for identification and traceability.

AGT can be invoked either from within TXS Design Studio graphical interface or from the command line.

Before generating any output file, AGT will first execute a collection of syntactic, semantic, and consistency checks. Each check focuses on verifying a specific property (for example, consistency checks of objects defined within the I&C application and checks related to hardware constraints of TXS COMPACT technology). Checks are described in AGT technical documentation.

Execution of checks is automatic and compulsory every time AGT is invoked. Once the checking step is finished, the technical specification is considered syntactically and semantically correct, as well as corruption-free. AGT can then proceed safely with generating the Application Program.

While there is no compilation step on TXS COMPACT, AGT can be considered a translator: it converts the human-readable descriptive JavaScript Object Notation files created with TXS Design Studio into binary configuration files. The binary files contained in the Application Program are directly processed by the Automation Units' main PM1s to configure their internal state machine and controllers.

3.1.4 Verification of Generated Application Program

The TXS COMPACT toolchain provides a tool called Application Verification Toolkit (AVT). This tool can be invoked at any time once the technical specification and the Application Program are available, and in any case must be invoked before the Application Program is loaded onto the Automation Unit.

AVT parses both the technical specification and the safety-related files contained in the Application Program to build an in-memory model for each of them. The tool then compares both models, including all properties important to safety, such as the sequence of execution of function blocks, configuration of I/O and communication controllers, failsafe behavior configuration of the channels, etc.

When AVT identifies a discrepancy between models, a detailed report with contextual information is provided to the user.

To avoid common cause failure between AGT and AVT which would prevent the latter from catching an inconsistency in the generated configuration files, the following precautions have been taken during development of AVT:

- The AVT has been developed by individuals not involved in development of AGT.
- The AVT has been developed using a different programming language than the one used for development of AGT.
- The AVT does not share any common programming library with AGT, except for the operating system libraries.

With this set of precautions in place, it is not credible that a defect in AGT would propagate to AVT in a way which would prevent it from detecting the issue.

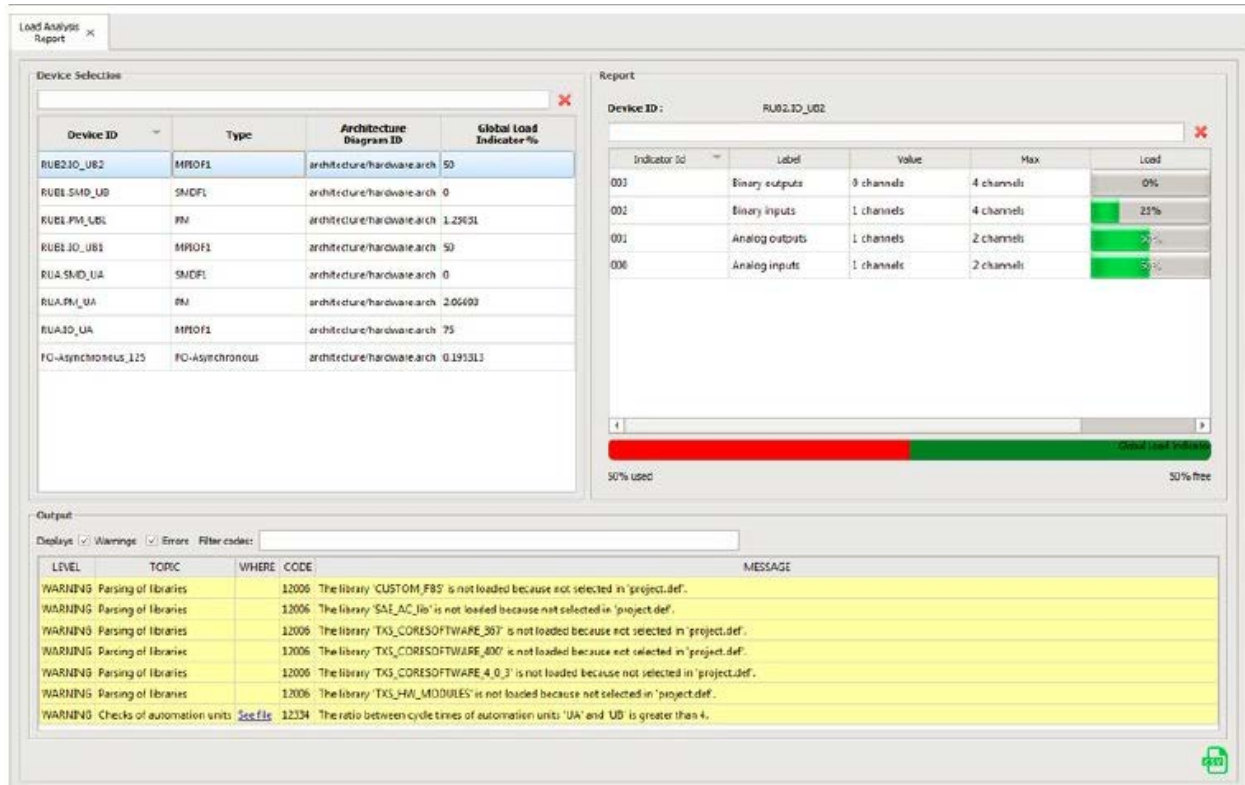
3.1.5 Verification of the Limits and Margins

As TXS COMPACT is a fully deterministic safety I&C platform, consumption of resources and processing time can be calculated statically from a technical specification.

TXS Design Studio invokes AGT, which will make sure the checks are passed successfully. TXS Design Studio will then display a list of resources for each hardware module present in the system. For each resource, the limit value and calculated value are displayed. A global indicator showing whether one or more limits have been violated is also displayed.

Resources to be monitored are different for each type of hardware module and depend on practical limitations; e.g., internal memory buffers of each type of module.

Figure 3-9
Calculation and Display of Limits and Margins



The requirements specification for the I&C system may specify acceptable margins. These margins are often more stringent than the physical limits of the system, as they incorporate provisions for future functional evolutions of the system. This tool can be used to verify that such requirements are achieved by system implementation.

3.1.6 Simulation of Generated Application Program

CS² is a command-line tool used to simulate I&C systems implemented with TXS COMPACT technology. It reproduces the behavior of interconnected Automation Units and offers appropriate properties to support debugging of I&C system implementation and test procedures. CS² provides a compatible function block library.

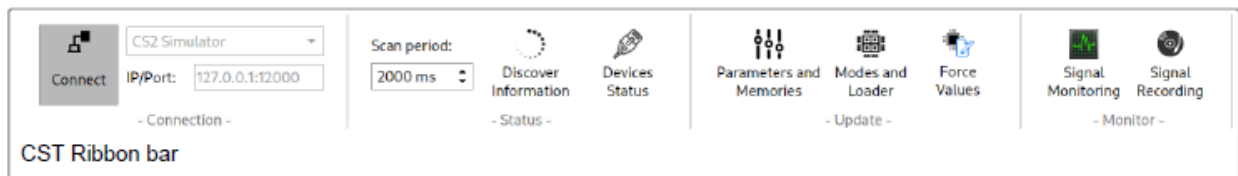
It builds the virtual simulated TXS COMPACT-based system by reading data files from the I&C project repository and loading the Application Program prepared by the Application Generation Toolkit (AGT) for the actual TXS COMPACT hardware.

CS² simulates the input and output channels supported by I/O modules and allows the user to control them and read their values and statuses. The values of I/O signals for the simulated system are stored in a database.

CS² can be accessed through the network by Service Unit tools (CST or DS), similarly to the actual TXS COMPACT hardware. It replies to commands dedicated to simulation control, diagnosis, maintenance, and monitoring of the simulated TXS COMPACT-based I&C system.

CS² offers a Python application programming interface (API) to control it through Python scripts. BUUsing this Python API and the signals database, test engineers can automate testing of the simulated system in a convenient way by writing test scripts that can be repeated, or connect the simulator to external test automation tools (the latter is out of the scope of this topical report).

Figure 3-10
Access to CS² via COMPACT Service Tools (CST)



3.2 *TXS COMPACT Diagnostics and Fault Indications*

TXS COMPACT implements means to detect erroneous behavior of the hardware and Field-Programmable Gate Array (FPGA) Hardware Description Language (HDL) program through self-diagnostics (permanently running self-monitoring and for-purpose self-tests).

Implementation of supplementary platform self-tests at the project level is not needed; however, platform self-tests can be complemented by engineered diagnostic functions, which are part of the application program, to further detect functionally inappropriate situations (e.g., issues with interfaces or sensor coincidence) or to forward status and diagnosis information to the control room or to a plant computer according to specific project requirements (see Section 3.2.4).

The purpose of the self-monitoring features and self-tests is to detect as many errors as possible during system operation and guarantee the integrity of safety functions.

Regarding TXS COMPACT automation racks, numerous self-tests and self-diagnosis features allow for a reduction in the need for periodic tests or calibration to demonstrate compliance with the technical characteristics of the platform during the lifetime of the equipment. No external device (besides the TXS COMPACT Service Unit) nor metrological equipment is necessary.

Regarding tests required to demonstrate compliance of the I&C system with customer requirements, either initially or periodically during the lifetime of the equipment, only those parts of the system where errors can accumulate during operation without being immediately detected by the self-monitoring features must be considered.

Self-tests are part of the platform and are designed and tested with the same high level of quality as the processing part of the platform, including Independent Verification and Validation (IV&V).

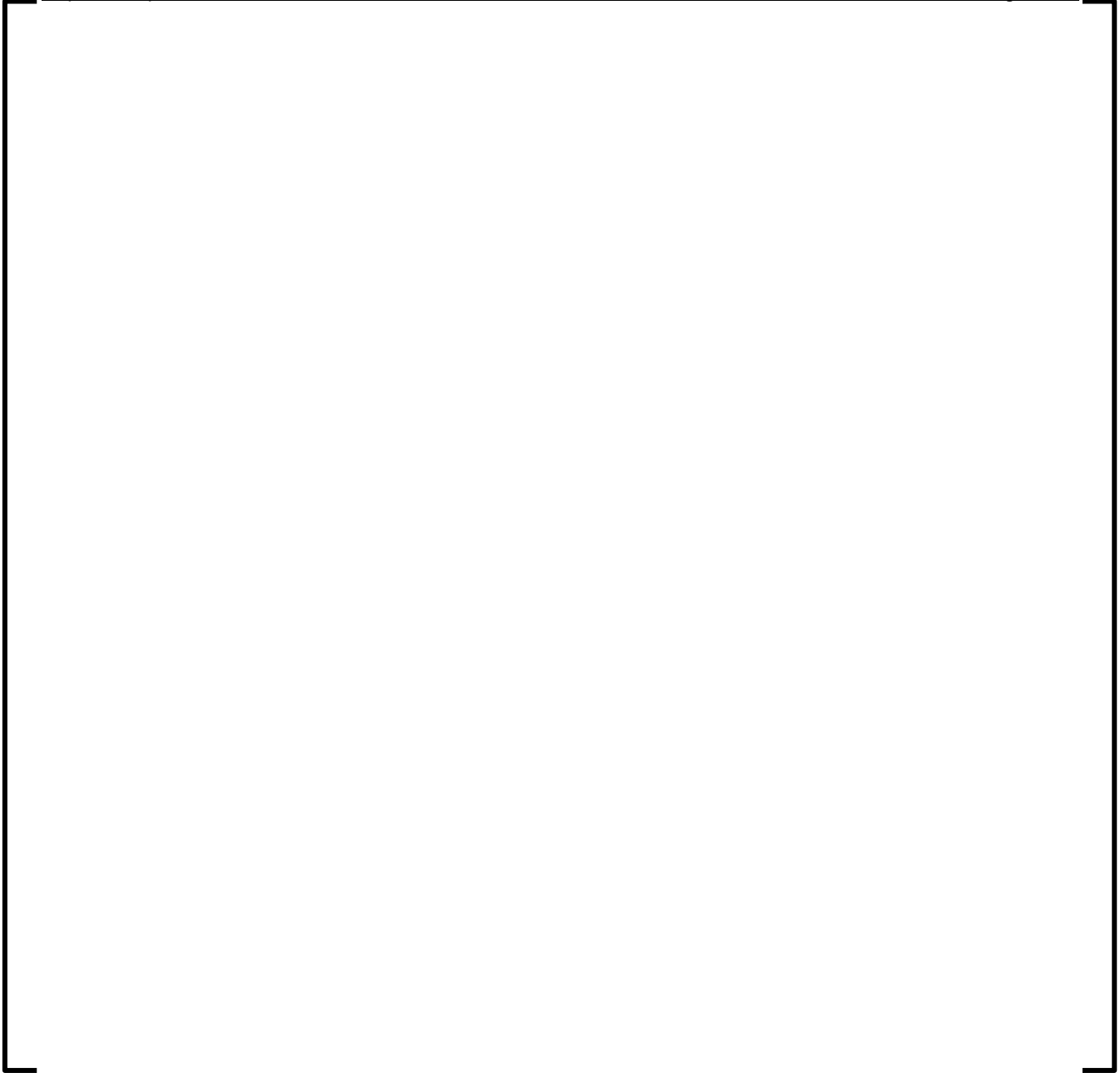
3.2.1 Self-Tests and Self-Monitoring

The self-test task performs verifications on each safety-related module of the Automation Unit when their FPGAs are not actively processing the engineered I&C functions, while self-monitoring is always active during normal operation of the Automation Units.

Self-monitoring/self-test results for all modules are pushed cyclically by each module to the main PM1 on each Automation Unit.

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Table 3-3
MPIOF1 Self-monitoring / Self-test



Based on self-test and self-monitoring results, errors are classified as presented in Table 3-5.

Table 3-5
Severity of Errors of TXS COMPACT Platform

Severity of the Error	Description
Fatal permanent	The error is fatal. The module is unable to perform its intended function.
Fatal transient	The error is fatal. The module is unable to perform its intended function. Nevertheless, the error may disappear after restart or external action (e.g., configuration frame).
Non-fatal	This error is related to parts of the hardware clearly separated or not directly used for the full set of functions of the TXS COMPACT (e.g., MPIOF1 has an error in one input channel).

When an error is detected, according to its severity, the main reactions are to:

- Stop cyclic activity.
- Modify module state.
- Invalidate affected I&C signals (validity status set to ERROR).
- Indicate current state with light-emitting diode (LED).
- Send status and diagnosis information to the Service Unit via the SMDF1 through the unidirectional monitoring line on the backplane bus (if communication is not affected).

3.2.2 Reporting of Faulty Conditions

Reporting of fault conditions can be achieved in multiple ways and can be combined, depending on I&C system specification.

3.2.2.1 LED Indicators

Each TXS COMPACT module provides a set of four LEDs on the front plate of the module, which are immediately visible when looking at the chassis when the cabinet is open. The meaning of the LED indicators is consistent on all modules so the maintenance operator can promptly detect the faulty module.

To keep the meaning of the LED indicator easily understandable by the maintenance operator, the number of combinations is limited; therefore, LEDs display summarized information which allows the operator to determine:

- Mode of the Automation Unit.
- Status of the module.
- Whether one or more non-fatal conditions have been reported.
- Whether one or more fatal errors are present.

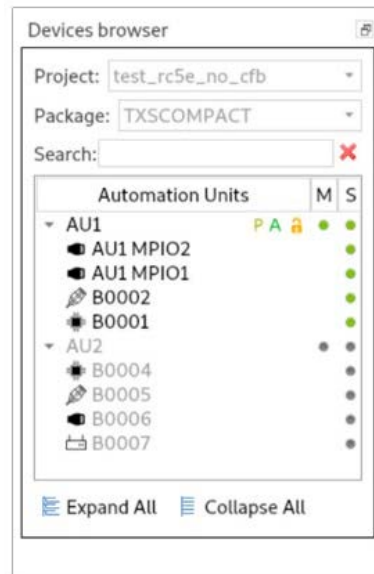
However, LEDs generally cannot be used for detailed diagnosis of faults.

3.2.2.2 Reporting on the Service Unit Computer

The Service Unit computer, when connected to the Automation Units, cyclically receives detailed status and diagnosis information from each AU to which it is connected to through the SMDF1.

The Service Unit computer can be connected to all Automation Units at the same time and hence provides a global overview of system health from a central place. The information is displayed on a GUI, either as graphical items or using text information.

Figure 3-11
Devices Browser



Compared to LEDs, the Service Unit computer is able to display additional information:

- Mode of every Automation Unit.
- Status of each individual module.
- Detailed list and value for each individual self-monitoring and status flag for each module.

This allows much more precise investigation and diagnosis of the root cause of any issue occurring on the system.

Figure 3-12
Device Status Flags

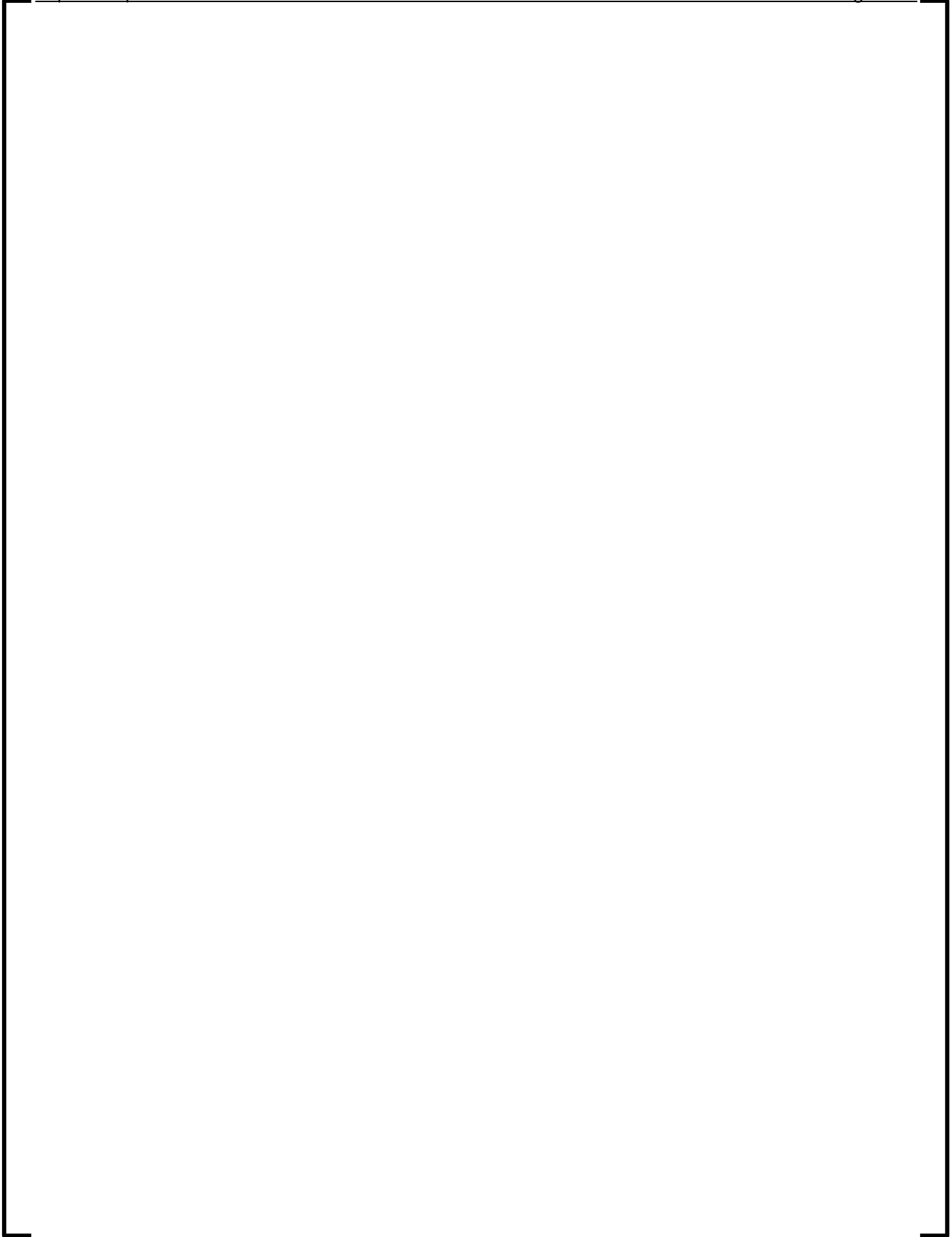
AU1 (B0008)							✖
Device ▾	Type	Rack	Symbol	Description	Data Type	Value	▲
PMMaster	PM	R001	MPIOF1_ANAIN0_LIVE0	analog input 1 live 0 detection status	Bool	true	
PMLoc	PM	R001	MPIOF1_ANAIN0_SELFTEST	analog input 1 self-test status	Bool	true	
PMExt	PM	R002	MPIOF1_ANAIN1_LIVE0	analog input 2 live 0 detection status	Bool	true	
GW_AU1	GWFI	R003	MPIOF1_ANAIN1_SELFTEST	analog input 2 self-test status	Bool	true	
B0008	SMDFI	R001	MPIOF1_ANAIN2_LIVE0	analog input 3 live 0 detection status	Bool	false	
B0005	MPIOF1	R001	MPIOF1_ANAIN2_SELFTEST	analog input 3 self-test status	Bool	false	
			MPIOF1_ANAIN3_LIVE0	analog input 4 live 0 detection status	Bool	false	
			MPIOF1_ANAIN3_SELFTEST	analog input 4 self-test status	Bool	false	▼

3.2.2.3 Reporting through the Application

Status information can also be retrieved from within the application. As a result, the I&C system can inspect itself and forward necessary information to the local HMI, main control room, or the plant computer using either electrical binary outputs or safety-to-non-safety computerized network link.

Function block PM-STATUS provides the following individual status flags:

Table 3-6
PM-STATUS Flags



[

] Detailed investigation can be carried

out by the plant maintenance operator, either through visual inspection using LEDs or from the Service Unit.

Furthermore, TXS COMPACT Automation Units (AUs) can acquire and process signals elaborated by the TXS COMPACT Cabinet Monitoring Unit (CMU1) and combine them with other errors, if needed.

The design of such alarms, including whether CMU1 shall be used in addition to TXS COMPACT AUs, is part of the system application specification.

3.2.3 Self-Detection and Management of Faulty Input Signals

TXS COMPACT provides a generic, embedded way to manage invalidity of signals.

[

]

[

Status indicators are propagated between Automation Units, so it is trivial for a receiving chassis to detect whether signals must be incorporated in calculation or whether the sending unit must be bypassed (e.g., maintenance operation in progress).

[

]

The system application can control the invalidity of each signal using dedicated function blocks, and specific processing or alarm generation can be implemented based on this information. The design of such processing or alarms is part of the system application specification.

3.2.4 Application Self-Diagnostics

As previously mentioned, as soon as no fatal error is detected, TXS COMPACT allows the application to access the result of self-monitoring using function block PM-STATUS. Outputs of this function block can be processed the same as any other binary signal to initiate actions such as seamless degradation of calculation logic.

Application self-diagnostics are functions of each I&C system specification. Typical examples of application self-diagnostics are:

- Monitoring and evaluation of the signal status received from other processing modules.
- Consistency checks: Exchange of redundant signals with other processing modules and crosschecking for consistency.
- Sanity checks: For example, range monitoring of analog input signals or monitoring congruence of binary input signals. This also includes, as a special case, live-zero monitoring for analog signals.
- Engineered relay check-backs: Monitoring of check-back contacts of interposing relays or other relay circuits.

3.3 TXS COMPACT Platform Maintenance Features

Maintenance of TXS COMPACT-based I&C systems consists of the following operations:

- Checking results of self-tests and self-monitoring, as described in previous sections.
- Investigating potential system faults.
- Replacing faulty hardware modules.
- Changing values of functional parameters (e.g., setpoint).
- Supporting periodic testing.
- Replacing the application with a newer version (functional update of the system).

As explained in previous sections, updating the application consists of updating configuration files. When such operation must be performed, it is never required to update the FPGA HDL program. Consequently, updating the HDL program is not part of normal maintenance operations.

3.3.1 Service and Maintenance Architecture

Service and maintenance features are provided by computer tools running on an industrial computer called the Service Unit. This computer is connected to the Automation Units by an Ethernet-based network which is separated from the process network.

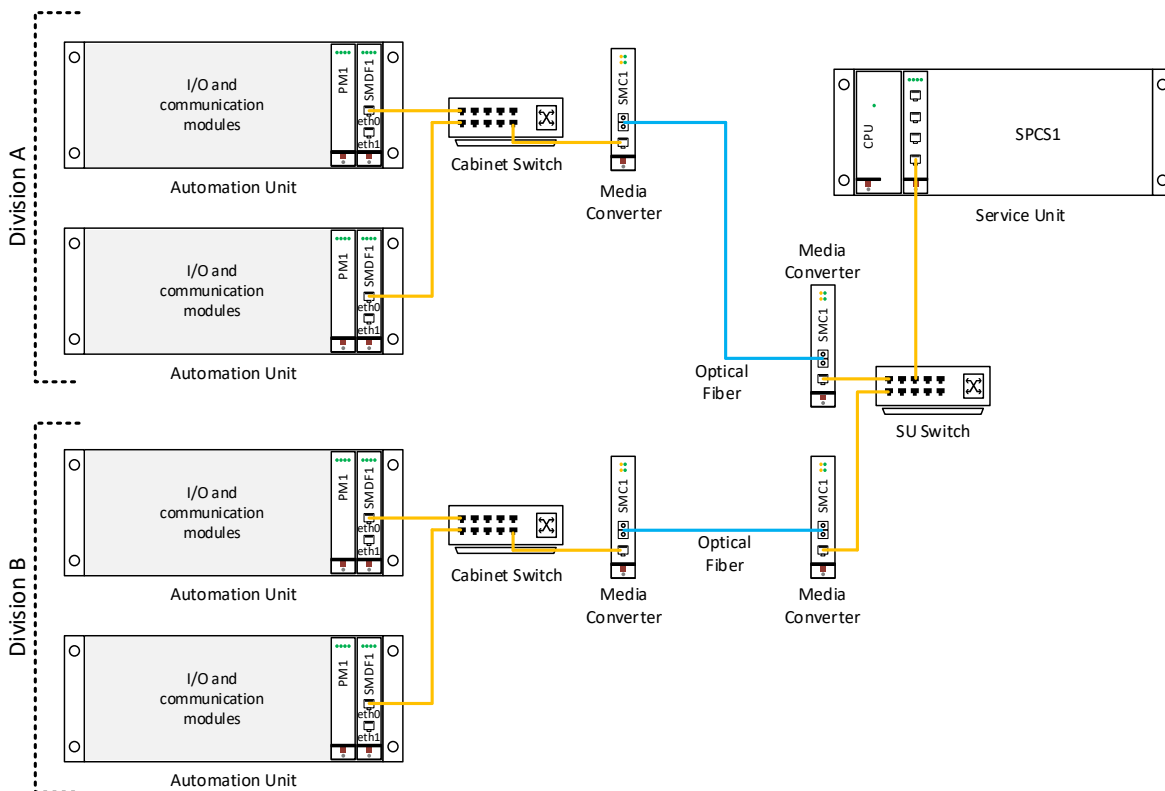
This Ethernet network gets connected to the SMDF1 on each Automation Unit. This module oversees:

- Cyclically collecting the values of functional signals, monitoring statuses on the backplane bus, and sending them to the Service Unit using the appropriate network protocol.

- Converting service commands received from the Service Unit (using a cyber-secured protocol) into plain messages on the backplane bus for the PM1. Provided modes and releases allow it, the PM1 will effectively receive and process the command; otherwise, the command will either not reach the PM1 or will be discarded.

Figure 3-13 illustrates a typical arrangement of a Service Unit connected to multiple Automation Units in multiple divisions. The actual arrangement for each I&C system depends on the system specification.

Figure 3-13
Service Unit Connected to Multiple Automation Units in Multiple Divisions

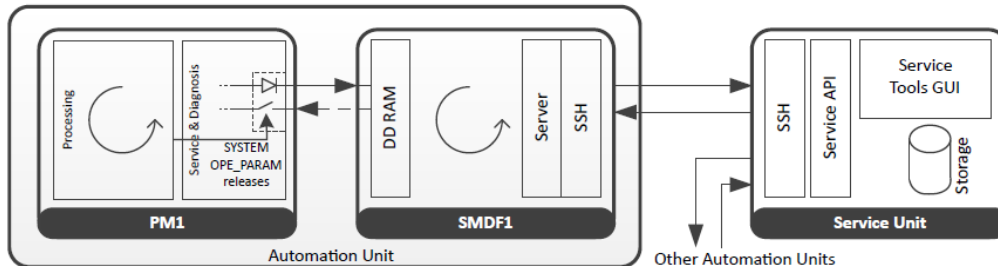


Diagnosis information and service commands do not flow on the same network as signals involved in the actuation path, preventing any degradation of safety functions by non-safety support functions.

Functional isolation of the non-safety service network processing part is achieved [This safety barrier blocks any incoming communication from the SMDF1 (and hence, from the Service Unit) when the Automation Unit is in OPERATION mode [On the contrary, it allows outward communication from the PM1 to the SMDF1 at any time. This design allows for:

- Permanent monitoring of the execution of safety functions from the Service Unit.
- Prevention of service and maintenance commands from degrading execution of the safety functions.

Figure 3-14
Communications Between Automation Unit and Service Unit



In multi-division systems, it is possible to engineer fault-resilient systems where one division can be turned to maintenance mode while it gets bypassed by the other divisions. Systems with four divisions can be engineered in a way that they will continue being resistant to spurious actuation of one division while another one is being maintained. Implementation details depend on the system specification.

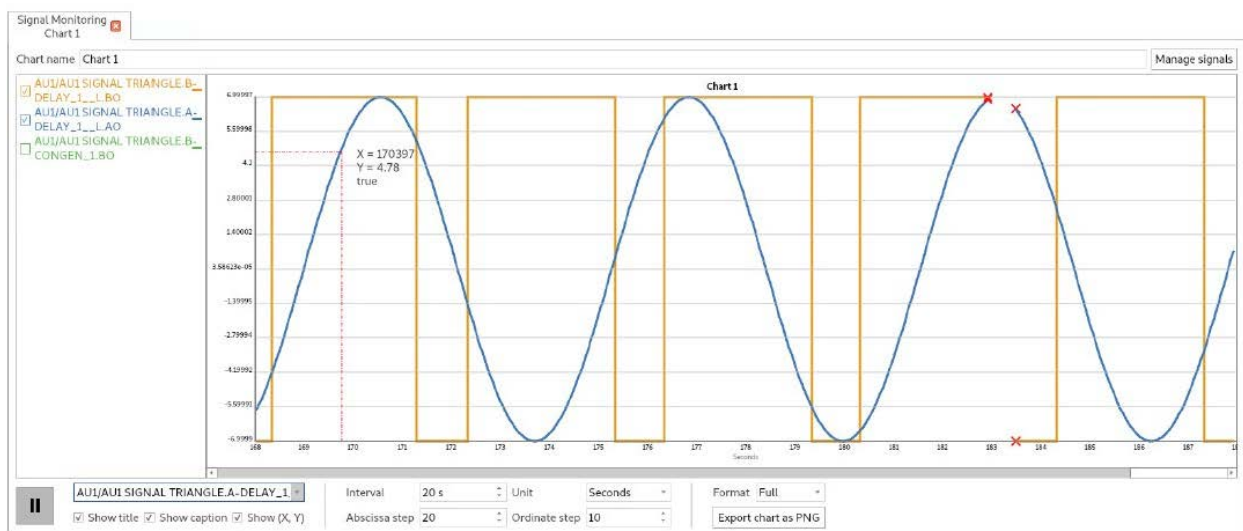
3.3.2 Features for System Monitoring and Fault Diagnosis

Service Unit tools provide features for permanently observing the status of each Automation Unit and each TXS COMPACT module. These functions are already described in Section 3.2.2.2.

In addition, the Service Unit provides the ability to trace and plot values of individual signals flowing between function block instances, diagrams, and Automation Units. This can be achieved for any of these signals as soon as they belong to the application.

Depending on the available computing power of the Service Unit (SU) computer and its actual load, multiple signals can be plotted simultaneously.

Figure 3-15
Signal Monitoring



In addition to plotting the values of signals on screen, it is possible to:

- Record the signals' value and validity in a comma-separated text file for a specified duration.
- Access the signals' value and validity through a Python API.

By using these two options, it is possible to interface the Service Unit with external tools (e.g., evolved calculation software).

[]

tracing can be done at any time without any influence on processing of safety functions.

Modern I&C systems can be relatively fast and manipulate a significant volume of data. While TXS COMPACT AUs are fully deterministic, the Service Unit runs on standard personal computer architecture and where load and response time cannot be guaranteed. Therefore, some values may not always be processed on a specific time period; for instance, when the Service Unit computer's operating system is busy executing other processes. In such situation, missing points are clearly identified as such (e.g., with a red cross when plotting values) so they cannot be confused with functionally invalid values.

3.3.3 Features for System Parameters and Application Update

The Service Unit allows for:

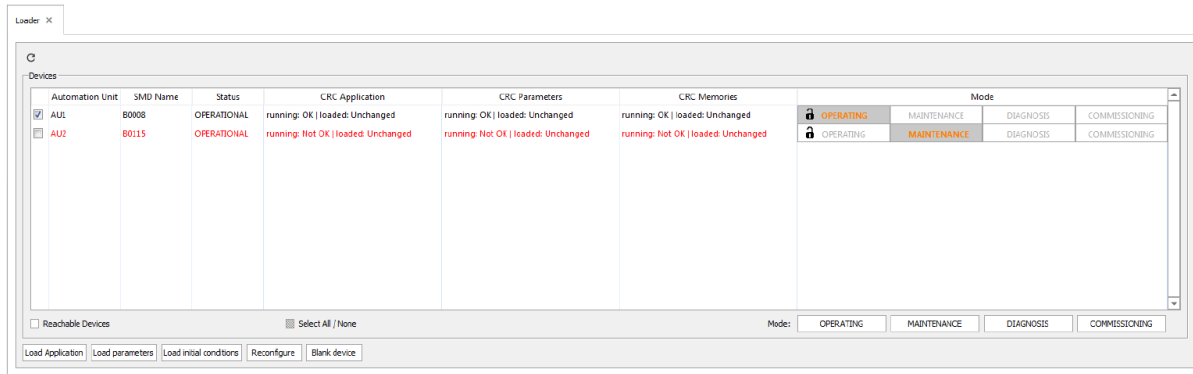
- Updating functional parameters of the application, whose details are provided in Section 3.6.
- Updating the application; i.e., changing the behavior of safety functions.

The latter is not a regular maintenance operation, as it most likely requires retesting and partial requalification of the system, but can be done during an outage in the case where a functional modification of the system is required.

Both operations require that:

1. The appropriate set of releases is positioned by the application.
2. Appropriate authorizations are granted on the Service Unit (see sections on cybersecurity).
3. The Automation Unit to which the parameter set must be updated is placed in maintenance mode (see Section 2.5), which can be done through the GUI as shown below.

Figure 3-16
Maintenance Mode Setting Through GUI



Associated with appropriate application design, such controls make it impossible to disturb normal system behavior with maintenance operations when not appropriate (e.g., when the division is not bypassed).

Transfer of application and parameter files between the Service Unit and Automation Units is done through a secured channel:

Failure of any of these checks leads to the whole set of files being discarded by the device and the original configuration being kept unchanged.

The SMDF1 and Service Unit act only as a pass-through. [

]

Consequently, any alteration of the file by SMDF1 software or Service Unit software would be detected by the safety PM1. [

]

When either the application or the parameters (or both) change, the HDL program running on the FPGA is not touched. Only new configuration tables are loaded into non-volatile application memory by the PM1. Therefore, it is never possible to introduce a fault that would result in functional misbehavior of the system. In other words, the generic part of the system cannot be altered when performing maintenance operations.

As explained above, the Service Unit also displays whether the application and the parameters loaded in each unit are consistent with those available locally on the Service Unit [

]

This allows identifying:

- Pending actions on the Automation Units which must be updated when safety conditions are satisfied.
- Any potential involuntary human mistakes.

These features are equally available through a Python-based API, which can be used to automatically couple the Service Unit to an external system; e.g., a plant configuration management database. Statuses and checks are also available when using the API.

3.3.4 Features for Factory Acceptance and Periodic Testing

The Service Unit can be used to support automated factory acceptance tests and periodic testing of the system in the plant.

The Service Unit allows overwriting the startup values of internal memory of function block instances which use such memories. This can be achieved only when the system is in MAINTENANCE mode and will be active after the system restarts.

Overwriting startup values of memories can be used during factory acceptance tests to:

- Reach steady-state conditions more quickly and with less effort, which allows performing more tests during the same period of time.
- Test unlikely or theoretically impossible signal paths to check whether defense-in-depth is appropriately implemented.

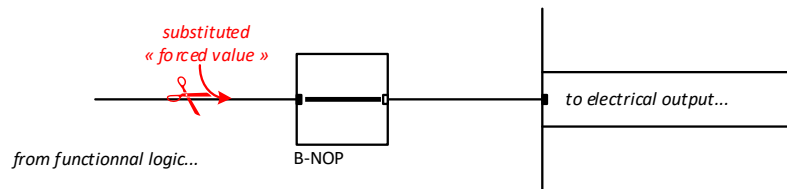
In addition, the Service Unit allows overwriting the values of signals flowing on function block diagrams. Any function block's input can be selected to be overwritten. When this function is activated, the PM1 stops considering either the signal's value generated by the preceding function block (as designed in the function block diagram) or the input value from the MPIOF1 and replaces with a constant value set by the operator of the Service Unit.

Figure 3-17
Overwriting the Values of Function Block Signals

show all	diagram	macros	block	port / NES	data type	nature	CRC	value	validity
AUS	AUS/AUS D1 SEIS		I-1_1	BD	Binary	FE input	OK		
AUS	AUS/AUS D1 SEIS		A-NOP_1	AI	Analog	FE input	OK		
AUS	AUS/AUS D1		B-UNGROUP_1	ME	BinaryGroup	FE input	OK	0111111111111111	1111111111111111
AUS				AUS D1 SEIS 8000	Binary	NES	OK		
AUS				AUS D2 SEIS 8000	Binary	NES	OK		
AUS				AUS D3 SEIS 8000	Binary	NES	OK		
AUS				AUS D4 SEIS 8000	Binary	NES	OK		
AUS				AUS PM 8000	Binary	NES	OK		
AUS				AUS PM 8002	Binary	NES	OK		
AUS				AUS PM 8003	Binary	NES	OK		
AUS				AUS PM 8004	Binary	NES	OK		
AUS				MULTI905	Binary	NES	OK		
AUS				AUS D1 SEIS 4001	Analog	NES	OK		
AU2	AU2/AU2 PM		PM-CONTROL_3	P2	Binary	FE input	Not OK		
AU2	AU2/AU2 PM		PM-CONTROL_3	P1	Binary	FE input	Not OK		
AU2	AU2/AU2 PM		PM-CONTROL_3	A	Binary	FE input	Not OK		
AU2	AU2/AU2 PM		PM-CONTROL_3	W5	Binary	FE input	Not OK	1	1
AU2	AU2/AU2 D1 SEIS		MUX-E_1	2A	Analog	FE input	Not OK	5	1
AU2	AU2/AU2 D1 SEIS		MUX-E_1	A0	Analog	FE input	Not OK		
AU2	AU2/AU2 D1 SEIS		MUX-E_1	A02	Analog	FE input	Not OK		
AU2	AU2/AU2 D1 SEIS		MUX-E_1	A03	Analog	FE input	Not OK		

This feature is called “forced values” and can only be activated when the Automation Unit is in DIAGNOSIS or COMMISSIONING mode (i.e., it is bypassed). When the Automation Unit exits from DIAGNOSIS or COMMISSIONING mode [] the forced values are automatically reset and the system resumes processing calculated values.

Figure 3-18
Implementation of “Forced Values” Feature



This function can be used to:

- Test internal logic of the Automation Unit.
- Selectively trigger the system’s electrical and/or network outputs in a way which supports realization of periodic testing of the voting and actuation chain.

Whether the Service Unit shall be used to support factory acceptance and/or periodic testing depends on each I&C system’s specific architecture and test strategy.

3.4 TXS COMPACT Calibration of MPIOF1

During manufacturing, a calibration sequence of the MPIOF1’s analog channels is performed to get the right accuracy. This concerns the analog digital converter of the analog input channels and the digital analog converters of the analog output channels. A very precise value is injected on one given channel and read back by the FPGA. A gain and/or an offset are then added to compensate for the deviation in the electronic device. Once calibrated, the calibration coefficients are written in a non-volatile memory (NVM) and are used by the module’s final configware.

No calibration is later required during the lifetime of the module.

The analog inputs are self-tested through dedicated circuitry. [

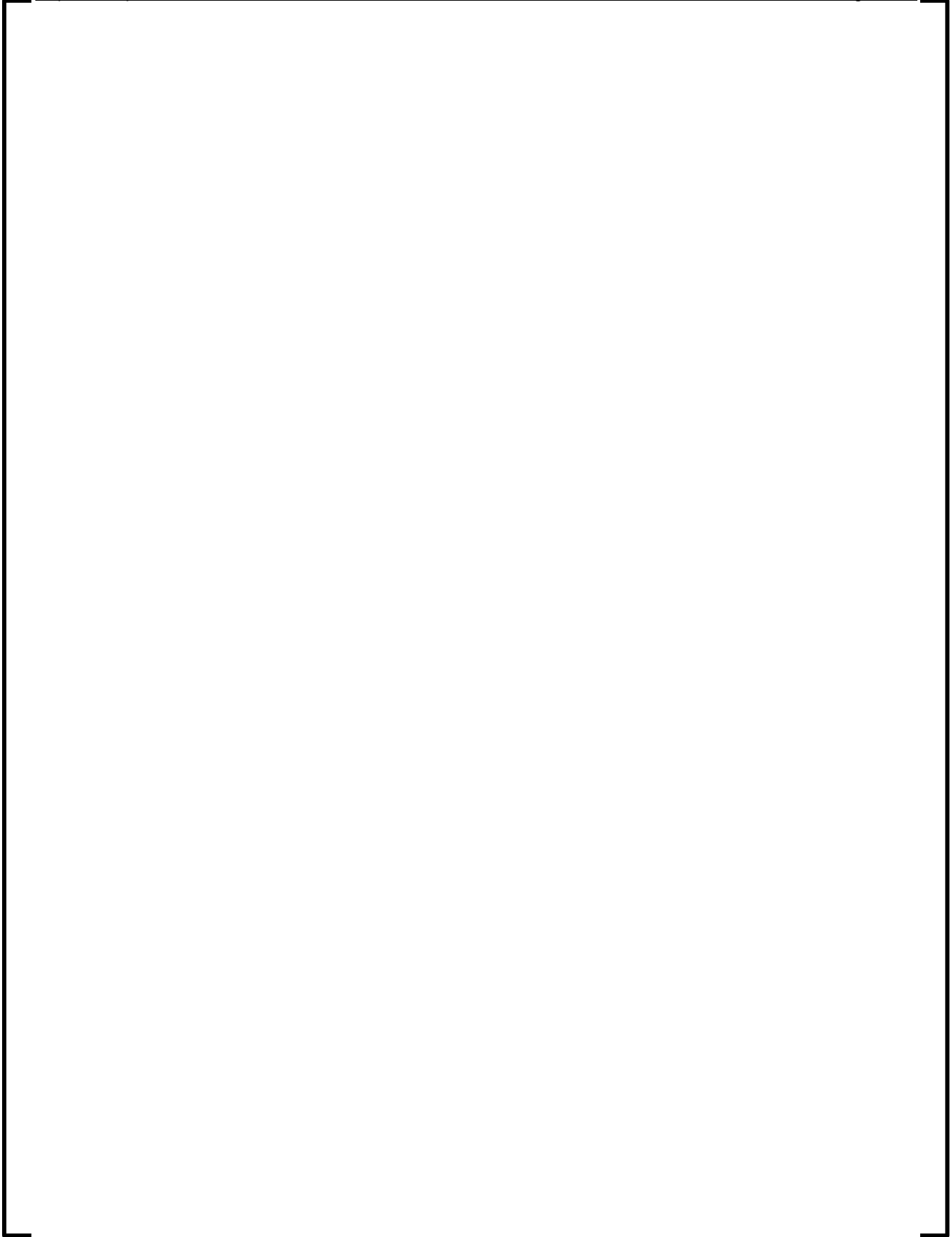
]

3.5 TXS COMPACT Test of MPIOF1

The tests performed by the MPIOF1 aim at ensuring the validity of I&C signals and correct internal operation of the module itself.

Concerning the validity of I&C signals, the tests performed are considered non-fatal errors at the module level and mainly aim at reporting faults on the acquisition or output of analog and binary channels and setting signal validity.





3.6 *TXS COMPACT Access and Control of Setpoints and Parameters*

Every TXS COMPACT I&C system consists of:

- Pre-qualified and generic hardware modules.
- Pre-qualified and generic HPD configware.

- I&C system-specific application configuring the HPD with the logic of engineered I&C functions.
- I&C system-specific set of parameters configuring the application.

Parameters are attached to function blocks. Each parameter has a fixed type (integer, Boolean, or floating-point number), and its value can either be set once during initial design of the application (fixed parameter) or flagged as “online-changeable” (also called “mutable”) in engineering tools.

Mutable parameters can be changed later in the test bay or the plant from the Service Unit computer, while fixed parameters are constants. A situation where values of fixed parameters need to be changed will, therefore, require re-generating the application program.

Not all function blocks have parameters; for instance, Boolean logic blocks, such as AND-E, do not have any parameters, while some blocks, such as linearization block MRC, have many of them.

TXS COMPACT does not distinguish between setpoints and other parameters. On top of built-in function block parameters, application engineers can create custom parameters using function block CONGEN (CONstant GENerator).

3.6.1 Initial Configuration of Parameter Values

Each function block placed on a function block diagram can have parameters. Parameters always have a default value, which is specified in platform user documentation.

Using the TXS Design Studio tool, the system design engineer can display and edit each parameter by clicking on the function block. Then the following properties can be changed for each parameter:

- Platform default value can be replaced by a system initial value (or kept as is).

- Parameters can be made visible on the layout of the function block diagram.
- The parameter can be made changeable or read-only from the Service Unit.
Non-changeable parameters are constant values which are fixed until the application program gets updated.

When the application program is generated, the AGT considers these parameters and inserts them in the generated configuration files.

3.6.2 Update of Changeable Parameters and Setpoints

Parameters can be edited in two ways:

- **Spreadsheet view**

A spreadsheet view is provided by CST on the Service Unit for conveniently modifying parameters.

**Figure 3-19
Spreadsheet View**

The screenshot shows a window titled 'Parameters' with a close button. Inside, there are dropdowns for 'Automation Unit' (AU1) and 'Data' (04_param_bin_fb.tbl). Below these is a section titled 'Parameters and memory' containing a table. The table has columns: diagram, macros, block, parameter, offset, and value. Two rows are visible in the table. At the bottom of the window are buttons for 'Import TBL', 'Generate for target', and 'Save'.

diagram	macros	block	parameter	offset	value
AU1/AU1 SIGNAL TRIANGLE.diag		COMP_MAX	Type	0:2	1
AU1/AU1 SIGNAL TRIANGLE.diag		COMP_MIN	Type	0:3	0

Individual parameter values can be changed on the graphical interface and saved to a local non-volatile buffer. Parameters are sorted per Automation Unit and per data type, and a filter is available to sort the list of parameters to be displayed.

- **File import**

It is possible to import a file specifying updated values of parameters identified by name. By doing so, updated parameters can be prepared in advance; for instance, prepared by staff at engineering office or created by external calculation software.

In both cases, the result is stored in human-readable text files on the SU hard drive, whose content can be verified by the operator.

3.6.3 Loading Updated Parameters to the Automation Units

TXS COMPACT does not allow parameters to be individually modified on Automation Units. This is done intentionally, as a means of maintaining parameter integrity. Parameters for each Automation Unit are gathered in a parameter set. Each parameter set is transferred as a consistent block of data to the Automation Unit by the Service Unit, where it is stored in NVM.

Each parameter set contains:

- The data (values) of parameters.
- A [] checksum.
- An identifier of the corresponding application.

The checksum and the application identifier are created by AGT and are immediately verified by the Automation Unit once a new parameter set is received. In the event that one or the other does not match, the update is refused. This check is repeated every time the Automation Unit starts or restarts. If the check should fail, the Automation Unit would refuse to transition to OPERATION mode and would move to ERRORSTOP mode. Doing so guarantees that the parameter sets are not altered and correspond to the correct version of engineered I&C functions.

TXS COMPACT Automation Units would not receive a parameter set when the appropriate release is not activated. Likewise, it would refuse to apply this parameter set in case the appropriate release is activated but the Automation Unit is not placed in an appropriate mode.

Depending on the requirements applicable to the I&C system, two options are possible:

- If determined acceptable for the system to receive updated parameters while in operation, then the release [] must be activated using the dedicated function block. In such case, changing Automation Unit mode is not required. This feature can be permanently disabled during engineering of the system.
- When the above is not acceptable or when it is more appropriate to switch the Automation Unit to failsafe mode while changing parameters, then [] releases must be activated using the dedicated function block. The Automation Unit must then be switched to MAINTENANCE mode from the Service Unit computer.

These conditions allow avoiding any unexpected update of system parameters.

When one of these two sequences is realized, the Automation Unit is ready to accept a new parameter set. In both cases, the PM1 will consider it immediately (at next processing cycle).

When new parameters are sent to an Automation Unit, a backup copy is automatically generated and stored in a dedicated directory tree to allow tracking and/or restoring.

In practice, once the expected parameters have been changed on the Service Unit and Automation Units have been placed in an appropriate mode, the AGT is called to gather all parameters into binary parameter sets. The operator can then send the modified parameter sets to the corresponding Automation Units using the “Loader” panel of the CST.

CST itself never modifies the binary files of the parameter sets. [

] hence, it cannot introduce any defect that would not be detected by the receiving AU, thanks to the above-mentioned protective features introduced by AGT [

]

In addition to using the CST graphical interface, TXS COMPACT provides programming interfaces for creating application-specific solutions for updating parameters. This can be useful, for instance, to automatically perform cross-checking of certain parameters.

4.0 TXS COMPACT EQUIPMENT QUALIFICATION

This section of the Topical Report details equipment qualification of TXS COMPACT hardware: Processing Module (PM1), Multi-Purpose I/O Module (MPIOF1), GWF1, SMDF1, and Backplane integrated into chassis (SRACKCR) (including BPF1) as described in Section 2.0.

4.1 *Equipment Qualification Approach*

Equipment qualification is based on the TXS COMPACT – Qualification Plan [78], which provides a link to the generic specification for type testing TXS hardware modules [77]. Type testing is the preferred approach for equipment qualification. The generic specification [77] describes the type testing procedure and specifies the test cases which shall be performed in type testing hardware modules of the TXS platform.

The test cases form an overlap of requirements for qualification of modules used in Class 1 systems as defined in the following standards:

- International standards:
IEC/IEEE 60780-323:2016 [46] and
IEC/IEEE 60980-344:2020 [47]
- French nuclear safety standard: RCC-E:2019 [51]
- German nuclear safety standard: KTA 3503:2015 [52]

Figure 4-1 provides an overview of the theoretical assessments, visual inspections, and practical tests (e.g., electromagnetic compatibility (EMC), environmental, and seismic).

Figure 4-1
TXS – Generic Equipment Qualification

4.1.1 Qualified Life

According to TXS platform requirements, hardware modules of the TXS System Platform shall be suitable for operation in mild environments (temperature, humidity, chemical, and radiation). Section 5.1 of IEC/IEEE 60780-323:2016 [46] states: “A qualified life is not required for equipment located in a mild environment and which has no significant aging mechanisms and is operated within the limits established by applicable specifications and standards.” Hardware modules qualified according to the generic test specification [77] are intended to operate in mild environmental conditions and have no significant aging mechanisms. Therefore, definition of a qualified life period is not necessary.

4.1.2 Test Specimens

For practical testing, three factory-tested specimens of each TXS COMPACT module were used, as required by the listed national nuclear standards.

As defined in Section 6.2.1, Table 6-1, the TXS COMPACT SMDF1 does not perform safety functions. The Software and HDL-Programmed Device (HPD) of the SMDF1 are defined as “not classified;” however, the hardware of this module is classified for use in Class 1 systems.

To demonstrate that the SMDF1 has no impact on safety functions within a TXS COMPACT Automation Unit, the SMDF1 was integrated into the function monitoring system which was used during TXS COMPACT system level practical testing (EMC, climatic, and seismic testing).

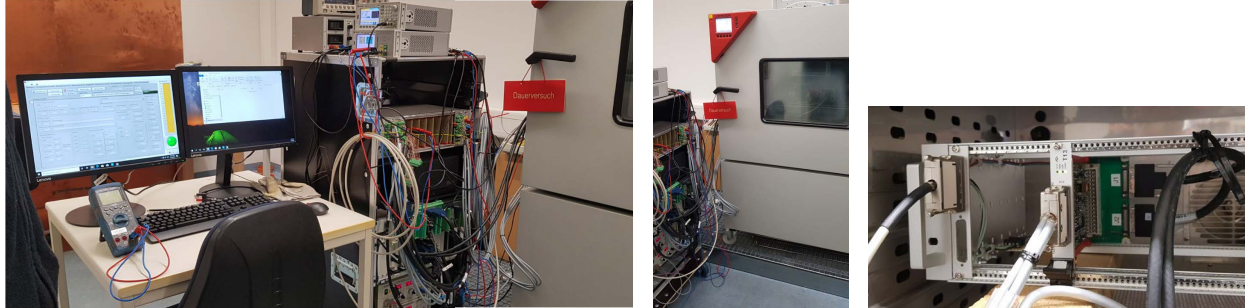
4.1.3 Test Setup

4.1.3.1 Functional Testing on Module Level – Test Bench

For execution of the functional tests, an automated test system (test bench) was developed for each distinct TXS COMPACT hardware module. Setup and operation of these test benches are documented in the hardware module-specific test equipment description (References to TXS COMPACT: Test Equipment Description for PM1 [128], TXS COMPACT: User manual for MPIOF1 test bench for functional tests [130], TXS COMPACT: GWF1 test equipment description [129]).

In Figure 4-2, the left picture shows the MPIOF1 test bench for functional testing. The test chassis, including the MPIOF1 (right picture) as the equipment under test (EUT), is placed inside the climatic chamber (middle picture).

Figure 4-2
TXS COMPACT MPIOF1 Equipment Qualification – Functional Testing

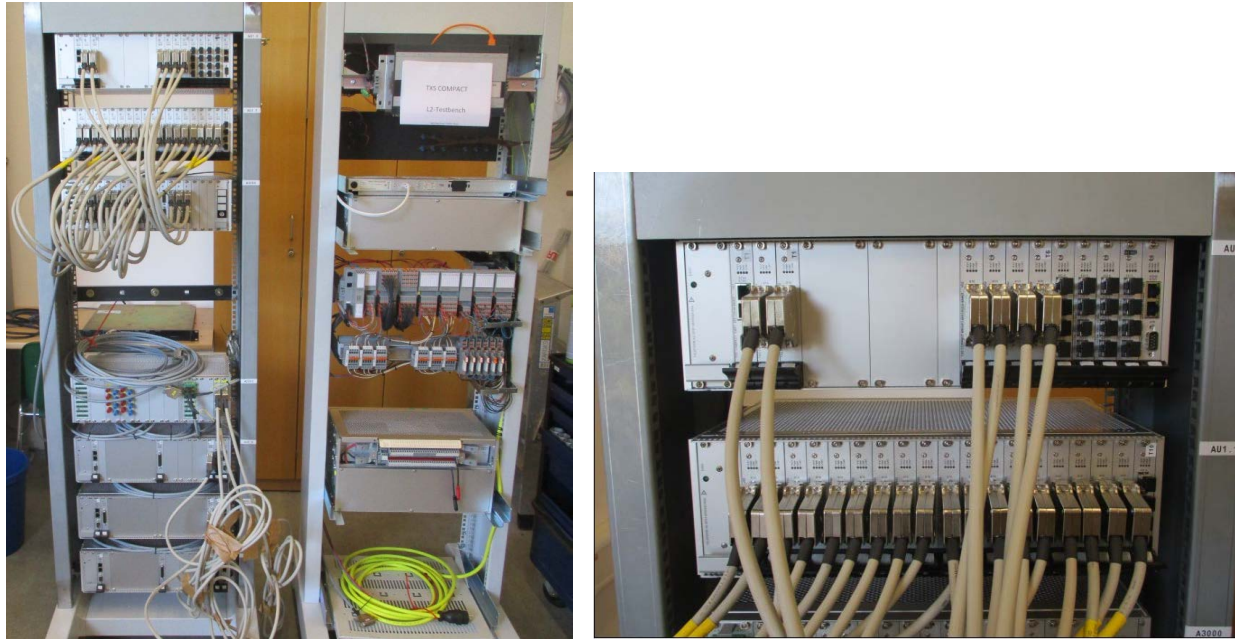


4.1.3.2 Environmental Testing on System Level – Function Monitoring

For environmental testing (EMC, climatic, and seismic), a TXS COMPACT system has been prepared.

The test setup comprises four TXS COMPACT Automation Units (AUs) and one fully equipped SRACKCR, which serves as Extension I/O. In addition to the Automation Units, two chassis are employed: the first chassis interfaces with the signal lines of the test specimen and routes these signals to the second chassis, which houses the output loads and function monitoring equipment. Figure 4-3 illustrates the test setup; however, certain interconnections, such as Ethernet cables and fiber optic lines between the AUs, are not shown for clarity.

Figure 4-3
TXS COMPACT Equipment Qualification – Function Monitoring



A schematic of the configuration and connections of the four Automation Units is shown in Figure 4-4. Additional details, including operation of the function monitoring test setup, are documented in the User Manual for Level 2 Function Monitoring [131].

Figure 4-4
Function Monitoring Test Setup – Several Interacting TXS COMPACT
Modules Arranged in Four Automation Units



On each TXS COMPACT Automation Unit, a typical nuclear power plant (NPP) safety application is running. The applications were designed using TXS Design Studio, one of the TXS COMPACT engineering tools (see Section 3.1.2).

4.1.3.3 Intermediate Function Test

The test case T_IntermediateFunctionTest must be performed at specific hold points during practical testing.

For TXS COMPACT equipment qualification, the function monitoring test setup was also used for the intermediate function test.

4.1.4 Test Documentation

The results of practical tests are documented in a dedicated test report for the initial functional test, EMC, climatic, seismic, and the final functional test.

The summary qualification reports summarize the test results of the equipment qualification for each of the type tested TXS COMPACT modules (PM1 Summary Qualification Report [137], MPIOF1 Summary Qualification Report [138], GWF1 Summary Qualification Report [139], and SMDF1 Summary Qualification Report [140]).

4.1.5 Test Locations

Initial functional tests, final functional tests, and electrical tests were performed in the laboratory of Framatome Products Development Competence Center in Erlangen. All other practical tests were performed by the ISO/IEC 17025:2017 [50] accredited laboratory at EMCCons Dr. Rasek GmbH & Co. KG in Stoernhofer Berg 15, 91364 Unterleinleiter, Germany.

4.1.6 Test Procedure

Test cases and test steps performed during TXS COMPACT equipment qualification are described in greater detail in the following subsections. EUT are the TXS COMPACT modules listed in Section 4.1.3.

4.2 Assessments and Analyses

4.2.1 Documentation

<i>T_ComponentDocumentation</i>		
Test objective	TXS COMPACT equipment documentation checked for consistency and correctness.	
	For detailed information, refer to: IEC/IEEE 60780-323:2016, Section 7.2.2; RCC-E:2019, Section I.2300 and Section VII.4100; KTA 3503:2015, Section 4.2.	
Step	Action	Result

4.2.2 Reliability

Expected failure rate for TXS COMPACT equipment has been calculated based on the part count method. For electronic parts, the reference failure rates as given in SIEMENS standard SN 29500 [53] have been used. Total failure rate of TXS COMPACT equipment has been calculated as the sum of all individual failure rates from the electronic parts for the composition of each TXS COMPACT module. To have a unique database for all TXS COMPACT equipment, the TXS database is used for calculation.

<i>T_Reliability</i>		
Test objective	Failure rate calculation. For detailed information, refer to: KTA 3503:2015, Section 4.3; RCC-E:2019, Section III.3000.5.3; SN 29500; IEC 61709:2017.	
Step	Action	Result

4.2.3 Critical Load Analysis

A theoretical assessment of the design under consideration of limit load conditions, including examination of effects caused by tolerances of electronic parts, has been performed. Evidence has been provided to indicate that electronic parts are not subjected to load conditions which exceed permissible limits during intended operation.

<i>T_CriticalLoadAnalysis</i>		
Test objective	Limit load analysis to check use of electronic parts within permitted static and dynamic limits. For detailed information, refer to: KTA 3503:2015, Section 4.4.	
Step	Action	Result

4.2.4 Failure Effect Analysis

In addition to the calculation of failure rate, the Failure Modes and Effects Analysis (FMEA) considers functional aspects, including self-monitoring features and methods for failure detection by engineered monitoring. For this purpose, TXS COMPACT equipment has been subdivided into function blocks (FBs); the effects of the failure modes of these function blocks have been analyzed, and the associated failure rates have been determined. The FMEA provides data related to detailed failure effects. This data can be used as input information; e.g., for an Instrumentation and Control (I&C) system level FMEA, specification of engineered self-monitoring functions and periodic tests of I&C applications.

<i>T_FMEA</i>		
Test objective	Determination of failure effects for the TXS COMPACT equipment by means of an FMEA. For detailed information, refer to: KTA 3503:2015, Section 4.3.3; RCC-E:2019, Section III.3000.5.3.	
Step	Action	Result

<i>T_SelfMonitoring</i>		
Test objective	Verification of documents describing implemented self-monitoring functions. For detailed information, refer to: KTA 3503:2015, Section 4.2.8 and EUT specific functional test specification.	
Step	Action	Result

4.3 *Visual Inspection*

T_IdentifyVerification		
Test objective	Compliance of TXS COMPACT equipment with manufacturing documents listed in register of documents.	
	For detailed information, refer to: KTA 3503:2015, Section 5.2; RCC-E:2019, Section VII.4120.	
Step	Action	Result

T_VisualInspection**Test objective**

Quality of realized manufacturing process.

For detailed information, refer to: KTA 3503:2015, Section 5.2; RCC-E:2019, Section VII.4120; IPC-A-610 (Institute for Printed Circuits (IPC) standard for Acceptability of Electronic Assemblies), Class 3.

Step**Action****Result*****T_CreepageAndClearance*****Test objective**

Correct PCB layout according to clearances and creepage distances.

For detailed information, refer to: IEC 60664-1:2020, Section 6.8.

Step**Action****Result**

T_MechanicalImpactProtection**Test objective**

Resistance of enclosure against external mechanical impacts.
For detailed information, refer to: RCC-E:2019, Section V.5211-2; IEC 62262:2002.

Step**Action****Result*****T_ForeignBodyAndWaterProtection*****Test objective**

Resistance of enclosure against penetration by solid foreign objects and water.
For detailed information, refer to: RCC-E:2019, Section V.5211-2; IEC 60529:2013.

Step**Action****Result**

4.4 Initial Functional Tests

To validate that TXS COMPACT modules performed intended safety functions correctly at the beginning of the qualification program, the initial functional test was performed for the PM1, MPIOF1, and GWF1. For the other modules (BPF1, SRACKCR, and SMDF1), the initial functional test was not necessary because the SRACKCR is mechanical equipment and the BPF1 is mostly mechanical equipment with few resistors and one solid state relay which was tested during factory testing. Functionality of the SMDF1 is defined as non-safety. However, the SMDF1 is included in the seismic and environmental qualification testing program as it is installed in the TXS COMPACT chassis.

Test cases to be performed within the initial functional test are defined in the attachment of the TXS COMPACT – Qualification Plan [78] and described in the module specific test specification: TXS COMPACT: PM1 Functional Test Specification [101], TXS COMPACT: MPIOF1 Functional Test Specification [109], and TXS COMPACT: GWF1 Functional Test Specification [110]. The tests were performed under limit load conditions at the minimum and maximum ambient temperature [

]

<i>T_InitialFunctionalTest</i>		
Test objective	TXS COMPACT equipment operation under nominal and limit load conditions.	
	For detailed information, refer to: KTA 3503:2015, Section 5.3; RCC-E:2019, Section V.3220; and EUT specific functional test specification.	
Step	Action	Result

Results of the initial functional test are documented in the dedicated test reports for PM1 [112], MPIOF1 [113], and GWF1 [114].

4.5 *Electrical Characteristics*

Testing of electrical characteristics of the TXS COMPACT equipment has been performed under nominal conditions.

T_DielectricStrengthTestAC**Test objective**

Strength of galvanic isolation between electrically isolated circuits.

For detailed information, refer to: RCC-E:2019, Section V.3220; RCC-E:2019, Section VII.4230.

Step**Action****Result*****T_DielectricStrengthTestDC*****Test objective**

Strength of galvanic isolation between electrically isolated circuits.

For detailed information, refer to: RCC-E:2019, Section V.3220; RCC-E:2019, Section VII.4230.

Step**Action****Result*****T_InsulationResistanceMeasurement*****Test objective**

Measurement of insulation resistance between galvanically isolated circuits.

For detailed information, refer to: RCC-E:2019, Section V.3220; RCC-E:2019, Section VII.4240.

Step**Action****Result**

<i>T_CurrentConsumptionAndPowerDissipation</i>		
Test objective		Current consumption and power dissipation. For detailed information, refer to: KTA 3503:2015, Section 5.3 and EUT specific functional test specification.
Step	Action	Result

<i>T_OutputOverload</i>		
Test objective		Resistance of binary outputs regarding overload. For detailed information, refer to: EUT specific functional test specification.
Step	Action	Result

<i>T_OutputShortCircuit</i>		
Test objective	Resistance of binary outputs regarding short-circuit.	
	For detailed information, refer to: EUT specific functional test specification.	
Step	Action	Result

<i>T_OutputReverseVoltage</i>		
Test objective	Protection against reverse voltage at TXS COMPACT equipment outputs.	
	For detailed information, refer to: EUT specific functional test specification.	
Step	Action	Result

<i>T_InputInversePolarity</i>		
Test objective	Protection against inverse polarity of TXS COMPACT equipment inputs.	
	For detailed information, refer to: EUT specific functional test specification.	
Step	Action	Result

<i>T_PowerSupplyVoltage35vImpulse</i>		
Test objective	Immunity of TXS COMPACT equipment power supply to non-periodic rise of supply voltage.	
	For detailed information, refer to: EUT specific functional test specification.	
Step	Action	Result

T_PowerSupplyVoltageShortInterruption**Test objective**

Immunity of TXS COMPACT equipment power supply to short-term voltage interruptions of supply voltage (supply circuit disrupted).

For detailed information, refer to: IEC 61131-2:2017, Section 6.2.2.7.

Step**Action****Result**

<i>T_PowerSupplyVoltageRipple</i>		
Test objective		Immunity of TXS COMPACT equipment power supply to superimposed AC voltage (ripple) of a 50 and 60 Hz grid. For detailed information, refer to: IEC 62003:2020, Section 7.4, Table 5 and EUT specific functional test specification.
Step	Action	Result

<i>T_PowerSupplyVoltageSlowOnOff</i>		
Test objective		Immunity of TXS COMPACT equipment power supply to slow rises and drops of supply voltage. For detailed information, refer to: IEC 61131-2:2017, Section 6.2.2.4.
Step	Action	Result

Results of the electrical tests are included in the initial function test reports for PM1 [112], MPIOF1 [113], and GWF1 [114].

4.6 *EMC Testing*

EMC testing has been performed according to the IEC 62003:2020 standard “Nuclear power plants – Instrumentation, control and electrical power systems – Requirements for electromagnetic compatibility testing” [32], which refers to the IEC 61000-x-y series for EMC testing.

During EMC testing, modules are placed inside the chassis as shown in Figure 4-4. Electromagnetic attenuation of the TXS Cabinet or another enclosure was not credited during the tests.

Below, the performed EMC tests are listed. The tests are divided into emission and immunity tests. For these tests, test setup with function monitoring was used as described in Section 4.1 of this report.

4.6.1 Electromagnetic Emissions

<i>T_EM-ConductedEmissionPowerSupplyLinesDC</i>		
Test objective		Compliance with permissible conducted emission limits on the input/output (I/O) DC power ports of TXS COMPACT equipment. For detailed information, refer to: IEC 62003:2020, Section 8, Table 7; RCC-E:2019, Section II.4233; IEC 61000-6-4:2018.
Step	Action	Result

<i>T_EMCRadiatedEmission</i>		
Test objective		Compliance with permissible radiated emission limits from the enclosure port of TXS COMPACT equipment. For detailed information, refer to: IEC 62003:2020, Section 8, Table 6; RCC-E:2019, Section II.4233; IEC 61000-6-4:2018.
Step	Action	Result

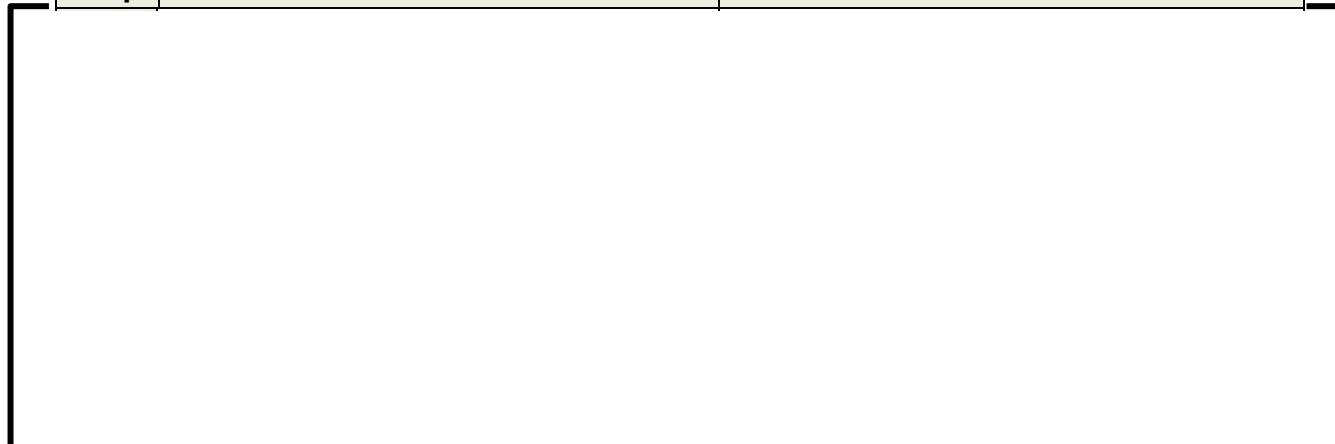
<i>T_EMCConductedEmissionSignalPorts</i>		
Test objective		Compliance with pre-defined conducted emission limits on the signal ports of TXS COMPACT equipment. For detailed information, refer to: KTA 3503:2015, Section 5.6; International Special Committee on Radio Interference (CISPR), CISPR16-2-1:2014; CISPR16-1-2:2014.
Step	Action	Result

4.6.2 Electromagnetic Immunity

4.6.2.1 Acceptance Criteria



<i>T_EMCImmunityToElectrostaticDischarges</i>		
Test objective	Immunity of TXS COMPACT equipment against electrostatic discharge. For detailed information, refer to: IEC 62003:2020, Section 7, Table 2; RCC-E:2019, Section II.4234; IEC 61000-4-2:2008.	
Step	Action	Result



<i>T_EMCImmunityToRadioElectromagneticFields</i>		
Test objective	Immunity of TXS COMPACT equipment against interference caused by radio-frequency electromagnetic fields on the enclosure port. For detailed information, refer to: IEC 62003:2020, Section 7, Table 2; RCC-E:2019, Section II.4234; IEC 61000-4-3:2020.	
Step	Action	Result

<i>T_EMCImmunityToRadioElectromagneticFieldsDECT</i>		
Test objective	Immunity of TXS COMPACT equipment against interference caused by radio-frequency electromagnetic fields on the enclosure port. For detailed information, refer to: IEC 62003:2020, Section 7, Table 2; IEC 61000-4-3:2020.	
Step	Action	Result

4.6.2.2 Immunity to Interference on the AC Supply Ports

The test cases “Immunity to interfaces on AC supply ports,” as required by IEC 62003:2020 [32], are not applicable for TXS COMPACT, which has no AC supply ports.

4.6.2.3 Immunity to Interference on the DC Supply Ports

<i>T_EM-DC-PS-ImmunityToBurst</i>		
Test objective	Immunity of TXS COMPACT equipment against electrical fast transients (burst) on the input/output DC power ports. For detailed information, refer to: IEC 62003:2020, Section 7, Table 5; RCC-E:2019, Section II.4234; IEC 61000-4-4:2012.	
Step	Action	Result

<i>T_EM-DC-PS-ImmunityToSurge</i>		
Test objective	Immunity of TXS COMPACT equipment against surge disturbances on the input/output DC power port. For detailed information, refer to: IEC 62003:2020, Section 7, Table 5; RCC-E:2019, Section II.4234; IEC 61000-4-5:2017.	
Step	Action	Result

T_EM-DC-PS-ImmunityToDampedOscillatoryWave**Test objective**

Immunity of TXS COMPACT equipment against conducted slow (100 kHz) damped oscillatory disturbances on the input/output DC power port.

For detailed information, refer to: RCC-E:2019, Section II.4234; IEC 61000-4-18:2019.

Step**Action****Result*****T_EM-DC-PS-ImmunityToRadioFrequencyInterference*****Test objective**

Immunity of TXS COMPACT equipment against conducted disturbances induced by radio-frequency fields on the input/output DC power port.

For detailed information, refer to: IEC 62003:2020, Section 7, Table 5; RCC-E:2019, Section II.4234; IEC 61000-4-6:2013.

Step**Action****Result**

<i>T_EM-DC-PS-ImmunityToConductedCommonModeDisturbances</i>		
Test objective		Immunity of TXS COMPACT equipment against conducted common mode disturbances on the input/output DC power port. For detailed information, refer to: IEC 62003:2020, Section 7, Table 5; IEC 61000-4-16:2015.
Step	Action	Result

T_EM-DC-PS-ImmunityToConductedCommonModeDisturbancesMains**Test objective**

Immunity of TXS COMPACT equipment against conducted common mode disturbances at mains frequencies on the input/output DC power port.

For detailed information, refer to: IEC 62003:2020, Section 7, Table 5; IEC 61000-4-16:2015.

Step**Action****Result*****T_EM-DC-PS-ImmunityToRingWave*****Test objective**

Immunity of TXS COMPACT equipment against ring wave disturbances on the input/output DC power port.

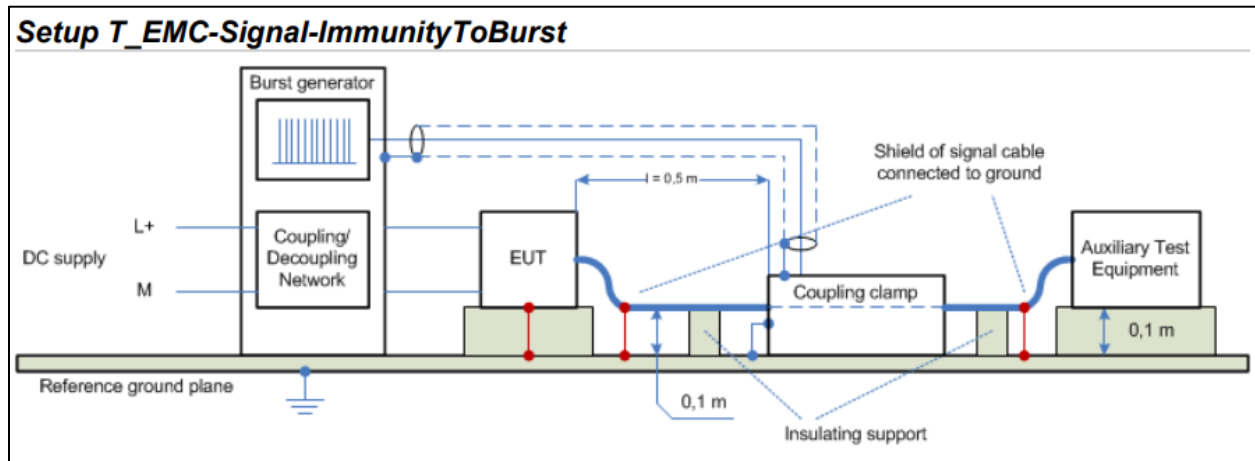
For detailed information, refer to: IEC 62003:2020, Section 7, Table 5; IEC 61000-4-12:2017.

Step**Action****Result**

4.6.2.4 Immunity to Interference on Signal Ports

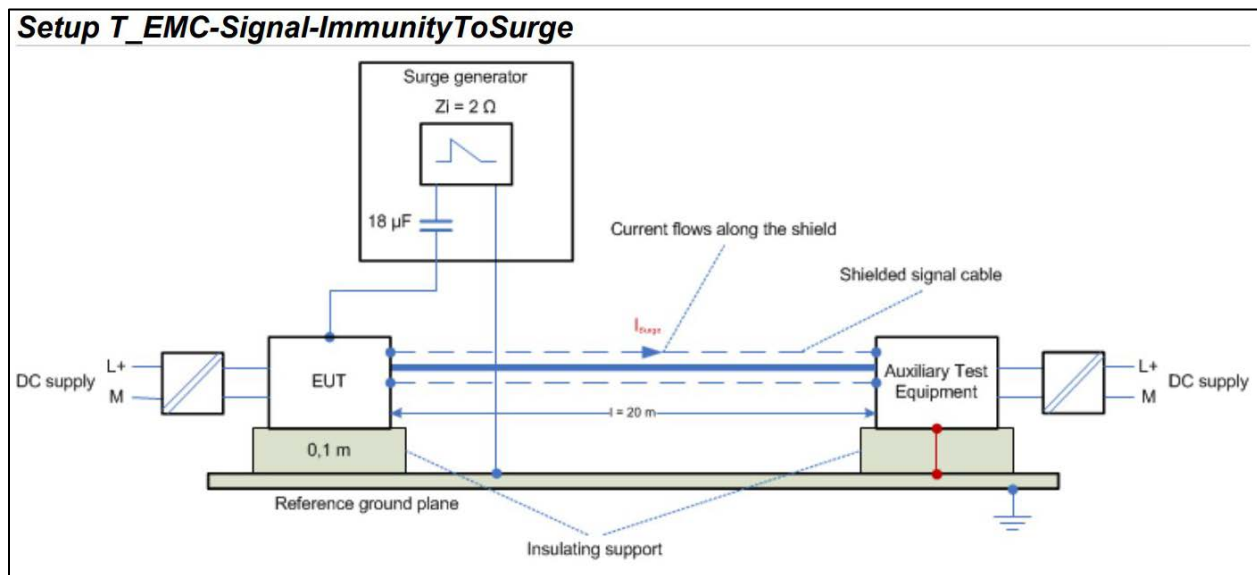
<i>T_EMCSignalImmunityToBurst</i>		
Test objective	Immunity of TXS COMPACT equipment against electrical fast transients (burst) on the signal ports.	
	For detailed information, refer to: IEC 62003:2020, Section 7, Table 3; RCC-E:2019, Section II.4234; IEC 61000-4-4:2012.	
Step	Action	Result

Figure 4-5
Setup EMC Burst Test on Signals



<i>T_EM</i>C-Signal-ImmunityToSurge		
Test objective	Immunity of TXS COMPACT equipment against surge disturbances on the signal ports.	
	For detailed information, refer to: IEC 62003:2020, Section 7, Table 3; RCC-E:2019, Section II.4234; IEC 61000-4-5:2017.	
Step	Action	Result

Figure 4-6
Setup EMC Surge Test on Signals



T_EMC-Signal-ImmunityToConductedRadioFrequencyInterference**Test objective**

Immunity of TXS COMPACT equipment against conducted disturbances induced by radio-frequency fields on the signal ports.

For detailed information, refer to: IEC 62003:2020, Section 7, Table 3; RCC-E:2019, Section II.4234; IEC 61000-4-6:2013.

Step**Action****Result*****T_EMC-Signal-ImmunityToConductedCommonModeDisturbances*****Test objective**

Immunity of TXS COMPACT equipment against conducted common mode disturbances on the signal ports.

For detailed information, refer to: IEC 62003:2020, Section 7, Table 3; IEC 61000-4-16:2015.

Step**Action****Result**

<i>T_EMC-Signal-ImmunityToConductedCommonModeDisturbancesMains</i>		
Test objective		Immunity of TXS COMPACT equipment against conducted common mode disturbances at mains frequencies on the signal ports. For detailed information, refer to: IEC 62003:2020, Section 7, Table 3; RCC-E:2019, Section II.4234; IEC 61000-4-16:2015.
Step	Action	Result

<i>T_EM-Signal-ImmunityToRingWave</i>		
Test objective		Immunity of TXS COMPACT equipment against ring wave disturbances on the signal ports. For detailed information, refer to: IEC 62003:2020, Section 7, Table 3; IEC 61000-4-12:2017.
Step	Action	Result

The result of EMC testing is documented in the EMC Test Report [147].

4.7 *Tests to Demonstrate Behavior Over Time / Operational Vibration and Climatic Tests*

The following tests demonstrate that the behavior and functionality of TXS COMPACT equipment is not degraded by simulated aging over time.

In addition, this set of tests demonstrates that the functionality of TXS COMPACT equipment is not degraded if the TXS COMPACT equipment is exposed to climatic conditions defined in the user manual for storage, transportation, and operation.

TXS COMPACT equipment has been mounted inside the SRACKCR (TXS COMPACT chassis) in a position that simulates its expected installation as recommended for operation within the cabinets of an NPP I&C system. The test chassis has been mounted at its designated installation points.

<i>T_DisconnectConnectPermanentlyInstalled</i>		
Test objective	Suitability of permanently installed connectors (e.g., backplane, field wiring) during plugging and unplugging. For detailed information, refer to: KTA 3503:2015, Section 5.9; IEC 61131-2:2017, Section 6.9.1.	
Step	Action	Result

<i>T_DisconnectConnectNonPermanentlyInstalled</i>		
Test objective	Suitability of non-permanently installed connectors (e.g., diagnostic connectors, electrical network ports) during plugging and unplugging. For detailed information, refer to: KTA 3503:2015, Section 5.9 and EUT specific functional test specification.	
Step	Action	Result

4.7.1 Operational Vibrations

<i>T_Seismic_OperationalVibration_TransientSinusoidal</i>		
Test objective	Resistance of TXS COMPACT equipment to transient sinusoidal operational vibrations in the frequency range of 5 to 500 Hz (including determination of resonance frequency).	
	For detailed information, refer to: RCC-E:2019, Section II.4213-1; IEC 61131-2:2017, Section 5.3.2; IEC 60068-2-6:2007 Test Fc. Note: EUT in mounting position within chassis.	
Step	Action	Result

4.7.2 Climatic – Non Operation

<i>T_Climatic-NonOperationFastTemperatureVariation</i>		
Test objective		Suitability of TXS COMPACT equipment for transport and storage at fast temperature changes. For detailed information, refer to: IEC 60068-2-14:2009 Test Na.
Step	Action	Result

<i>T_Climatic-NonOperationDryHeat</i>		
Test objective		Suitability of TXS COMPACT equipment for transport and storage at high ambient temperature and low humidity. For detailed information, refer to: KTA 3503:2015, Section 5.7.3; IEC 60068-2-2:2007 Test Bb.
Step	Action	Result

<i>T_Climatic-NonOperationDampHeatCyclic</i>		
Test objective		Suitability of TXS COMPACT equipment for storage and transportation at high humidity and rapid temperature change followed by condensation. For detailed information, refer to: KTA 3503:2015, Section 5.7.5; IEC 60068-2-30:2005 Test Db Variant 1.
Step	Action	Result

T_Climatic-NonOperationCold**Test objective**

Suitability of TXS COMPACT equipment for transport and storage at low temperatures.

For detailed information, refer to: KTA 3503:2015, Section 5.7.2; IEC 60068-2-1:2007 Test Ab.

Step**Action****Result*****T_Climatic-NonOperationDampHeatSteadyState*****Test objective**

Suitability of TXS COMPACT equipment for storage at high ambient temperature and high humidity.

For detailed information, refer to: KTA 3503:2015, Section 5.7.4; IEC 60068-2-78:2012 Test Cab.

Step**Action****Result**

4.7.3 Climatic – Operation

<i>T_Climatic-OperationDampHeatSteadyState</i>		
Test objective	Suitability of TXS COMPACT equipment installed in a TXS chassis (or similar) during operation in damp heat without condensation. For detailed information, refer to: KTA 3503:2015, Section 5.7.4; IEC 60068-2-78:2012 Test Cab.	
Step	Action	Result

<i>T_Climatic-OperationDampHeatCyclic</i>		
Test objective	Suitability of TXS COMPACT equipment installed in a TXS chassis (or similar) during operation in high temperature and high humidity environment. For detailed information, refer to: IEC 60068-2-30:2005 Test Db Variant 1.	
Step	Action	Result

<i>T_Climatic-OperationChangeOfTemperature</i>		
Test objective		Suitability of TXS COMPACT equipment installed in a TXS chassis (or similar) for operation during change of temperature. For detailed information, refer to: IEC 60068-2-14:2009 Test Nb.
Step	Action	Result

Figure 4-7
Cycle Profile of Temperature Change Test Case
T_Climatic-OperationChangeOfTemperature

The approach of the following climatic long term test cases is the combination and fulfillment of RCC-E:2019 [51] and KTA 3503:2015 [52]. The test cases shall demonstrate long-term stability over 1000 hours and, in addition, to apply thermal stress into the electronic and mechanical components of the TXS COMPACT equipment. Test cases shall be executed in the given order without interruption to operation of the TXS COMPACT equipment and function monitoring to ensure that the TXS COMPACT equipment is exposed to the specified ambient test temperature.

<i>T_Climatic-OperationLongTermTest1000h</i>		
Test objective		Suitability of TXS COMPACT equipment installed in a TXS chassis (or similar) for long term operation. For detailed information, refer to: RCC-E V3240; IEC 60068-2-2:2007 Test Be.
Step	Action	Result

Figure 4-8
Cycle Profile of Long-Term Test Case
T_Climatic-OperationLongTermTest1000h

<i>T_Climatic-OperationLongTermTestCyclic</i>		
Test objective	Suitability of TXS COMPACT equipment installed in a TXS chassis (or similar) for long term cyclic operation. For detailed information, refer to: KTA 3503:2015, Section 5.7.6; IEC 60068-2-14:2009 Test Nb.	
Step	Action	Result

Figure 4-9
Cycle Profile of Long-Term Test Case
T_Climatic-OperationLongTermTestCyclic



The result of climatic testing is documented in the Environmental Test report [148].

4.8 *Mechanical and Seismic Tests*

4.8.1 Seismic Test Approach

4.8.1.1 Description of the Plant Independent Approach for Seismic Tests (earthquake and airplane crash)

The seismic test approach is based on the approach described in IEC/IEEE 60980-344 [47], [

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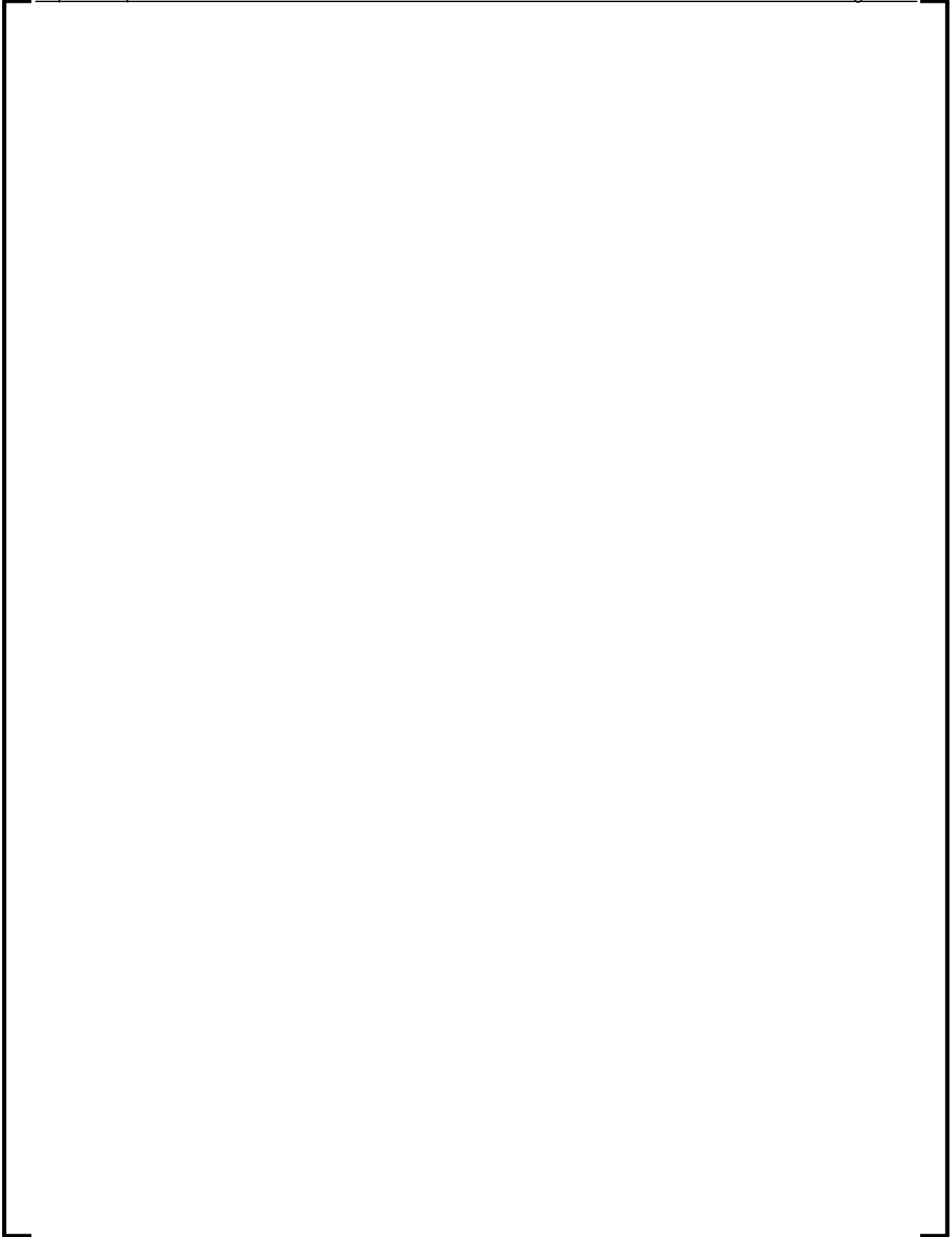
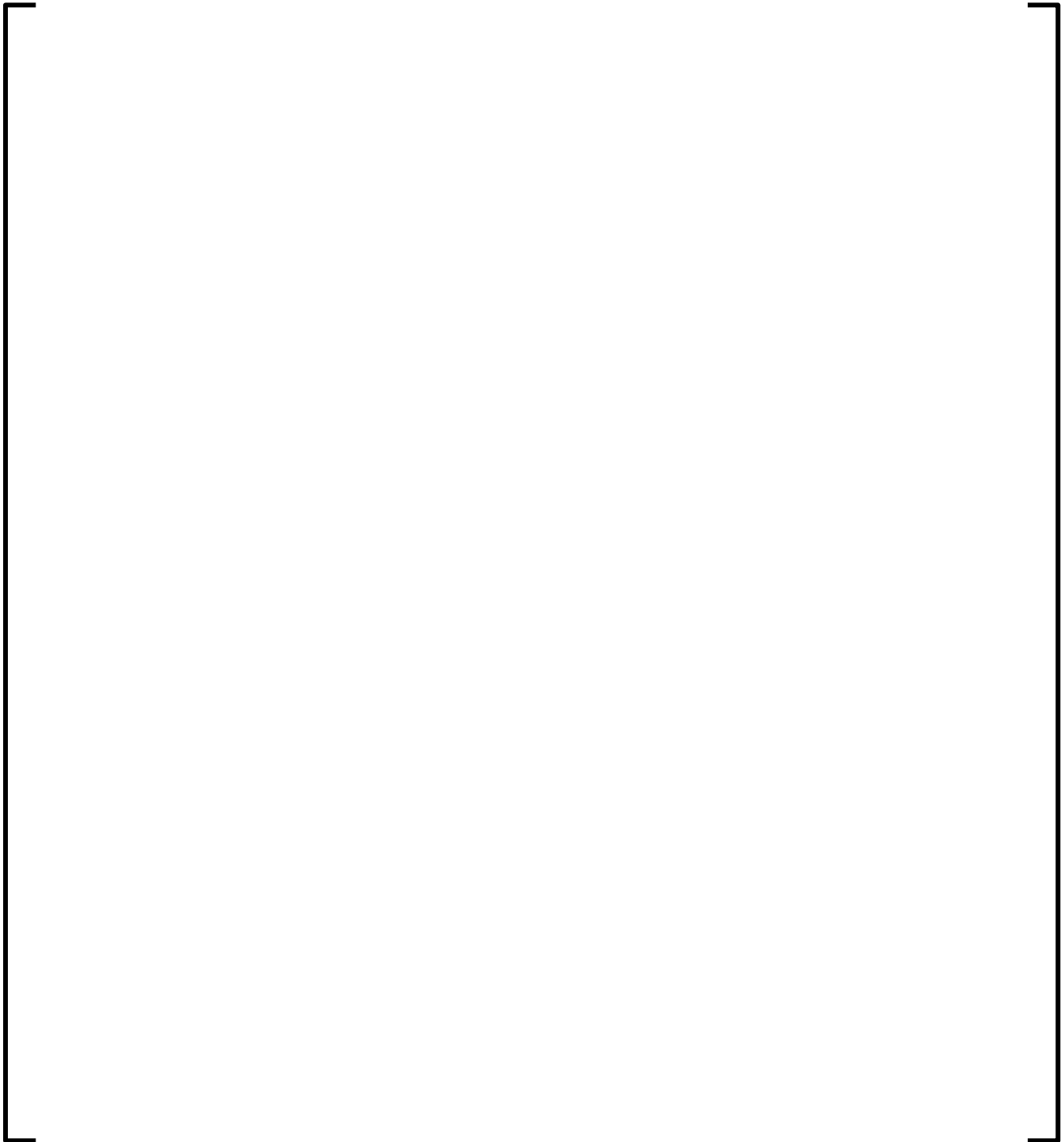


Figure 4-10
TXS Cabinet Basic Structure



4.8.1.2 Description of the Plant-Specific Approach for Seismic Test

4.8.1.3 Mechanical and Seismic Tests

4.8.1.4 Definition of Test Sequence and Test Axis for Mechanical and Seismic Tests

Table 4-1
Test Sequences on Each Single Axis

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Figure 4-11
Definition of X,Y, and Z Axes

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4.8.2 Mechanical Stress During Transport

<i>T_Seismic_TransportRandomVibrationPackaged</i>		
Test objective	Resistance of packaged TXS COMPACT equipment against broadband random vibrations.	
	For detailed information, refer to: IEC 60721-3-1:2018, Section 5.7; IEC 60721-3-2:2018, Section 5.6; IEC 60068-2-64:2019 Test Fh, Table A.1, Category 2.	
Step	Action	Result

T_Seismic_TransportShockPackaged**Test objective**

Resistance of TXS COMPACT equipment against shock (EUT packaged).

For detailed information, refer to: KTA 3503:2015, Section 5.8.4; IEC 60721-3-2:2018, Section 5.6; IEC 60068-2-27:2008 Test Ea.

Step**Action****Result*****T_IntermediateFunctionTest_Packaged*****Test objective**

Intermediate function test and visual inspection after packaged test sequence.

Step**Action****Result**

<i>T_ResonanceScanning_BeforeMech</i>		
Test objective	Resonance frequency scanning before mechanical test sequence.	
	Note: EUT in mounting position within chassis.	
Step	Action	Result

<i>T_Seismic_TransportRandomVibrationUnpackaged</i>		
Test objective	Resistance of unpackaged TXS COMPACT equipment against broadband random vibrations.	
	For detailed information, refer to: IEC 60721-3-1:2018, Section 5.7; IEC 60721-3-2:2018, Section 5.6; IEC 60068-2-64:2019 Test Fh, Table A.1, Category 2. Note: EUT in mounting position within chassis.	
Step	Action	Result

T_Seismic_TransportShockUnpackaged**Test objective**

Resistance of TXS COMPACT equipment against shock.
For detailed information, refer to: KTA 3503:2015,
Section 5.8.4; IEC 60721-3-2:2018, Section 5.6; IEC
60068-2-27:2008 Test Ea.
Note: EUT in mounting position within chassis.

Step**Action****Result**

4.8.3 Mechanical Stress During Operation

<i>T_Seismic_OperationalVibration_TransientRandom</i>		
Test objective		Resistance of TXS COMPACT equipment to transient random operational vibrations in the frequency range of 5 to 200 Hz. For detailed information, refer to: IEC 60721-3-3:2019, Section 5.7; IEC 60068-2-64:2019, Table A.3 Category 2. Note: EUT in mounting position within chassis.
Step	Action	Result



<i>T_Seismic_OperationShock</i>		
Test objective	Resistance of TXS COMPACT equipment against shock. For detailed information, refer to: IEC 61131-2:2017, Section 5.3.3; IEC 60068-2-27:2008 Test Ea. Note: EUT in mounting position within chassis.	
Step	Action	Result

<i>T_ResonanceScanning_AfterMech</i>		
Test objective	Resonance frequency scanning after mechanical test sequence. Note: EUT in mounting position within chassis.	
Step	Action	Result

T_ResonanceScanning_BeforeSeism**Test objective**

Resonance frequency scanning before seismic test sequence.
Note: EUT in mounting position within chassis.

Step**Action****Result*****T_Seismic_OperationAbnormal_MILA_and_SteadyStateAccel*****Test objective**

Resistance of TXS COMPACT equipment against seismic loads during abnormal operation (e.g., caused by earthquake).
For detailed information, refer to: KTA 3503:2015, Section 5.8.2; IEC 60721-3-2:2018, Section 5.6; IEC 60068-2-6:2007 Test Fc.
Note: EUT in mounting position within chassis.

Step**Action****Result**

<i>T_Seismic_OperationAbnormal_APC</i>		
Test objective	Resistance of TXS COMPACT equipment against loads during abnormal operation (e.g., caused by airplane crash).	
	For detailed information, refer to: KTA 3503:2015, Section 5.8.3; IEC 60068-2-6:2007 Test Fc.	
	Note: EUT in mounting position within chassis.	
Step	Action	Result

<i>T_ResonanceScanning_AfterSeism</i>		
Test objective	Resonance frequency scanning after seismic test sequence.	
	Note: EUT in mounting position within chassis.	
Step	Action	Result

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4.9 *Final Functional Tests*

After completing environmental testing (EMC, climatic, seismic), the TXS COMPACT equipment was checked to verify it still performs its safety function as described in the module specific user manual.

For this demonstration, the test performed at the beginning of the equipment qualification program was repeated.

<i>T_FinalFunctionalTest</i>		
Test objective		TXS COMPACT equipment operation under nominal and limit load conditions. For detailed information, refer to: KTA 3503:2015, Section 5.3; RCC-E:2019, Section V.3220 and EUT specific functional test specification.
Step	Action	Result

The results of the final functional test are documented in the dedicated test reports for PM1 [115], MPIOF1 [116], and GWF1 [117].

4.10 Compliance with U.S. Standards and Supplementary Equipment Qualification Testing

Requirements for equipment qualification are given in Chapter 6 of EPRI TR 107330, December 1996 [22].

In addition, guidance from the following more recent applicable Regulatory Guides (RGs) is considered in this chapter:

- RG 1.100, Revision 4, May 2020 [23] for Seismic, which endorses IEEE Std 344:2013.
- RG 1.209, Revision 0, March 2007 [24] for Environmental (temperature, humidity), which endorses IEEE Std 323:2003.
- RG 1.180 Revision 2, December 2019 [25] for EMC and ESD testing, which endorses IEC 61000-x-y Series.

TXS COMPACT was previously qualified for use in international markets, which have similar, but different, acceptance criteria and test limits for products and systems classified as nuclear safety related. This equipment qualification process for the TXS COMPACT modules is described in Section 4.2 to Section 4.9 of this report. It is based on the Generic test specification for TXS [77].

The qualification was performed using the type testing method with additional analysis. The TXS COMPACT Qualification plan [78] describes the process for equipment qualification using type testing and additional analyses in more detail.

The utilized type test samples were manufactured according to the module-specific manufacturer data package and, in accordance with TXS processes, an RMD (Register of Documents) and REMD (Register of Extended Documents) are available for each TXS COMPACT module in the Framatome Product Lifecycle Management Data tool.

The module-specific RMD is the baseline for the type test samples and qualification of modules.

Based on the test specification for supplementary U.S. testing [160], the following test cases have been performed:

T_EMC-ImmunityToElectrostaticDischarges_EPRI**Test objective**

Immunity of TXS COMPACT equipment against electrostatic discharge.

For detailed information refer to: IEC 61000-4-2:2008.

Step**Action****Result*****T_EMC-ImmunityToPowerMagneticFields_EPRI*****Test objective**

Immunity of TXS COMPACT equipment against interference caused by power-frequency magnetic fields on the enclosure port.

For detailed information refer to: IEC 61000-4-8:2009.

Step**Action****Result**

T_EMCImmunityToImpulseMagneticFields_EPRI**Test objective**

Immunity of TXS COMPACT equipment against interference caused by impulse magnetic fields on the enclosure port.
For detailed information refer to: IEC 61000-4-9:2016.

Step**Action****Result*****T_EMCImmunityToDampedOscillatoryMagneticFields_EPRI*****Test objective**

Immunity of TXS COMPACT equipment against interference caused by damped oscillatory magnetic fields on the enclosure port.
For detailed information refer to: IEC 61000-4-10:2016.

Step**Action****Result**

The result of supplementary EMC testing is documented in the supplementary EMC Test Report [164].

<i>T_Climatic-OperationEnvironmentalWithstandSpecificRequirements_EPRI</i>		
Test objective		Suitability of TXS COMPACT equipment installed in a TXS chassis (or similar) during operation in high and low temperature with high humidity environment. For detailed definition of environmental test parameters and tolerances refer to: EPRI TR 107330:1996, Section 4.3.6.3, Table 5-1, Figure 4-4.
Step	Action	Result

Figure 4-12

**Cycle Profile of Temperature and Humidity Change Test T_Climatic-
OperationEnvironmentalWithstandSpecificRequirements_EPRI**

<i>T_Seismic_Operation_EPRI</i>		
Test objective	Resistance of TXS COMPACT equipment against seismic loads during abnormal operation (e.g. caused by earthquake). For detailed information refer to: IEC 60068-2-57:2013 Test Ff. Note: EUT in mounting position within chassis.	
Step	Action	Result

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5.0 TXS COMPACT PLATFORM COMMUNICATIONS

TXS COMPACT is part of a flexible and modular safety Instrumentation and Control (I&C) system platform. Safety I&C systems which fulfill the requirements imposed by the structure of an NPP's safety systems can be built using TXS platform components. This section shows the architecture of a typical TXS-COMPACT-based I&C system and the architecture of such a system's primary building blocks:

- TXS-COMPACT hardware/configware, the TXS COMPACT application.

An example of TXS-based I&C system architecture is shown in Figure 5-1. The main parts of this architecture are:

- APU: Automation Unit acting as Acquisition and Processing Unit.
- ALU: Automation Unit acting as Actuator Logic Unit.
- MI: Automation Unit acting as Monitoring Interface.
- SU: Service Unit for service, diagnostics, and maintenance.

Additional TXS platform building blocks available, but not shown in the simplified example architecture, are the following:

- Priority modules.
- Hardware (HW) voting modules.
- QDS: Qualified Display System.
- GW: Gateway.
- Data diodes (permanent or temporary unidirectional communication).
- PICS: Process Information and Control System.
- Control room panels with analog/binary indicators and push button controls.

Possible system architecture supported by the TXS system platform and the main design features are presented below. I&C systems with high availability requirements (single failure criterion even when one redundant division is in maintenance) require deployment of three or four redundant divisions. This is the typical architecture of Reactor Protection Systems (RPSs) or an Engineered Safety Features Actuation System. Figure 5-1 shows possible architecture with four independent divisions, physically and electrically separated from each other. Automation Units are the core parts of a TXS-based I&C system. They implement application functions and perform the actual signal processing. The system consists of two processing lines, APUs and ALUs. The APUs and ALUs are all AUs with dedicated hardware configuration and engineered applications to perform their respective tasks.

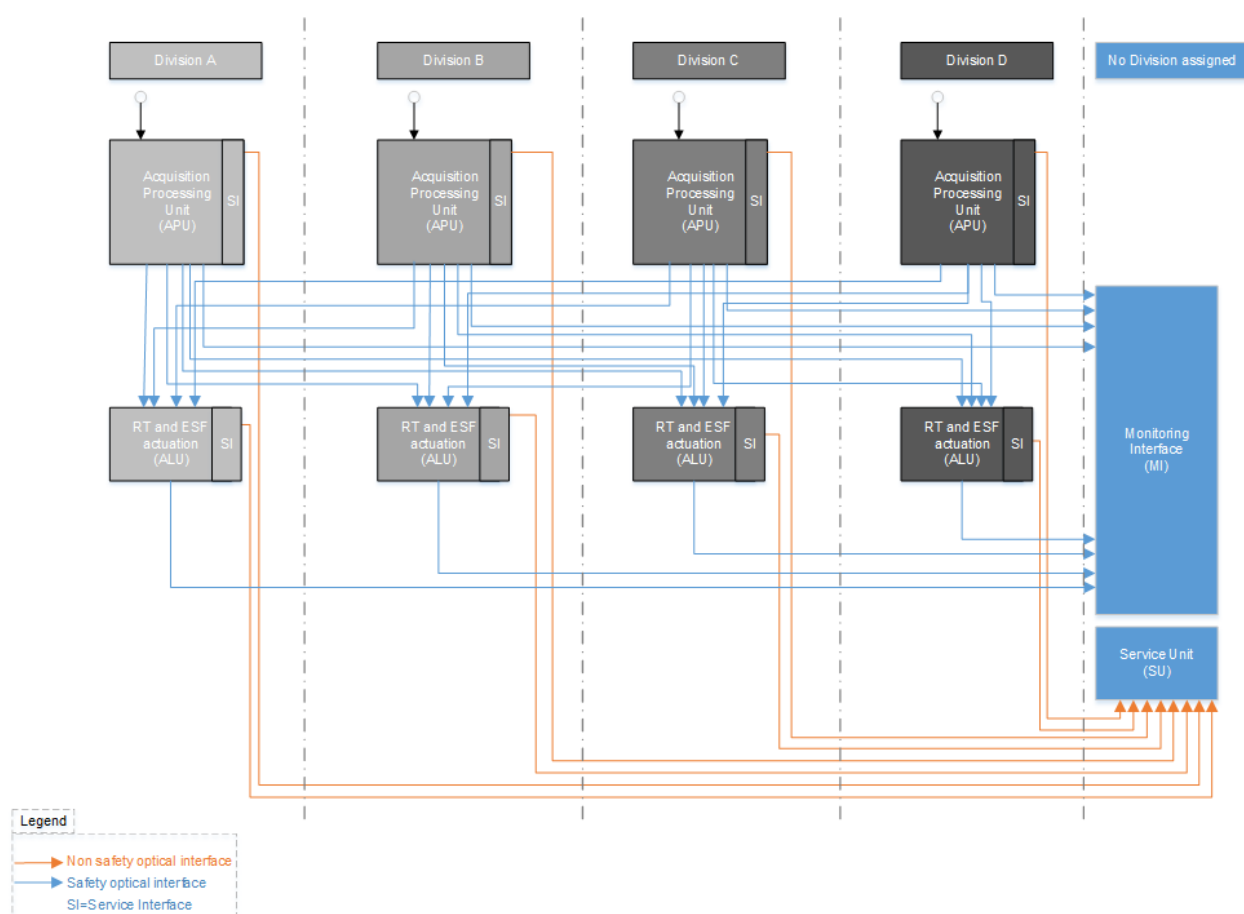
Four independent Automation Units (APU1...APU4) are responsible for data acquisition and function processing. They acquire signals from the process sensors to validate, preprocess, and filter them. Output signals of the acquisition and processing AUs (APU1...APU4) are distributed via fiber-optic cables to the four actuator AUs (ALU1...ALU4). Each ALU validates signals from the upstream level (for example, by 2-out-of-4 voting on binary signals) and actuates output signals according to engineered I&C function. Before triggering actuators, output signals may pass priority control devices or may be subject to hardware voting devices (neither shown in Figure 5-1). Signals also may be used in trip breakers. These devices protect against single failures and spurious actuation. When a failure is detected, AUs mark all affected signals with the ERROR attribute. Values of such signals are excluded from any subsequent use. This effectively confines the propagation of failure effects within the I&C system. AUs (APUs and ALUs) operate independently from each other without being affected by failure of communication links or other AUs.

Figure 5-1 shows an MI (Monitoring Interface) linked to other AUs via fiber-optic communication lines. The MI may be used as an interface to the control room for alarms and signal indicator. MIs are built using the same qualified components as other AUs.

Service Units (SUs) for maintenance are connected via a dedicated network to each AU. Non-interaction is ensured by the SMDF1. Details regarding how electrical and functional non-interaction is made certain are described in Section 6.2.1.

Third-party systems, such as the process information and control system (PICS), are connected to the TXS-based I&C system via a gateway (GW) for protocol conversion.

Figure 5-1
Recommended Architecture for a TXS COMPACT-based I&C System



5.1 *TXS COMPACT Intra-Divisional / Inter-Divisional Safety-to-Safety Communication*

Communication within network architecture (intra-Divisional or inter-Divisional safety-to-safety communication) is operated through the PM1 (via front optical fiber interface implementing Modbus protocol) or a TXS COMPACT Gateway Module (GWF1) (via Ethernet port for connection to a TXS-Ethernet network).

The same communication hardware and method are used for both intra- and inter-divisional safety-to-safety communication. Safety communication between different Automation Units is based on principles presented in Table 5-1:

Table 5-1
Safety Communication Principles

5.1.1 Communication between AU and Equipment over TXS-Ethernet Network

When the AU receives a new message on the GWF1 module (for communication between AU and another equipment over TXS-Ethernet network, such as a QDS unit), the GWF1 module performs the following checks:

- Appropriate frequency for message reception: the expected reception period Δt for each network message can be calculated based on information provided during system design. The receiving AU measures actual duration between reception of two consecutive network messages. In case this duration exceeds $2x\Delta t$ (including when no new message is received at all), then the receiving AU sets the ERROR attribute for each signal belonging to the faulty network message so the application program can detect the issue and react appropriately.
- Integrity of the network message: this is monitored by means of CRC, which is used to protect the message from bit errors. [

] The sending unit calculates the

CRC of all bytes directly following the CRC field (i.e., checksum over the status-byte of the sending unit and the version-byte of the payload data, and the payload data itself). Then the receiving unit calculates the same CRC and ignores all messages whose calculated CRC does not match the received CRC.

- Message ID (sender identification) and Sequence numbers (“age monitoring”): I&C signals are combined into one network message. This network message is then split into one or more packets which fit into the Maximum Transmission Unit of the underlying physical transport.
 - ◆ The message ID is part of the packet header content and is used to identify a stream of messages. Messages with the same ID share the same sender, receiver, length, and layout of its content. Messages are sent cyclically with changing sequence numbers. Verification of message ID ensures the message is from the expected sender.

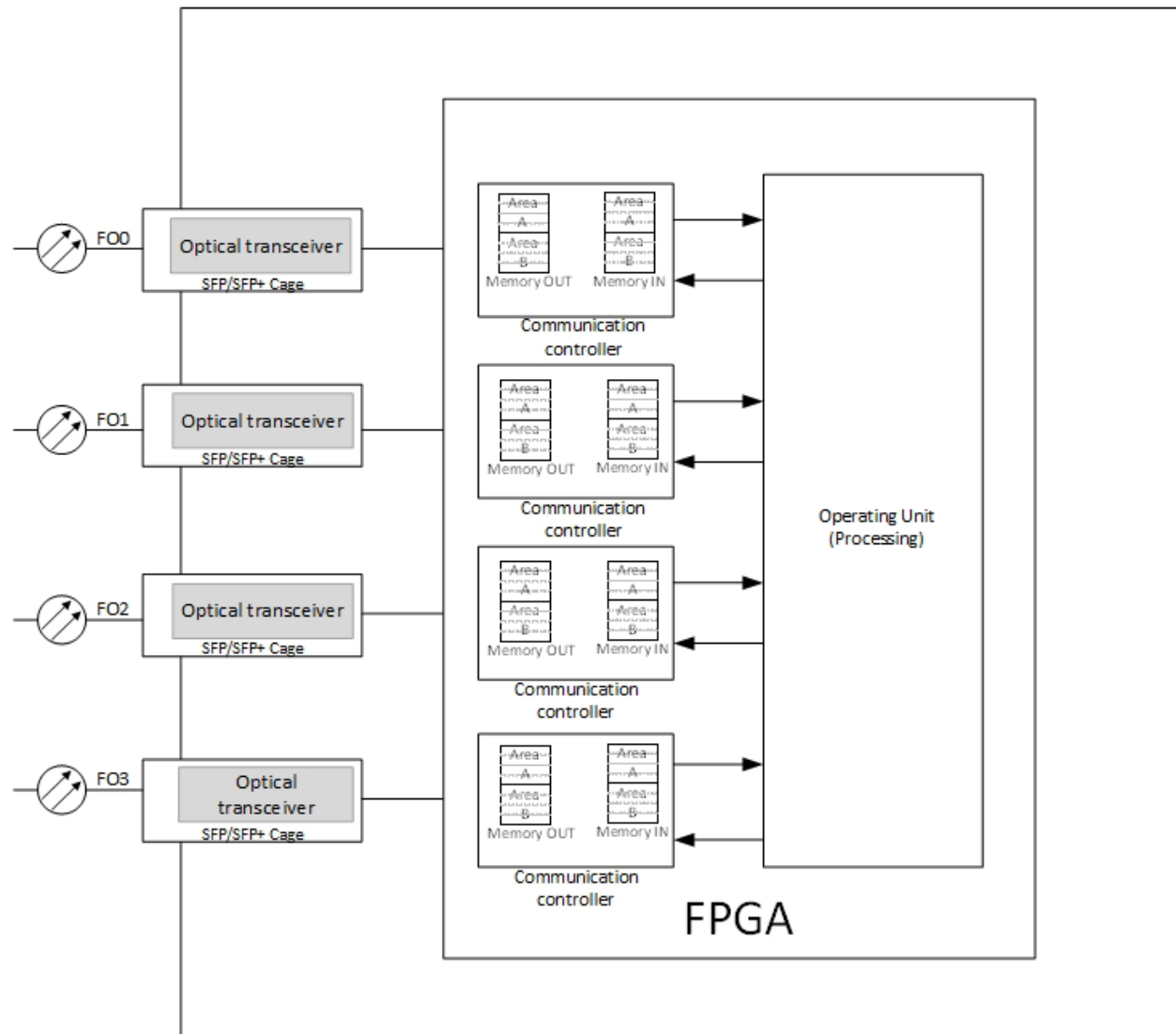
- ◆ The sequence number is part of the packet header content and used to identify all packets belonging to the same message instance. The sequence number is incremented each time a new message is issued. Verification of the sequence number field ensures that a new message has been received.

The main PM1 cyclically streams status and diagnosis information of the Automation Unit to the SMDF1. Then the Service Unit computer, when connected to Automation Units, receives this information for reporting. Details are provided in Sections 3.2.2.2 and 3.2.2.3.

5.1.2 Communication between AUs

Optical fiber memory implementation of the PM1 is presented in Figure 5-2.

Figure 5-2
PM1 Optical Fiber Memory Implementation



For communication between AUs, the receiver PM1 browses and checks the message fields and processes it if the content received in:

- The address field is the one expected.
- The function code field is authorized in the interface.
- The frame number field is the one expected.

- The data size field respects the static data size expected according to the function code received.
- The CRC field is correct (ensuring consistency of the message).

For communication between AUs and equipment over TXS-Ethernet network, the main PM1 cyclically streams status and diagnosis information of the Automation Unit to the SMDF1 for reporting to the connected Service Unit computer. Details are provided in Sections 3.2.2.2 and 3.2.2.3.

Each AU_{Send} (= sending AU) sends, after each cyclic operation (during the acquisition step), both a word message (containing analog and binary group data) and a binary message (containing binary data) to the AU_{Rec} with no precondition. The AU_{Rec} receives and stores all messages in buffers. Each buffer has two portions, each capable of storing one message, and can be locked (write-protected) independently.

When the AU starts, status of the previous messages is meaningless. Therefore, these messages are ignored and the next valid message will be used once received. In the meantime, corresponding signals have their ERROR attribute set.

During the acquisition step, both buffers are unlocked. The OPU checks each incoming message and replaces the oldest message present in the message buffer. At the beginning of the computing cycle, the buffer with the latest complete message is selected as the locked buffer. The message in the locked buffer is used for the application program during the computing cycle.

During the computing cycle, the application program uses information from the locked buffer for any computation during this cycle. The Operating Unit (OPU) checks each incoming message and stores the message in the unlocked buffer. This is performed each time a new message arrives.

Figure 5-3
PM1 Module Buffer Management



Buffer overflow can be excluded because the OPU empties the buffer and stores the message in the unlocked buffer. During execution of the application program, one buffer is locked and cannot be overwritten. The locked message buffer is used by the application program. Two message buffers are needed to avoid any loss of messages, because at least one buffer is not locked.

5.2 *TXS COMPACT Safety-to-Non-Safety Communication*

TXS COMPACT physically segregates safety and non-safety communications; specifically, non-safety communications use a dedicated medium which is independent from the one used for safety-related communications.

Within a TXS COMPACT-based system, safety-to-non-safety communication can occur for two distinct purposes:

- To send signal and diagnosis information to another non-safety I&C system (like a plant computer) or a non-safety supervision HMI.
- To send monitoring and diagnosis information to the Service Unit, and to receive configuration data under certain circumstances.

Use of the first case is dependent on the requirements for each I&C system. The second case is implemented on every TXS COMPACT-based system to allow proper configuration and monitoring of the system.

5.2.1 Communication Between Automation Units and Other Non-Safety I&C Equipment and Supervision Systems

TXS COMPACT Automation Units can send process information (i.e., values of internal binary and analog signals) as well as diagnosis information (such as status and error flags) to external peers using the Modbus Transmission Control Protocol (TCP) protocol. This communication channel is kept unidirectional (from safety to non-safety) under every operational condition after successful startup (i.e., regardless of Automation Unit mode).

Modbus TCP protocol is a widely used industrial communication protocol over TCP/IP. While the protocol supports bi-directional exchanges, TXS COMPACT only allows for exporting information out of the safety system and will not process any write queries for obvious safety integrity reasons.

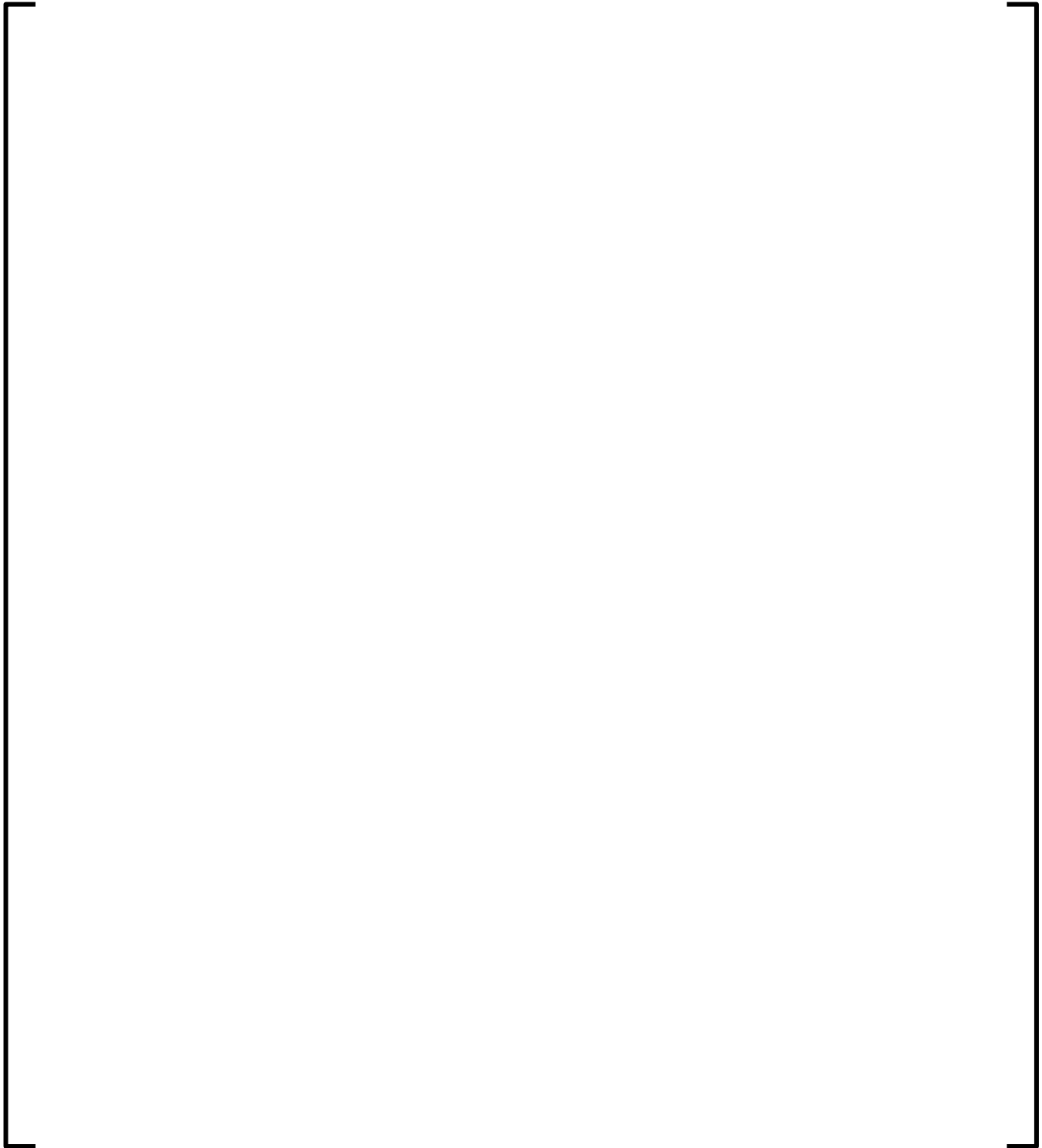
At every processing cycle, the main PM1 pushes the content of some of its internal memory blocks over the backplane bus, on a communication line, to the SMDF1.

The TCP/IP and Modbus TCP stacks run on a microprocessor on the SMDF1, which acts as a Modbus slave (TCP server). Data are fetched from a shared memory, which is constantly refreshed with the most recent available signal values read from the backplane bus by a Field-Programmable Gate Array (FPGA). The Modbus TCP server decodes the memory blocks by mapping Modbus addresses with displacements in the memory blocks using a configuration supplied by the Service Unit.

Communication is kept strictly unidirectional by combining the following protections:

- Software barrier: Modbus TCP servers do not incorporate any means to modify shared memory, only read commands are processed. Furthermore, the FPGA on the SMDF1 does not incorporate any means to send back data contained in shared memory to the backplane bus.
- Hardware barrier: when the Automation Unit operates in OPERATION mode, communication between the main PM1 and the SMDF1 is made physically unidirectional using an optocoupler, which is located on the PM1 in front of the bus controller. The line from the SMDF1 to the PM1 is then physically interrupted, making any download operation impossible.

Figure 5-4
Safety to Non-Safety Modbus TCP Communication



When the SYSTEM or OPE_PARAM release is activated, the optocoupler activates the communication line temporarily to enable maintenance of the unit, however this does not influence the Modbus TCP server.

It should be noted that connection is managed at Automation Unit level and not the global system. In case an external system needs to collect data distributed over multiple Automation Units, the following solutions are possible:

- Open several connections, one to each Automation Unit.
- Add an Automation Unit in charge of gathering data from the other Automation Units and redistributing to the external system(s).

The selected solution is dependent on design constraints of each specific I&C system.

5.2.2 Communication Between Automation Units and Service Unit

TXS COMPACT Automation Units always send process information (i.e., values of internal binary and analog signals) as well as diagnosis information (such as status and error flags) to the I&C system's Service Unit. They can receive configuration data from the Service Unit under certain circumstances. Consequently, this communication channel is either unidirectional (from safety to non-safety) or bidirectional, depending on the mode of the Automation Unit.

5.2.2.1 Communication from the Automation Units to the Service Unit

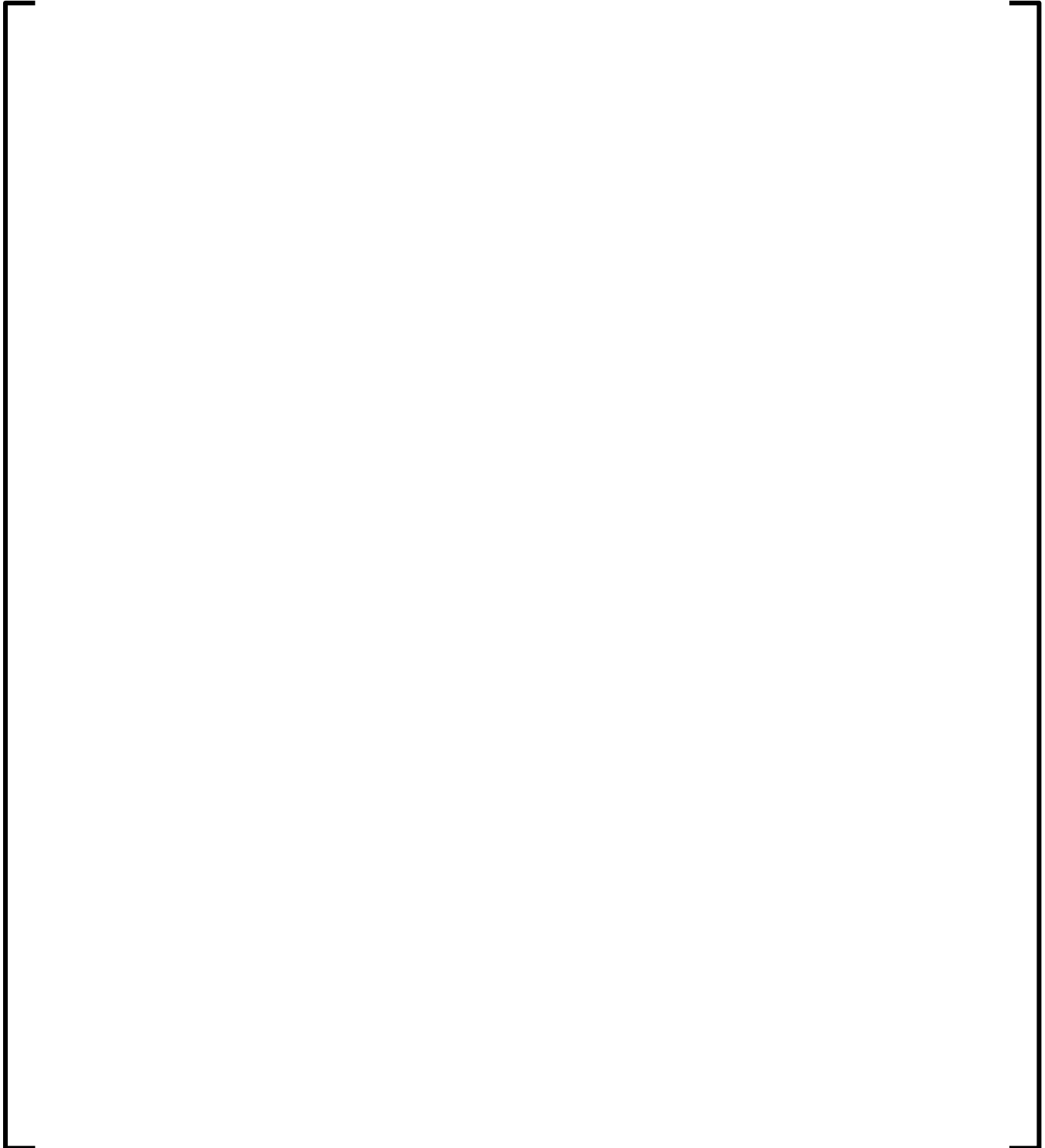
The Service Unit collects values of signals monitoring and diagnosis information permanently from all Automation Units connected to it. Such data is used to report the status of the system to the maintenance operator.

This communication channel is kept unidirectional (from safety to non-safety) under every operational condition after successful startup (i.e., regardless of the mode of the Automation Unit). Even when bidirectional communication is activated (see next section), this communication channel remains unidirectional.

The architecture is identical to the one described in the previous section for Modbus TCP for the main PM1 and SMDF1; data pulled from the OPU through this way is shared and used for both use cases.

At the Service Unit level, each tool first sends a registration query to the SU UDP Sender server on the SMDF1 (not shown on the figure below), which then establishes a permanent UDP/IP communication channel with the requesting tool. The SMDF1 only wraps the content of the memory block pulled from the shared memory to a UDP/IP datagram. Decoding the datagram to extract the values of individual signals is done on the Service Unit.

Figure 5-5
Safety to Non-Safety Service Unit Communication



5.2.2.2 Communication from the Service Unit to an Automation Unit

When the SYSTEM or OPE_PARAM release is activated on an Automation Unit, an optocoupler on the PM1 temporarily activates a communication line to enable maintenance of this Automation Unit.

As explained in the applicable sections, this communication channel can be used to parameterize the unit by changing configuration data, such as the application, parameters, etc.

The appropriate Service Unit tool first opens a secure communication channel with the SMDF1 using SSH protocol over TCP/IP. SSH ciphers the data so it cannot be tampered with. Then the tool can submit a configuration request, which consists of request code plus the content of the appropriate configuration files to be downloaded to the Automation Unit.

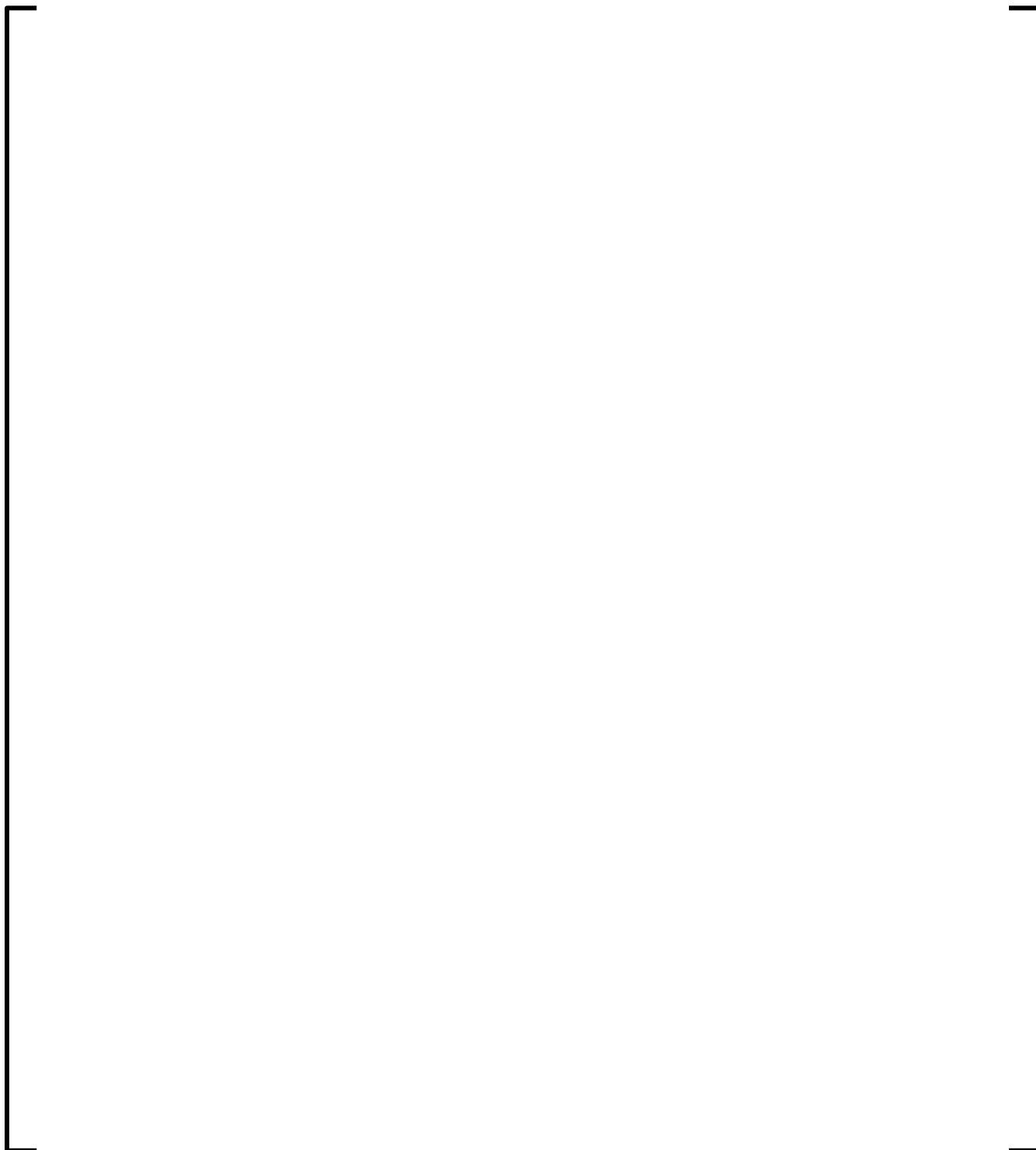
The SMDF1's Configuration Server receives the request. After confirming validity using a consistency check, it copies the query code and configuration files to the shared memory at the right location. This query is then cyclically processed by the HDL-Programmed Device (HPD) of the SMDF1 and transmitted to the PM1 through the backplane bus.

In case the optocoupler would be deactivated (i.e., circuit open due to absence of release), then the request would timeout at that stage.

When the request is properly received by the Service and Maintenance module on the main PM1, another local consistency check is carried out. If the files are correct, they are copied into the appropriate configuration memory zone.

In case the release is removed by the system, the maintenance operator, or Automation Unit reset, then this communication channel is immediately closed by the optocoupler and any ongoing request is discarded if not executed properly.

Figure 5-6
Non-Safety to Safety Service Unit Communication



5.3 *TXS COMPACT Multidivisional Control in Multiple Safety Divisions*

Section 3 of Interim Staff Guidance 04 (ISG-04) [18] provides guidance concerning multidivisional control, display, and maintenance; specifically concerns related to a central computer or operator workstation controlling safety-related equipment in multiple divisions simultaneously.

Further, guidance is provided for concerns related to a central computer or operator workstation that can be used to program, modify, and maintain safety-related equipment in multiple divisions simultaneously.

5.3.1 Multidivisional Control

Each TXS COMPACT Automation Unit can be connected to a central computer for permanent data display or recording using the Modbus TCP protocol. Details are provided in Section 5.2.1.

5.3.2 Multidivisional Maintenance



Any further requirements on bypass endorsed by ISG-04 are application and plant-specific and, therefore, outside the scope of this Topical Report.

6.0 TXS COMPACT LIFE CYCLE MANAGEMENT

As a Safety Instrumentation and Control (I&C) Platform, the development process of the TXS COMPACT platform follows guidelines from international standards IEC 60987 [31], IEC 61513 [27], IEC/IEEE 60780-323 [46], IEC 60880 [42], IEC 62138 [43], and IEC 62566 [28]; and national regulations RCC-E [51] and KTA [52].

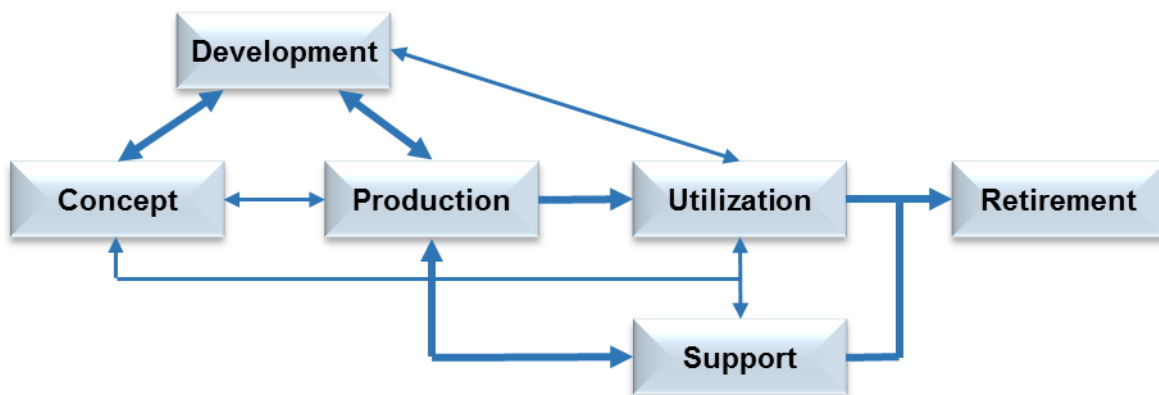
6.1 *TXS COMPACT Life Cycle Model*

The TXS COMPACT life cycle is regulated by [

] This work instruction describes the missions and tasks of the product manager and the procedure applied during the life cycle of Framatome I&C products. It provides overall guidance for product managers' interactions with the main contributors to product activities along the various stages of the product life cycle.

In accordance with ISO/IEC/IEEE 24748-1 [44], the following product life cycle model (Figure 6-1) is applied to the TXS COMPACT platform. The life cycle is organized as stages with interactions between them. Therefore, progress is explicitly gated and the criteria for each step of progress-moving to the next stage is explicit.

Figure 6-1
TXS COMPACT Life Cycle Model



The purpose of each stage of the TXS COMPACT platform life cycle is described as follows:

- The Concept stage is executed to assess the strategic business mission and perspective for a product and to develop preliminary product requirements, feasible architecture, and design solutions. [

]

- The Development stage is executed to design a product (respectively, product update) that meets stakeholder requirements and can be produced, tested, qualified, operated, and supported accordingly.
- The Production stage is executed to produce or manufacture the product, test it to meet acceptance criteria as needed, and to run product logistics needed to provide the product for utilization. [

]

- The Utilization stage is executed to operate the product in accordance with its potential capabilities and intended applications, to deliver services related to product operation, and to ensure continuing operational effectiveness.
- The Support stage is executed to provide logistics, maintenance, and support services that enable continuing the product's operation and related services throughout its scheduled service life.
- The Retirement Stage is executed to provide for removal of operational and support services related to the product. Planning for product retirement is performed and communicated early in the Support stage.

[

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Figure 6-2
Product Life Cycle Overview Including Corresponding Work
Instructions



6.2 *TXS COMPACT Development and Verification and Validation (V&V) Processes*

IEC 61513 standard [27] gives guidance applicable to I&C at the system level. It is supplemented by guidance at the hardware level (IEC 60987 [31]) and software (SW) level (IEC 60880 [42] and IEC 62138 [43]).

IEC 62566 [28] focuses on activities when HPDs are developed. It complements IEC 60987 [31], which deals with generic issues of hardware design of computer-based systems. It refers to IEC 60880 [42] when issues identical to those of software development are addressed.

As a safety Class 1 I&C platform, TXS COMPACT is being developed according to the requirements of IEC 61513 [27], IEC 60987 [31], IEC 62566 [28], and IEC 60880 [42].

6.2.1 TXS COMPACT Development

[

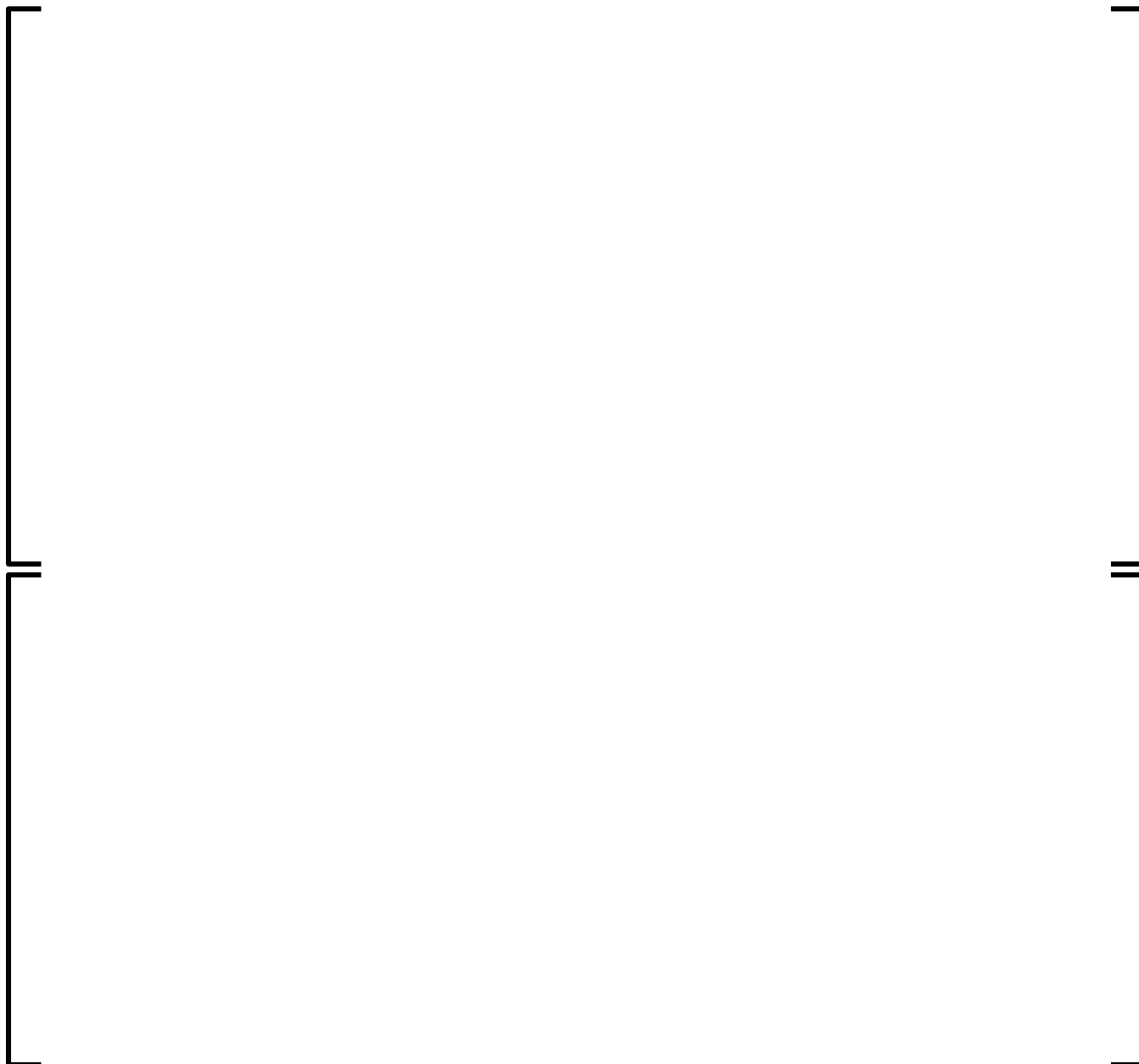
]

This work instruction provides a description of the development process which shall be applied for Safety I&C platform development and a manual for creation of a QA Plan for a development project.

This work instruction is compliant with IEC 61513 [27], IEC 60880 [42], IEC 62138 [43], IEC 60987 [31], and IEC 62566 [28] and considers requirements from ISO/IEC/IEEE 12207 [48].



Figure 6-3
Product Breakdown Structure



TXS COMPACT Products enable development of Class 1 safety I&C systems according to IEC standards and to system needs and functional requirements (except for SMDF1 software). Table 6-1 summarizes the IEC standards applied to each module during the development stage.

Table 6-1
Applicable Standards to TXS COMPACT AU Modules

		IEC 61513	IEC 60987 for Class 1	IEC 62566 for Class 1	Not Classified
PM1	System aspects	x			
	HW		x		
	HPD			x	
MPIOF1	System aspects	x			
	HW		x		
	HPD			x	
GWF1	System aspects	x			
	HW		x		
	HPD			x	
SMDF1	System aspects	x			
	HW		x		
	HPD				x (*)
	SW				x (*)
BPF1	System aspects	x			
	HW		x		

[

]

TXS COMPACT Engineering and Service Tools support design, generation, verification, validation, and operation of a TXS COMPACT-based safety-related I&C system. TXS COMPACT Engineering and Service Tools consist of software components

[

]

- Service Unit connected to TXS COMPACT-based system via a network to perform local diagnosis and service tasks.

- Engineering Unit used to develop TXS COMPACT-based systems.
- Testing Unit used to test TXS COMPACT-based systems.

The TXS COMPACT is developed under a V shape life cycle, which is an iterative process with respect to the following principle: each phase is terminated only if the preceding phases have been completed, and if its outputs were consistent with the inputs provided by these preceding activities.

Moreover, V&V is performed at each Level to ensure integrity of the V life cycle.

Figure 6-4
Development Life Cycle Overview Including Corresponding Work
Instructions



The V-process defined by the work instructions of Figure 6-4 is illustrated in Figure 6-5. Starting at the left side of the V are specifications, design, and implementation phases; followed by integration, testing, documentation, and qualification phases. [

]

Figure 6-5
TXS COMPACT Platform Development Process



6.2.1.1 Planning Phase

The TXS COMPACT platform Quality Assurance plan is established at an early stage of the development life cycle. It identifies the development organization, [] and defines the roles, responsibilities, and interactions within it. The TXS COMPACT platform Quality Assurance plan also presents planned activities (plans, specification, design, implementation, prototype, tests, and reviews) to accomplish the project goals and their dependencies.

The main outcomes of the planning phase are issuance of:

- QA plan: TXS COMPACT platform Quality Assurance plan [71] and TXS COMPACT Engineering and Service Tools Quality Assurance plan [72].
- V&V plan: TXS COMPACT platform V&V plan [73] and TXS COMPACT Engineering and Service Tools V&V plan [74].
- CCM plan: TXS COMPACT platform Configuration and Change Management plan (CCMP) [75] (applicable to hardware, software, and configware components).

These plans constitute quality references for the development process of the TXS COMPACT platform and the TXS COMPACT Engineering and Service Toolchain.

6.2.1.2 Requirements Phase

[

] This allows

refinement of specifications from System to Components according to the System Breakdown Structure.

The TXS COMPACT Requirements Engineering activity [] It includes identification and analysis of external interface requirements, functional requirements, performance requirements, and constraints, as well as quantitative and qualitative measures related to these requirements. These technical requirements are recorded in a requirements specification, which is the output of this process.

[

] This task aims at

enriching the definition of these modules by providing new requirements consistent with parent design decisions.

[

]

This phase is regulated by [] which describes how requirements shall be documented in a way that is understandable, traceable, unambiguous, and concise during the requirements analysis process.

6.2.1.2.1 Requirements Traceability



6.2.1.3 Design Phase

Similar to the Requirements phase, the Design phase is addressed [

] Thus, at each Level, a design activity is executed after the Requirement activity using outputs of the latter as inputs and establishing traceability between the requirements and design decisions. Design documents rely on drawings and text to clarify the design.

This phase is regulated by [] which describes how to document design decisions in an understandable, traceable, and concise way.

6.2.2 TXS COMPACT Verification and Validation

[

]

This work instruction specifies a common framework of V&V processes, activities, and tasks necessary for development of hardware and software components and system integration for a safety I&C platform. It also defines the necessary V&V tasks, required inputs, and required outputs for each development phase.

This work instruction is compliant with IEC 61513 [27] and RCC-E [51] for system, IEC 60880 [42] and IEC 62138 [43] for software, IEC 60987 [31] for hardware, and IEC 62566 [28] for configware. It follows the recommendations of IEEE 1012 [10].

The organization of the TXS COMPACT IV&V team ensures the required technical and managerial level of independence for a safety Class 1 I&C platform performing category A functions.



[illegible]

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1

[illegible]

[

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Table 6-4
TXS COMPACT V&V Activities

Sections 6.2.2.1 and 6.2.2.2 provide a detailed discussion on V&V of the HPD and the qualification strategy of TXS COMPACT Engineering and Service tools.

6.2.2.1 TXS COMPACT HPD Validation Towards IEC 62566 Standard

V&V activities are performed following a bottom-up approach for each module developed within HPD development. Thus, a qualification strategy of the HPD of the TXS COMPACT modules is established and documented [] In accordance with recommendations from IEC 62566 standard [28], methods and procedures are implemented for TXS COMPACT V&V:



[

] This

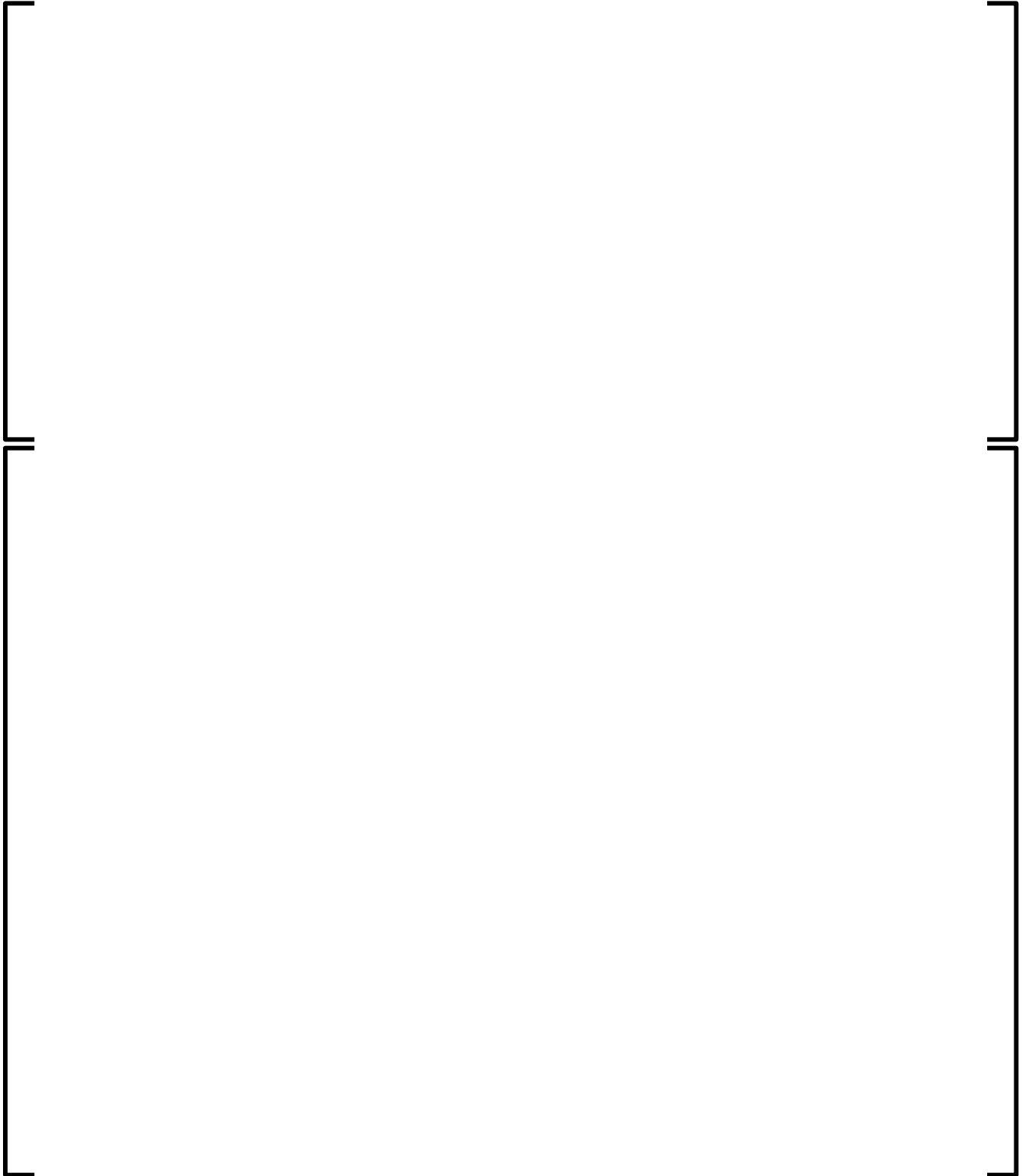
demonstrates that provisions implemented by the process or component in the frame of TXS COMPACT platform development fulfill IEC 62566 [28] requirements.

6.2.2.2 TXS COMPACT Engineering and Service Tools and Commercial Off-the-Shelf (COTS) Tools Qualification

6.2.2.2.1 Tools Qualification Approach



Figure 6-6
Overview of Tools Assessment and Qualification Process



6.2.2.2.2 Qualification of TXS COMPACT Engineering and Service Tools

A generic qualification approach is applied to TXS COMPACT Engineering and Service Tools. It relies on two pillars:

Table 6-5
Developed Tool Type and Assignment of Corresponding Tool
Development Level

6.2.2.2.3 Assessment of COTS Tools

COTS tools are used to support development and V&V of the TXS COMPACT platform.

[

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Table 6-6
COTS Tool Type and Assignment of Corresponding Tool
Assessment Level

[

]

[COTS tools are controlled under configuration management and are stored in the Framatome Information Technology (IT) infrastructure software configuration management system.

6.3 TXS COMPACT Production Stage

In the Manufacture Phase, standard platform modules and assemblies are fabricated and tested per approved design drawings and procedures to produce fully functional hardware assemblies. Standard platform modules and assemblies are then combined to form the completed system hardware capable of achieving the functions specified in application-specific system requirements. [

]

7.0 TXS COMPACT RELIABILITY AND FMEA

As part of the development process for TXS modules, hardware is analyzed for expected failure rates of components. This analysis is based on [] and includes stress factors such as operating temperature and electrical conditions. Results are documented []

[] This report is used together with the module's user manual and other technical reports as basis for a Failure Mode and Effects Analysis (FMEA), according to IEC 60812 [45], restricted to the module level.

In addition to the "calculation of failure rates," the FMEA considers functional aspects, including self-monitoring features and methods for failure detection by engineered monitoring. The FMEA provides data related to detailed failure effects. []

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[

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The reliability analysis is performed for each module. []

]

The FMEA is performed for each module and documented []

]

8.0 TXS COMPACT QUALITY ASSURANCE (QA)

8.1 *Regulatory Basis*

NUREG 0800, Standard Review Plan, 17.5 “Quality Assurance Program Description – Design Certification, Early Site Permit and New License Applicants” describes requirements associated with Quality Assurance Program Descriptions submitted by applicants for design certification (DC), combined license (COL), early site permit (ESP), construction permit (CP), and operating license (OL).

For the TXS COMPACT Platform Topical Report, design engineering was completed by the Framatome SAS organization in accordance with applicable European Standards. The decision to apply for the NRC approval to use the TXS COMPACT Platform for safety-related applications in the U.S. nuclear power plants was made after the design was fully complete.

The TXS COMPACT Platform Topical Report is being submitted by Framatome Inc. in accordance with the Framatome Inc. Quality Assurance Program [69].

8.2 *Framatome Quality Assurance (QA) Program*

Framatome Inc. Quality Assurance Program applicability is based on those elements of the program applicable to product development in Framatome SAS. TXS COMPACT Platform components will be provided by Framatome SAS to Framatome Inc. as basic components designed and manufactured under the applicable elements of the Framatome Integrated Management System Manual [54]. Therefore, regarding the TXS COMPACT Platform and implementing procedures, as defined in the TXS COMPACT Quality Management Plan [72], Framatome SAS is considered a “supplier” to Framatome Inc. subject to the controls imposed under the Framatome Inc. Quality Assurance Program. Applicable elements of the Framatome Inc. Quality Assurance Program are as follows:

- “Quality Assurance Program” – 10 CFR Part 50, Appendix B, Criterion II.

- “Control of Purchased Materials, Items, and Services” – 10 CFR Part 50, Appendix B, Criterion VII.
- “Control of Nonconforming Items” – 10 CFR Part 50, Appendix B, Criterion XV.
- “Corrective Action” – 10 CFR Part 50, Appendix B, Criterion XVI.
- “Audits” – 10 CFR Part 50, Appendix B, Criterion XVIII.

The following elements of the Framatome Inc. Quality Assurance Program are applicable to Framatome Inc.’s procurement of TXS COMPACT platform basic components:

- “Design Control” – 10 CFR Part 50, Appendix B, Criterion III.
- “Procurement Document Control” – 10 CFR Part 50, Appendix B, Criterion IV.
- “Quality Assurance Records” – 10 CFR Part 50, Appendix B, Criterion XVII.

8.2.1 Quality Assurance Program

The Framatome Inc. Quality Assurance Program complies with Criterion II of 10 CFR Part 50, Appendix B, Quality Assurance Program, and Requirement 2, Quality Assurance Program, ASME NQA-1 2015. This section defines the Quality Assurance Program implemented for nuclear safety-related activities.

The Quality Assurance Program establishes prerequisites for achieving quality, such as the need for specialized equipment and skills; use of suitable administrative, process, and environmental controls; training and indoctrination of personnel performing activities affecting quality; and the need for verification of quality by reviews, inspection, examination, and test.

The Framatome Inc. QA Program is established through written policies, procedures, and instructions. Indoctrination and training are provided for personnel performing quality-related activities.

Control of activities affecting quality is achieved through supplier qualification audits, source surveillance, and receipt inspection, performed by trained and qualified personnel in accordance with the Framatome Inc. QA Program.

8.2.2 Control of Purchased Materials, Items, and Services

The Framatome Inc. Quality Assurance Program, Section 7, governs control of purchased safety-related materials, items, and services including source evaluation and selection, source inspection, and receiving inspection in accordance with regulatory and contract requirements. This Section complies with Section VII of 10 CFR Part 50, Appendix B, "Control of Purchased Material, Equipment, and Services" and Requirement 7, "Control of Purchased Items and Services," ASME NQA-1 2015.

Control of purchased safety-related materials, items, and services is in accordance with written procedures and instructions. The Quality and Performance organization audits the capability of suppliers of safety-related materials, items, and services and maintains a list of approved suppliers.

Acceptability of suppliers of safety-related materials, items, or services are based on the following items:

- An evaluation of their QA Program to 10 CFR Part 50, Appendix B and ASME NQA-1 to determine the capability to supply materials, items, or services meeting procurement document requirements.
- A survey/audit of the supplier's facility.

Framatome Inc. Quality Assurance Program controls, such as supplier audits, source surveillance, receipt inspection, and testing, are relied upon for product acceptance. These activities ensure procured items satisfy procurement document requirements and provide verification of the effectiveness of supplier quality controls.

8.2.3 Control of Nonconforming Items

The Framatome Inc. Quality Assurance Program, Section 15, “Control of Nonconforming Items” applies to safety-related materials and items and their supporting documentation. It addresses characteristics, documentation, or procedure deficiencies that render an item or activity unacceptable or indeterminate. This Section complies with Criterion XV of 10 CFR Part 50, Appendix B, “Control of Nonconforming Items” and Requirement 15, “Control of Nonconforming Items” of ASME NQA-1 2015 and all earlier editions endorsed by the NRC.

Procedures are established to control documentation and items (materials, parts, and components) that do not conform to specified requirements to prevent their inadvertent use or installation. Specific requirements include procedures for controlling identification, documentation, and segregation of nonconforming items pending notification of affected individuals and/or organizations, review of nonconformance, and approval of disposition. Nonconforming items are reviewed and deemed accepted, rejected, or reworked in accordance with documented procedures.

Personnel performing evaluations to determine a disposition have demonstrated competence in the specific area they are evaluating, have an adequate understanding of the requirements, and have access to pertinent background information.

8.2.4 Corrective Action

Framatome Inc. Quality Assurance Program, Section 16, defines the elements of the corrective action generation, implementation, and verification system for safety-related items or services. This Section complies with Criterion XVI, “Corrective Action,” and Requirement 16, “Corrective Action,” of ASME NQA-1 2015.

Procedures are established to ensure prompt identification and correction of conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances during design, procurement, fabrication, inspection, and testing of items. These procedures require the cognizant function ensures that:

- Nonconformances and failures are evaluated to determine the need for corrective action and that such action is taken as necessary.
- Cause of the nonconformance or failure is determined, and action is taken to preclude recurrence.
- Appropriate levels of management are informed of significant conditions adverse to quality, cause of the conditions, corrective action taken, and preventive action taken to preclude recurrence.
- Follow-up is conducted to verify proper implementation of both corrective and preventive actions and to close corrective action documentation.

Condition Reports are generated and managed as described in Section 15 of this Quality Assurance Program. Significance Level 1 and 2 Condition Reports are analyzed by the Quality and Performance organization to determine whether more extensive actions are required in addition to corrective action applied to the specific nonconformance.

In case of significant conditions adverse to quality, measures are taken that ensure the cause of the condition is determined and corrective action is taken to preclude repetition. Identification of the significant condition adverse to quality, cause of the condition, and corrective action taken are documented and reported to the appropriate levels of management.

8.2.5 Audits

Framatome Inc. Quality Assurance Program, Section 18 describes the elements of quality auditing. This Section complies with Criterion XVIII, “Audits,” and Requirement 18, “Audits,” of ASME NQA-1 2015. In addition, personnel who perform audits are qualified to the requirements of ANSI N45.2.23.

Procedures are established to provide program definition, as well as direction, for performance of audits and supporting activities. Audits are performed in accordance with pre-established written procedures or checklists and conducted by personnel who have no direct responsibilities in the areas being audited.

Audits for suppliers of safety-related items and services are performed to ensure only qualified suppliers are used. Qualified suppliers are audited on a triennial basis. Framatome may utilize audits conducted by outside organizations for supplier qualification when appropriate. Industry programs, such as those applied by ASME, Nuclear Industry Assessment Committee (NIAC), or other established utility groups, are used as input or the basis for supplier qualification when appropriate.

Additional evaluations of supplier performance are performed periodically or when issues warrant additional oversight.

8.3 *Audit of the TXS COMPACT Platform*

The Framatome Inc. QA organization performed an independent audit of the Quality Assurance Program and TXS COMPACT Platform activities in the following locations:

- Erlangen, GmbH Hardware Verification September 9-19, 2023
- Paris, France Hardware, HDL, and Software Tools October 9-17, 2023
- Lyon, France HDL Design October 18-19, 2023

The audit purpose was to evaluate program compliance and effectiveness of activities supporting the TXS COMPACT Platform project implementation and lifecycle processes, as described in Section 6.0 of this Topical Report, in accordance with the Framatome Integrated Management System, 10 CFR Part 50 Appendix B, and applicable references in Erlangen, Paris, and Lyon in support of submittal of the TXS COMPACT Platform Topical Report.

The audit concluded that *“Framatome Inc. has completed a 10CFR50, App. B assessment and documented issues as appropriate in the applicable Corrective Action Program. These issues will be managed in accordance with the Framatome Inc. Quality Assurance Program through resolution.”*

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8.4 TXS COMPACT Platform Commercial Grade Dedication





9.0 TXS COMPACT SECURITY

9.1 *TXS COMPACT Security Overview*

TXS COMPACT considers cyber-security a main objective in addition to safe behavior. A secure state is always achieved through a multi-layer approach:

- Precautions taken to limit the risk of security threats caused by individuals within the Framatome organization (Section 9.2).
- Precautions taken during development and life cycle of the TXS COMPACT platform (Section 9.3).
- Active and passive security features included in the software tool chain to secure the design and testing phases of the Instrumentation and Control (I&C) system (Section 9.4).
- Active and passive security features embedded in the automation platform to further increase the level of security of the system in the test bay and on site (Section 9.4).

Security of the development environment is placed under the responsibility of a Security Officer.

When a specific I&C system is being engineered, a system security plan is created, which summarizes the provisions related to security of the system, responsibilities of the parties, and identifies potential security concerns and vulnerabilities along all phases of the system's life cycle which may not be covered by the organization or the platform generic features. If such concerns or vulnerabilities are identified, the system security plan defines mitigation measures (for instance, by requiring redundancies or network isolation devices be used). Details of such measures are dependent on the design of each specific I&C system.

9.2 TXS COMPACT People Check

Security procedures are applied to make sure that individuals working for Framatome on nuclear-related activities are following country-related applicable laws and regulations.

These security checks are performed both for individuals who are Framatome employees and individuals who are employees of other companies working under a flowdown of Framatome's quality program.

Checks are performed for people working on generic TXS COMPACT platform development activities, for people working on specific I&C projects, and more generally for any individual involved in nuclear-related activities (including support functions).

Legal requirements related to background checks vary, depending on the location of individuals:



9.3 *TXS COMPACT Life Cycle Security*

This section describes provisions taken to ensure security of design, development, testing, and manufacturing of the TXS COMPACT safety I&C platform itself, which is the generic product provided to system designers to implement a specific I&C system. Application specific requirements are not considered here.

DI&C-ISG-06 [21] provides guidance related to requirements applicable to the Secured Development Environment (SDE). These requirements are satisfied by the TXS COMPACT SDE.

Both technical and process-based measures are applied to security of the SDE and hence of the platform life cycle.

The TXS COMPACT Verification and Validation (V&V) Plan [73] and TXS COMPACT Engineering and Service Tools V&V Plan [74] require that extensive verification and validation activities are performed:

While all these measures already significantly reduce the risk of having unwanted or unattended modifications being undetected in the product, additional technical measures are in place to further minimize security risks.

Development and validation activities of the safety I&C platform life cycle are carried out using two separate environments:

- Activities which do not require specific Information Technology (IT) items of equipment, environment, and infrastructures, such as project management activities and authoring and storage of platform technical documentation (general design of the platform, recording and documentation of requirements and design decisions, preparation of test cases, elaboration of manufacturing documentation, and user manuals). These activities are carried out using the Framatome IT environment.
- Activities which do require specific IT items of equipment, infrastructures, tools, or technical environments, such as detailed design and implementation and execution of test cases. These activities are carried out using the TXS Development Environment.

Both environments together constitute the Secured Development Environment for the TXS COMPACT platform.

9.3.1 Activities Carried Out on the Framatome IT Environment

These activities are those which require office automation, requirements management, project management, and communication software. Such features are provided through the Framatome corporate IT infrastructure, which is documented and managed by Framatome's IT entities. The corresponding infrastructure, equipment, and procedures are shared amongst all Framatome activities (i.e., not limited to instrumentation and control). It is continuously maintained by Framatome corporate IT entities. Related documentation is generally confidential and stored in a secured location.

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The Framatome corporate IT environment focuses on integrity, confidentiality, and availability.

9.3.2 Activities Carried Out Using the TXS Development Environment

These activities lead to, amongst other results, creation of the binary assets of the platform:

- The generic bitstream files running on the hardware module's Field-Programmable Gate Arrays (FPGAs).
- The software tool's executable files.

[

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Controls and vulnerability analysis for the TXS Development network are documented in a Security Plan, which is under responsibility of the Security Officer.

The main focus of this dedicated environment is to guarantee the integrity of products being implemented or tested. Confidentiality and availability are considered.

9.4 *Security Attributes of the TXS COMPACT Platform*

TXS COMPACT platform has adopted a secure-by-design-type approach; the platform provides intrinsic characteristics and security features. These characteristics and features can then be coupled with more traditional perimeter-type protection (physical and logical) as part of a wider security strategy to achieve a security target defined for a given I&C system.

These features focus on ensuring the following security properties:

- Integrity of the bitstream and Application Program (configuration data), including application-changeable parameters: Automation Units always behave as engineered when the system was designed and tested; it is not possible to unintentionally alter this behavior.
- Integrity of communication between Automation Units and the Service Unit: It is not possible to tamper with configuration data (such as Application Program or Parameter Sets) when sent by the maintenance operator from the Service Unit to Automation Units.
- Integrity of communication between Automation Units: a destination Automation Unit has means to detect any modification of data that would have occurred after being sent by the source Automation Unit.

9.4.1 Integrity of Configuration Data, Including Update from Service Unit to Automation Units

As explained in previous sections, behavior of each module composing an Automation Unit is entirely defined by:

- System configware: the generic bitstream loaded into the FPGA chips on each module at manufacturing time.
- The Application Program created by I&C system engineers for each specific system using the platform's toolchain.

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The Application Program is created using the platform's toolchain. Workflow can be summarized by the following:

- System engineers use TXS Design Studio to author the application using diagrams; i.e., to create source data files.
- System engineers use the Data Management Toolkit (DMT) to store and manage versions of these source files.
- System engineers use the Application Generation Toolkit (AGT) to convert source files into binary files (the Application Program).
- The plant maintenance operator uses COMPACT Service Tools (CST) to load the application program onto Automation Units.

This can be repeated entirely or partially in case of iterations or findings during system testing.

Later, the plant maintenance operator can use CST to prepare and load an updated version of changeable parameters, for instance to update setpoints and tuning constants.

Security of this data flow is ensured by applying the following principles:

- The Automation Unit must authorize any change using releases.
- Principle of least privilege is applied everywhere by default.

In practice, the DMT server which hosts the source files plays a key role for security of the system. Although relying on industry-standard Git software, it implements the following additional security features:

Therefore, every single change to each data item can be traced to the author of the change and authenticated. Validity of signatures can be verified (audited) at any time.

Of course, intrinsic security features are efficient only when secrets that protect the execution environment are properly configured and managed over time. [

] it is the responsibility of the project team developing the specific I&C system to act appropriately with respect to their project's security plan, the platform's user manuals, and to incorporate good practices to preserve cryptographic secrets.

9.4.2 Integrity of Communication

TXS COMPACT allows for protection of network communication between Automation Units. As a reminder, such communication links are point-to-point optical fiber links using a proprietary safety-oriented protocol.

Exchanges can be protected using cryptographic signatures on both halves of the link. The feature can be activated during I&C system design in TXS Design Studio.



This allows I&C system engineers to design the way to appropriately react to such an alert specifically for each I&C system. Such reaction could typically be a combination of annunciation on the local panel or in the main control room, possibly combined with invalidation of selected signals or degradation of voting.

By combining message signing and use of monotone message counters, the platform can detect potential tampering of communication links; [

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[

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10.0 TXS COMPACT TRAINING

10.1 *TXS COMPACT Training of Development Personnel*

Framatome has a dedicated department for safety platform development (for instance, TXS Platform). [

]

The work instruction recommends defining the necessary roles for development and the trainings and education required to master each role.

In addition, regarding competent personnel, Framatome has a generic process at the company level which is documented in [

] One part of this management manual deals with human resources and assignment of personnel, which is a management responsibility. [

]



Management is also responsible for identifying individual training needs and to monitor participation in training sessions. A catalogue of training sessions is managed by Human Resources at the Framatome corporate level. Framatome entities also develop specific training sessions related to their activities. These training sessions are conducted in accordance with written procedures.

The effectiveness of training is measured through formal evaluation, supervision, and/or during the annual personal development assessment.

The files related to training and qualification of individuals are archived, protected, and maintained in accordance with implemented procedures.

10.2 TXS COMPACT Training of Application Personnel

All personnel assigned responsibilities for a TXS COMPACT platform-based project are informed of their responsibilities, [] All personnel assigned to the project are technically qualified in terms of formal education, specific product training, specific training on methods, engineering tools, quality procedures, and relevant professional experience.

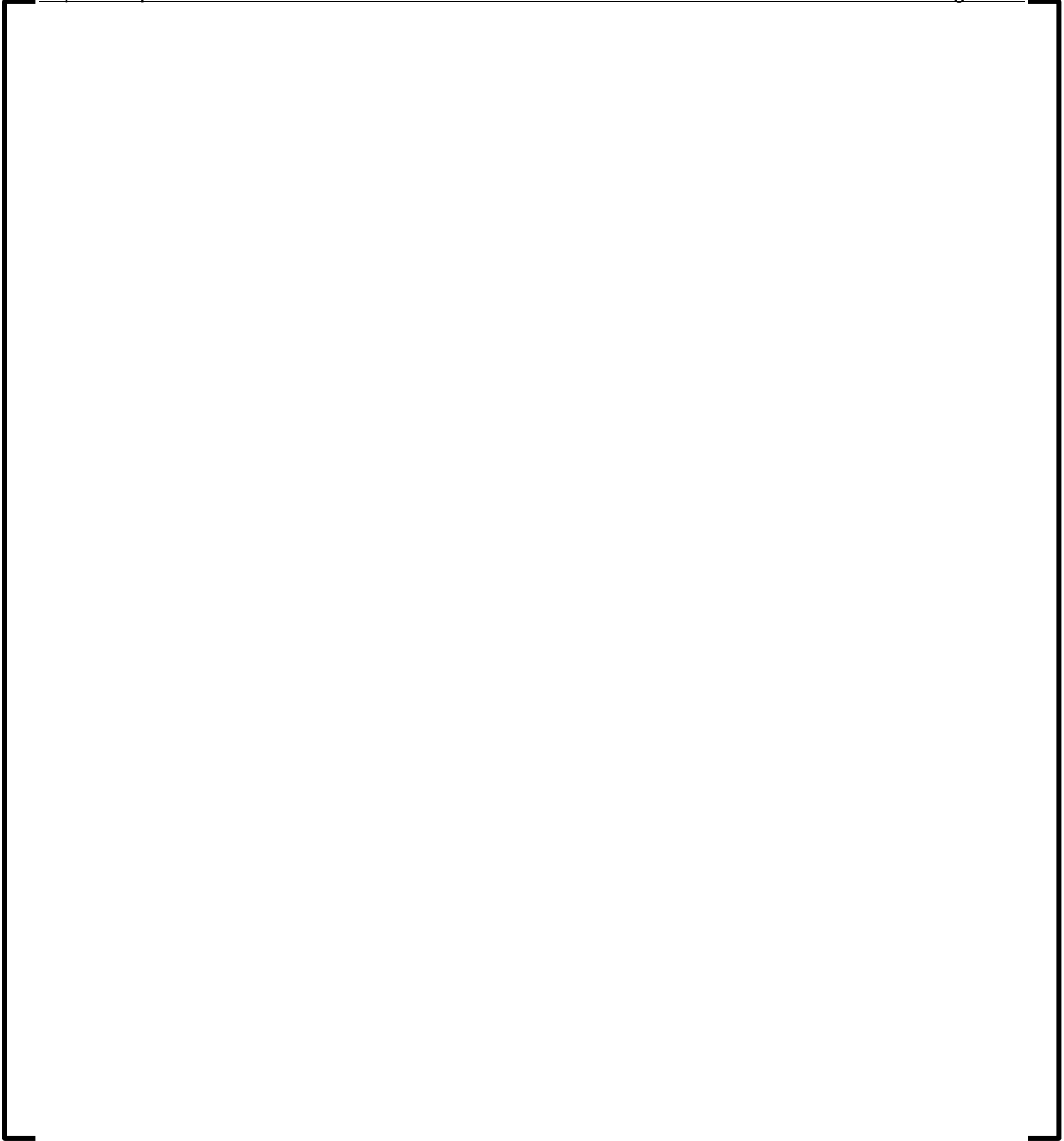
[

] This allows for enough resources to design and validate Safety systems in all situations, even in case of workload variation.

To follow this training, selected trainees have prerequisites in the domain of instrumentation and control, such as Engineer education or equivalent experience.

This training, organized over an intensive period, offers an important practical component that takes place after academic courses, so individuals can learn by doing.

Training content includes several modules as described below:



In addition to training, individuals learn about project organization, the different roles of engineers, and, more generally, the environment of project execution.

Trainers give instructions to execute all tasks of the engineering V cycle and follow the progress of engineering activities. They intervene whenever necessary to ensure good understanding and proper implementation of methods.

Continuous improvement principles based on trainees, trainers, and managers' surveys and feedback are implemented to improve the training program and ensure alignment with specific projects and customer needs.

Training records include training material, participant lists, feedback forms, and training results. Training records for each employee are maintained by the Human Resources organization. The training instructor is responsible for determining whether training objectives were met for each student.

Regular technical refresher training may be offered depending on experience needs and importance of the contribution to projects using the technology.

10.3 TXS COMPACT Training of Customer Personnel

Operation and Maintenance training is tailored to project specific requirements as detailed in the project specific management plan and the project specific training plan. Training depends on customer specific plans to operate and maintain the facility in a safe manner in all modes of operation as detailed in 10 CFR 50.120.

This required qualification of personnel authorized to operate equipment is ensured by general training for the TXS COMPACT platform and specific training for the provided safety I&C.

The project-specific training plan shall detail the customer requirement to identify the qualified facility personnel who will operate and maintain the TXS COMPACT platform. The plan shall include adequate time for the qualified instructor to prepare training materials based on completed and approved Project-Specific Operation and Maintenance Manuals. [

]

A training program is offered based on the TXS COMPACT standard training concept for safety I&C projects. [

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The Guidebook on Nuclear Power Plant Personnel Training and its Evaluation represents official IAEA guidance on training of NPP personnel using the systematic approach to training (SAT), and also provides information on SAT applications for training operating personnel, maintenance personnel, management, emergency preparedness, and instructors, and on project management to introduce SAT-based training.

SAT is a methodology which applies QA to training and thus assures NPP personnel competence. Use of SAT offers significant advantages over more conventional, curricula-driven training in terms of consistency, efficiency, and management control. With a systematic approach to training, competence requirements for all jobs in an NPP can be established and met. Furthermore, with SAT-based training, it can be demonstrated that all required competencies have been attained.

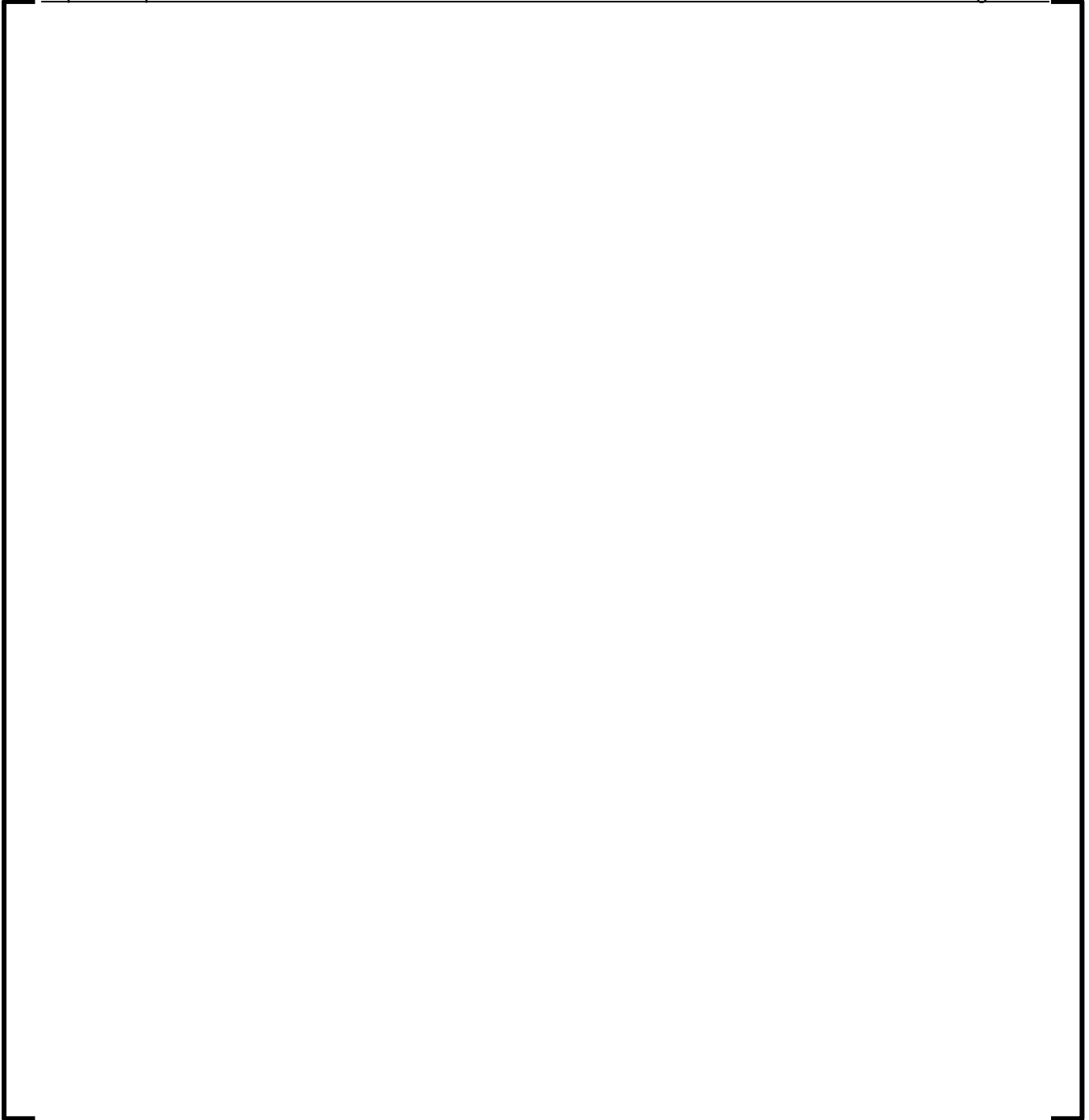
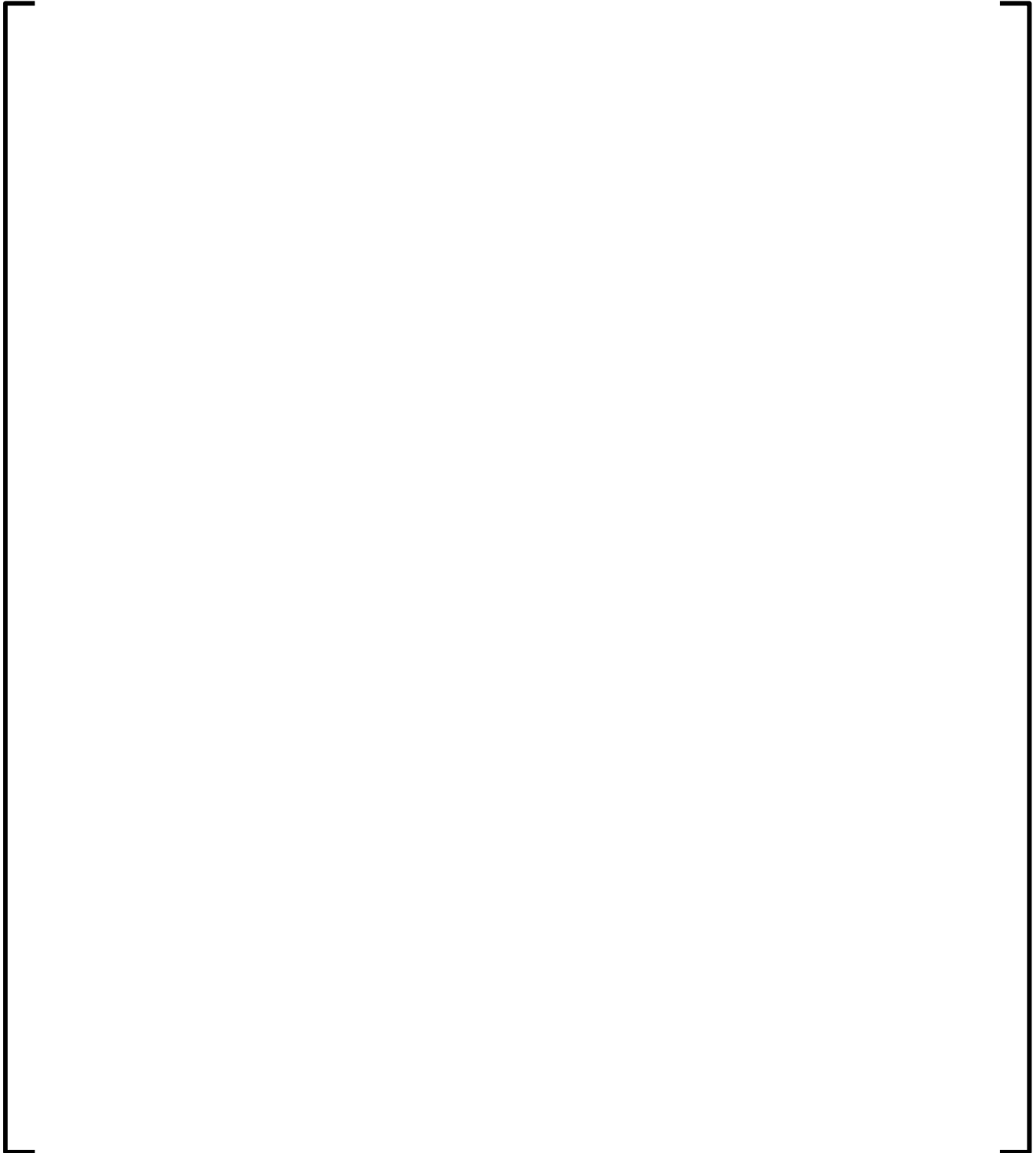




Figure 10-1
SAT Process



11.0 TXS COMPACT REGULATORY COMPLIANCE

11.1 *TXS COMPACT Compliance with IEEE Std 603-1991*

11.1.1 General

10 CFR 50.55a(h), "Protection and safety systems," incorporates by reference the 1991 version of IEEE Standard 603, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," including the correction sheet dated January 30, 1995.

IEEE 603-1991 [1] specifies functional and design requirements for the power, instrumentation, and control portions of nuclear power generating station safety systems.

Compliance is assessed in a structured way, by going through requirements one by one, and

- Citing the requirement,
- Analyzing fulfillment of the requirement by platform features or explaining which requirement or part of the requirement will be satisfied by application-specific provisions (not in the scope of this Topical Report),
- Pointing to evidence, and
- Giving an overall assessment of compliance.

Some requirements incorporate other standards by reference. Such referenced standards are not included in the clause-by-clause analysis but analyzed (case-by-case) in separate sections of this Topical Report.

11.1.2 Safety System Designation

4	<i>A specific basis shall be established for the design of each safety system of the nuclear power generating station. The design basis shall also be available as needed to facilitate the determination of the adequacy of the safety system, including design changes. The design basis shall be consistent with the requirements of ANSI/ANS 51.1–1983 or ANSI/ANS 52.1–1983 and shall document as a minimum:</i>
4.1	<i>The design basis events applicable to each mode of operation of the generating station along with the initial conditions and allowable limits of plant conditions for each such event.</i>
4.2	<i>The safety functions and corresponding protective actions of the execute features for each design basis event.</i>
4.3	<i>The permissive conditions for each operating bypass capability that is to be provided.</i>
4.4	<i>The variables or combinations of variables, or both, that are to be monitored to manually or automatically, or both, control each protective action; the analytical limit associated with each variable, the ranges (normal, abnormal, and accident conditions); and the rates of change of these variables to be accommodated until proper completion of the protective action is ensured.</i>
4.5	<i>The minimum criteria for each action identified in 4.2 whose operation may be controlled by manual means initially or subsequent to initiation. See IEEE Std 494–1974 (R1990)...</i>
4.6	<i>For those variables in 4.4 that have a spatial dependence (that is, where the variable varies as a function of position in a particular region), the minimum number and locations of sensors required for protective purposes.</i>
4.7	<i>The range of transient and steady-state conditions of both motive and control power and the environment (for example, voltage, frequency, radiation, temperature, humidity, pressure, and vibration) during normal, abnormal, and accident circumstances throughout which the safety system shall perform.</i>
4.8	<i>The conditions having the potential for functional degradation of safety system performance and for which provisions shall be incorporated to retain the capability for performing the safety functions (for example, missiles, pipe breaks, fires, loss of ventilation, spurious operation of fire suppression systems, operator error, failure in non-safety-related systems).</i>
4.9	<i>The methods to be used to determine that the reliability of the safety system design is appropriate for each safety system design and any qualitative or quantitative reliability goals that may be imposed on the system design.</i>
4.10	<i>The critical points in time or the plant conditions, after the onset of a design basis event,...</i>

4.11 *The equipment protective provisions that prevent the safety systems from accomplishing their safety functions.*

4.12 *Any other special design basis that may be imposed on the system design (example: diversity, interlocks, regulatory agency criteria).*

11.1.3 Safety System Criteria

5	<i>The safety systems shall, with precision and reliability, maintain plant parameters within acceptable limits established for each design basis event. The power, instrumentation, and control portions of each safety system shall be comprised of more than one safety group of which any one safety group can accomplish the safety function.</i>

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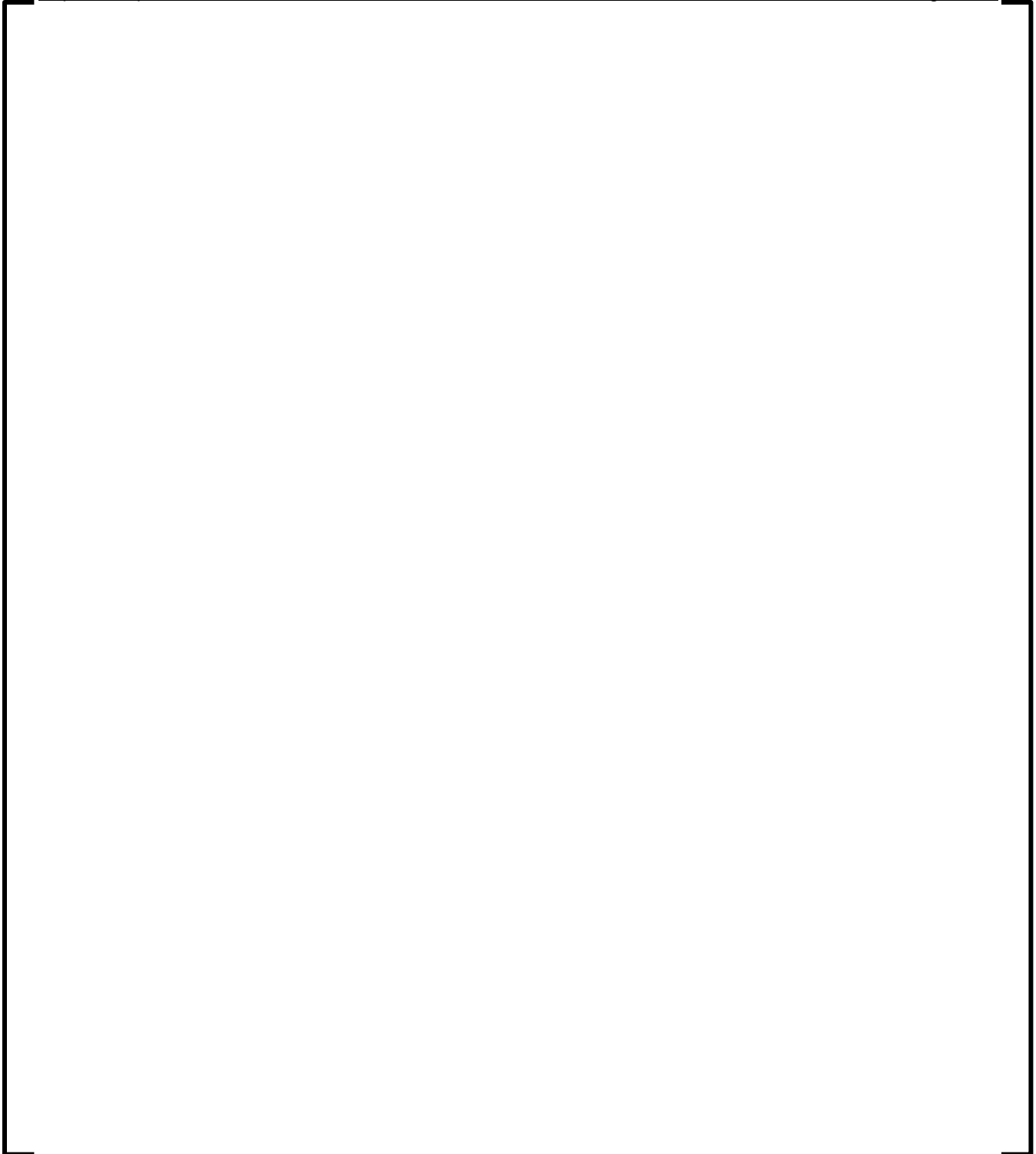
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11.1.3.1 Single-Failure Criterion

5.1 §1	<i>The safety systems shall perform all safety functions required for a design basis event in the presence of. (1) any single detectable failure within the safety systems concurrent with all identifiable but non-detectable failures; (2) all failures caused by the single failure; and (3) all failures and spurious system actions that cause or are caused by the design basis event requiring the safety functions. The single-failure criterion applies to the safety systems whether control is by automatic or manual means.</i>

[

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5.1 §2 & §3 *This criterion does not invoke coincidence (or multiple-channel) logic within a safety group; however, the application of coincidence logic may evolve from other criteria or considerations to maximize plant availability or reliability. An evaluation has been performed and documented in other standards to show that certain fluid system failures need not be considered in the application of this criterion. The performance of a probable assessment of the safety systems may be used to demonstrate that certain postulated failures need not be considered in the application of the criterion. A probable assessment is intended to eliminate consideration of events and failures that are not credible; it shall not be used in lieu of the single-failure criterion.*

Where reasonable indication exists that a design that meets the single-failure criterion may not satisfy all the reliability requirements specified in 4.9 of the design basis, a probable assessment of the safety system shall be performed. The assessment shall not be limited to single failures. If the assessment shows that the design basis requirements are not met, design features shall be provided or corrective modifications shall be made to ensure that the system meets the specified reliability requirements.

11.1.3.2 Completion of Protective Action

5.2 *The safety systems shall be designed so that, once initiated automatically or manually, the intended sequence of protective actions of the execute features shall continue until completion. Deliberate operator action shall be required to return the safety systems to normal. This requirement shall not preclude the use of equipment protective devices identified in 4.11 of the design basis or the provision for deliberate operator interventions. Seal-in of individual channels is not required.*

11.1.3.3 Quality

5.3	<i>Components and modules shall be of a quality that is consistent with minimum maintenance requirements and low failure rates. Safety system equipment shall be designed, manufactured, inspected, installed, tested, operated, and maintained in accordance with a prescribed quality assurance program (ANSI/ASME NQA1–1989).</i>

[

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11.1.3.4 Equipment Qualification

5.4	<i>Safety system equipment shall be qualified by type test, previous operating experience, or analysis, or any combination of these three methods, to substantiate that it will be capable of meeting, on a continuing basis, the performance requirements as specified in the design basis. Qualification of Class 1E equipment shall be in accordance with the requirements of IEEE Std 323–1983 and IEEE Std 627–1980.</i>

11.1.3.5 System Integrity

5.5	<i>The safety systems shall be designed to accomplish their safety functions under the full range of applicable conditions enumerated in the design basis.</i>

[

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11.1.3.6 Independence

11.1.3.6.1 Between Redundant Portions of a Safety System

5.6.1 *Redundant portions of a safety system provided for a safety function shall be independent of and physically separated from each other to the degree necessary to retain the capability to accomplish the safety function during and following any design basis event requiring that safety function.*

[

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11.1.3.6.2 Between Safety Systems and Effects of Design Basis Event

5.6.2 *Safety system equipment required to mitigate the consequences of a specific design basis event shall be independent of, and physically separated from, the effects of the design basis event to the degree necessary to retain the capability to meet the requirements of this standard. Equipment qualification in accordance with 5.4 is one method that can be used to meet this requirement.*

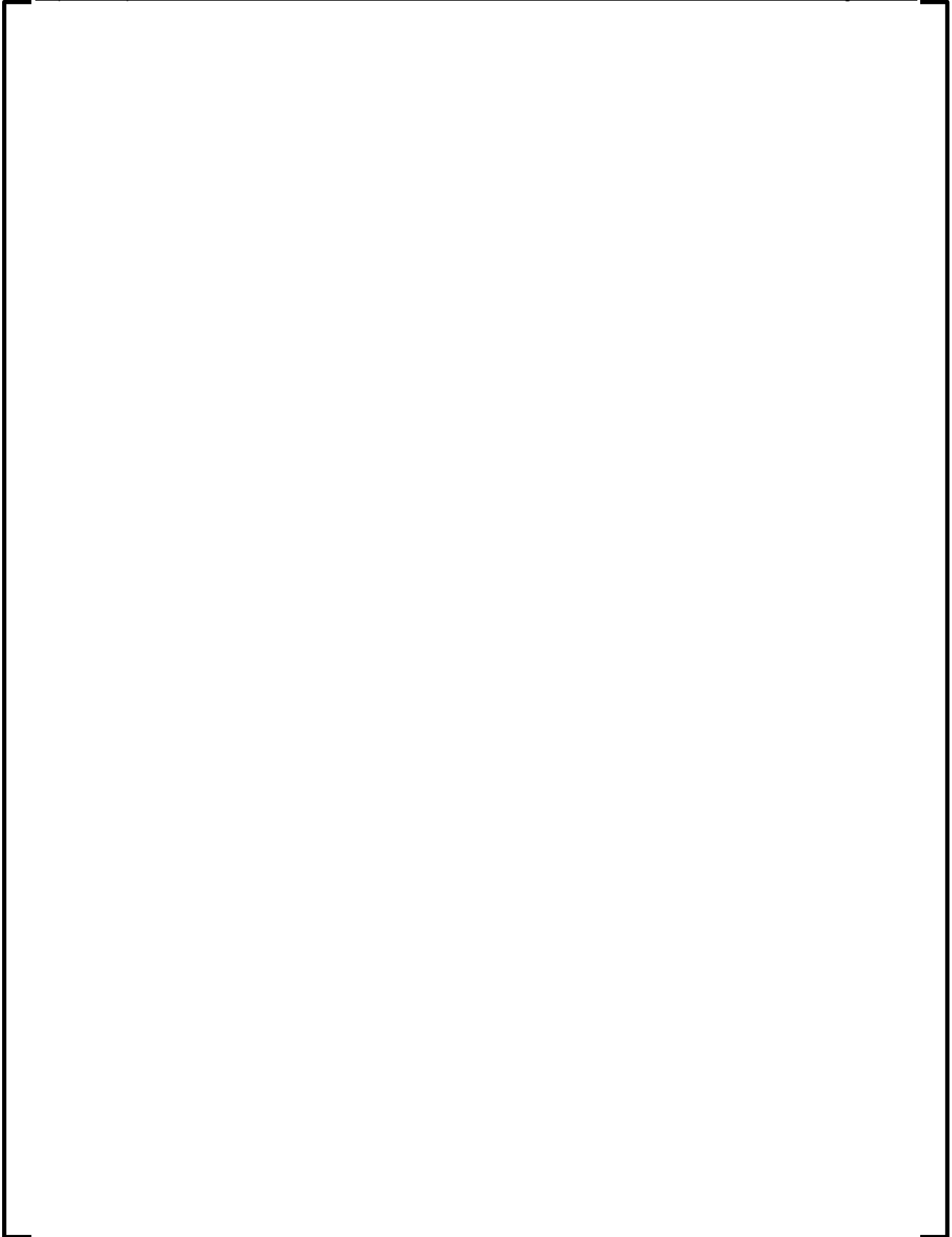
11.1.3.6.3 Between Safety Systems and Other Systems

5.6.3 *The safety system design shall be such that credible failures in and consequential actions by other systems, as documented in 4.8 of the design basis, shall not prevent the safety systems from meeting the requirements of this standard.*

5.6.3.1 *Interconnected Equipment*

1) Classification: Equipment that is used for both safety and nonsafety functions shall be classified as part of the safety systems. Isolation devices used to effect a safety system boundary shall be classified as part of the safety system.

2) Isolation: No credible failure on the non-safety side of an isolation device shall prevent any portion of a safety system from meeting its minimum performance requirements during and following any design basis event requiring that safety function. A failure in an isolation device shall be evaluated in the same manner as a failure of other equipment in a safety system.



[

]

5.6.3.2 Equipment in Proximity

1) Separation: Equipment in other systems that is in physical proximity to safety system equipment, but that is neither an associated circuit nor another Class 1E circuit, shall be physically separated from the safety system equipment to the degree necessary to retain the safety systems' capability to accomplish their safety functions in the event of the failure of non-safety equipment. Physical separation may be achieved by physical barriers or acceptable separation distance. The separation of Class 1E equipment shall be in accordance with the requirements of IEEE Std 384-1981.

2) Barriers: Physical barriers used to effect a safety system boundary shall meet the requirements of 5.3, 5.4 and 5.5 for the applicable conditions specified in 4.7 and 4.8 of the design basis.

5.6.3.3 Effects of a Single Random Failure

Where a single random failure in a nonsafety system can (1) result in a design basis event, and (2) also prevent proper action of a portion of the safety system designed to protect against that event, the remaining portions of the safety system shall be capable of providing the safety function even when degraded by any separate single failure.

11.1.3.6.4 Detailed Criteria

5.6.4 *IEEE Std 384-1981 provides detailed criteria for the independence of Class 1E equipment and circuits.*

11.1.3.7 Capability for Test and Calibration

- 5.7 *Capability for testing and calibration of safety system equipment shall be provided while retaining the capability of the safety systems to accomplish their safety functions. The capability for testing and calibration of safety system equipment shall be provided during power operation and shall duplicate, as closely as practicable, performance of the safety function. Testing of Class 1E systems shall be in accordance with the requirements of IEEE Std 338-1987. Exceptions to testing and calibration during power operation are allowed where this capability cannot be provided without adversely affecting the safety or operability of the generating station. In this case:*
- 1) appropriate justification shall be provided (for example, demonstration that no practical design exists),*
 - 2) acceptable reliability of equipment operation shall be otherwise demonstrated, and*
 - 3) the capability shall be provided while the generating station is shut down.*

11.1.3.8 Information Displays

5.8.1 *Displays for Manually Controlled Actions*

The display instrumentation provided for manually controlled actions for which no automatic control is provided and that are required for the safety systems to accomplish their safety functions shall be part of the safety systems and shall meet the requirements of IEEE Std 497-1981. The design shall minimize the possibility of ambiguous indications that could be confusing to the operator.

5.8.2 *System Status Indication*

Display instrumentation shall provide accurate, complete, and timely information pertinent to safety system status. This information shall include indication and identification of protective actions of the sense and command features and execute features. The design shall minimize the possibility of ambiguous indications that could be confusing to the operator. The display instrumentation provided for safety system status indication need not be part of the safety systems.

5.8.3 *Indication of Bypasses*

If the protective actions of some part of a safety system have been bypassed or deliberately rendered inoperative for any purpose other than an operating bypass, continued indication of this fact for each affected safety group shall be provided in the control room.

- 5.8.3.1 *This display instrumentation need not be part of the safety systems.*
- 5.8.3.2 *This indication shall be automatically actuated if the bypass or inoperative condition (a) is expected to occur more frequently than once a year, and (b) is expected to occur when the affected system is required to be operable.*
- 5.8.3.3 *The capability shall exist in the control room to manually activate this display indication.*
- 5.8.4 *Location*
- Information displays shall be located accessible to the operator. Information displays provided for manually controlled protective actions shall be visible from the location of the controls used to effect the actions.*

11.1.3.9 Control of Access

5.9

The design shall permit the administrative control of access to safety system equipment. These administrative controls shall be supported by provisions within the safety systems, by provision in the generating station design, or by a combination thereof.

11.1.3.10 Repair

5.10 *The safety systems shall be designed to facilitate timely recognition, location, replacement, repair, and adjustment of malfunctioning equipment.*

11.1.3.11 Identification

5.11 *In order to provide assurance that the requirements given in this standard can be applied during the design, construction, maintenance, and operation of the plant, the following requirements shall be met:*

1) Safety system equipment shall be distinctly identified for each redundant portion of a safety system in accordance with the requirements of IEEE Std 384-1981 and IEEE Std 420-1982.

2) Components or modules mounted in equipment or assemblies that are clearly identified as being in a single redundant portion of a safety system do not themselves require identification.

3) Identification of safety system equipment shall be distinguishable from any identifying markings placed on equipment for other purposes (for example, identification of fire protection equipment, phase identification of power cables).

4) Identification of safety system equipment and its divisional assignment shall not require frequent use of reference material.

5) The associated documentation shall be distinctly identified in accordance with the requirements of IEEE Std 494-1974 (R1990).

11.1.3.12 Auxiliary features

5.12.1 *Auxiliary supporting features shall meet all requirements of this standard.*

5.12.2 *Other auxiliary features that (1) perform a function that is not required for the safety systems to accomplish their safety functions, and (2) are part of the safety systems by association (that is, not isolated from the safety system) shall be designed to meet those criteria necessary to ensure that these components, equipment, and systems do not degrade the safety systems below an acceptable level.*

11.1.3.13 Multi-Unit Stations

- 5.13 *The sharing of structures, systems, and components between units at multi-unit generating stations is permissible provided that the ability to simultaneously perform required safety functions in all units is not impaired. Guidance on the sharing of electrical power systems between units is contained in IEEE Std 308-1980. Guidance on the application of the single failure criterion to shared systems is contained in IEEE Std 379-1988.*

11.1.3.14 Human Factors Considerations

- 5.14 *Human factors shall be considered at the initial stages and throughout the design process to assure that the functions allocated in whole or in part to the human operator(s) and maintainer(s) can be successfully accomplished to meet the safety system design goals, in accordance with IEEE Std 1023-1988.*

11.1.3.15 Reliability

5.15 *For those systems for which either quantitative or qualitative reliability goals have been established, appropriate analysis of the design shall be performed in order to confirm that such goals have been achieved. Std 352-1987 and IEEE Std 577-1976 provide guidance for reliability analysis.*

11.1.4 Sense and Command Features—Functional and Design Requirements

11.1.4.1 Automatic Control

6.1 *Means shall be provided to automatically initiate and control all protective actions except as justified in 4.5. The safety system design shall be such that the operator is not required to take any action prior to the time and plant conditions specified in 4.5 following the onset of each design basis event. At the option of the safety system designer, means may be provided to automatically initiate and control those protective actions of 4.5.*

[

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11.1.4.2 Manual Control

6.2.1	<i>Means shall be provided in the control room to implement manual initiation at the division level of the automatically initiated protective actions. The means provided shall minimize the number of discrete operator manipulations and shall depend on the operation of a minimum of equipment consistent with the constraints of 5.6.1.</i>
6.2.2	<i>Means shall be provided in the control room to implement manual initiation and control of the protective actions identified in 4.5 that have not been selected for automatic control under 6.1. The displays provided for these actions shall meet the requirements of 5.8.1.</i>
6.2.3	<i>Means shall be provided to implement the manual actions necessary to maintain safe conditions after the protective actions are completed as specified in 4.10. The information provided to the operators, the actions required of these operators, and the quantity and location of associated displays and controls shall be appropriate for the time period within which the actions shall be accomplished and the number of available qualified operators. Such displays and controls shall be located in areas that are accessible, located in an environment suitable for the operator, and suitably arranged for operator surveillance and action.</i>

11.1.4.3 Interaction Between the Sense and Command Features and Other Systems

6.3.1	<i>Where a single credible event, including all direct and consequential results of that event, can cause a non-safety system action that results in a condition requiring protective action and can concurrently prevent the protective action in those sense and command feature channels designated to provide principal protection against the condition, one of the following requirements shall be met:</i>

- 6.3.2
- 1) *Alternate channels not subject to failure resulting from the same single event...*
 - 2) *Equipment not subject to failure caused by the same single credible event...*
- Provisions shall be included so that the requirements in 6.3.1 can be met in conjunction with the requirements of 6.7 if a channel is in maintenance bypass. These provisions include reducing the required coincidence, defeating the nonsafety system signals taken from the redundant channels, or initiating a protective action from the bypassed channel.*

11.1.4.4 Derivation of System Inputs

- 6.4
- To the extent feasible and practical, sense and command feature inputs shall be derived from signals that are direct measures of the desired variables as specified in the design basis.*

11.1.4.5 Capability for Testing and Calibration

- 6.5.1
- Means shall be provided for checking, with a high degree of confidence, the operational availability of each sense and command feature input sensor required for a safety function during reactor operation. This may be accomplished in various ways; for example:*
- 1) *by perturbing the monitored variable,*
 - 2) *within the constraints of 6.6, by introducing and varying, as appropriate, a substitute input to the sensor of the same nature as the measured variable, or*

3) by cross-checking between channels that bear a known relationship to each other and that have readouts available.

6.5.2

One of the following means shall be provided for assuring the operational availability of each sense and command feature required during the post-accident period:

1) Checking the operational availability of sensors by use of the methods described in 6.5.1.

2) Specifying equipment that is stable and retains its calibration during the post-accident time period.

11.1.4.6 Operating Bypasses

6.6

Whenever the applicable permissive conditions are not met, a safety system shall automatically prevent the activation of an operating bypass or initiate the appropriate safety function(s). If plant conditions change so that an activated operating bypass is no longer permissible, the safety system shall automatically accomplish one of the following actions:

1) Remove the appropriate active operating bypass(es).

2) Restore plant conditions so that permissive conditions once again exist.

3) Initiate the appropriate safety function(s).

11.1.4.7 Maintenance Bypass

- 6.7 *Capability of a safety system to accomplish its safety function shall be retained while sense and command features equipment is in maintenance bypass. During such operation, the sense and command features shall continue to meet the requirements of 5.1 and 6.3. ...*

11.1.4.8 Setpoints

- 6.8.1 *The allowance for uncertainties between the process analytical limit documented in Section 4.4 and the device setpoint shall be determined using a documented methodology. Refer to ISA S67.040-1987.*
- 6.8.2 *Where it is necessary to provide multiple setpoints for adequate protection for a particular mode of operation or set of operating conditions, the design shall provide positive means of ensuring that the more restrictive setpoint is used when required. The devices used to prevent improper use of less restrictive setpoints shall be part of the sense and command features.*

11.1.5 Executive Features—Functional and Design Requirements

[

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7.1 Automatic Control

Capability shall be incorporated in the execute features to receive and act upon automatic control signals from the sense and command features consistent with 4.4 of the design basis.

7.2 Manual Control

If manual control of any actuated component in the execute features is provided, the additional design features in the execute features necessary to accomplish such manual control shall not defeat the requirements of 5.1 and 6.2. Capability shall be provided in the execute features to receive and act upon manual control signals from the sense and command features consistent with the design basis.

7.3 Completion of Protective Action

The design of the execute features shall be such that once initiated, the protective actions of the execute features shall go to completion. This requirement shall not preclude the use of equipment protective devices identified in 4.11 of the design basis or the provision for deliberate operator interventions. When the sense and command features reset, the execute features shall not automatically return to normal; they shall require separate, deliberate operator action to be returned to normal. After the initial protective action has gone to completion, the execute features may require manual control or automatic control (that is, cycling) of specific equipment to maintain completion of the safety function.

7.4 Operating Bypass

Whenever the applicable permissive conditions are not met, a safety system shall automatically prevent the activation of an operating bypass or initiate the appropriate safety function(s). If plant conditions change so that an activated operating bypass is no longer permissible, the safety system shall automatically accomplish one of the following actions:

- 1) Remove the appropriate active operating bypass(es).*
- 2) Restore plant conditions so that permissive conditions once again exist.*
- 3) Initiate the appropriate safety function(s).*

7.5 Maintenance Bypass

The capability of a safety system to accomplish its safety function shall be retained while execute features equipment is in maintenance bypass. Portions of the execute features with a degree of redundancy of one shall be designed such that when a portion is placed in maintenance bypass (that is, reducing temporarily its degree of redundancy to zero), the remaining portions provide acceptable reliability.

11.1.6 Power Source Requirements

8.1 *Electrical Power Sources*

Those portions of the Class 1E power system that are required to provide the power to the many facets of the safety system are governed by the criteria of this document and are a portion of the safety systems. Specific criteria unique to the Class 1E power systems are given in IEEE Std 308-1980.

8.2 *Non-electrical Power Sources*

Non-electrical power sources, such as control-air systems, bottled-gas systems, and hydraulic systems, required to provide the power to the safety systems are a portion of the safety systems and shall provide power consistent with the requirements of this standard. Specific criteria unique to non-electrical power sources are outside the scope of this standard and can be found in other standards.

8.3 *Maintenance Bypass*

The capability of the safety systems to accomplish their safety functions shall be retained while power sources are in maintenance bypass. Portions of the power sources with a degree of redundancy of one shall be designed such that when a portion is placed in maintenance bypass (that is, reducing temporarily its degree of redundancy to zero), the remaining portions provide acceptable reliability.

11.2 TXS COMPACT Compliance with NRC Regulatory Guide 1.152 Revision 4-2023 and IEEE Std 7-4.3.2-2016

11.2.1 Safety System Design Basis

11.2.2 Safety System Criteria

11.2.2.1 Single-Failure Criterion

5.1 *In addition to the requirements in IEEE Std 603-2009, the following criteria apply for programmable digital devices in safety systems:*

a) Functions that are assumed to malfunction independently in the safety analysis shall not be affected by failure of a single programmable digital device (PDD).

b) Functions shall be configured (e.g., functionally distributed) such that a single PDD malfunction or software error shall not result in spurious actuations that are not enveloped in the plant design bases, accident analyses, anticipated transient without scram (ATWS) provisions, or other provisions for abnormal conditions. This includes spurious actuation of more than one plant device or system as a result of a single PDD malfunction or software error.

11.2.2.2 Completion of Protective Action

11.2.2.3 Quality

5.3 *A typical system development process should consist of the following life cycle processes:*

- a) Creating the conceptual design of the system*
- b) Translation of the concepts into specific system requirements*
- c) Using the requirements to develop a detailed system design*
- d) Implementing the design into hardware and software functions*
- e) Testing the functions to confirm that the requirements have been correctly implemented*
- f) Installing the system and performing site acceptance testing*
- g) Operating and maintaining the system*
- h) Retiring the system*

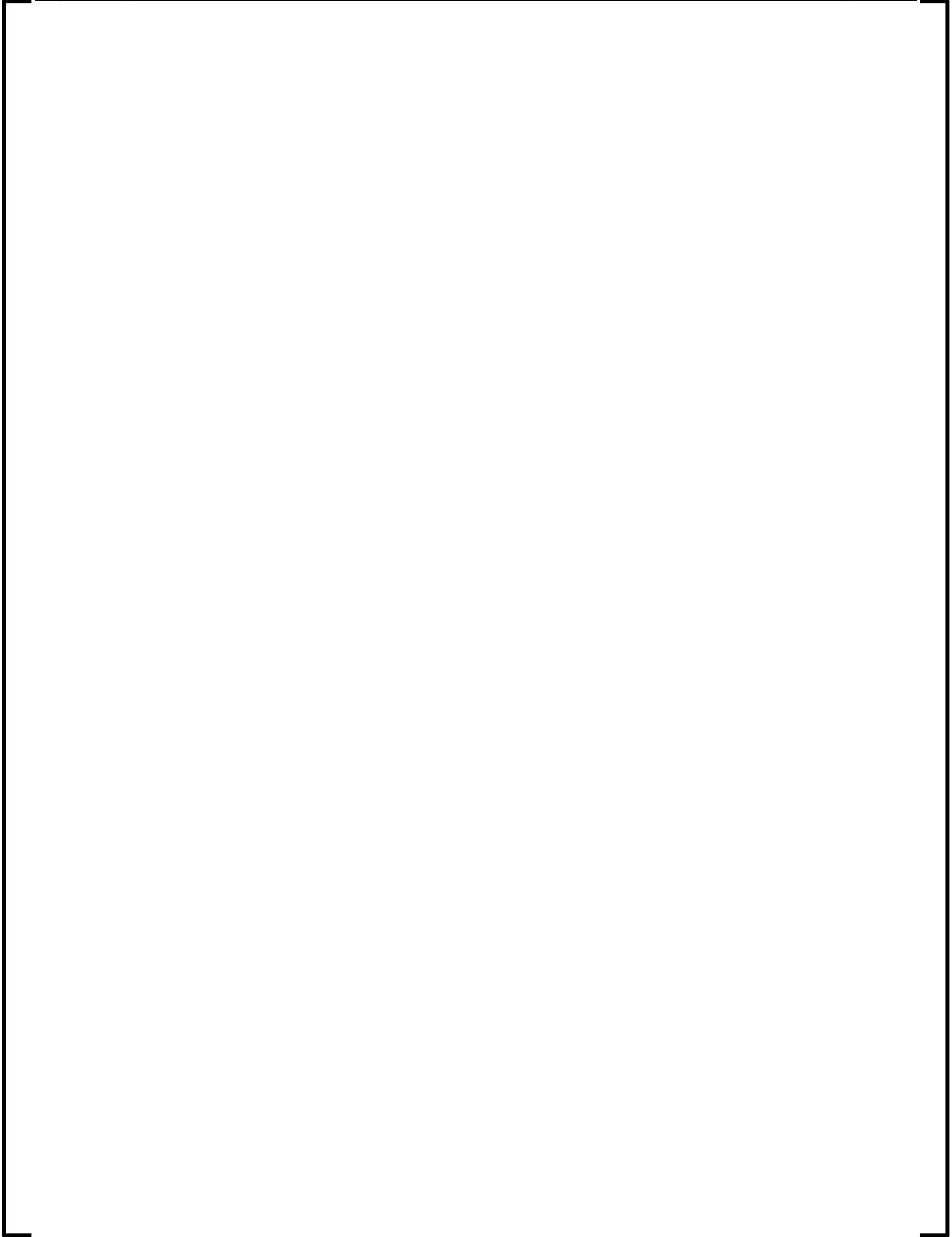
The following activities shall be performed in addition to the quality criteria provided by IEEE Std 603-2009:

- Software development*
- Qualification of existing commercial PDDs (see 5.17)*
- Use of software tools*
- Verification and validation*
- Configuration management*
- Risk management*

11.2.2.3.1 Software Development

5.3.1 *Software shall be developed, modified, or accepted in accordance with a software quality assurance (QA) plan consistent with the requirements of ISO/IEC 12207:2008 (IEEE Std 12207-2008). The software QA plan shall address all software that is resident on the PDD at run time (i.e., application software, network software, interfaces, operating systems, and diagnostics). Guidance for developing software QA plans can be found in IEC 60880 Ed. 2 (2006-05) [B13] and IEEE Std 730™-2002 [B18].*

The software QA plan shall also address software tools used for system development and maintenance as described in 5.3.2.



5.3.1.1

The use of software quality metrics shall be considered throughout the software life cycle to assess whether software quality requirements are being met. Software quality metrics should be used to improve performance.

The following life cycle phase characteristics should be considered:

- a) Correctness/Completeness (Requirements phase)*
- b) Compliance with requirements (Design phase)*
- c) Compliance with design (Implementation phase)*
- d) Functional compliance with requirements (Test and Integration phase)*
- e) On-site functional compliance with requirements (Installation and Checkout phase)*
- f) Performance history (Operation and Maintenance phase)*

The basis for the metrics selected to evaluate software quality characteristics should be included in the software development documentation. IEEE Std 1061™-1998 [B20] provides a methodology for the application of software quality metrics.

11.2.2.3.2 Software Tools

5.3.2 *Software tools used to support the software life cycle process of safety-related PDD shall be incorporated into the secure development and operational environment and controlled under configuration management. Only approved and documented software tools shall be used to support the development of safety-related PDD. The software tools shall be used within their design capabilities.*

11.2.2.3.3 Verification and Validation

5.3.3 *The V&V effort shall be performed in accordance with IEEE Std 1012-2012 for software V&V tasks. IEEE Std 1012 also addresses V&V activities for system and hardware. IEEE Std 1012 establishes an integrity level schema but states that other integrity schemas are acceptable. For any selected integrity schema, the selected integrity levels shall be mapped to the IEEE Std 1012's four-level schema to demonstrate that the minimum V&V requirements are satisfied. The safety system V&V plan shall define and justify the V&V integrity level applied to the system and the required documented outputs. See IEEE Std 1012-2012 for a definition of integrity level.*

11.2.2.3.4 V&V Independence Requirements

5.3.4	<i>Independent verification and validation is required for safety-related system. In order to have independent verification and validation, three different types of independence are required as follows:</i>

a) The verification and validation staff shall report to a separate organization with sufficient authority and organizational freedom, including sufficient independence from cost and schedule limitations, as defined in Annex C of IEEE Std 1012-2012.

b) The development activities and tests shall be verified and validated by individuals or groups with appropriate technical competence, other than those who developed the original design.

c) The designers, people who contributed to the design, design and development project management, and staff supervising the designers shall not perform or oversee independent verification and validation on safety-related systems.

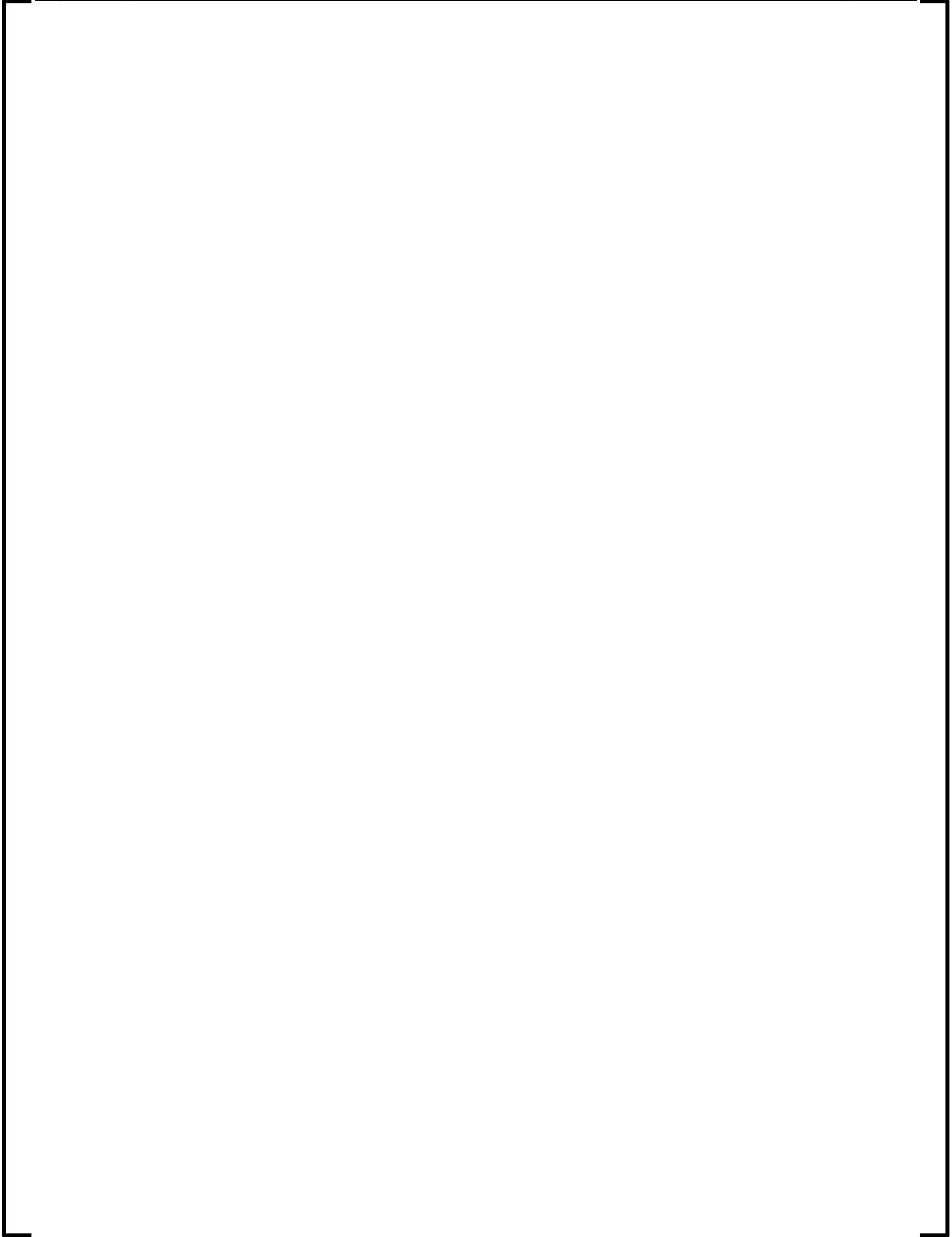
Testing throughout the life cycle process may be conducted by the V&V organization or the design organization or both. Regardless of who actually writes the procedures and/or conducts the tests, the test procedures and reports shall be independently verified.

11.2.2.3.5 Configuration Management

- 5.3.5 *The minimum set of software activities shall address the following:*
- a) Identification and control of all software designs and implementation*
 - b) Identification and control of all software design functional data (e.g., data templates and databases)*
 - c) Identification and control of all software design interfaces*
 - d) Control of all software design changes*
 - e) Control of software documentation (user, operating, and maintenance documentation)*
 - f) Control of development activities for the supplied safety system software*
 - g) Control and retrieval of qualification information associated with software designs and implementation*
 - h) Software configuration audits*
 - i) Status accounting*

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11.2.2.3.6 Project Risk Management

- 5.3.6 *Risk management shall include the following steps:*
- a) Determine the scope of risk management to be performed for the PDD.*
 - b) Define and implement appropriate risk management strategies.*
 - c) Identify risks to the project in the project risk management strategy and as they develop during the conduct of the project.*
 - d) Analyze risks to determine the priority for their mitigation.*
 - e) Develop risk mitigation plans for risks that have the potential to significantly impact quality goals, with appropriate metrics for tracking resolution progress. (These risks may include technical, schedule, or resource-related project risks that could compromise the ability of the safety PDD to perform safety-related functions.)*
 - f) Take corrective actions when expected quality is not achieved.*
 - g) Establish a project environment that supports effective communications between individuals and groups for the resolution of software project risks.*

11.2.2.4 Equipment Qualification

- 5.4 *Equipment qualification testing shall be performed with the system functioning with software and diagnostics representative of those intended to be used in actual operation. The PDD functions necessary to perform safety functions and those PDD functions whose operation or failure could impair safety functions shall be exercised during testing. This includes, as appropriate and practicable, exercising and monitoring the memory, the logic, inputs and outputs, display functions, diagnostics, associated components, communication paths, and interfaces. Testing shall demonstrate that the performance requirements related to safety functions have been met in the presence of all defined environmental and plant input and output stressors. Equipment qualification is required for commercial grade items as well as equipment produced under a nuclear quality assurance program.*

11.2.2.5 System Integrity

11.2.2.5.1 Design for PDD Integrity

5.5.1	<i>The PDD shall be designed to perform its safety function when subjected to hazards, external or internal, that have significant potential for defeating the safety function. Such hazards include input and output processing failures; precision or roundoff problems; improper recovery actions; electrical supply, input voltage and frequency fluctuations; maximum credible number of coincident signal changes; and environmental stressors.</i> <i>If the system requirements identify a safety system preferred failure mode, failures of the PDD shall not preclude the safety system from being placed in that mode. Performance of PDD restart operations shall not result in the safety system being inhibited from performing its function including causing a spurious safety system actuation.</i>

A hazard analysis (see Annex D for guidance) shall be performed to identify and address potential hazards of the system.

11.2.2.5.2 Design for Test and Calibration

5.5.2 *Test and calibration functions shall not adversely affect the ability of the system to perform its safety function. Appropriate bypass of one redundant channel is not considered an adverse effect in this context. The test and calibration functions shall not affect system functions that are not included in a calibration change (e.g., setpoint change).*

V&V, configuration management, and QA shall be required for test and calibration functions on separate PDDs (e.g., test and calibration computer) when the test and calibration functions provide the sole verification of test and calibration data. V&V, configuration management, and QA shall be required when the test and calibration function is inherent to the PDD that is part of the safety system. The calibration shall be traceable to an appropriate national standard.

V&V, configuration management, and QA are not required when the test and calibration function is resident on a separate PDD and does not provide the sole verification of test and calibration data for the PDD that is part of the safety system.

11.2.2.5.3 Fault Detection and Self-Diagnostics

5.5.3 *Self-diagnostics are a means to provide timely detection of failures. Self-diagnostics are not required for systems in which failures can be detected by alternate means in a timely manner. If self-diagnostic functions are integrated into the safety system, these functions shall be subject to the same V&V processes as the safety functions.*

If reliability requirements warrant self-diagnostics, then PDD software shall incorporate functions to detect and report PDD system faults and failures in a timely manner. Self-diagnostic functions shall not adversely affect the ability of the PDD system to perform its safety function, or cause spurious actuations of the safety function.

11.2.2.5.4 Prioritization of Functions

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11.2.2.6 Independence

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11.2.2.6.1 Between Redundant Portions of a Safety System

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11.2.2.6.2 Between Safety Systems and Effects of Design Basis Event

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11.2.2.6.3 Between Safety Systems and Other Systems

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Interconnected equipment

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Equipment in proximity

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Effects of a single random failure

11.2.2.6.4 Detailed Criteria

11.2.2.7 Capability for Test and Calibration

5.7

The following criteria shall be followed in addition to the requirements of IEEE 603-2009. The safety system configuration shall be confirmed through periodic automated or manual surveillance.

The safety system configuration shall not require change or modification to support periodic automated or manual surveillance testing.

The measurement and test equipment (M&TE) used for safety systems shall not adversely affect the safety system functionality. Safety system functionality includes the entire safety system functionality and is not limited to the channel or division under test. Wireless receivers/transmitters on temporarily-connected M&TE shall be disabled prior to connecting to safety-related equipment.

11.2.2.8 Information Displays

11.2.2.8.1 Independence and Isolation Requirements for Multidivisional Control and Display Stations

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11.2.2.8.2 Malfunctions and Spurious Actuations

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11.2.2.9 Control of Access

11.2.2.9.1 Physical Security

11.2.2.9.2 Access Controls

11.2.2.9.3 Interaction between Cyber Security Features and Safety Functions

11.2.2.9.4 Life Cycle Approach

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11.2.2.9.5 Maintenance

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11.2.2.10 Repair**11.2.2.11 Identification**

- 5.11 *In addition to the requirements in 5.11 in IEEE Std 603-2009, the following identification requirements specific to digital safety systems shall be met:*
- a) Software and hardware identification, including version control, shall be provided and used to verify that the correct software is installed in the correct hardware component.*
 - b) Means shall be included in the software such that the identification may be retrieved from the software using software maintenance tools.*

11.2.2.12 Auxiliary Features



11.2.2.13 Multi-unit Stations



11.2.2.14 Human Factors Considerations



11.2.2.15 Reliability

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11.2.2.16 Common Cause Failure Criteria

11.2.2.17 Use of Commercial Digital Equipment

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11.2.2.18 Simplicity

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11.2.3 Sense and Command Features—Functional and Design Requirements

11.2.4 Execute Features—Functional and Design Requirements

11.2.5 Power Source Requirements

11.3 *TXS COMPACT Compliance with DI&C ISG-04 Revision 1, 2009*

11.3.1 Interdivisional Communications

1.1

A safety channel should not be dependent upon any information or resource originating or residing outside its own safety division to accomplish its safety function. This is a fundamental consequence of the independence requirements of IEEE603. It is recognized that division voting logic must receive inputs from multiple safety divisions.

1.2

The safety function of each safety channel should be protected from adverse influence from outside the division of which that channel is a member. Information and signals originating outside the division must not be able to inhibit or delay the safety function. This protection must be implemented within the affected division (rather than in the sources outside the division), and must not itself be affected by any condition or information from outside the affected division. This protection must be sustained despite any operation, malfunction, design error, communication error, or software error or corruption existing or originating outside the division.

1.3

A safety channel should not receive any communication from outside its own safety division unless that communication supports or enhances the performance of the safety function. Receipt of information that does not support or enhance the safety function would involve the performance of functions that are not directly related to the safety function. Safety systems should be as simple as possible. Functions that are not necessary for safety, even if they enhance reliability, should be executed outside the safety system. A safety system designed to perform functions not directly related to the safety function would be more complex than a system that performs the same safety function, but is not designed to perform other functions. The more complex system would increase the likelihood of failures and software errors. Such a complex design, therefore, should be avoided within the safety system. For example, comparison of readings from sensors in different divisions may provide useful information concerning the behavior of the sensors (for example, On-Line Monitoring). Such a function executed within a safety system, however, could also result in unacceptable influence of one division over another, or could involve functions not directly related to the safety functions, and should not be executed within the safety system. Receipt of information from outside the division, and the performance of functions not directly related to the safety function, if used, should be justified. It should be demonstrated that the added system/software complexity associated with the performance of functions not directly related to the safety function and with the receipt of information in support of those functions does not significantly increase the likelihood of software specification or coding errors, including errors that would affect more than one division. The applicant should justify the definition of "significantly" used in the demonstration.

- 1.4 *The communication process itself should be carried out by a communications processor separate from the processor that executes the safety function, so that communications errors and malfunctions will not interfere with the execution of the safety function. The communication and function processors should operate asynchronously, sharing information only by means of dual-ported memory or some other shared memory resource that is dedicated exclusively to this exchange of information. The function processor, the communications processor, and the shared memory, along with all supporting circuits and software, are all considered to be safety-related, and must be designed, qualified, fabricated, etc., in accordance with 10 C.F.R. Part 50, Appendix A and B. Access to the shared memory should be controlled in such a manner that the function processor has priority access to the shared memory to complete the safety function in a deterministic manner. For example, if the communication processor is accessing the shared memory at a time when the function processor needs to access it, the function processor should gain access within a timeframe that does not impact the loop cycle time assumed in the plant safety analyses. If the shared memory cannot support unrestricted simultaneous access by both processors, then the access controls should be configured such that the function processor always has precedence. The safety function circuits and program logic should ensure that the safety function will be performed within the timeframe established in the safety analysis, and will be completed successfully without data from the shared memory in the event that the function processor is unable to gain access to the shared memory.*

- 1.5 *The cycle time for the safety function processor should be determined in consideration of the longest possible completion time for each access to the shared memory. This longest-possible completion time should include the response time of the memory itself and of the circuits associated with it, and should also include the longest possible delay in access to the memory by the function processor assuming worst-case conditions for the transfer of access from the communications processor to the function processor. Failure of the system to meet the limiting cycle time should be detected and alarmed.*

- 1.6 *The safety function processor should perform no communication handshaking and should not accept interrupts from outside its own safety division.*

- 1.7 *Only predefined data sets should be used by the receiving system. Unrecognized messages and data should be identified and dispositioned by the receiving system in accordance with the pre-specified design requirements. Data from unrecognized messages must not be used within the safety logic executed by the safety function processor.*

Message format and protocol should be pre-determined. Every message should have the same message field structure and sequence, including message identification, status information, data bits, etc. in the same locations in every message. Every datum should be included in every transmit cycle, whether it has changed since the previous transmission or not, to ensure deterministic system behavior.

- 1.8 *Data exchanged between redundant safety divisions or between safety and nonsafety divisions should be processed in a manner that does not adversely affect the safety function of the sending divisions, the receiving divisions, or any other independent divisions.*

1.9 *Incoming message data should be stored in fixed predetermined locations in the shared memory and in the memory associated with the function processor. These memory locations should not be used for any other purpose. The memory locations should be allocated such that input data and output data are segregated from each other in separate memory devices or in separate pre-specified physical areas within a memory device.*

1.10 *Safety division software should be protected from alteration while the safety division is in operation. On-line changes to safety system software should be prevented by hardwired interlocks or by physical disconnection of maintenance and monitoring equipment. A workstation (e.g. engineer or programmer station) may alter addressable constants, setpoints, parameters, and other settings associated with a safety function only by way of the dual-processor / shared-memory scheme described in this guidance, or when the associated channel is inoperable. Such a workstation should be physically restricted from making changes in more than one division at a time. The restriction should be by means of physical cable disconnect, or by means of keylock switch that either physically opens the data transmission circuit or interrupts the connection by means of hardwired logic. "Hardwired logic" as used here refers to circuitry that physically interrupts the flow of information, such as an electronic AND gate circuit (that does not use software or firmware) with one input controlled by the hardware switch and the other connected to the information source: the information appears at the output of the gate only when the switch is in a position that applies a "TRUE" or "1" at the input to which it is connected. Provisions that rely on software to effect the disconnection are not acceptable. It is noted that software may be used in the safety system or in the workstation to accommodate the effects of the open circuit or for status logging or other purposes.*

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1.11 Provisions for interdivisional communication should explicitly preclude the ability to send software instructions to a safety function processor unless all safety functions associated with that processor are either bypassed or otherwise not in service. The progress of a safety function processor through its instruction sequence should not be affected by any message from outside its division. For example, a received message should not be able to direct the processor to execute a subroutine or branch to a new instruction sequence.

1.12 Communication faults should not adversely affect the performance of required safety functions in any way. Faults, including communication faults, originating in nonsafety equipment, do not constitute "single failures" as described in the single failure criterion of 10 C.F.R. Part 50, Appendix A. Examples of credible communication faults include, but are not limited to, the following:

1.12.1 Messages may be corrupted due to faults in communications processors, faults introduced in buffer interfaces, faults introduced in the transmission media, or from interference or electrical noise.

1.12.2 *Messages may be repeated at an incorrect point in time.*

1.12.3 *Messages may be sent in the incorrect sequence.*

1.12.4 *Messages may be lost, which includes both failures to receive an uncorrupted message or to acknowledge receipt of a message.*

1.12.5

Messages may be delayed beyond their permitted arrival time window for several reasons, including faults in the transmission medium, congested transmission lines, interference, or by delay in sending buffered messages.

1.12.6 *Messages may be inserted into the communication medium, from unexpected or unknown sources.*

1.12.7 *Messages may be sent to the wrong destination, which could treat the message as a valid message.*

1.12.8 *Messages may be longer than the receiving buffer, resulting in buffer overflow and memory corruption.*

1.12.9 *Messages may contain data that is outside the expected range.*

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1.12.10 *Messages may appear valid, but data may be placed in incorrect locations within the message.*

1.12.11 *Messages may occur at a high rate that degrades or causes the system to fail (i.e., broadcast storm).*

1.12.12 *Message headers or addresses may be corrupted.*

1.13 Vital communications, such as the sharing of channel trip decisions for the purpose of voting, should include provisions for ensuring that received messages are correct and are correctly understood. Such communications should employ error-detecting or error-correcting coding along with means for dealing with corrupt, invalid, untimely or otherwise questionable data. The effectiveness of error detection/correction should be demonstrated in the design and proof testing of the associated codes, but once demonstrated is not subject to periodic testing. Error-correcting methods, if used, should be shown to always reconstruct the original message exactly or to designate the message as unrecoverable. None of this activity should affect the operation of the safety-function processor.

1.14 Vital communications should be point-to-point by means of a dedicated medium (copper or optical cable). In this context, "point-to-point" means that the message is passed directly from the sending node to the receiving node without the involvement of equipment outside the division of the sending or receiving node. Implementation of other communication strategies should provide the same reliability and should be justified.

1.15 *Communication for safety functions should communicate a fixed set of data (called the "state") at regular intervals, whether data in the set has changed or not.*

1.16 *Network connectivity, liveness, and real-time properties essential to the safety application should be verified in the protocol. Liveness, in particular, is taken to mean that no connection to any network outside the division can cause an RPS/ESFAS communication protocol to stall, either deadlock or livelock. (Note: This is also required by the independence criteria of: (1) 10 C.F.R. Part 50, Appendix A, General Design Criteria ("GDC") 24, which states, "interconnection of the protection and control systems shall be limited so as to assure that safety is not significantly impaired."; and (2) IEEE 603-1991 IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.) (Source: NUREG/CR-6082, 3.4.3)*

1.17 *Pursuant to 10 C.F.R. § 50.49, the medium used in a vital communications channel should be qualified for the anticipated normal and post-accident environments. For example, some optical fibers and components may be subject to gradual degradation as a result of prolonged exposure to radiation or to heat. In addition, new digital systems may need susceptibility testing for EMI/RFI and power surges, if the environments are significant to the equipment being qualified.*

1.18 Provisions for communications should be analyzed for hazards and performance deficits posed by unneeded functionality and complication.

1.19 If data rates exceed the capacity of a communications link or the ability of nodes to handle traffic, the system will suffer congestion. All links and nodes should have sufficient capacity to support all functions. The applicant should identify the true data rate, including overhead, to ensure that communication bandwidth is sufficient to ensure proper performance of all safety functions. Communications throughput thresholds and safety system sensitivity to communications throughput issues should be confirmed by testing.

1.20 The safety system response time calculations should assume a data error rate that is greater than or equal to the design basis error rate and is supported by the error rate observed in design and qualification testing.

11.3.2 Command Prioritization

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11.3.3 Multidivisional Control and Display Stations

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11.4 TXS COMPACT Compliance to NRC Branch Technical Position (BTP) 7-14 Revision 6, 2016

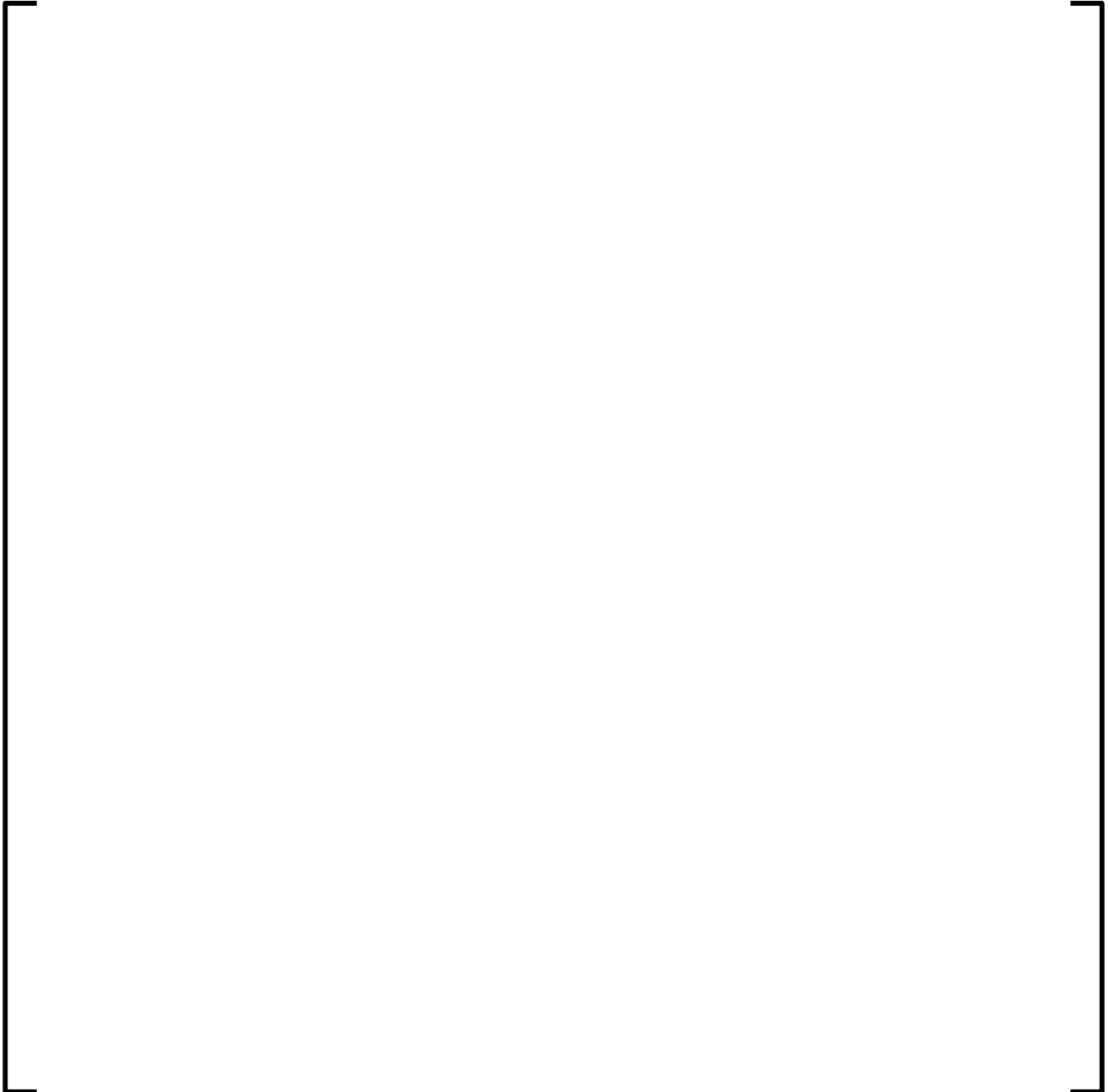
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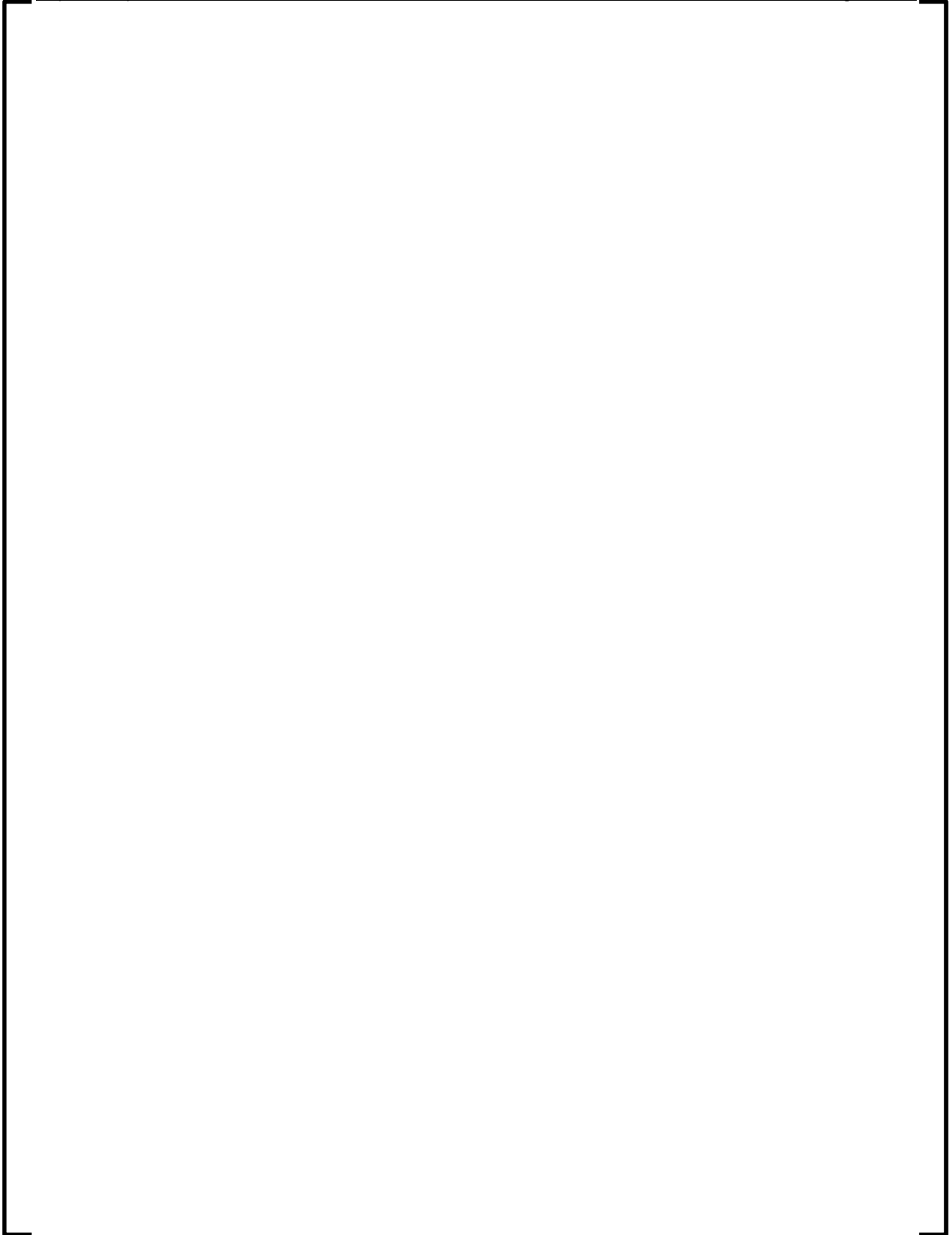
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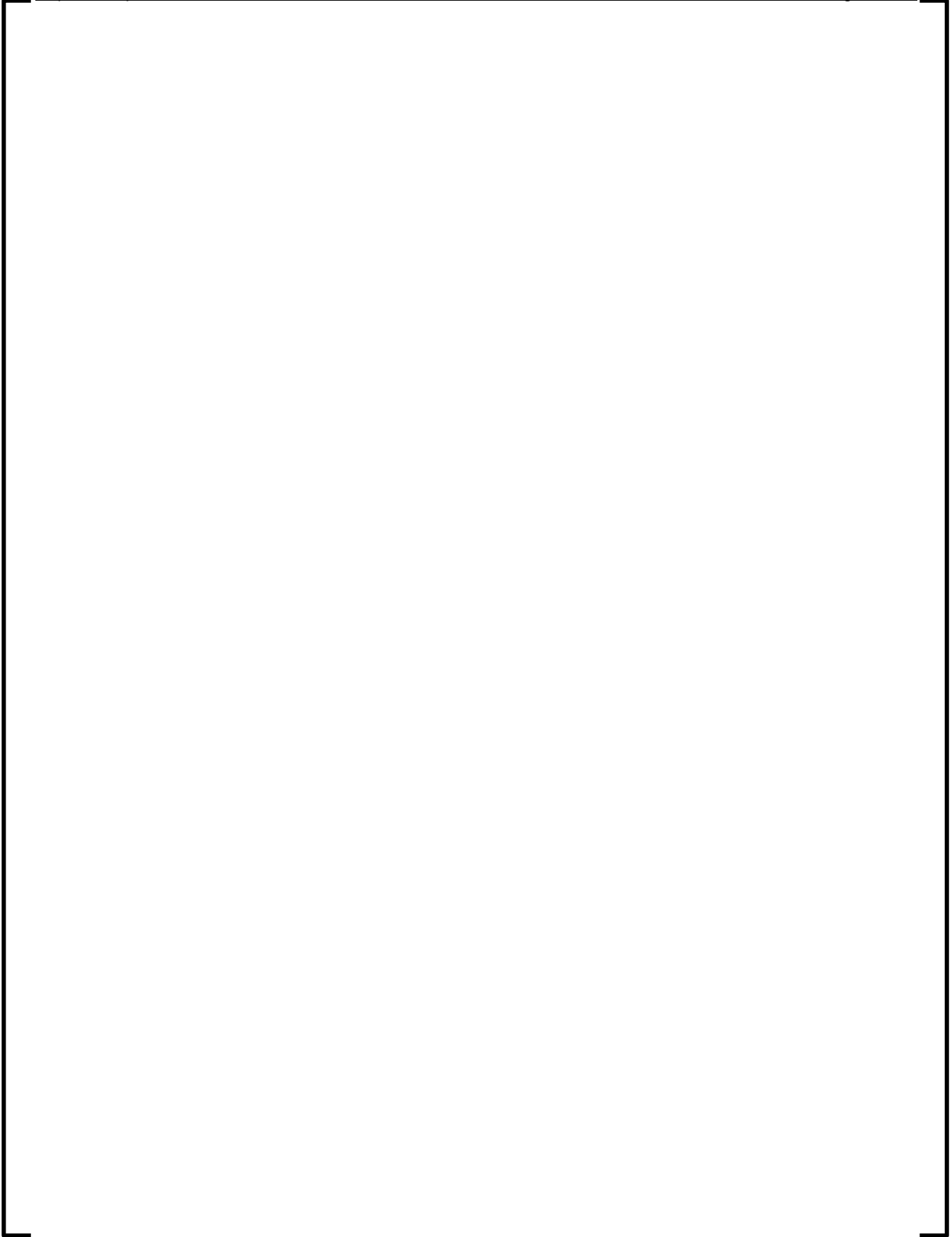
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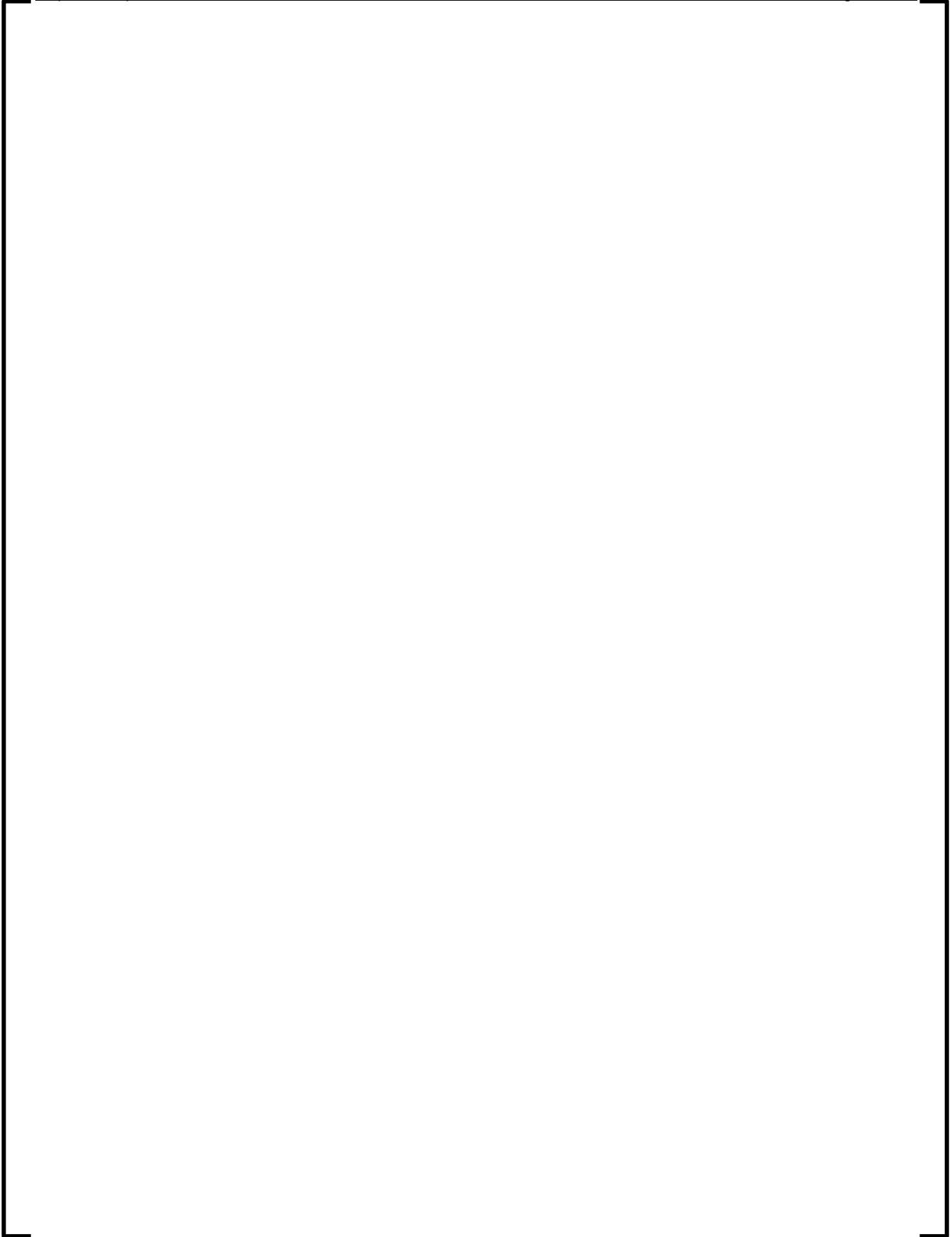
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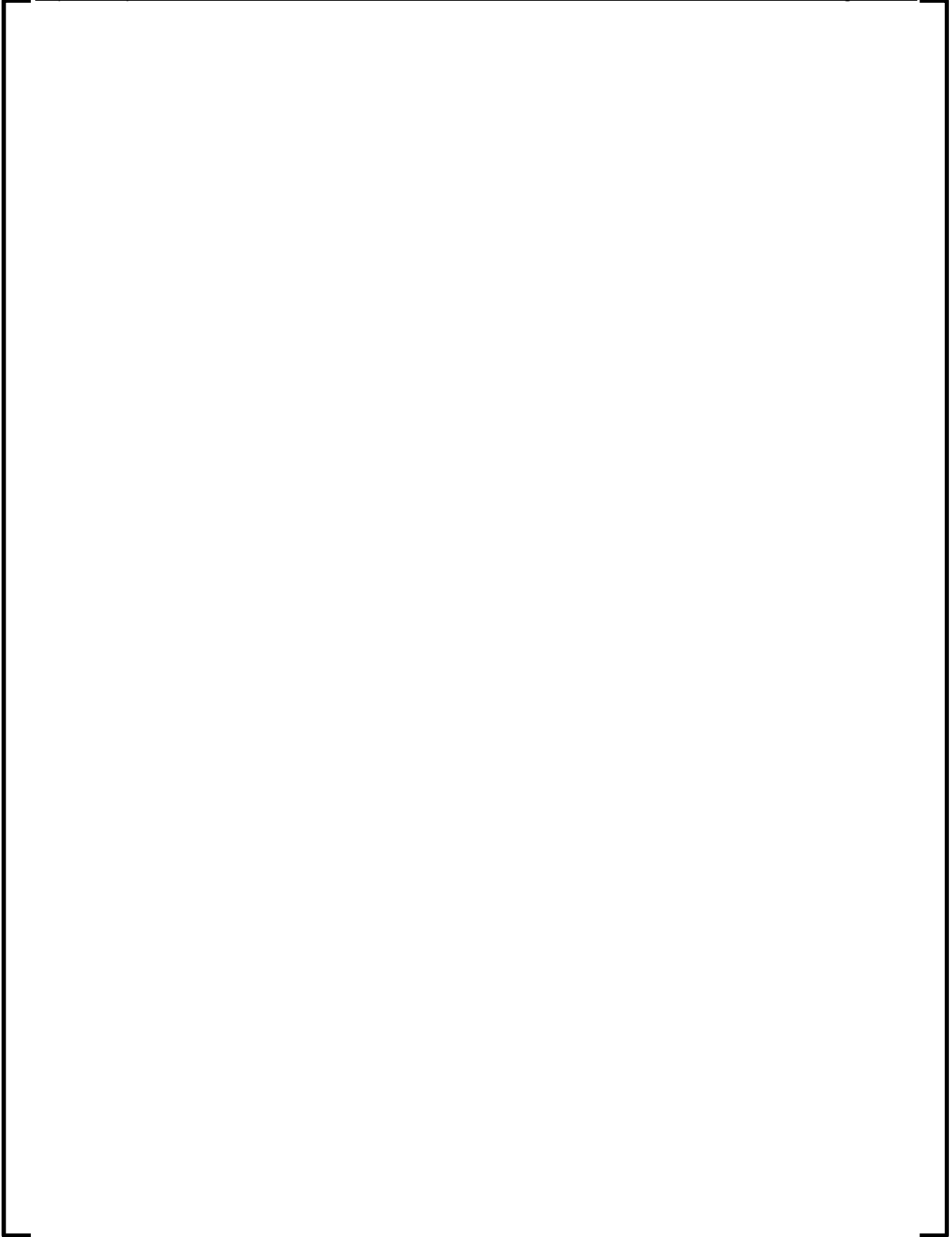
11.5 TXS COMPACT Compliance to NUREG 0800 Table 7-1 Criteria Revision 6, 2016

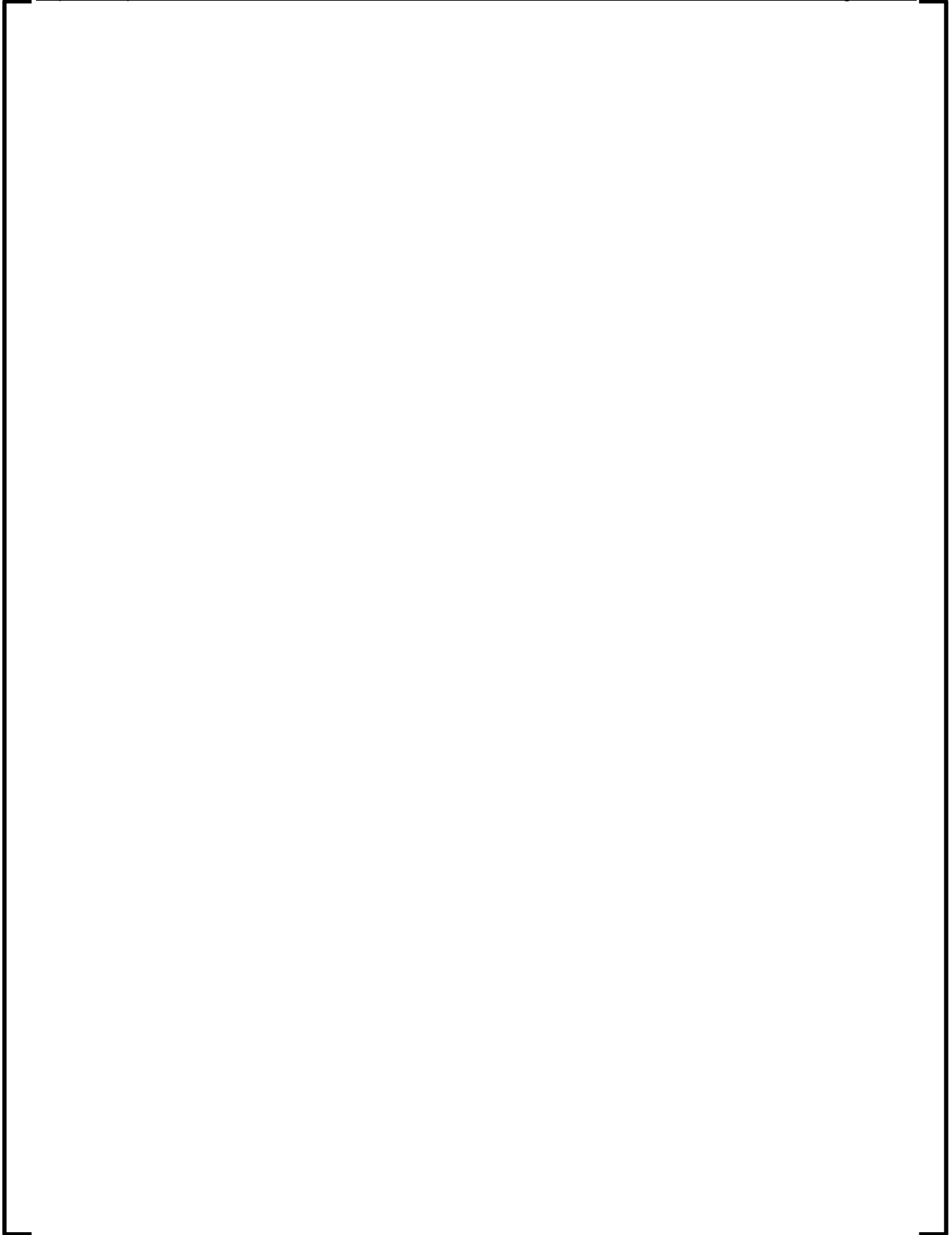


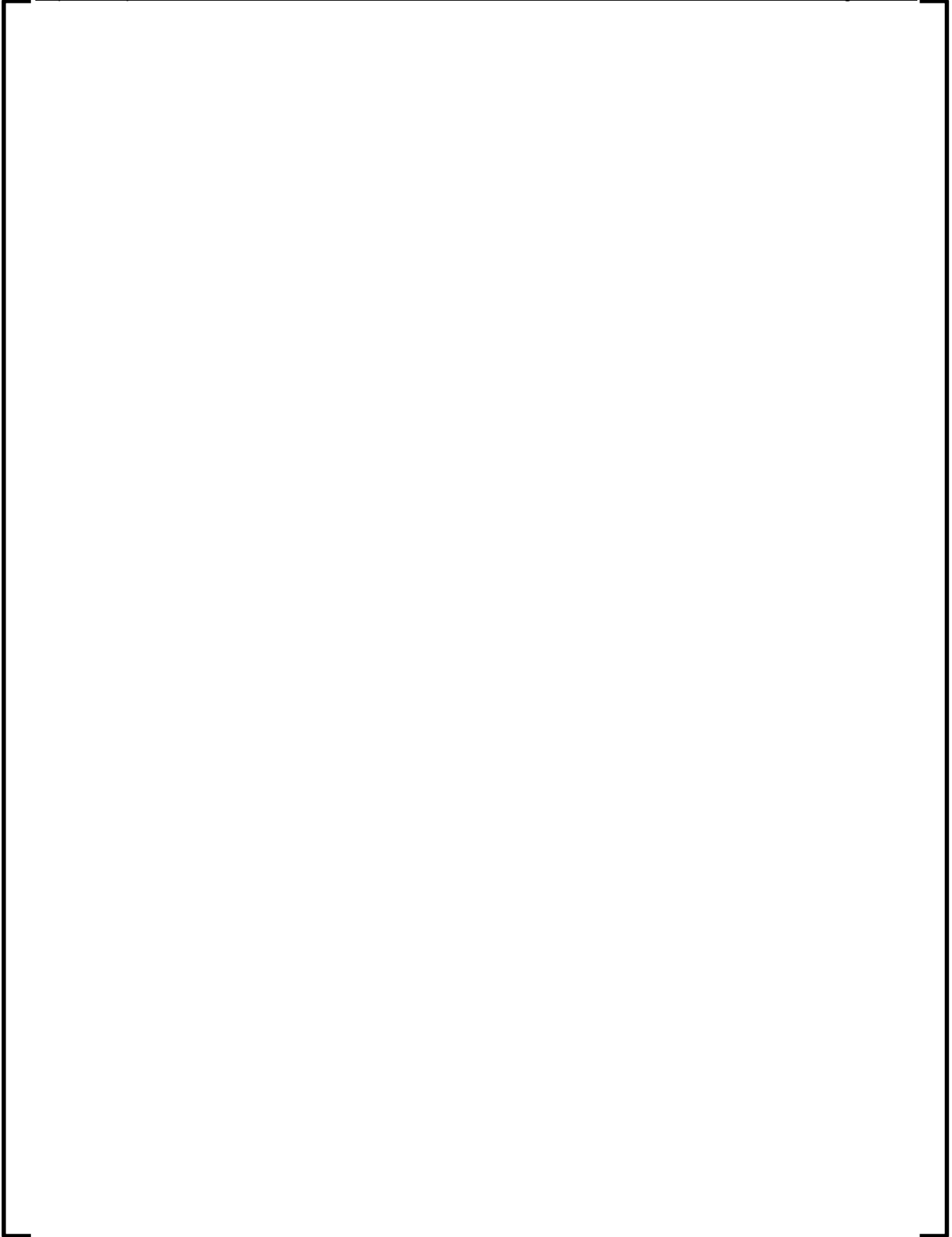












11.6 *TXS COMPACT Compliance with DI&C ISG-06 Licensing Process*

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11.6.1 D.1 Plant System Description

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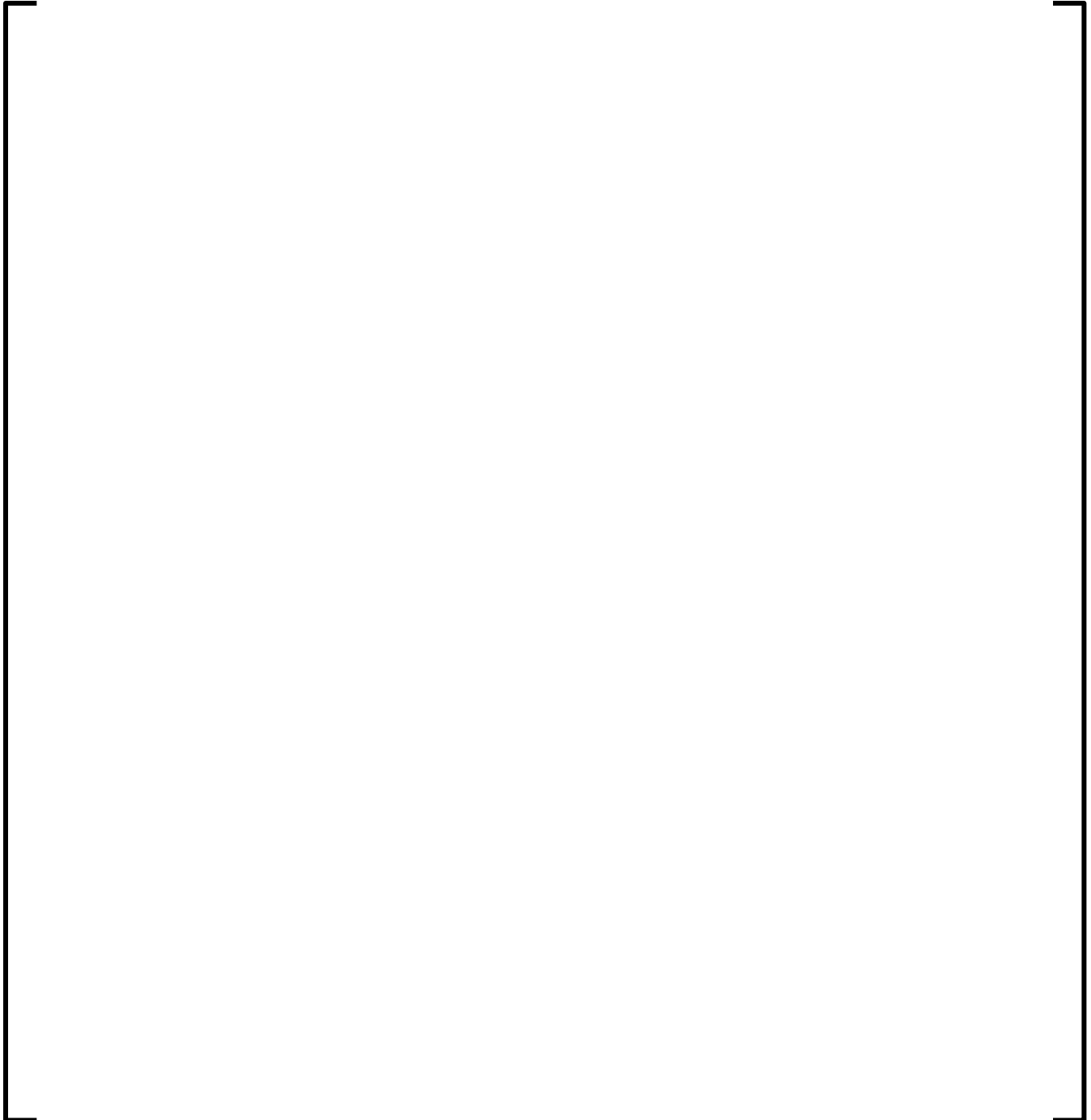
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11.6.2 D.2 System Architecture

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11.6.3 D.3 Hardware Equipment Qualification



11.6.4 D.4 Digital Instrumentation and Control System Development Processes

11.6.5 D.5 Applying a Referenced Topical Report Safety Evaluation

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11.6.6 D.6 Compliance/Conformance Matrix for IEEE Standards 603-1991 and 7-4.3.2-2003

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11.6.7 D.7 Technical Specifications

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11.6.8 D.8 Secure Development and Operational Environment

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11.6.9 D.9 Other Review Guidance for Tier 1, 2, and 3 Reviews

11.6.9.1 D.9.1 Software Requirements Specification

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11.6.9.2 D.9.2 Software Design Specification

11.6.9.3 D.9.3 Changes to Referenced Platform Design

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11.6.9.4 D.9.4 Software Safety Analysis

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11.6.9.5 D.9.5 Configuration Management Activities

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11.6.9.6 D.9.6 Testing Activities

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11.6.9.7 D.9.7 System Integrity—Time Response/Deterministic Performance

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11.6.9.8 D.9.8 Platform- and System-Level Failure Modes

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11.6.9.9 D.9.9 Commercial-Grade Dedication of Digital Equipment

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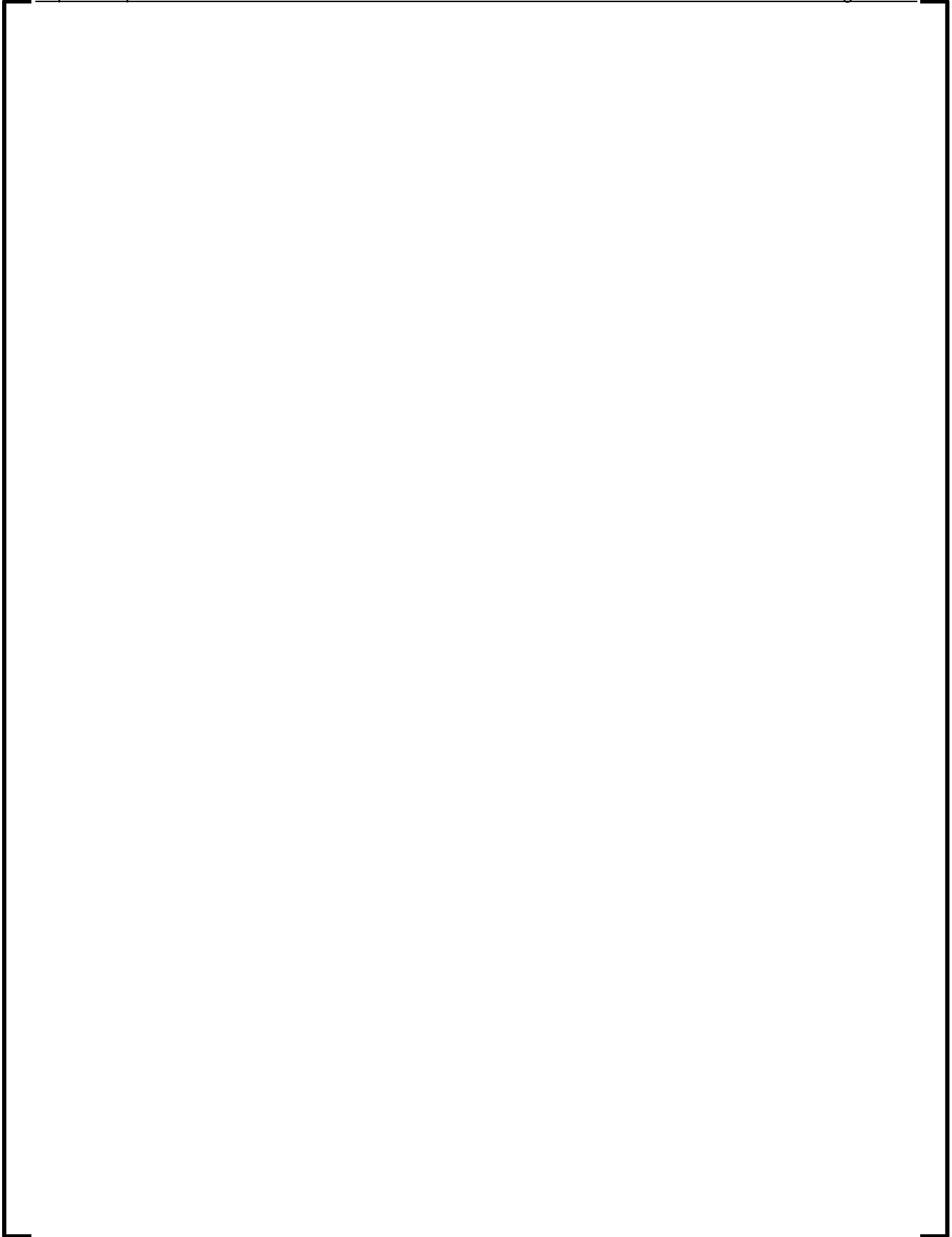
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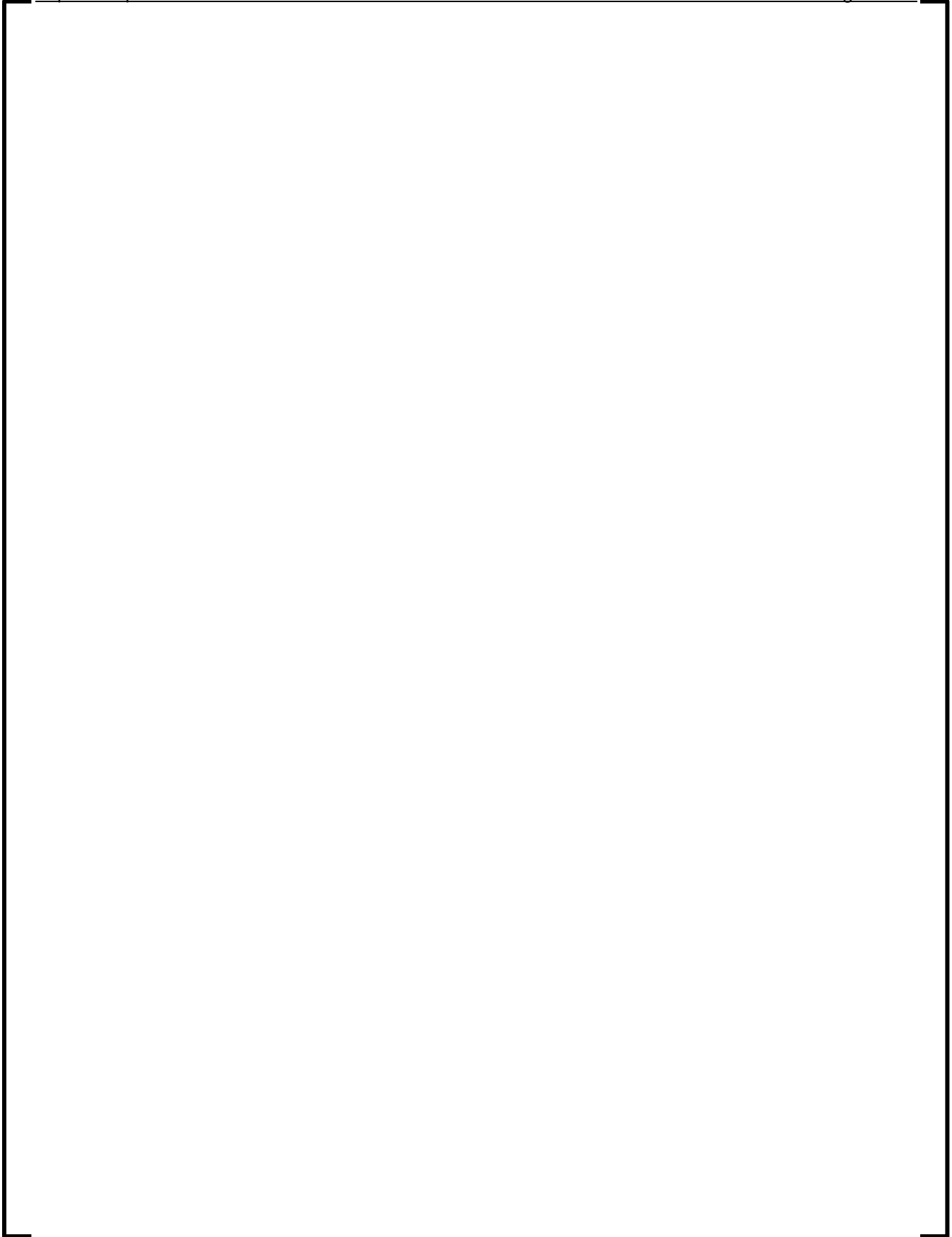
11.6.9.10 D.9.10 Hardware Development Process

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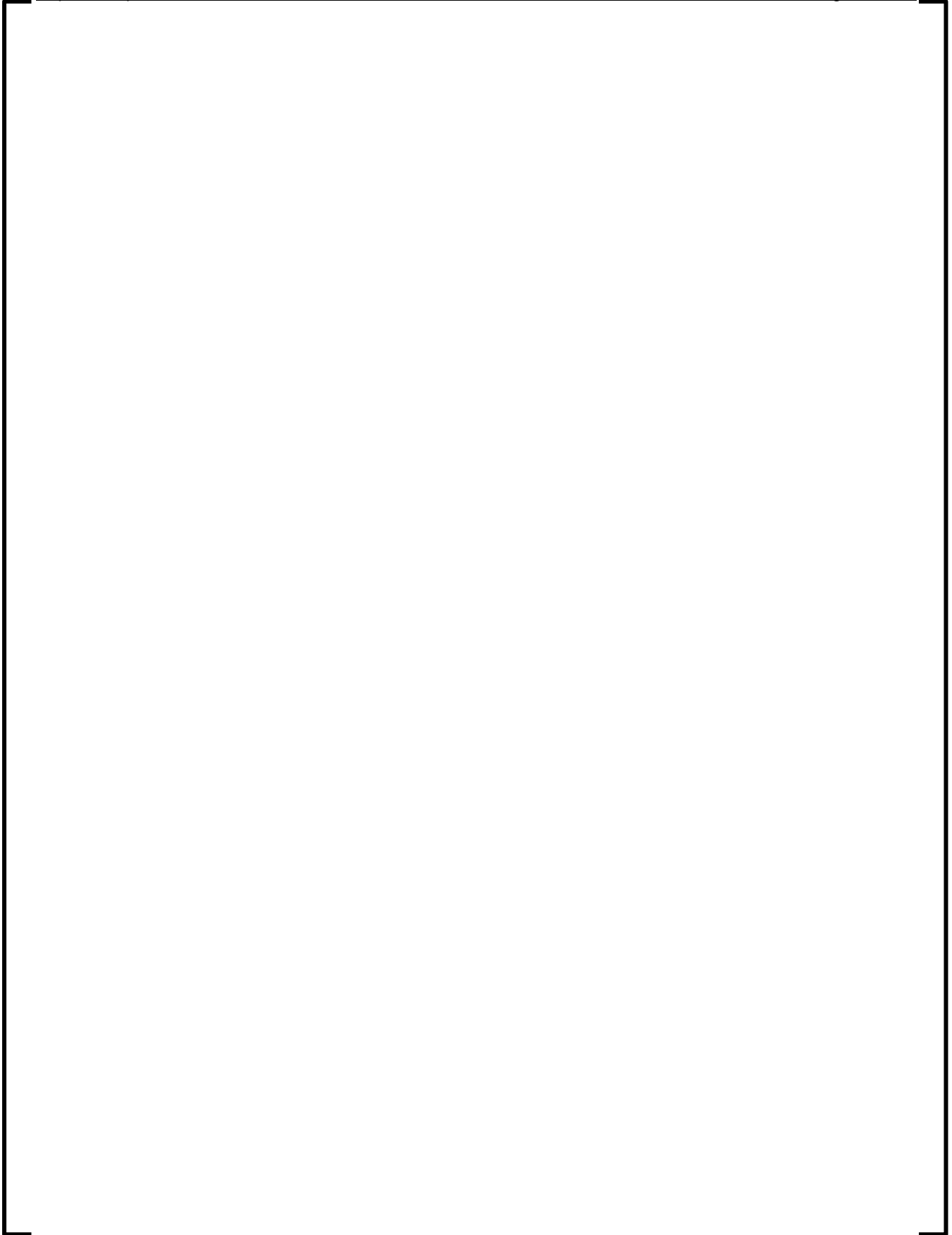
11.7 *Relationship Between TXS COMPACT Program Development in U.S. NRC RG Criteria*

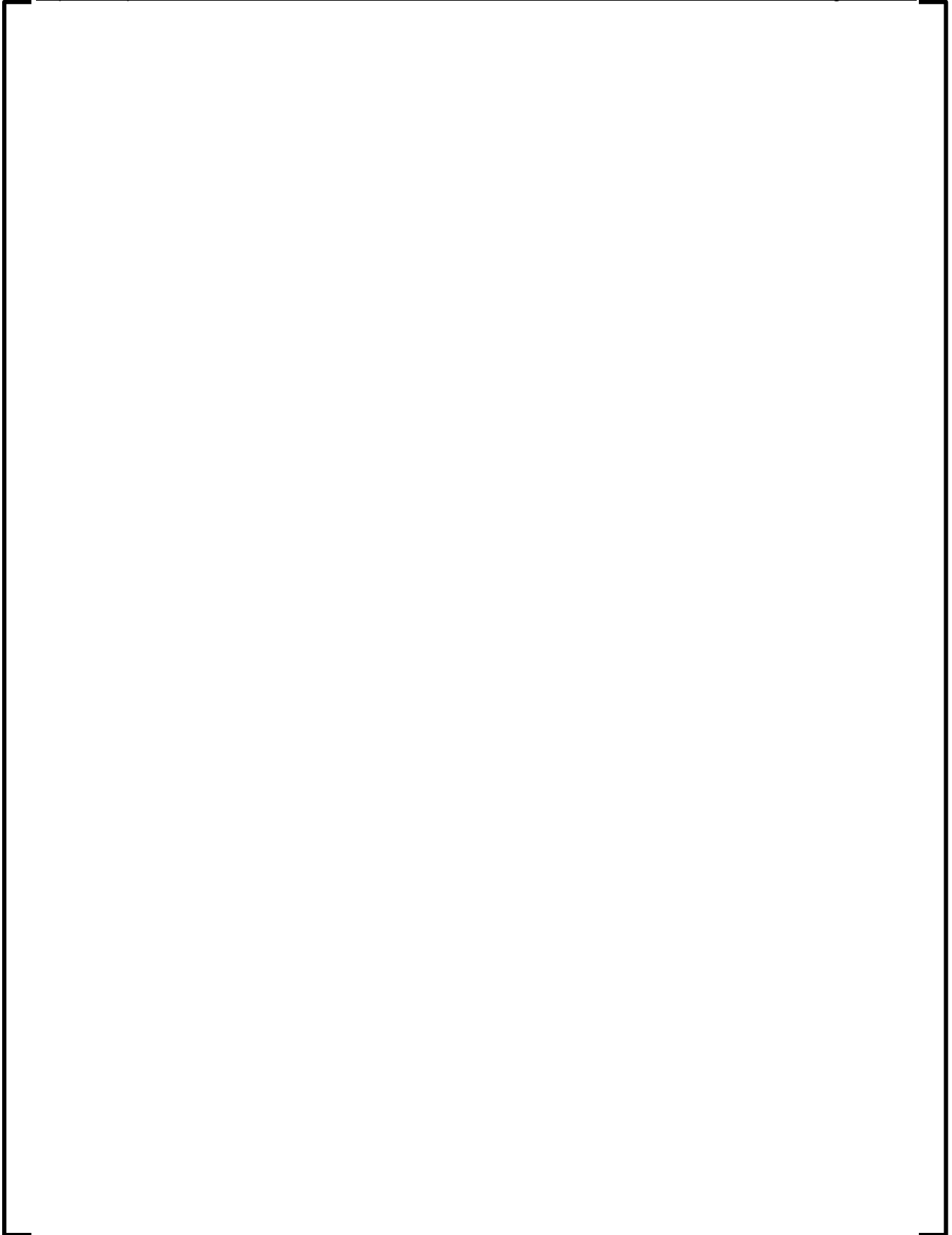
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2	ADARSH K	102	10	Maths	78	
3	ADITHYAN K	103	10	Maths	92	
4	ADITHYAN K	104	10	Maths	88	
5	ADITHYAN K	105	10	Maths	75	
6	ADITHYAN K	106	10	Maths	82	
7	ADITHYAN K	107	10	Maths	79	
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11	ADITHYAN K	111	10	Maths	87	
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64	ADITHYAN K	164	10	Maths	84	
65	ADITHYAN K	165	10	Maths	87	
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69	ADITHYAN K	169	10	Maths	85	
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Correspondence for
ANP-10357, Revision 0



August 2, 2024
NRC:24:015

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Request for Review and Approval of ANP-10357P, Revision 0, "TXS COMPACT PLATFORM Topical Report"

Framatome Inc. (Framatome) requests NRC review and approval of Topical Report ANP-10357P, Revision 0, "TXS COMPACT PLATFORM Topical Report" for referencing in licensing actions. This report presents the generic application of the TXS COMPACT which has been developed as platform based on Field-Programmable Gate Array (FPGA) technology that can be integrated with different modules from the TXS portfolio to implement safety Instrumentation and Control (I&C) systems in accordance with applicable regulatory requirements for safety-related I&C systems in nuclear power plants (NPPs).

The TXS system platform is intended for the design of safety I&C systems for NPPs of different reactor technologies and in many countries, subject to various licensing requirements. Therefore, hardware and configware/application qualification of the TXS system platform components is performed based on the requirements from international standards, namely International Atomic Energy Agency (IAEA) and International Electrotechnical Commission (IEC) standards. In addition, nuclear Institute of Electrical and Electronics Engineers (IEEE) standards, such as IEEE 603, are considered, being representative for applications in many countries with influence from the USA. This report presents design features and characteristics and explains how the qualification of TXS COMPACT is performed. Also discussed are the structured development and Verification and Validation (V&V) processes involving independent assessor organizations.

Framatome considers some of the material contained in the enclosed document to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support withholding the information from public disclosure. Proprietary and non-proprietary versions of the report are enclosed.

There are no commitments within this letter or its enclosures.

If you have any questions related to this information, please contact Mr. Philip A. Opsal by telephone at (434) 534-1223, or by e-mail at Philip.Opsal@framatome.com.

Sincerely,

Gayle Elliott, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: Ngola Otto
Project 728

Enclosures:

1. ANP-10357P, Revision 0 (PROPRIETARY)
2. ANP-10357NP, Revision 0 (NON-PROPRIETARY)
3. Affidavit



**UNITED STATES
NUCLEAR REGULATORY COMMISSION**
WASHINGTON, D.C. 20555-0001

October 7, 2024

Gayle Elliott, Director
Licensing and Regulatory Affairs
Framatome Inc.
3315 Old Forest Road
Lynchburg, VA 24501

**SUBJECT: THE U.S. NUCLEAR REGULATORY COMMISSION STAFF'S ACCEPTANCE
FOR THE REVIEW OF FRAMATOME'S TOPICAL REPORT, ANP-10357P,
REVISION 0, "TXS COMPACT PLATFORM TOPICAL REPORT"
(EPID L-2024-TOP-0029)**

Dear Gayle Elliott:

By letter dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), Framatome, Inc. (Framatome) submitted Topical Report (TR) ANP-10357P, Revision 0, "TXS Compact Platform Topical Report," for U.S. Nuclear Regulatory Commission (NRC) staff's review. As stated in your letter, the TR presents the generic application of the TXS COMPACT which has been developed as a platform based on Field-Programmable Gate Array (FPGA) technology that could be integrated with different modules from the TXS portfolio to implement safety Instrumentation and Control systems in nuclear power plants. The TR describes the TXS COMPACT platform modules, including configuration, diagnostics, monitoring, equipment qualification, communications, life cycle management, reliability, quality assurance, security, and regulatory compliance. A pre-submittal meeting was held on July 23, 2024 (ADAMS Accession No. ML24193A240), where Framatome representatives indicated that additional documents were available to support the NRC staff's review.

After the submittal, Framatome made documents (as required in Interim Staff Guidance-06, Revision 2) available for NRC staff's review via their electronic reading room. However, the regulatory compliance evaluation in the TR (e.g., Section 11, "TXS Compact Regulatory Evaluation," supporting documentation) pointed to only some of these documents as evidence of compliance. The NRC staff requested that all the documents needed for the staff's safety evaluation be submitted on the docket to support its detailed technical review. Framatome plans to docket these documents by April 4, 2025.

The NRC staff have found that ANP-10357P, Revision 0, in addition to the requested documents is sufficient to begin its detailed technical safety review. Below are discussions and the NRC staff's rationale for the planned schedule and level of effort for the TR review. The NRC staff plans to conduct an in-person audit by the end of March 2025 (tentative), and issue 2 sets of Requests for Additional Information (RAIs) by July 2025, the draft safety evaluation (SE) by February 20, 2026, and final SE by April 30, 2026, as annotated in the enclosed schedule. The draft SE completion date assumes 60 days for RAI responses and availability of all

documents required to be docketed and may be adjusted, if necessary, to accommodate any delays in the submittals. The enclosed schedule includes planned milestones dates for the overall review.

Additionally, the NRC staff estimates that it will require approximately 2000 hours to complete the safety review. The NRC staff may need to increase the planned level of effort if the staff deems necessary for review of platform modules that were developed in accordance with International Electrotechnical Commission standards, which are not NRC endorsed criteria. No Advisory Committee on Reactor Safeguards review is needed for this TR.

Section 170.21 of Title 10 of the *Code of Federal Regulations* requires that TRs are subject to fees based on the full cost of the review. You did not request a fee waiver; therefore, NRC staff-hours will be billed accordingly.

If you have any questions regarding the TR review, please contact me at 301-415-6695 or via email at Ngola.Otto@nrc.gov.

Sincerely,

/RA/

Ngola A. Otto, Project Manager
Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No.: 99902041

Enclosure:
Initial Review Schedule

Initial Review Schedule

<u>Milestone</u>	<u>Planned Date</u>
Initial Submittal	August 2, 2024
Acceptance	October 1, 2024
Audit (In-person)	March 2025 (tentative)
Supporting documentation Submittal	April 4, 2025
Issue Request for Additional Information (RAI) – Set #1	May 30, 2025
Issue RAI – Set #2	July 31, 2025
Response to RAI – Set #1	July 31, 2025
Response to RAI – Set #2	September 30, 2025
Issue Draft SE	February 20, 2026
Issue Final SE	April 30, 2026

SUBJECT: THE U.S. NUCLEAR REGULATORY COMMISSION STAFF'S ACCEPTANCE
FOR THE REVIEW OF FRAMATOME'S TOPICAL REPORT, ANP-10357P,
REVISION 0, "TXS COMPACT PLATFORM TOPICAL REPORT"
(EPID L-2024-TOP-0029) DATED: OCTOBER 7, 2024

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ADAMS Accession Number: ML24256A027***via email**

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DATE	09/24/2024	09/25/2024	10/02/2024	10/02/2024
OFFICE	NRR/DORL/LLPB/PM			
NAME	NOtto			
DATE	10/07/2024			

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REQUEST FOR ADDITIONAL INFORMATION (RAI)-10637

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ANP-10357P, REVISION 0, "TXS COMPACT PLATFORM TOPICAL REPORT"

FRAMATOME INC.

DOCKET NO. 99902041

ISSUE DATE: 06/13/2025

Background

By letter dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), Framatome, Inc. (Framatome) submitted ANP-10357P, Revision 0, "TXS Compact Platform Topical Report" (TR) for U.S. Nuclear Regulatory Commission (NRC) staff's review and approval. The NRC staff has reviewed the proposed TR, conducted an audit (ADAMS Accession No. ML24352A156), and determined that additional information is needed to complete the review. The NRC staff's request for additional information (RAI)-10637 is provided below.

Regulatory Basis

The regulatory basis for this RAI can be found in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(h) which incorporates the requirements of Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and Regulatory Guide (RG) 1.75, "Criteria for Independence of Electric Safety Systems."

Question 1

The regulation at 10 CFR 50.55a(h) incorporates by reference the requirements of IEEE Std. 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995. Clause 5.4, "Equipment Qualification," of IEEE Std. 603-1991 requires, in part, that safety system equipment shall be qualified by type test, previous operating experience, or analysis, or any combination of these three methods, to substantiate that it will be capable of meeting, on a continuing basis, the performance requirements as specified in the design basis.

As part of the equipment qualification, the Class 1E to non-Class 1E isolation qualification testing shall be performed. The regulatory guidance on the Class 1E to non-Class 1E isolation testing is included in RG 1.75, and Section 6.3.6 of EPRI TR-107330, "Requirements Compliance Traceability Matrix," as endorsed in RG 1.209, "Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants."

However, the NRC staff found that Class 1E to non-Class 1E isolation qualification testing has not been addressed in the submitted TXS COMPACT TR. The NRC staff requests that the application provides additional information to substantiate compliance with the regulatory requirement on the qualification of the Class 1E to non-Class 1E isolation for the TXS COMPACT Platform.

ADAMS Accession No.: ML25160A110 (RAI – Non-Proprietary)

OFFICE	NRR/DORL/LLPB/PM	NRR/DORL/LLPB/LA	NRR/DEX/EICB/BC
NAME	NOtto	DHarrison	FSacko
DATE	6/11/2025	6/11/2025	6/12/2025
OFFICE	NRR/DORL/LLPB/BC	NRR/DORL/LLPB/PM	
NAME	JRankin	NOtto	
DATE	6/13/2025	6/13/2025	

REQUEST FOR ADDITIONAL INFORMATION-10636
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
ANP-10357P, REVISION 0, TXS COMPACT PLATFORM TOPICAL REPORT
FRAMATOME INC.
DOCKET NO. 99902041
ISSUE DATE: 06/16/2025

Background

By letter dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), Framatome, Inc. submitted ANP-10357P, Revision 0, "TXS Compact Platform Topical Report (TR)," for U.S. Nuclear Regulatory Commission (NRC) staff's review and approval. The NRC staff has reviewed the proposed TR, conducted an audit (ADAMS Accession No. ML24352A156) and determined that additional information is needed to complete the review. The NRC staff's request for additional information (RAI)-10636 is provided below.

Regulatory Basis

The regulatory basis for this RAI can be found in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(h) which incorporates the requirements of the Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," and Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

Question 1

The regulation at 10 CFR 50.55a(h) incorporates by reference the requirements of IEEE Std. 603-1991 and the correction sheet dated January 30, 1995. Clause 5.4, "Equipment Qualification" of IEEE Std. 603-1991 requires, in part, that safety system equipment shall be qualified by type test, previous operating experience, or analysis, or any combination of these three methods, to substantiate that it will be capable of meeting, on a continuing basis, the performance requirements as specified in the design basis.

Appendix B to 10 CFR Part 50 prescribes requirements for quality assurance to ensure that structures, systems, and components will perform satisfactorily in service. Criterion VII of Appendix B, "Control of Purchased Material, Equipment, and Services," requires, in part, that measures shall be established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection.

During the regulatory audit from March 31 to April 4, 2025, the NRC staff noted that equipment qualification (EQ) testing service for the TXS COMPACT Platform was conducted by third parties contracted by Framatome GmbH. However, Framatome did not perform commercial grade dedication (CGD) for the EQ testing service until the EQ testing service was already completed. The NRC staff requests that the applicant clarifies or justifies the use of the EQ testing service provided by third parties before performing the CGD for the EQ testing service.

ADAMS Accession Nos.:

ML25161A164 (RAI - Non-Proprietary)

OFFICE	NRR/DORL/LLPB/PM	NRR/DORL/LLPB/LA	NRR/DEX/EICB/BC
NAME	NOtto	DHarrison	FSacko
DATE	06/11/2025	06/12/2025	06/16/2025
OFFICE	NRR/DORL/LLPB/BC	NRR/DORL/LLPB/PM	
NAME	JRankin	Notto	
DATE	06/16/2025	06/16/2025	

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REQUEST FOR ADDITIONAL INFORMATION-10638

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ANP-10357P, REVISION 0, "TXS COMPACT PLATFORM TOPICAL REPORT"

FRAMATOME INC.

DOCKET NO. 99902041

ISSUE DATE: 06/16/2025

Background

By letter dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), Framatome, Inc. submitted ANP-10357P, Revision 0, "TXS Compact Platform Topical Report," (TR) for U.S. Nuclear Regulatory Commission (NRC) staff's review and approval. The NRC staff has reviewed the proposed TR, conducted an audit (ADAMS Accession No. ML24352A156) and determined that additional information is needed to complete the review. The NRC staff's request for additional information (RAI)-10638 is provided below.

Regulatory Basis

The regulatory basis for this RAI can be found in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(h) which incorporates the requirements of Institute of Electrical and Electronic Engineers (IEEE) Standard (Std.) 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and Regulatory Guide (RG) 1.152, "Criteria for Programmable Digital Devices in Safety-Related Systems of Nuclear Power Plants."

Question 1

The regulation at 10 CFR 50.55a(h) incorporates by reference the requirements of IEEE Std. 603-1991 and the correction sheet dated January 30, 1995. Clause 5.6.3, "Between Safety Systems and Other Systems," requires, in part, that, "The safety system design shall be such that credible failures in and consequential actions by other systems, as documented in Section 4.8 of the design basis, shall not prevent the safety systems from meeting the requirements of this standard". RG 1.152, Revision 4, and its endorsed IEEE Std. 7-4.3.2-2016, "IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations," provide regulatory guidance on how to meet the requirement on independence between safety systems and other non-safety systems.

In Section 5.2.2.2, "Communication from the Service Unit to an Automation Unit," of the TXS COMPACT TR, it states, in part, that "When the SYSTEM or OPE_PARAM release is activated on an Automation Unit, an optocoupler on the PM1 temporarily activates a communication line to enable maintenance of this Automation Unit." It also states in Section 5.2.2.2 that "this communication channel can be used to parameterize the unit by changing configuration data, such as the application, parameters, etc."

The NRC staff noted that the OPE_PARAM mode allows update of parameters while still in OPERATION mode. Although this feature can be permanently or temporarily inhibited when configuring the instrumentation & control system, the NRC staff requests that the applicant provides additional information to clarify or justify the use of non-safety-related Service Unit to parameterize the safety-related automation unit during operation if the above feature is not inhibited.

ADAMS Accession No.:
ML25160A168 (RAI – Non-Proprietary)

OFFICE	NRR/DORL/LLPB/PM	NRR/DORL/LLPB/LA	NRR/DEX/ELTB/BC	NRR/DORL/LLPB/BC(A)
NAME	NOtto	DHarrison	FSacko	JRankin
DATE	06/11/2025	06/12/2025	06/16/2025	06/16/2025
OFFICE	NRR/DORL/LLPB/PM			
NAME	NOtto			
DATE	06/16/2025			



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

June 30, 2025

Ms. Gayle Elliott, Director
Licensing and Regulatory Affairs
Framatome Inc.
3315 Old Forest Road
Lynchburg, VA 24501

SUBJECT: REPORT REGARDING MARCH 31 - APRIL 4, 2025, REGULATORY AUDIT
FOR FRAMATOME INC. ANP-10357P, REVISION 0, "TXS COMPACT
PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)

Dear Ms. Elliott:

By application dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), Framatome, Inc. submitted Topical Report (TR) ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report," for U.S. Nuclear Regulatory Commission (NRC) staff's review.

The NRC staff conducted an in-person regulatory audit (ADAMS Accession No. ML24352A156) on March 31- April 4, 2025, to obtain additional information needed to complete the review of TR ANP-10357P, Revision 0. The scope of the audit included equipment qualification, system development life-cycle process management, and quality assurance for the TXS COMPACT Platform. The NRC staff will determine if additional audits are needed. The results of the audit will support the NRC staff's safety evaluation for TR ANP-10357P, Revision 0. The proprietary and non-proprietary audit reports are enclosed.

**NOTICE: Enclosure 1 to this letter contains Proprietary Information. When
this letter is separated from Enclosure 1, this letter is decontrolled.**

G. Elliott

- 2 -

If you have any questions, please contact me at (301) 415-6695 or via e-mail at Ngola.Otto@nrc.gov regarding this letter.

Sincerely,

/RA/

Ngola A. Otto, Project Manager
Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 99902041

Enclosures:

1. Audit Report (Proprietary)
2. Audit Report (Nonproprietary)

SUBJECT: REPORT REGARDING MARCH 31 - APRIL 4, 2025, REGULATORY AUDIT
FOR FRAMATOME INC. ANP-10357P, REVISION 0, "TXS COMPACT
PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)
DATED JUNE 30, 2025

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Phil.Opsal@framatome.com

ADAMS Accession Nos.:

ML25154A657 (Package)

ML25154A652 (Letter)

ML25154A653 (Audit Report - Proprietary)

ML25154A659 (Audit Report - Non-proprietary)

OFFICE	NRR/DORL/LLPB/PM	NRR/DORL/LLPB/LA	NRR/DEX/ECIB/BC	NRR/DRO/QVIB
NAME	NOtto	DHarrison	FSacko	KKavanagh
DATE	06/4/2025	06/11/2025	06/12/2025	06/16/2025
OFFICE	NRR/DORL/LLPB/BC	NRR/DORL/LLPB/PM		
NAME	JRankin	NOtto		
DATE	06/16/2025	06/30/2025		

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MARCH 31 - APRIL 4, 2025, REGULATORY AUDIT REPORT
REGARDING FRAMATOME INC. TOPICAL REPORT ANP-10357P, REVISION 0
TXS COMPACT PLATFORM TOPICAL REPORT
PROJECT NO. 728
EPID L-2024-TOP-0029

1.0 BACKGROUND

By application dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), Framatome, Inc. submitted Topical Report (TR) ANP-10357P, Revision 0, "TXS Compact Platform Topical Report", for U.S. Nuclear Regulatory Commission (NRC) staff's review and approval. The TXS Compact Platform is based on a field programmable gate array (FPGA) technology and includes different module options that are designed for implementation in safety-related instrumentation and control (I&C) system applications in nuclear power plants (NPPs). On March 31- April 4, 2025 (ADAMS Accession No. ML24352A156), the NRC staff conducted an in-person regulatory audit of the TXS Compact Platform at Framatome headquarters in La Defense business district in Courbevoie, France. The audit supports the NRC staff's safety evaluation (SE) pertaining to the TXS Compact Platform TR (hereafter referred to as the TR) review. This audit was performed in accordance with the Office of Nuclear Reactor Regulation procedure as described in LIC 111, "Regulatory Audits," and regulatory guidance listed in the audit plan.

The scope of the audit included equipment qualification (EQ), system development life cycle process, and quality assurance (QA) which covered several topic areas of the TR including the following: TXS Compact Platform architecture, modules, communications, configuration, diagnostic, monitoring, EQ, life cycle management, reliability, failure modes effects and analysis, QA, security, and regulatory compliance.

Per the NRC staff's request, a list of reference documents was available on the Framatome online portal to support the audit, and additional documents were added to facilitate responses to the NRC staff's questions. The NRC staff's informational needs requests were addressed by Framatome representatives during the audit.

2.0 REGULATORY AUDIT OBJECTIVES

The overall objectives and goals for the audit are provided below. The in-person audit facilitated the NRC staff's review through direct interaction with Framatome's technical experts.

Equipment Qualification

- Ensuring common cause failure is negligible due to environmental, electromagnetic interference and radio frequency interference, seismic, and Class 1E to non-Class 1E isolation effects.
- Review documentation and observe simulations to ensure that the TXS Compact Platform can perform its intended safety function.

- Review EQ program, testing plans, and procedures utilized to perform qualification testing (environmental, seismic, electromagnetic compatibility (EMC), and Class 1E to non-Class 1E isolation).
- Verify testing summary results by reviewing signed onsite testing records, safety function performance results, qualifications of testing personnel, and test facilities accreditation.

Digital System Development Lifecycle

- Verify performance of the critical functional requirements (e.g., built-in self-diagnostic capabilities, fail-safe actions, internal fault detections) and the handling of anomalies identified during digital system development lifecycle process.
- Review the process used to establish requirements specifications for the TXS Compact Platform.
- Review the use of requirements traceability matrix at all phases of digital system development lifecycle activities.
- Confirm that acceptable plans were prepared to control software development activities.
- Verify that the software development lifecycle plans were executed appropriately and that the lifecycle process produced acceptable design outputs.

Quality Assurance

- Assess Framatome Inc.'s procurement and supplier oversight activities of Framatome SAS¹ and Framatome GmbH².
- Assess the relationship among the Framatome Inc. QA Program, Framatome Integrated Management System Manual, TXS QA Plan for TXS Compact Automation System (AS) FPGA, TXS Compact Engineering and Service Tools QAP, and TXS Compact Quality Management Plan to understand how the requirements of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," are met.

Those who participated in the audit are listed below.

Name	Title	Affiliation
Jack Zhao	Senior Electronics (Digital I&C) Engineer	NRC

¹ Framatome SAS based in France is owned by EDF Group (80.5%) and Mitsubishi Heavy Industries (MHI - 19.5%).

² Framatome GmbH, based in Erlangen, Germany is a wholly owned subsidiary of Framatome SAS in France.

Name	Title	Affiliation
Dinesh Taneja	Senior Electronics (Digital I&C) Engineer	NRC
Deanna Zhang (remote)	Senior Reactor Operations Engineer	NRC
Ngola Otto	Project Manager	NRC
Mathieu ALLORY	Director, Safety Automation Product Line	Framatome SAS
Manfred AUER	EQ Engineer	Framatome GmbH
Fanny CHESNAY	Quality Engineer	Framatome SAS
Mehdi EL OUAFI	Director Strategic Development & Industrialization	Framatome Inc
Larry ERIN	Director, I&C Licensing	Framatome Inc
Bernd GEIER	Quality Manager	Framatome GmbH
Hayder HAOUANEB	Project Leader	Framatome SAS
Mark HARVEY	Director, Quality, Performance and Operational Support	Framatome Inc
Miriane KENFACK MEZATIO	EQ Engineer	Framatome GmbH
Didier LECOEUR	Director, Quality Assurance	Framatome SAS
Ulrich LUIG	EQ Engineer	Framatome GmbH
Christian LUSCHMANN	Licensing Expert	Framatome GmbH
Brian MCMAHON	Application Engineer	Framatome Inc
Matthieu NOBRE	Supplier & Processes Manager	Framatome SAS
Stephane NOUKETCHESSI SIMO	Qualification and Licensing Engineer	Framatome SAS
Ryan REYNOLDS	EQ Manager	Framatome Inc
Laurent THIEFFRY	Senior VP, I&C Business Unit	Framatome SAS

3.0 **REGULATORY AUDIT BASES**

Regulations relevant to the audit and NRC staff's review of the TR include:

- 10 CFR 50.54(jj) and 10 CFR 50.55(i) require that structures, systems, and components (SSCs) subject to the codes and standards in 10 CFR 50.55a, "Codes and Standards," must be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.
- Appendix A, General Design Criterion (GDC) 2, "Design bases for protection against natural phenomena," of 10 CFR Part 50, which states, in part, that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their safety functions.
- Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases," of 10 CFR Part 50, which states, in part, that SSCs important to safety shall be designed to

accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.

- Appendix A, GDC 21, "Protection System Reliability and Testability," of 10 CFR Part 50 requires, in part, that protection systems be designed for high functional reliability commensurate with the safety function to be performed.
- 10 CFR 50.55a(h) states that protection systems of nuclear power reactors of all types must meet the requirements specified in 10 CFR 50.55a(h), and each combined license for a utilization facility is subject to the conditions in 10 CFR 50.55a(h). 10 CFR 50.55a(h)(2) mandates compliance with the requirements stated in IEEE Standard (Std) 279-1968, "Proposed IEEE Criteria for Nuclear Power Plant Protection Systems," IEEE Std 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations," or IEEE Std 603-1991, "IEEE Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995, for NPPs with construction permits (CPs) issued before January 1, 1971. 10 CFR 50.55a(h)(2) requires compliance with their plant-specific licensing basis or CPs issued between January 1, 1971, and May 13, 1999. For NPPs, IEEE Std 603-1991 and the correction sheet dated January 30, 1995. For applicants for CPs, operating licenses, combined licenses, standard design approvals, design certifications, or manufacturing licenses filed after May 13, 1999, 10 CFR 50.55a(h)(3) requires compliance with IEEE Std 603-1991 and the correction sheet dated January 30, 1995.

There is a clause in both IEEE Std 279 and Std 603 on EQ requiring safety system equipment shall be qualified by type test, previous operating experience, or analysis, or any combination of these three methods, to substantiate that it will be capable of meeting, on a continuing basis, the performance requirements as specified in the design basis.

- Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 prescribes requirements for QA to ensure that SSCs will perform satisfactorily in service. This includes:
 - Criterion II, "Quality Assurance Program," requires the identification of SSCs to be covered by the QA program.
 - Criterion III, "Design Control," requires in part that (1) measures be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety-related functions of SSCs, and (2) quality standards be specified and that design control measures shall provide for verifying or checking the adequacy of design.
 - Criterion IV, "Procurement Document Controls," requires that measures be established to assure that applicable regulatory requirements, design bases, and other requirements are suitably included or referenced in the documents for procurement of materials, equipment, and services.
 - Criterion V, "Instructions, Procedures, and Drawings," requires in part that activities affecting quality shall be prescribed by "documented ...procedures... of a type appropriate to the circumstances..." Branch Technical Position (BTP) 7-14 of the NRC outlines such procedures for software quality assurance.

- Criterion VI, "Document Control," addresses control of purchased material, equipment, and services and requires measures shall be established to control the issuance of documents...which prescribe all activities affecting quality...These measures shall assure documents, including changes, are reviewed for adequacy and approved for release by authorized personnel.
- Criterion VII, "Control of Purchased Material, Equipment, and Services," addresses control of purchased material, equipment, and services.
- Criterion XI, "Test Control," requires in part that a test program be established to demonstrate that systems and components will perform satisfactorily in service.

4.0 DISCUSSION

Framatome presentations addressed the NRC staff's questions including the audit plan (ADAMS Accession No. ML24352A156) information requests. The presentations included discussions on EQ, QA, system lifecycle process and design, and independent verification and validation (IV&V). Framatome personnel provided additional information as necessary to facilitate responses and resolutions to the NRC staff's questions. The Framatome representatives facilitated the NRC staff review by providing several supporting documents on EQ, overall life cycle process for the TXS Compact modules, and QA process.

The audit provided the NRC staff with an in-depth understanding of the process used to develop and test the TXS Compact Platform. The NRC in-person staff were able to inspect a prototype of the TXS Compact Platform and witnessed several tests performed by the Framatome personnel. A description of the TXS Compact Platform modules is provided in Table 1.

Table 1: TXS Compact Platform Modules

Module	Description	Function
PM1	TXS COMPACT Processing Module	Processing and communication module
MPIOF1	TXS COMPACT Multi-Purpose Input/Output (I/O) Module	Multi-purpose I/O module
SMDF1	TXS COMPACT Service, Maintenance, and Diagnosis Module	Service, maintenance and diagnosis module
GWF1	TXS COMPACT Gateway Module	Interface a TXS COMPACT automation unit to the TXS Ethernet network



Figure 1: TELEPERM XS Compact in Cabinet³

During the audit the NRC staff covered the following areas of review to verify that the TXS Compact modules were qualified and tested for use in U.S. NPP applications. The NRC staff observed tests of the prototype TXS Compact Platform during the demonstrations. A summary of the results of the audit are described below.

- **Life cycle process**

- User V-model
- IV&V
- Secure development and operational environment
- Test coverage
- Tools qualification – all tools used
- Functional block development process
- Self-diagnostic capabilities
- Security by design – ensure that the safety function is not impaired.

Based on the results of the review and discussions, the NRC staff observed that:

- Presentations made by the Framatome staff and demonstrations of the TXS Compact development activities in their laboratory confirmed that a well-documented process is being followed in compliance with industry codes and standards.

³ <https://www.framatome.com/solutions-portfolio/portfolio/product/A3169/txs-compact-digital-safety-i-c-platform>. TELEPERM XS (TXS) Compact.

- Framatome staff provided details related to mean times before failure (MTBF) which demonstrated the long lifetime of the modules. Requirements for periodic maintenance will be addressed in operations & maintenance manual.
- NRC staff witnessed the use of TXS Compact toolchain to build, load and monitor I&C applications.
- The NRC staff witnessed the use of FPGA development independent V&V tool sets that are certified and broadly used in the industry with a large experience base.
- Concurrent with the NRC review of the TXS Compact platform, Framatome is pursuing International Electrotechnical Commission (IEC) 61513 certification by TÜV Sud, which is requiring a rigorous evaluation of the TXS Compact platform development lifecycle activities.
- A tour of the TXS Compact development lab confirmed a secure system development environment.
- **Equipment qualification**
 - Climatic (environmental) testing
 - Seismic testing
 - EMC testing
 - Isolation testing
- Based on the results of the review and discussions, the NRC staff observed that:
 - Criterion VII of Appendix B to 10 CFR Part 50, "Control of Purchased Material, Equipment, and Services," requires, in part, that measures shall be established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection. During the regulatory audit, the NRC staff noted that EQ testing service for the TXS Compact Platform was conducted by third parties contracted by Framatome GmbH. However, Framatome did not perform commercial grade dedication (CGD) for the EQ testing service until the EQ testing service was already completed. This observation will be addressed by a request for additional information asking the applicant to clarify or justify the use of the EQ testing service provided by third parties without prior implementation of CGD.
 - The NRC staff identified additional documents including EQ testing plans, specifications, procedures, and testing results which need to be submitted and docketed to support the NRC staff's SE.
- **Quality Assurance**

The NRC staff reviewed the QA documentation associated with Framatome's oversight of Framatome SAS and its subsidiary companies for the design, development, and manufacturing of the TXS Compact Platform. Specifically, the NRC staff reviewed and discussed with Framatome Inc. staff the:

- Framatome Inc.'s QA Program Description
- Framatome Integrated Management System Manual

- Framatome Inc. audit report, including the associated findings for Framatome SAS's QA Program implementation for the TXS Compact Platform design, development, procurement, and manufacturing activities
- Procedures and work instructions for the design and development of a safety related I&C platform and products, and dedication of commercial grade items and services
- TXS QA Plan for TXS Compact AS FPGA
- TXS Compact Quality Management Plan
- TXS Compact CGD Plan for manufacturing services and TXS Compact commercial grade survey checklist and report for a TXS compact module manufacturer
- Purchase order issued from Framatome SAS to its supplier

Based on the results of the review and discussions, the NRC staff observed that:

- Framatome Inc. (based in the U.S.), the submitter of the TR, does not own the design of the TXS Compact Platform and it does not intend to be the owner.
- Framatome Inc. intends to procure the platform from Framatome SAS and GmbH as a safety-related product; however, based on the results of Framatome Inc.'s audit of Framatome SAS and GmbH, []

[]As such, Framatome Inc. could not place Framatome SAS and GmbH on the approved supplier list of Framatome Inc without conditions.

- Framatome Inc. stated that the resolution of findings it identified during a 2023 QA audit of Framatome SAS and GmbH will not be resolved until the [] [] in a best-case scenario.
- Framatome SAS and GmbH did not have [] [] of the versions of the TXS Compact modules (as referenced in the Framatome Inc. TXS COMPACT TR).
- Since the creation of the Framatome SAS [] [] However, the NRC staff identified during the regulatory audit that Framatome SAS failed to recognize that the scope of services provided [] [] included hardware design, which [] []. Framatome SAS stated it created a corrective action report in response to the NRC staff's observation.

5.0 CONCLUSION

The NRC staff's audit objectives were accomplished through face-to-face discussions with the Framatome technical experts and engineers, document review, and verification of information and test results. More specifically, the NRC staff gained an in-depth understanding of the TXS Compact Platform and verified the associated functional and performance results. Additionally, the NRC staff verified that the process used to establish requirements specifications for the TXS Compact Platform and audited the use of the requirements traceability matrix at all phases of digital system development lifecycle activities. The NRC staff confirmed that acceptable plans

were prepared to control FPGA and tools development activities and there was evidence that the plans were followed in an acceptable FPGA and tools development lifecycle, and evidence that the lifecycle process produced acceptable design outputs.

Finally, the NRC staff assessed all non-docketed EQ program documentation including testing plans, specifications, and procedures utilized to perform qualification testing (e.g., environmental, seismic, EMC, and Class 1E to non-Class 1E isolation). Performance of the critical functional requirements under the specified hazards, such as built-in self-diagnostic capabilities resulting in safe state, fail-safe actions, internal fault detections resulting in desired outcome, etc., and handling of anomalies identified during digital system development lifecycle processes were observed.

No regulatory decisions were made during the audit. The NRC staff and Framatome representatives held a follow-up meeting on May 22, 2025 (ADAMS Accession No. ML25164A315).



June 30, 2025
NRC:25:014

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Response to Request for Additional Documents to Be Docketed for the Review of ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report (TR)"

Framatome Inc. (Framatome) requested the NRC's review and approval of the topical report ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report (TR)." The NRC reviewed the proposed TR, conducted an audit (ADAMS Accession No. ML24352A156), and determined that additional documents are needed to be docketed to complete the review. The NRC requested a list of 25 documents to be docketed on April 25, 2025. The list is enclosed as Attachment A and identifies that three of the requested documents were duplicated thus reducing the list to 22. However, Framatome maintained the numbering of the initial request with the duplicates identified as "Not Used." (Documents 12, 17 and 25)

All 22 documents contain Framatome proprietary information. To protect this proprietary information from public disclosure under 10 CFR 2.390(b), an affidavit is enclosed for each document in accordance with NRC LIC 204, Revision 4, "Handling Requests to Withhold Proprietary Information from Public Disclosure."

- 1) Framatome proprietary information was identified in 10 documents. These documents have been appropriately marked as Framatome Proprietary and a Non-Proprietary version of each has been created and is being supplied. (Documents 7, 8, 9, 10, 11, 13, 18, 19, 20, and 21)
- 2) The remaining twelve documents, as explained in their individual associated Affidavits, contain extensive proprietary information to the extent that a redacted version would be of no value to the public. Therefore, a Non-Proprietary Version is not being submitted to the NRC for these 12 documents. (Documents 1, 2, 3, 4, 5, 6, 14, 15, 16, 22, 23, and 24)

There are no commitments within this letter or its enclosures.

If you have any questions related to this information, please contact Mr. Philip Opsal, Licensing Manager, by telephone at (434) 534-1223, or by e-mail at Philip.Opsal@framatome.com.

Sincerely,

ELLIOTT Gayle

Digitally signed by ELLIOTT
Gayle
Date: 2025.06.30 15:37:30
-04'00'

Gayle Elliott, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: Ngola Otto

Attachment A: List of Additional Documents to Be Docketed for the Review of TXS COMPACT Platform TR

Document Components for NRC:25:014:

000 Transmittal Letter NRC_25_014.pdf, 225,280 bytes
01a D02_ARV_01_160_510 Qualification Plan AFFIDAVIT.pdf, 92,355 bytes
01b D02_ARV_01_160_510 Qualification Plan 38_9393941_000 SUNSI.pdf, 3,216,295 bytes, Proprietary
02a D02_ARV_01_176_856 PM1 Functional Test Spec AFFIDAVIT.pdf, 91,441 bytes
02b D02_ARV_01_176_856 PM1 Functional Test Spec 38_9393942_000 SUNSI.pdf, 5,126,213 bytes, Proprietary
03a D02_ARV_01_173_512 Functional Test Spec AFFIDAVIT.pdf, 91,541 bytes
03b D02_ARV_01_173_512 Functional Test Spec 38_9393943_000 SUNSI.pdf, 2,472,708 bytes, Proprietary
04a D02_ARV_01_173_640 GWF1 Functional Test Spec AFFIDAVIT.pdf, 93,387 bytes
04b D02_ARV_01_173_640 GWF1 Functional Test Spec 38_9393944_000 SUNSI.pdf, 2,233,298 bytes, Proprietary
05a D02_ARV_01_178_612 SMDF1 Functional Test Spec AFFIDAVIT.pdf, 91,570 bytes
05b D02_ARV_01_178_612 SMDF1 Functional Test Spec 38_9393945_000 SUNSI.pdf, 1,399,255 bytes, Proprietary
06a D02_ARV_01_174_276 Test Set_Up for System Integration AFFIDAVIT.pdf, 92,101 bytes
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OSM#2 (Public Information Only):

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Attachment A: List of Additional Documents Needed to Be Docketed for the Review of TXS COMPACT TR

1. D02-ARV-01-160-510, TXS Compact - Qualification Plan
2. D02-ARV-01-176-856, TXS Compact - PM1 Functional Test Specification
3. D02-ARV-01-173-512, TXS COMPACT: MPIOF1 - Functional Test Specification
4. D02-ARV-01-173-640, TXS COMPACT - GWF1 Functional Test Specification
5. D02-ARV-01-178-612, TXS COMPACT - SMDF1 Functional Test Specification
6. D02-ARV-01-174-276, TXS COMPACT - Test Set-Up for System Integration
7. D02-ARV-01-145-025, TXS COMPACT - PM1 HPD and OPU Functional Test Report.
8. D02-ARV-01-143-605, NSIC CSC - FPU Functional Test Report.
9. D02-ARV-01-145-024, TXS COMPACT - PM1 FBs Functional Test Report.
10. D02-ARV-01-148-529, TXS COMPACT - MPIOF1 HPD Functional Test Report.
11. D02-ARV-01-155-755, TXS COMPACT - GWF1 HPD functional test report.
12. Not Used. (Duplicate, refer to items 18, 19, 20 and 21)
13. D02-ARV-01-236-646, TXS Compact: Supplementary Equipment Qualification Plan
14. D02-ARV-01-176-992, Generic specification for type testing of TXS hardware modules
15. D02-ARV-01-238-128, Test Specification for supplementary US qualification
16. PO 102 QUA 0107, Dedication of Commercial Grade Items and Services
17. Not Used. (Duplicate, refer to items 23 and 24)
18. D02-ARV-01-236-054, TXS Compact - PM1 Summary Qualification Report
19. D02-ARV-01-236-056, TXS Compact - MPIOF1 Summary Qualification Report
20. D02-ARV-01-236-060, TXS COMPACT - GWF1 Summary Qualification Report
21. D02-ARV-01-236-061, TXS COMPACT - SMDF1 Summary Qualification Report
22. 820009.2Q, EPRI EMC Testing Report on TXS Compact
23. D02-ARV-01-249-690, TXS Compact Supplementary Climatic and Seismic Testing – CGD testing lab IABG
24. D02-ARV-01-248-415, TXS Compact Supplementary EMC Testing – CGD testing lab Rasek
25. Not Used. (Duplicate, refer to items 18, 19, 20 and 21)

**REQUEST FOR ADDITIONAL INFORMATION
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
FRAMATOME ANP-10357P, REVISION 0, TXS COMPACT PLATFORM TOPICAL REPORT
FRAMATOME INC.
DOCKET NO. 99902041
ISSUE DATE: 07/02/2025**

Background

By letter dated August 2, 2024, Framatome Inc. (Framatome) submitted ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report" (hereafter referred to as the TR) (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), for the U.S. Nuclear Regulatory Commission (NRC)'s staff review and approval. Based on the NRC staff's review of the information presented in the TR, the NRC staff identified that additional information is needed for the review of the TR. The NRC staff also conducted an audit (ADAMS Accession No. ML24352A156) of the TR.

The NRC staff's request for additional information (RAI)-10688 is provided below.

Regulatory Basis

The regulatory basis for this RAI can be found in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants," and 10 CFR 52.47, "Contents of Applications; Technical Information," (a)(19).

Question 1

The regulation at 10 CFR 52.47(a)(19) requires the applicant of a design certification to include in the application a description of the quality assurance (QA) program applied to the design of structures, systems, and components of the facility. Appendix B to 10 CFR Part 50 sets forth the requirements for QA programs for nuclear power plants. The description of the QA program for a nuclear power plant shall include a discussion of how the applicable requirements of Appendix B to 10 CFR Part 50 were satisfied.

Section 8.1, "Regulatory Basis," of the TR, states that for the TR, the submittal is considered a design certification (DC) activity. The NRC staff requests Framatome to clarify whether this TR is only intended to apply to DC applications. If applicable to DC applicants, the NRC staff requests that Framatome address how the requirements of 10 CFR 52.47(a)(19) are satisfied.

Question 2

Section 8.1 of the TR states that design engineering for the TXS COMPACT platform was completed by the Framatome SAS organization in accordance with applicable European Standards. The decision to certify the TXS COMPACT Platform for NRC safety-related applications was made after the design was fully complete. The TXS COMPACT Platform TR is being submitted by Framatome in accordance with its Quality Assurance Program (QAP). Section 8.2, "Framatome QA Program," of the TR states that the Framatome QAP applicability is based the elements of the Framatome Inc. QAP applicable to product development in

Framatome SAS. TXS COMPACT Platform components will be provided to Framatome as basic components design and manufactured under the applicable elements of the Framatome Integrated Management System Manual (IMS).

Therefore, regarding the TXS COMPACT Platform and implementing procedures, as defined in the TXS COMPACT Quality Management Plan (QMP), Framatome SAS is considered a “supplier” subject to the controls imposed under the Framatome QAP. Applicable elements of Framatome QAP are as follows:

- “Quality Assurance Program” – 10 CFR Part 50, Appendix B, Criterion II.
- “Control of Purchased Materials, Items, and Services” – 10 CFR Part 50, Appendix B, Criterion VII.
- “Control of Nonconforming Items” – 10 CFR Part 50, Appendix B, Criterion XV.
- “Corrective Action” – 10 CFR Part 50, Appendix B, Criterion XVI.
- “Audits” – 10 CFR Part 50, Appendix B, Criterion XVIII.”

Section 6.0, “TXS Compact Life Cycle Management,” of the TR describes the development processes for the TXS COMPACT platform, and credits the processes and procedures used by Framatome SAS and Framatome Inc. to develop and qualify the TXS COMPACT platform. The NRC staff reviewed the information contained in Sections 6 and 8 of the TR and the following supporting documents:

- 56-9141754-012, “Framatome Inc. Quality Assurance Program,” dated January 19, 2023
- D02-ARV-01-101-817, “Framatome Integrated Management System Manual,” Revision F
- D02-AR-01-230-852, “TXS COMPACT Quality Management Plan (QMP),” Revision A

Based on the NRC staff’s review of the information, the NRC staff finds that additional information is required to demonstrate how the applicable criteria in Appendix B to 10 CFR Part 50 are satisfied as specified below:

- a. The TXS COMPACT QMP, does not address the role of “supplier” in terms of Framatome SAS. Framatome SAS and Framatome GmbH roles are identified to be the owner of the QAP. The NRC staff requests that Framatome address this discrepancy.
- b. Given that Framatome Inc. considers Framatome SAS as a supplier of the TXS COMPACT Platform, it is not clear why Criterion III, “Design Control,” Criterion IV, “Procurement Document Control,” and Criterion XVII, “Quality Assurance Records” of Appendix B to 10 CFR Part 50 are not identified as applicable elements of the Framatome QAP that apply to the procurement. The NRC staff requests that Framatome address this issue and modify the TR, as necessary.
- c. Section 6.0 of the TR credits Framatome SAS processes and procedures used to develop the TXS Compact Platform, which are governed by Framatome IMS Manual. It is not clear whether Framatome is crediting Framatome SAS’s IMS processes and procedures to address Criterion III and Criterion VII of Appendix B to 10 CFR Part 50. The NRC staff requests that Framatome clarify this information and revise the TR, as necessary.

d. [[

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Question 3

Criterion II of Appendix B to 10 CFR Part 50, requires, in part, that “the applicant shall identify the structures, systems and components, to be covered by the quality assurance program and the major organizations participating the program, together with the designated functions of these organizations. Activities affecting quality shall be accomplished under suitably controlled conditions. The program shall take into account the need for processes, and skills to attain the required quality, and the need for verification of quality by inspection and tests...The program shall provide for indoctrination and training of personnel performing activities affecting quality as necessary to assure that suitable proficiency is achieved and maintained.”

Section 8.2.1, "Quality Assurance Program," of the TR states that the Framatome QAP complies with Criterion II of 10 CFR Part 50, Appendix B, and Requirement 2 of ASME NQA-1-2015. This section states that Framatome QAP provides for development, control, and use of computer programs. The NRC staff reviewed Section 8.2.1 of the TR and the Framatome QAP and finds it is not clear how the TR's description of Framatome QAP conforms to Criterion II of Appendix B to 10 CFR Part 50 as applied to the procurement of TXS COMPACT Platform from Framatome SAS.

Specifically, the NRC staff find that for the procurement of the TXS COMPACT platform:

- a. Framatome did not identify that the TXS Platform is classified as safety-related, subject to the Framatome QAP in the TR.
- b. It is not clear to the NRC staff whether Framatome is imposing its QAP Section 2.6 on Framatome SAS personnel.
- c. It is not clear to the NRC staff whether Framatome is imposing Sections 3.6.10, 3.11, and 3.12 of the Framatome QAP onto Framatome SAS as part of a purchase order.

Therefore, the NRC staff requests that Framatome provides the necessary clarification and address the issues identified above.

Question 4

Criterion VII, "Control of Purchased Material, Equipment, and Services," of Appendix B to 10 CFR Part 50, states, in part, that measures are established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection, objective evidence of quality

furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery. Documentary evidence that material and equipment conform to the procurement requirements shall be available procurement requirements prior to installation or use of such material and equipment. This documentary evidence shall be retained and shall be sufficient to identify the specific requirements, such as codes, standards, or specifications, met by the purchased material and equipment. The effectiveness of control of quality by contractors and subcontractors shall be assessed by the applicant or designee at intervals consistent with importance, complexity, and quantity of the products or services.

Section 8.2.2, "Control of Purchased Materials, Items, and Services," of the TR states that the Framatome QAP, Section 7, "governs control of purchased safety-related materials, items, and services including source evaluation and selection, source inspection, and receiving inspection in accordance with regulatory and contract requirements...The Quality and Performance organization audits the capability of suppliers of safety-related materials, items, and services, and maintains a list of approved suppliers. Acceptability suppliers of safety-related materials, items, or service are based on the following items:

- An evaluation of their QA Program to 10 CFR Part 50, Appendix B and NQA-1 to determine the capability to supply materials, items, or services meeting procurement document requirements.
- A survey/audit of the supplier's facility."

The NRC staff reviewed Framatome's report of QA Audit, including the audit findings, and Framatome SAS and GmbH's corrective actions to address the findings. Based on the review of this information, the NRC staff requests Framatome to:

- a. Clarify why Section 8.2.2 of the TR only addresses the source evaluation and selection requirements in Criterion VII of Appendix B to 10 CFR Part 50 and no other aspects of Criterion VII such as objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery.
- b. Incorporate into the TR a description of the specific activities performed by Framatome to place Framatome SAS and Framatome GmbH on their approved supplier's list to issue purchase orders for safety-related procurement of the TXS Compact Platform.

c. [[

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- d. Provide the results of the gap analysis performed to address audit findings on gaps between the Framatome SAS and Framatome GmbH's QA Program and procedures and Appendix B to 10 CFR Part 50 and the impact on completed activities affecting quality for the versions of TXS Compact Modules referenced in the TR.

ADAMS Accession Nos.:
ML25178A329 (Package)
ML25178A323 (Proprietary)
ML25178A444 (Non-Proprietary)

NRR-088

OFFICE	NRR/DORL/LLPB/PM	NRR/DORL/LLPB/BC	NRR/DRO/IQVB/BC
NAME	NOtto	JRankin	KKavanagh
DATE	06/26/2025	06/26/2025	06/25/2025
OFFICE	NRR/DORL/LLPB/LA	NRR/DORL/LLPB/BC	
NAME	DHarrison	NOtto	
DATE	06/30/2025	07/02/2025	

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July 22, 2025
NRC:25:017

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Response to Request for Additional Documents to Be Docketed for the Review of ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report (TR)"

- Ref. 1: Letter: Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Request for Review and Approval of ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report," NRC:24:015, August 2, 2024.
- Ref. 2: Letter, Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Response to Request for Additional Documents to Be Docketed for the Review of ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report (TR)," NRC:25:014, June 30, 2025.

Framatome Inc. (Framatome) requested the NRC's review and approval of the topical report ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report (TR)" in Reference 1. The NRC reviewed the proposed TR, conducted an audit (ADAMS Accession No. ML24352A156) and determined that additional documents were needed to be docketed to complete the review. The NRC requested a list of 25 documents to be docketed on April 25, 2025. These were provided on June 30, 2025 (Reference 2).

On June 24, 2025, the NRC requested five additional documents to be docketed to support the NRC's review of the subject TR. Four of the five requested documents are provided by this letter. The need to docket the fifth document is the subject of a clarification meeting requested by Framatome and, if determined necessary, will be docketed by a future letter.

Framatome considers the material contained in the enclosed documents to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support withholding the information from public disclosure. For three of the four documents, as discussed in their associated affidavit, due to the extent of the Framatome proprietary information contained within, a non-proprietary version would be of no value to the public. Therefore, a non-proprietary version is not being submitted to the NRC. (Documents 1, 2 and 4 listed on Attachment A).

There are no commitments within this letter or its enclosures.

If you have any questions related to this information, please contact Mr. Philip Opsal, Licensing Manager, by telephone at (434) 534-1223, or by e-mail at Philip.Opsal@framatome.com.

Sincerely,

Gayle Elliott, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: Ngola Otto

Enclosures:

Affidavit for Withholding

Attachment A: List of Four of Five Additional Documents to be Docketed for the Review of TXS COMPACT Platform TR requested on June 24, 2025

01a NRC_25_017 D02_ARV_01_101_817 IMS Manual AFFIDAVIT.pdf
01b NRC_25_017 D02_ARV_01_101_817 IMS Manual 38_9394822_000
SUNSI.pdf
02a NRC_25_017 D02_AR_01_230_852 TXS QMP AFFIDAVIT.pdf
02b NRC_25_017 D02_AR_01_230_852 TXS QMP 38_9394823_000
SUNSI.pdf
03a NRC_25_017 730_1 Audit Report AFFIDAVIT.pdf
03b NRC_25_017 730_1 Audit Report 730_1 SUNSI.pdf
03c NRC_25_017 730_1 Audit Report PUBLIC.pdf
04a NRC_25_017 D02_ARV_01_112_702 TXS QAP AFFIDAVIT.pdf
04b NRC_25_017 D02_ARV_01_112_702 TXS QAP 38_9394824_000
SUNSI.pdf

Attachment A: List of Four of Five Additional Documents to Be Docketed for the Review of TXS COMPACT Platform TR requested on June 24, 2025

1. D02-ARV-01-101-817, "Framatome Integrated Management System Manual," Revision F
2. D02-AR-01-230-852, "TXS COMPACT Quality Management Plan (QMP)," Revision A
3. Framatome Inc.'s Report of QA Audit for Audit No. 730-1
4. D02-ARV-01-112-702, "TXS Quality Assurance Plan: TXS Compact AS FPGA," Revision B



July 30, 2025

NRC:25:018

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Response to First Set of Requests for Additional Information Regarding Framatome ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report", RAIs 10636, 10637, 10638 and 10688

Framatome Inc. (Framatome) requested the NRC's review and approval of the topical report ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report (TR)" in Reference 1. The NRC reviewed the proposed TR, conducted an audit (ADAMS Accession No. ML24352A156) and determined that additional information is needed to complete the review. The NRC provided Requests for Additional Information (RAIs) in References 2, 3, 4 and 5. Framatome's response to these RAIs are provided in Attachment A.

Framatome considers some of the material contained in Attachment A to be proprietary. As required by 10 CFR 2.390(b), an affidavit is provided in Enclosure 1 to support withholding of the information from public disclosure. A non-proprietary version of Attachment A is provided as Attachment B.

There are no commitments within this letter or its enclosures.

If you have any questions related to this information, please contact Mr. Philip A. Opsal, Licensing Manager, by telephone at (434) 534-1223, or by e-mail at Philip.Opsal@Framatome.com.

Sincerely,

Gayle Elliott, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: Ngola Otto

References:

- Ref. 1: Letter: Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Request for Review and Approval of ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report," NRC:24:015, August 2, 2024.
- Ref. 2: Request for additional information – 10636, by the Office of Nuclear Reactor Regulation, ANP-10357P, Revision 0, TXS Compact Platform Topical Report, Framatome Inc., Docket NO. 99902041, 06/16/2025, NRC ADAMS ML25161A164 (RAI – Non-Proprietary).
- Ref 3: Request for additional information – 10637, by the Office of Nuclear Reactor Regulation, Framatome Topical Report, ANP-10357P, Revision 0, "TXS Compact Platform Topical Report" Framatome Inc., Docket NO. 99902041, 06/13/2025, NRC ADAMS ML25160A110 (RAI – Non-Proprietary).
- Ref 4: Request for additional information – 10638, by the Office of Nuclear Reactor Regulation Framatome Topical Report, ANP-10357P, Revision 0, "TXS Compact Platform Topical Report" Framatome Inc., Docket NO. 99902041, 06/16/2025, NRC ADAMS ML25160A168 (RAI – Non-Proprietary).
- Ref 5: Request for additional information, by the office of Nuclear Reactor Regulation Framatome, ANP-10357P, Revision 0, TXS Compact Platform Topical Report, Framatome Inc., Docket NO. 99902041, 07/02/2025, NRC ADAMS ML25178A329 (Package), ML25178A323 (Proprietary) and ML25178A444 (Non-Proprietary).

Attachments:

- A. Framatome response to NRC RAI 10636, RAI 10637, RAI 10638 and RAI 10688. (Proprietary)
- B. Framatome response to NRC RAI 10636, RAI 10637, RAI 10638 and RAI 10688. (Non-Proprietary)

Enclosure:

- 1. Affidavit

Request of Additional Information-10636

RAI Question 1:

“Regulation 10 CFR 50.55a(h) incorporates by reference the requirements of IEEE Std. 603-1991, “Criteria for Safety Systems for Nuclear Power Generating Stations,” and the correction sheet dated January 30, 1995. Clause 5.4, “Equipment Qualification” of IEEE Std. 603-1991 requires, in part, that safety system equipment shall be qualified by type test, previous operating experience, or analysis, or any combination of these three methods, to substantiate that it will be capable of meeting, on a continuing basis, the performance requirements as specified in the design basis.

Appendix B to “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” prescribes requirements for quality assurance (QA) to ensure that structures, systems, and components (SSCs) will perform satisfactorily in service. Criterion VII of Appendix B, “Control of Purchased Material, Equipment, and Services,” requires, in part, that measures shall be established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection.

During the regulatory audit from March 31 to April 4, 2025, the NRC staff noted that equipment qualification (EQ) testing service for the TXS COMPACT platform was conducted by third parties contracted by Framatome GmbH. However, Framatome did not perform commercial grade dedication (CGD) for the EQ testing service until the EQ testing service was already completed. The NRC staff requests that the applicant clarifies or justifies the use of the EQ testing service provided by third parties before performing the CGD for the EQ testing service.”

Response to Question 1:

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Request of Additional Information-10637

RAI Question 1:

"The regulation at 10 CFR 50.55a(h) incorporates by reference the requirements of IEEE Std. 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995. Clause 5.4, "Equipment Qualification," of IEEE Std. 603-1991 requires, in part, that safety system equipment shall be qualified by type test, previous operating experience, or analysis, or any combination of these three methods, to substantiate that it will be capable of meeting, on a continuing basis, the performance requirements as specified in the design basis.

As part of the equipment qualification, the Class 1E to non-Class 1E isolation qualification testing shall be performed. The regulatory guidance on the Class 1E to non-Class 1E isolation testing is included in RG 1.75, and Section 6.3.6 of EPRI TR-107330, "Requirements Compliance Traceability Matrix," as endorsed in RG 1.209, "Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants."

However, the NRC staff found that Class 1E to non-Class 1E isolation qualification testing has not been addressed in the submitted TXS COMPACT TR. The NRC staff requests that the application provides additional information to substantiate compliance with the regulatory requirement on the qualification of the Class 1E to non-Class 1E isolation for the TXS COMPACT Platform."

Response to Question 1:

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Request of Additional Information-10638

RAI Question 1:

“The regulation at 10 CFR 50.55a(h) incorporates by reference the requirements of IEEE Std. 603-1991 and the correction sheet dated January 30, 1995. Clause 5.6.3, “Between Safety Systems and Other Systems,” requires, in part, that, “The safety system design shall be such that credible failures in and consequential actions by other systems, as documented in Section 4.8 of the design basis, shall not prevent the safety systems from meeting the requirements of this standard”. RG 1.152, Revision 4, and its endorsed IEEE Std. 7-4.3.2-2016, “IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations,” provide regulatory guidance on how to meet the requirement on independence between safety systems and other non-safety systems.

In Section 5.2.2.2, “Communication from the Service Unit to an Automation Unit,” of the TXS COMPACT TR, it states, in part, that “When the SYSTEM or OPE_PARAM release is activated on an Automation Unit, an optocoupler on the PM1 temporarily activates a communication line to enable maintenance of this Automation Unit.” It also states in Section 5.2.2.2 that “this communication channel can be used to parameterize the unit by changing configuration data, such as the application, parameters, etc.”

The NRC staff noted that the OPE_PARAM mode allows update of parameters while still in OPERATION mode. Although this feature can be permanently or temporarily inhibited when configuring the instrumentation & control system, the NRC staff requests that the applicant provides additional information to clarify or justify the use of non-safety-related Service Unit to parameterize the safety-related automation unit during operation if the above feature is not inhibited.”

Response to Question 1:

The NRC staff requests Framatome to clarify or justify the use of non-safety-related Service Unit to parameterize the safety-related Automation Unit during operation, with respect to the criteria of Clause 5.6.3 of IEEE Std. 603-1991 amended by the correction sheet dated January 30th, 1995.

The abovementioned standard states that “the safety system design shall be such that credible failures in and consequential actions by other systems, as documented in Clause 4, item h) of the design basis, shall not prevent the safety systems from meeting the requirements of this standard.”. Clause 4, item h) explicitly identifies failure of a non-safety-related system as a condition having the potential for functional degradation of safety system performance.

As quoted by the present RAI, Section 5.2.2.2 of the TXS Compact Platform Topical Report, ANP-10357P Revision 0, (ML24218A279) highlights that when release OPE_PARAM is activated, then the Service Unit can upload parameters to the Automation Unit. When authorized by the regulator, this feature can be used by the I&C maintenance staff at the plant in order to, for example, optimize parameters of close loop control or adapting parameters in case of a stretch-out operation. Allowing to modify such parameters without the need to bypass the unit allows to maximize the availability of the system and its capability to actuate on demand.

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Request of Additional Information-10688

RAI Question 1:

Title 10 of the Code of Federal Regulation (10 CFR) 52.47 (a)(19) requires the applicant of a design certification to include in the application a description of the quality assurance (QA) program applied to the design of structures, systems, and components of the facility. Appendix B to 10 CFR Part 50 sets forth the requirements for QA programs for nuclear power plants. The description of the QA program for a nuclear power plant shall include a discussion of how the applicable requirements of Appendix B to 10 CFR Part 50 were satisfied.

Section 8.1, "Regulatory Basis," of the TR, states that for the TR, the submittal is considered a design certification (DC) activity. The NRC staff requests Framatome Inc. to clarify whether this TR is only intended to apply to DC applications. If applicable to DC applicants, the NRC staff requests that Framatome Inc. address how the requirements of 10 CFR 52.47(a)(19) are satisfied.

Response to Question 1:

Framatome Inc. acknowledges a revision to Section 8.1 of the Topical Report is in progress to remove the reference to "Design Certification" as agreed to in the Framatome – NRC Meeting in May 2025.

The Framatome Inc. position is that even without referring to a formal Design Certification for the TXS Compact, the Framatome Inc. Quality Assurance Program (QAP), aligned with 10 CFR 50, Appendix B, ensures that all applicable regulatory requirements are met.

10 CFR 50, Appendix B mandates that any "structures, systems, and components important to safety" be designed, procured, fabricated, tested, and controlled under a documented quality assurance program.

The Framatome Inc. Quality Assurance Program explicitly covers every phase addressed in 10 CFR 50, Appendix B, from design, purchasing, fabrication, handling, installation, testing, to maintenance, requiring controlled conditions and verification processes.

Framatome Inc. QAP

By stating that "Framatome Inc. Quality Assurance Program was applied as appropriate to ensure applicable requirements of 10 CFR 50, Appendix B were satisfied", the company is confirming:

- All safety related design, procurement, manufacturing, and testing of the TXS Compact were controlled and documented under policies and procedures aligned with Appendix B.
- Technical adequacy, traceability, inspection, verification, and revision controls were enforced.

As a result, the TXS Compact can legitimately be designated as a "safety-related platform for safety-related applications", without invoking a specific Design Certification.

RAI Question 2:

Section 8.1 of the TR states that design engineering for the TXS COMPACT platform was completed by the Framatome SAS organization in accordance with applicable European Standards. The decision to certify the TXS COMPACT Platform for NRC safety-related applications was made after the design was fully complete. The TXS COMPACT Platform TR is being submitted by Framatome Inc. in accordance with the Framatome Inc. Quality Assurance Program (QAP).

Section 8.2, "Framatome QA Program," of the TR states that the Framatome Inc. QAP applicability is based the elements of the Framatome Inc. QAP applicable to product development in Framatome SAS. TXS COMPACT Platform components will be provided to Framatome Inc. as basic components design and manufactured under the applicable elements of the Framatome Integrated Management System Manual (IMS).

Therefore, regarding the TXS COMPACT Platform and implementing procedures, as defined in the TXS COMPACT Quality Management Plan (QMP), Framatome SAS is considered a "supplier" subject to the controls imposed under the Framatome Inc. QAP. Applicable elements of Framatome Inc. QAP are as follows:

- "Quality Assurance Program" – 10 CFR Part 50, Appendix B, Criterion II.
- "Control of Purchased Materials, Items, and Services" – 10 CFR Part 50, Appendix B, Criterion VII.
- "Control of Nonconforming Items" – 10 CFR Part 50, Appendix B, Criterion XV.
- "Corrective Action" – 10 CFR Part 50, Appendix B, Criterion XVI.
- "Audits" – 10 CFR Part 50, Appendix B, Criterion XVIII."

Section 6.0, "TXS Compact Life Cycle Management," of the TR describes the development processes for the TXS COMPACT platform, and credits the processes and procedures used by Framatome SAS and Framatome Inc. to develop and qualify the TXS COMPACT platform.

The NRC staff reviewed the information contained in Sections 6 and 8 of the TR and the following supporting documents:

- 56-9141754-012, "Framatome Inc. Quality Assurance Program," dated January 19, 2023
- D02-ARV-01-101-817, "Framatome Integrated Management System Manual," Revision F
- D02-AR-01-230-852, "TXS COMPACT Quality Management Plan (QMP)," Revision A

Based on the NRC staff's review of the information, the NRC staff finds that additional information is required to demonstrate how the applicable criteria in Appendix B to 10 CFR Part 50 are satisfied as specified below:

- a. The TXS COMPACT QMP, does not address the role of "supplier" in terms of Framatome SAS. Framatome SAS and Framatome GmbH roles are identified to be the owner of the QAP. The NRC staff requests that Framatome Inc. address this discrepancy.

Framatome Response

The TXS Compact QMP (Quality Management Program) is authored and maintained by Framatome SAS and does not reflect or reference Framatome Inc.'s supplier relationship framework.

Similarly, the TXS Compact QAP (Quality Assurance Program) is a separate document, also generated and controlled by Framatome SAS under its own management structure.

- b. Given that Framatome Inc. considers Framatome SAS as a supplier of the TXS COMPACT platform, it is not clear why Criterion III, "Design Control," Criterion IV, "Procurement Document Control," and Criterion XVII, "Quality Assurance Records" of Appendix B to Part 50 are not identified as applicable elements of the Framatome Inc. QAP that apply to the procurement. The NRC staff requests that Framatome Inc. address this issue and modify the TR, as necessary.

Framatome Response

The TXS Compact QMP (Quality Management Program) and the TXS Compact QAP (Quality Assurance Program) are separately authored and owned by Framatome SAS.

Framatome Inc. is not the author of these documents; its reference in correspondence (e.g., the Topical Report) pertains solely to overseeing QAP-related *supplier management activities* linked to platform qualification and acceptance.

Framatome SAS and Framatome GmbH underwent comprehensive Quality Assurance audits that addressed the applicable quality requirements, including, but not limited to:

- Design Control
- Procurement Document Control
- Quality Assurance Records

These audits, conducted at each location supporting the TXS Compact, confirmed compliance with the applicable criteria under 10 CFR 50, Appendix B, ensuring that the safety-related processes are consistently implemented.

In the Topical Report, Framatome Inc.'s Quality Assurance Program is referenced exclusively for supplier and platform acceptance management.

No assertion is made that Framatome Inc. authored or owns the core QMP/QAP documentation used by Framatome SAS or Framatome GmbH.

- c. Section 6.0 of the TR credits Framatome SAS processes and procedures used to develop the TXS Compact platform, which are governed by Framatome IMS Manual. It is not clear whether Framatome Inc. is crediting Framatome SAS's IMS processes and procedures to address Criterion III and Criterion VII of Appendix B to 10 CFR Part 50. The NRC staff requests that Framatome Inc. clarify this information and revise the TR, as necessary.

Framatome Response

During qualification audits of Framatome SAS, Framatome Inc. identified that certain processes and procedures for the TXS Compact platform development, specifically those required to demonstrate compliance with 10 CFR 50, Appendix B, were not formally defined. The issue was formally documented as Audit Finding AF-730-01, "QA Program Definition", which noted the following:

“... the Framatome SAS documents which are applicable to the development, design and manufacturing of TXS Compact, V1 have not been appropriately defined. While Engineering personnel were able to identify several technical procedures that were used in this effort, many of the procedures have multiple sections ... applicable to either safety related or non-safety related activities.

Review of this documentation indicated that there is no objective evidence to demonstrate that the safety related (10CFR50, Appendix B) elements of these procedures were executed. Additionally, several quality affecting activities supporting TXS Compact development and design are not implemented by 10CFR50, Appendix B compliant procedures.

While a TXS Compact Quality Assurance Program has been developed, this document is primarily a technical document and does not address the manner in which compliance with 10CFR50, Appendix B, or any other applicable Quality Requirement or Standard is to be accomplished.

Review of Framatome SAS procedures indicate the appropriate documents for defining the manner in which Quality Assurance Program requirements are met are the Quality Management Plan and associated documentation, including implementing procedures.

In response to Finding AF-730-01, Framatome SAS implemented corrective measures under its Corrective Action Program (CAP), resulting in the development of the TXS Compact Quality Management Plan (QMP). This QMP established the necessary procedures and process definitions to ensure full compliance with 10 CFR 50, Appendix B requirements, including Audit, Design Control, Procurement Document Control, Corrective Action, Records Management, and other applicable criteria .

Framatome Inc. performed follow-up qualification audits which confirmed that the previously identified procedural gaps had been addressed and remediated in accordance with CAP requirements. The effectiveness of corrective actions was verified, and closure action items were completed.

This audit-compliant corrective action is documented in the TXS Compact Topical Report (TR), recognizing that Framatome Inc. QAP is referenced only regarding supplier oversight associated with platform qualification and acceptance.

Because the issue was properly captured via Finding AF-730-01, remediated per the Framatome SAS CAP, and verified as closed during follow-up audits, no further revisions to the QMP/QAP or TR are planned on this topic.

Should the NRC require additional evidence, such as CAP records, audit reports, or updated QMP/QAP documents, Framatome Inc. is prepared to provide them upon request.

d. [

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Framatome Response

Framatome Inc. acknowledges that [] currently do not maintain 10 CFR 50, Appendix B Quality Assurance Programs. As such, Framatome SAS is managing qualification of these suppliers through a Commercial Grade Dedication (CGD) process consistent with industry standard methodology (10 CFR 21; Regulatory Guide 1.164 Rev 1; NUREG-GG-0261, EPRI NP-5652).

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Framatome Inc. asserts that the CGD qualification method for [] executed by Framatome SAS, is fully compliant with NRC expectations for safety-related suppliers. This conclusion is based on Framatome Inc. audits of Framatome SAS and observation of select ongoing CGD activities. Completion of CGD activities [] remains on schedule. Framatome Inc. will reference this framework in ongoing regulatory documents and does not anticipate further revisions on this topic unless requested.

Detailed CGD documentation, such as survey checklists, inspection reports, or dedication records, are available for review if required.

RAI Question 3:

Criterion II of Appendix B to 10 CFR Part 50, requires, in part, that “the applicant shall identify the structures, systems and components, to be covered by the quality assurance program and the major organizations participating the program, together with the designated functions of these organizations. Activities affecting quality shall be accomplished under suitably controlled conditions. The program shall take into account the need for processes, and skills to attain the required quality, and the need for verification of quality by inspection and tests...The program shall provide for indoctrination and training of personnel performing activities affecting quality as necessary to assure that suitable proficiency is achieved and maintained.”

Section 8.2.1, "Quality Assurance Program," of the TR states that the Framatome Inc. QAP complies with Criterion II of 10 CFR part 50, Appendix B and Requirement 2 of ASME NQA-1-2015. This section states that Framatome Inc. QAP provides for development, control, and use of computer programs. The NRC staff reviewed Section 8.2.1 of the TR and the Framatome Inc.

QAP and finds it is not clear how the TR's description of Framatome Inc.'s QAP conforms to Criterion II of Appendix B to 10 CFR Part 50 as applied to the procurement of TXS COMPACT platform from Framatome SAS.

Specifically, the NRC staff find that for the procurement of the TXS COMPACT platform:

- a. Framatome Inc. did not identify that the TXS Platform is classified as safety-related, subject to the Framatome Inc. QAP in the TR.

Framatome Response

The TXS Compact is a safety-related platform, procured as a basic component. Its procurement, receipt, and management are governed by the Framatome Inc. Quality Assurance Program, ensuring control per 10 CFR 50, Appendix B requirements during those phases.

However, the Topical Report (TR) focuses solely on the TXS Compact platform and does not encompass the overall Framatome Inc. QA Program or procurement controls.

Design Control Responsibilities

Criterion II of 10 CFR 50, Appendix B mandates that the designing entity must establish and execute a documented Quality Assurance Program, identifying SSCs and controlling all activities affecting safety-related quality. .

In this case, Framatome SAS fulfills that role as the designing entity, responsible for implementing design control procedures to meet Criterion II.

Framatome Inc. Oversight

Framatome Inc. conducted Quality Assurance audits of Framatome SAS to assess the acceptability of design controls, procurement document controls, and record-keeping per 10 CFR 50, Appendix B.

These audits confirmed that Framatome SAS's processes and procedures are defined, managed, and compliant as required under Criterion II.

Summary

<u>Role</u>	<u>Entity</u>	<u>Responsibility</u>
Design Control (Criterion II)	Framatome SAS	Establish and implement Appendix B QA program for TXS Compact design
Procurement, Receipt, Management	Framatome Inc.	Apply its overall QA program to ensure procurement controls for safety-related basic components
Audit Oversight	Framatome Inc.	Verify SAS's compliance through audits ensuring ASA app B adherence

Framatome Inc. clarifies that:

1. Design control responsibility under Criterion II resides with Framatome SAS.
 2. These SAS-controlled processes have been evaluated and found acceptable through Framatome Inc. audits.
 3. Procurement management for the TXS Compact falls under Framatome Inc.'s QA Program, though this is outside the scope of the published TR.
- b. It is not clear to the NRC staff whether Framatome Inc. is imposing its QAP Section 2.6 on Framatome SAS personnel.

Framatome Response

Framatome QAP, Section 2.6 is titled "QAP Indoctrination and Training". Section 2.6.1 applies to "Company Personnel" as follows:

2.6.1 Company Personnel

Personnel performing or managing activities affecting quality shall receive indoctrination in their job responsibilities and authority that includes general criteria, technical objectives, requirements of applicable codes and standards, regulatory commitments, company procedures, and quality assurance program requirements. On-the-job training shall be used if direct hands-on applications or experience is needed to achieve and maintain proficiency. Indoctrination and training requirements of this QAP are **provided to all personnel engaged in activities covered by this QAP**.

Section 2.6.1 of Framatome Inc.'s QAP applies only to personnel working under that specific program, i.e. personnel performing or managing activities affecting quality under the Framatome Inc. QAP.

Since Framatome SAS personnel operate under the TXS Compact Quality Management Plan, and the Framatome IMS and associated procedures, they are not subject to section 2.6.1. Therefore, Framatome Inc. is not imposing its QA requirements on SAS staff as they are governed exclusively by the Framatome SAS quality system.

- c. It is not clear to the NRC staff whether Framatome Inc. is imposing Sections 3.6.10, 3.11, and 3.12 of the Framatome Inc. QAP onto Framatome SAS as part of a purchase order.

Framatome Response

Framatome QAP, Section 3 addresses Design Control. The applicability of this entire section is based on individuals conducting Design Control activities under the Framatome Inc. QAP.

Since Framatome SAS personnel are performing work under the TXS Compact Quality Management Plan and the Framatome IMS and applicable procedures, they are not conducting work under the Framatome Inc. Quality Assurance Program. This requirement is only applicable to individuals conducting work under the Framatome Inc. Quality Assurance Program.

Framatome Inc. is not “imposing” elements of their QA Program on Framatome SAS.

RAI Question 4:

Criterion VII, “Control of Purchased Material, Equipment, and Services” of Appendix B to 10 CFR Part 50, states, in part, that measures are established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection, objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery. Documentary evidence that material and equipment conform to the procurement requirements shall be available procurement requirements prior to installation or use of such material and equipment. This documentary evidence shall be retained and shall be sufficient to identify the specific requirements, such as codes, standards, or specifications, met by the purchased material and equipment. The effectiveness of control of quality by contractors and subcontractors shall be assessed by the applicant or designee at intervals consistent with importance, complexity, and quantity of the products or services.

Section 8.2.2, “Control of Purchased Materials, Items, and Services,” of the TR states that the Framatome Inc. QAP, Section 7, “governs control of purchased safety-related materials, items, and services including source evaluation and selection, source inspection, and receiving inspection in accordance with regulatory and contract requirements...The Quality and Performance organization audits the capability of suppliers of safety-related materials, items, and services, and maintains a list of approved suppliers. Acceptability suppliers of safety-related materials, items, or service are based on the following items:

- An evaluation of their QA Program to 10 CFR Part 50, Appendix B and NQA-1 to determine the capability to supply materials, items, or services meeting procurement document requirements.
- A survey/audit of the supplier’s facility.”

The NRC staff reviewed Framatome Inc.’s Report of QA Audit, including the audit findings, and Framatome SAS and GmbH’s corrective actions to address the findings. Based on the review of this information, the NRC staff requests Framatome Inc. to:

- a. Clarify why Section 8.2.2 of the TR only addresses the source evaluation and selection requirements in Criterion VII of Appendix B to 10 CFR Part 50 and no other aspects of Criterion VII such as objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery.

Framatome Response

10 CFR 50, Appendix B, Criterion VII mandates that purchasers establish controls ensuring that purchased materials, equipment, and services conform to procurement documents. These controls include:

- Source evaluation and selection
- Objective evidence of quality furnished by contractors/subcontractors
- Inspection at supplier locations
- Examination of products upon delivery
- Maintenance of documentary evidence at the receiving site

The TXS Compact is categorized as a safety-related platform; procurement under the Framatome Inc. QA program triggers the full scope of 10 CFR 50, Appendix B controls.

Framatome Inc. has conducted Quality Assurance audits at Framatome SAS to evaluate implementation of processes and procedures demonstrating compliance with 10 CFR 50, Appendix B, Criterion VII, ensuring processes for source evaluation, objective evidence collection, supplier-based inspection, and receipt examination are fully executed. During these audits, Framatome Inc. verified:

[

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The TXS Compact procurement is strictly controlled under Criterion VII of 10 CFR 50, Appendix B controls. Framatome Inc. internal audits confirm full compliance with source controls, quality documentation, inspections, and delivery examinations.

Though these procurement controls are not detailed in the Topical Report (which focuses on the platform) they are executed, and verified under Framatome Inc.'s QA program.

No additional revisions to the TR are planned; however, Framatome Inc. stands ready to furnish audit reports, inspection records, or objective evidence upon NRC request.

- b. Incorporate into the TR a description of the specific activities performed by Framatome Inc. to place Framatome SAS and Framatome GmbH on their approved supplier's list to issue purchase orders for safety-related procurement of the TXS Compact platform.

Framatome Response

Framatome Inc. will revise the Topical Report (TR) to explicitly document the Qualification Audits performed on Framatome SAS and Framatome GmbH, which were required to include these entities on the Framatome Inc. Approved Supplier List.

The revised TR will:

- Describe the scope and objectives of the Qualification Audits (covering design control, procurement, inspection, records, and criterion compliance).
- Identify audit dates, and locations.
- Summarize accreditations and certifications held by Framatome SAS and GmbH
- Provide evidence of audit outcomes and confirmation of compliance with 10 CFR 50, Appendix B.
- Conclude that, based on these audits, both entities meet the requirements to be included on the Approved Supplier List.

By including these Qualification Audits in the TR, Framatome Inc. will:

1. Provide transparent evidence of oversight and compliance.
2. Demonstrate that Framatome SAS and GmbH satisfy Framatome Inc.'s supplier qualification under Appendix B.
3. Clarify the link between these audits and the entities' inclusion in the Approved Supplier List.

c. [

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Framatome Response

Framatome Inc. confirms that the Commercial Grade Dedication (CGD) process for design and manufacturing activities remains ongoing and on track for completion [

]

As stipulated, any open issues or conditions identified are actively being managed through the Framatome Inc. and Framatome SAS Corrective Action Programs (CAP) as applicable. All resulting Condition Reports/Quality Events will be formally closed once corrective actions are fully implemented and verified.

Upon completion of corrective activity, Framatome Inc. will make the following available to the NRC:

- Copies of all Closed Condition Reports/Quality Events relating to CGD and qualification audit findings.
- Associated supporting documentation, including root cause analyses, correction verification records, and CAP closure confirmations.

Actions will be concluded per the project schedule [] Corrective Action Program documentation and supporting evidence will be available immediately thereafter for NRC review. Framatome Inc. is prepared to provide:

- Interim status updates,
- Draft CAP records,
- Formal summary left in the revised TR or as stand-alone attachments.

Summary

<u>Item</u>	<u>Status</u>
CGD Validation Completion	[]
Issue Management	Handled via CAP
NRC Clarification Requested	Specify preference: interim updates vs. final Closed Condition Reports
Documentation Provided	Condition Reports and supporting artifacts post-CAP closure

- d. Provide the results of the gap analysis performed to address audit findings on gaps between the Framatome SAS and Framatome GmbH's QA program and procedures and Appendix B to 10 CFR Part 50 and the impact on completed activities affecting quality for the versions of TXS Compact Modules referenced in the TR.

Framatome Response

Framatome Inc. Quality Assurance performed qualification audits of Framatome SAS (France) and Framatome GmbH (Germany) covering both ongoing work and TXS Compact product development. These audits assessed existing program requirements and execution as well as those in place during development cycles.

All audit findings (except those relating to Commercial Grade Dedication) have been formally resolved. As a result, both Framatome SAS and GmbH have been added to Framatome Inc.'s Approved Supplier List affirming their qualification status.

[]

Any remaining issues are tracked via Conditional Approvals within Framatome Inc.'s Corrective Action Program (CAP). All CGD and supplier-audit nonconformances are managed through the Framatome Inc. CAP and approved QA processes.

Once CGD activities are concluded, Framatome Inc. will issue closed Condition Reports and supporting CAP documentation which will be made available to the NRC for review, demonstrating full compliance with regulatory oversight.



August 14, 2025

NRC:25:019

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Response to Request for Additional Documents to Be Docketed for the Review of ANP-10357P Revision 0, "TXS COMPACT Platform Topical Report (TR)"

Ref. 1: Letter: Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Request for Review and Approval of ANP-10357P, Revision 0, 'TXS COMPACT Platform Topical Report'," NRC:24:015, August 2, 2024.

Ref. 2: Letter, Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Response to Request for Additional Documents to Be Docketed for the Review of ANP-10357P, Revision 0, 'TXS COMPACT Platform Topical Report (TR)'," NRC:25:014, June 30, 2025.

Ref. 3: Letter, Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Response to Request for Additional Documents to Be Docketed for the Review of ANP-10357P, Revision 0, 'TXS COMPACT Platform Topical Report (TR)'," NRC:25:017, July 22, 2025.

Framatome Inc. (Framatome) requested the NRC's review and approval of the topical report ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report (TR)" in Reference 1. The NRC reviewed the proposed TR, conducted an audit (ADAMS Accession No. ML24352A156) and determined that additional documents were needed to be docketed to complete the review. The NRC requested a list of 25 documents to be docketed on April 25, 2025. These were provided in Reference 2.

On June 24, 2025, the NRC requested five additional documents to be docketed to support the NRC's review of the subject TR. Four of the five requested documents were provided in Reference 3.

The need to docket the fifth document was the subject of a clarification meeting requested by Framatome which was held on July 24, 2025. As a result of that meeting, Framatome is providing the fifth and final of the five requested documents.

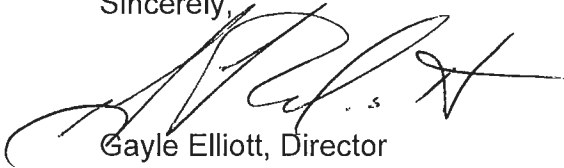
As agreed, this document is marked proprietary for the purpose of NRC's review of the topical report and is included as an Enclosure to this letter. As required by 10 CFR 2.390(b), an affidavit is enclosed to support withholding the information from public

disclosure. Due to the extent of the Framatome proprietary information contained within, a non-proprietary version would be of no value to the public. Therefore, a non-proprietary version is not being submitted to the NRC.

There are no commitments within this letter or its enclosure.

If you have any questions related to this information, please contact Mr. Philip Opsal, Product Manager, by telephone at (434) 534-1223, or by e-mail at Philip.Opsal@framatome.com.

Sincerely,

A handwritten signature in black ink, appearing to read 'Gayle Elliott', with a stylized flourish at the end.

Gayle Elliott, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: Ngola Otto

Enclosures:

Affidavit for Framatome Document 56-9141754-012, entitled, "Framatome Inc. Quality Assurance Program"

Framatome Document 56-9141754-012, entitled, "Framatome Inc. Quality Assurance Program," dated January 19, 2023



January 16, 2026
NRC:26:003

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

**Revised Response to Request for Additional Information 10688 – ANP-10357P,
Revision 0, “TXS Compact Platform”**

In Reference 1, Framatome Inc. (Framatome) requested NRC review and approval of Topical Report ANP-10357P, Revision 0, “TXS Compact Platform” for referencing in licensing actions. The NRC provided a Request for Additional Information (RAI) in Reference 2. Framatome provided an initial response to RAI 10688 in Reference 3.

A revised response to RAI 10688 is provided in Attachment 1. These responses and supporting information were discussed with NRC staff during the regulatory audit performed January 5-9, 2026 (Reference 4).

Framatome considers some of the material contained in Attachment 1 to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support withholding of information from public disclosure.

There are no regulatory commitments within this letter or its enclosures.

If you have any questions related to this information, please contact Mr. Nathan Hottle, Licensing Manager, by telephone at (434) 832-3864, or by e-mail at Nathan.Hottle@framatome.com.

Sincerely,
ELLIOTT
Gayle

Gayle Elliott, Director
Licensing & Regulatory Affairs
Framatome Inc.

Digitally signed by
ELLIOTT Gayle
Date: 2026.01.16 16:06:50
-05'00'

cc: N. Otto
Project 728

References:

1. Letter: Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Request for Review and Approval of ANP-10357P, Revision 0, 'TXS Compact Platform Topical Report'," NRC:24:015, August 2, 2024, ML24218A280.
2. Request for Additional Information by the Office of Nuclear Reactor Regulation – Framatome ANP-10357P, Revision 0, "TXS Compact Platform Topical Report" – Framatome Inc. Docket No. 99902041, July 2, 2025, ML25178A444.
3. Letter: Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC), "Response to First Set of Requests for Additional Information Regarding Framatome ANP-10357P, Revision 0, 'TXS COMPACT Platform Topical Report', RAIs 10636, 10637, 10638 and 10688," NRC:25:018, July 30, 2025, ML25212A178.
4. Letter: Michael Marshall (NRC) to Gayle Elliott (Framatome Inc.), "January 5-9, 2026, Regulatory Audit Plan for Framatome Inc. Topical Report, ANP-10357P, Revision 0, 'TXS Compact Platform Topical Report' Regarding Quality Assurance (EPID L-2024-TOP-0029)", ML25344A021.

Attachments:

- 1 Framatome response to NRC RAI 10688 (Proprietary)
- 2 Framatome response to NRC RAI 10688 (Non-Proprietary)
- 3 Affidavit

Response to Request for Additional Information 10688

This document provides the responses to request for additional information (RAI)-10688 by the office of Nuclear Reactor Regulation issued on July 2, 2025.

This RAI addresses the clarification on the implementation of QA framework in compliance with 10 CFR 50 requirements during TXS Compact development project. The responses have been discussed in a closed meeting with Framatome and NRC on September 19, 2025. When applicable, the responses clearly identify the modifications to implement for closure.

RAI Question 1:

“Title 10 of the Code of Federal Regulation (10 CFR) 52.47 (a)(19) requires the applicant of a design certification to include in the application a description of the quality assurance (QA) program applied to the design of structures, systems, and components of the facility. Appendix B to 10 CFR Part 50 sets forth the requirements for QA programs for nuclear power plants. The description of the QA program for a nuclear power plant shall include a discussion of how the applicable requirements of Appendix B to 10 CFR Part 50 were satisfied.

Section 8.1, "Regulatory Basis," of the TR, states that for the TR, the submittal is considered a design certification (DC) activity. The NRC staff requests Framatome Inc. to clarify whether this TR is only intended to apply to DC applications. If applicable to DC applicants, the NRC staff requests that Framatome Inc. address how the requirements of 10 CFR 52.47(a)(19) are satisfied.”

Framatome Inc. Response to RAI 10688 - Question 1:

Framatome Inc. will update the Topical Report (TR) in its entirety once all NRC Requests for Additional Information (RAIs) have been addressed. The TXS Compact Project Manager is tracking all required revisions to ensure incorporation into the final TR. Below is a screenshot of the change made to the TR.

8.1 Regulatory Basis

NUREG 0800, Standard Review Plan, 17.5 "Quality Assurance Program Description – Design Certification, Early Site Permit and New License Applicants" describes requirements associated with Quality Assurance Program Descriptions submitted by applicants for design certification (DC), combined license (COL), early site permit (ESP), construction permit (CP), and operating license (OL).

For the TXS COMPACT Platform Topical Report, design engineering was completed by the Framatome SAS organization in accordance with applicable European Standards. The decision to apply for the NRC approval to use the TXS COMPACT Platform for safety-related applications in the U.S. nuclear power plants was made after the design was fully complete.

The TXS COMPACT Platform Topical Report is being submitted by Framatome Inc. in accordance with the Framatome Inc. Quality Assurance Program [69].

Question 2:

"Section 8.1 of the TR states that design engineering for the TXS COMPACT platform was completed by the Framatome SAS organization in accordance with applicable European Standards. The decision to certify the TXS COMPACT Platform for NRC safety-related applications was made after the design was fully complete. The TXS COMPACT Platform TR is being submitted by Framatome Inc. in accordance with the Framatome Inc. Quality Assurance Program (QAP)."

Section 8.2, "Framatome QA Program," of the TR states that the Framatome Inc. QAP applicability is based the elements of the Framatome Inc. QAP applicable to product development in Framatome SAS. TXS COMPACT Platform components will be provided to Framatome Inc. as basic components design and manufactured under the applicable elements of the Framatome Integrated Management System Manual (IMS).

Therefore, regarding the TXS COMPACT Platform and implementing procedures, as defined in the TXS COMPACT Quality Management Plan (QMP), Framatome SAS is considered a "supplier" subject to the controls imposed under the Framatome Inc. QAP. Applicable elements of Framatome Inc. QAP are as follows:

- *"Quality Assurance Program" – 10 CFR Part 50, Appendix B, Criterion II.*
- *"Control of Purchased Materials, Items, and Services" – 10 CFR Part 50, Appendix B, Criterion VII.*
- *"Control of Nonconforming Items" – 10 CFR Part 50, Appendix B, Criterion XV.*
- *"Corrective Action" – 10 CFR Part 50, Appendix B, Criterion XVI.*
- *"Audits" – 10 CFR Part 50, Appendix B, Criterion XVIII."*

Section 6.0, "TXS Compact Life Cycle Management," of the TR describes the development processes for the TXS COMPACT platform, and credits the processes and procedures used by Framatome SAS and Framatome Inc. to develop and qualify the TXS COMPACT platform.

The NRC staff reviewed the information contained in Sections 6 and 8 of the TR and the following supporting documents:

- 56-9141754-012, "Framatome Inc. Quality Assurance Program," dated January 19, 2023
- D02-ARV-01-101-817, "Framatome Integrated Management System Manual," Revision F
- D02-AR-01-230-852, "TXS COMPACT Quality Management Plan (QMP)," Revision A

Based on the NRC staff's review of the information, the NRC staff finds that additional information is required to demonstrate how the applicable criteria in Appendix B to 10 CFR Part 50 are satisfied as specified below:"

"a. The TXS COMPACT QMP, does not address the role of "supplier" in terms of Framatome SAS. Framatome SAS and Framatome GmbH roles are identified to be the owner of the QAP. The NRC staff requests that Framatome Inc. address this discrepancy."

Framatome Inc. Response to RAI 10688 - Question 2 (a):

The TXS Compact Quality Management Plan (QMP) is a Framatome SAS document that defines the internal processes used by Framatome SAS to demonstrate compliance with 10 CFR 50, Appendix B.

Framatome will revise Section 8.2 of the TR to identify Framatome SAS as the owner of the TXS Compact QMP.

Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Revised Section 8.2 of the TR to clarify the Quality Management Plan applicability and ownership on September 29, 2025 (Below is a screenshot of the change made to the TR.

8.2 *Framatome Quality Assurance (QA) Program*

Framatome Inc. Quality Assurance Program applicability is based on those elements of the program applicable to product development in Framatome SAS. TXS COMPACT Platform components will be provided by Framatome SAS to Framatome Inc. as basic components designed and manufactured under the applicable elements of the Framatome Integrated Management System Manual [54]. Therefore, regarding the TXS COMPACT Platform and implementing procedures, as defined in the TXS COMPACT Quality Management Plan [72], Framatome SAS is considered a "supplier" to Framatome Inc. subject to the controls imposed under the Framatome Inc. Quality Assurance Program. Applicable elements of the Framatome Inc. Quality Assurance Program are as follows:

- "Quality Assurance Program" – 10 CFR Part 50, Appendix B, Criterion II.
- "Control of Purchased Materials, Items, and Services" – 10 CFR Part 50, Appendix B, Criterion VII.
- "Control of Nonconforming Items" – 10 CFR Part 50, Appendix B, Criterion XV.
- "Corrective Action" – 10 CFR Part 50, Appendix B, Criterion XVI.
- "Audits" – 10 CFR Part 50, Appendix B, Criterion XVIII.

The following elements of the Framatome Inc. Quality Assurance Program are applicable to Framatome Inc.'s procurement of TXS COMPACT platform basic components:

- "Design Control" – 10 CFR Part 50, Appendix B, Criterion III.
- "Procurement Document Control" – 10 CFR Part 50, Appendix B, Criterion IV.
- "Quality Assurance Records" – 10 CFR Part 50, Appendix B, Criterion XVII.

"b. Given that Framatome Inc. considers Framatome SAS as a supplier of the TXS COMPACT platform, it is not clear why Criterion III, "Design Control," Criterion IV, "Procurement Document Control," and Criterion XVII, "Quality Assurance Records" of Appendix B to Part 50 are not identified as applicable elements of the Framatome Inc. QAP that apply to the procurement. The NRC staff requests that Framatome Inc. address this issue and modify the TR, as necessary."

Framatome Inc. Response to RAI 10688 - Question 2 (b):

Framatome Inc. has performed 10CFR50, Appendix B qualification audits of Framatome SAS and Framatome GmbH, with participation from senior Technical Specialists from Engineering, IV&V, and Licensing.

Section 8.2 of the TR currently identifies the following criteria as applicable to Framatome Inc. procurement of the TXS Compact platform:

- Criterion II, Quality Assurance Program
- Criterion VII, Control of Purchased Material, Equipment, and Services
- Criterion XV, Nonconforming Materials, Parts, or Components
- Criterion XVI, Corrective Action

Section 8.2 of the TR will be revised to also identify the following criteria as applicable to Framatome Inc. procurement of the TXS Compact platform:

- Criterion III, Design Control
- Criterion IV, Procurement Document Control
- Criterion XVII, Quality Assurance Records

Activities under Criteria III, IV and XVII will be performed by Framatome Inc. personnel in accordance with the Framatome Inc. QA Program.

Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Revised Section 8.2 of the TR to clarify the 10 CFR 50, Appendix B applicability on September 29, 2025 (below is a screenshot of the change made to the TR).

8.2 *Framatome Quality Assurance (QA) Program*

Framatome Inc. Quality Assurance Program applicability is based on those elements of the program applicable to product development in Framatome SAS. TXS COMPACT Platform components will be provided by Framatome SAS to Framatome Inc. as basic components designed and manufactured under the applicable elements of the Framatome Integrated Management System Manual [54]. Therefore, regarding the TXS COMPACT Platform and implementing procedures, as defined in the TXS COMPACT Quality Management Plan [72], Framatome SAS is considered a “supplier” to Framatome Inc. subject to the controls imposed under the Framatome Inc. Quality Assurance Program. Applicable elements of the Framatome Inc. Quality Assurance Program are as follows:

- “Quality Assurance Program” – 10 CFR Part 50, Appendix B, Criterion II.
- “Control of Purchased Materials, Items, and Services” – 10 CFR Part 50, Appendix B, Criterion VII.
- “Control of Nonconforming Items” – 10 CFR Part 50, Appendix B, Criterion XV.
- “Corrective Action” – 10 CFR Part 50, Appendix B, Criterion XVI.
- “Audits” – 10 CFR Part 50, Appendix B, Criterion XVIII.

The following elements of the Framatome Inc. Quality Assurance Program are applicable to Framatome Inc.’s procurement of TXS COMPACT platform basic components:

- “Design Control” – 10 CFR Part 50, Appendix B, Criterion III.
- “Procurement Document Control” – 10 CFR Part 50, Appendix B, Criterion IV.
- “Quality Assurance Records” – 10 CFR Part 50, Appendix B, Criterion XVII.

“c. Section 6.0 of the TR credits Framatome SAS processes and procedures used to develop the TXS Compact platform, which are governed by Framatome IMS Manual. It is not clear whether Framatome Inc. is crediting Framatome SAS’s IMS processes and procedures to address Criterion III and Criterion VII of Appendix B to 10 CFR Part 50. The NRC staff requests that Framatome Inc. clarify this information and revise the TR, as necessary.”

Framatome Inc. Response to RAI 10688 - Question 2 (c):

Topical Report Sections 6.3.2 (“System Integration Testing”) and 6.3.3 (“Installation and Commissioning”) have been determined to be application-level activities outside the intended scope of the TR. These sections will be removed.

Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Deleted Sections 6.3.2 & 6.3.3 from TXS Compact TR (as out of scope of the TR; below is a screenshot of the change made to the TR).



Framatome Inc. Response to RAI 10688 - Question 2 (d):

[

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Question 3:

“Criterion II of Appendix B to 10 CFR Part 50, requires, in part, that “the applicant shall identify the structures, systems and components, to be covered by the quality assurance program and the major organizations participating the program, together with the designated functions of these organizations. Activities affecting quality shall be accomplished under suitably controlled conditions. The program shall take into account the need for processes, and skills to attain the required quality, and the need for verification of quality by inspection and tests...The program shall provide for indoctrination and training of personnel performing activities affecting quality as necessary to assure that suitable proficiency is achieved and maintained.”

Section 8.2.1, "Quality Assurance Program," of the TR states that the Framatome Inc. QAP complies with Criterion II of 10 CFR part 50, Appendix B and Requirement 2 of ASME NQA-1-2015. This section states that Framatome Inc. QAP provides for development, control, and use of computer programs. The NRC staff reviewed Section 8.2.1 of the TR and the Framatome Inc. QAP and finds it is not clear how the TR’s description of Framatome Inc.’s

QAP conforms to Criterion II of Appendix B to 10 CFR Part 50 as applied to the procurement of TXS COMPACT platform from Framatome SAS.

Specifically, the NRC staff find that for the procurement of the TXS COMPACT platform:

“a. Framatome Inc. did not identify that the TXS Platform is classified as safety-related, subject to the Framatome Inc. QAP in the TR.”

Framatome Inc. Response to RAI 10688 - Question 3 (a):

Framatome Inc. will revise Section 1.1 (“Objective”) of the TR to explicitly state the safety-related classification of the TXS Compact platform.

The current wording of Section 1.1, “Objective” is as follows:

This Topical Report describes attributes of the Framatome TELEPERM XS (TXS) COMPACT Field-Programmable Gate Array (FPGA) based Instrumentation and Control (I&C) platform for the purpose to obtain U.S. Nuclear Regulatory Commission (NRC) review and approval for use in nuclear power plant *safety-related I&C applications*.

The generic TXS COMPACT FPGA based platform does not utilize microprocessors or software but instead relies on a simple hardwired architecture. The safety system logic is implemented using qualified design tools and FPGA technology. The TXS COMPACT platform is designed and qualified by Framatome as a *nuclear safety-related product*.

Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Revised Section 1.1 of TXS Compact TR on November 5, 2025 to explicitly state that “The TXS COMPACT platform and associated Modules and Backplane are designed and qualified by Framatome as nuclear safety-related products” (below is a screenshot of the change made to the TR).

1.1 Objective

This Topical Report describes attributes of the Framatome TELEPERM XS (TXS) COMPACT Field-Programmable Gate Array (FPGA) based Instrumentation and Control (I&C) platform (herein identified as TXS Compact platform) for the purpose to obtain U.S. Nuclear Regulatory Commission (NRC) review and approval for use in nuclear power plant safety-related I&C applications.

The generic TXS COMPACT platform does not utilize microprocessors or software, but instead relies on simple hardwired architecture. Its safety system logic is implemented using qualified design tools and FPGA technology. The TXS COMPACT platform and associated Modules and Backplane are designed and qualified by Framatome as nuclear safety-related products.

“b. It is not clear to the NRC staff whether Framatome Inc. is imposing its QAP Section 2.6 on Framatome SAS personnel.”

Framatome Inc. Response to RAI 10688 - Question 3 (b):

Framatome Inc. recognizes that only certain elements of Criterion II, Quality Assurance are applicable to the TR. Control of activities affecting quality is achieved through supplier qualification audits, source surveillance, and receipt inspection, performed by trained and qualified personnel under the Framatome Inc. QA Program.

Framatome Inc. will revise Section 8.2.1 of the TR to document that:

- The QA Program is established through written policies, procedures, and instructions.
- Indoctrination and training are provided for personnel performing quality-related activities.

This revision provides explicit traceability to NRC requirements under Criterion II and Criterion VII.

Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Revised Section 8.2.1 of the TR to address the bulleted items above on September 29, 2025 (below is a screenshot of the change made to the TR).

8.2.1 Quality Assurance Program

The Framatome Inc. Quality Assurance Program complies with Criterion II of 10 CFR Part 50, Appendix B, Quality Assurance Program, and Requirement 2, Quality Assurance Program, ASME NQA-1 2015. This section defines the Quality Assurance Program implemented for nuclear safety-related activities.

The Quality Assurance Program establishes prerequisites for achieving quality, such as the need for specialized equipment and skills; use of suitable administrative, process, and environmental controls; training and indoctrination of personnel performing activities affecting quality; and the need for verification of quality by reviews, inspection, examination, and test.

The Framatome Inc. QA Program is established through written policies, procedures, and instructions. Indoctrination and training are provided for personnel performing quality-related activities.

Control of activities affecting quality is achieved through supplier qualification audits, source surveillance, and receipt inspection, performed by trained and qualified personnel in accordance with the Framatome Inc. QA Program.

“c. It is not clear to the NRC staff whether Framatome Inc. is imposing Sections 3.6.10, 3.11, and 3.12 of the Framatome Inc. QAP onto Framatome SAS as part of a purchase order.”

Framatome Inc. Response to RAI 10688 - Question 3 (c):

Framatome Inc. will revise Section 8.2.1 of the TR to remove the statement that the QA Program “provides for development, control, and use of computer programs,” as this is not applicable to the TR scope.

Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Revised Section 8.2.1 of the TR to remove the statement above on September 29, 2025 (below is a screenshot of the change made to the TR).

8.2.1 Quality Assurance Program

The Framatome Inc. Quality Assurance Program complies with Criterion II of 10 CFR Part 50, Appendix B, Quality Assurance Program, and Requirement 2, Quality Assurance Program, ASME NQA-1 2015. This section defines the Quality Assurance Program implemented for nuclear safety-related activities.

The Quality Assurance Program establishes prerequisites for achieving quality, such as the need for specialized equipment and skills; use of suitable administrative, process, and environmental controls; training and indoctrination of personnel performing activities affecting quality; and the need for verification of quality by reviews, inspection, examination, and test.

The Framatome Inc. QA Program is established through written policies, procedures, and instructions. Indoctrination and training are provided for personnel performing quality-related activities.

Control of activities affecting quality is achieved through supplier qualification audits, source surveillance, and receipt inspection, performed by trained and qualified personnel in accordance with the Framatome Inc. QA Program.

Question 4:

“Criterion VII, “Control of Purchased Material, Equipment, and Services” of Appendix B to 10 CFR Part 50, states, in part, that measures are established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection, objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery. Documentary evidence that material and equipment conform to the procurement requirements shall be available prior to installation or use of such material and equipment. This documentary evidence shall be retained and shall be sufficient to identify the specific requirements, such as codes, standards, or specifications, met by the purchased material and equipment. The effectiveness of control of quality by contractors and subcontractors shall be assessed by the applicant or designee at intervals consistent with importance, complexity, and quantity of the products or services.

Section 8.2.2, “Control of Purchased Materials, Items, and Services,” of the TR states that the Framatome Inc. QAP, Section 7, “governs control of purchased safety-related materials, items, and services including source evaluation and selection, source inspection, and receiving inspection in accordance with regulatory and contract requirements...The Quality and Performance organization audits the capability of suppliers of safety-related materials,

items, and services, and maintains a list of approved suppliers. Acceptability suppliers of safety-related materials, items, or service are based on the following items:

- An evaluation of their QA Program to 10 CFR Part 50, Appendix B and NQA-1 to determine the capability to supply materials, items, or services meeting procurement document requirements.*
- A survey/audit of the supplier's facility."*

The NRC staff reviewed Framatome Inc.'s Report of QA Audit, including the audit findings, and Framatome SAS and GmbH's corrective actions to address the findings. Based on the review of this information, the NRC staff requests Framatome Inc. to:"

"a. Clarify why Section 8.2.2 of the TR only addresses the source evaluation and selection requirements in Criterion VII of Appendix B to 10 CFR Part 50 and no other aspects of Criterion VII such as objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery."

Framatome Inc. Response to RAI 10688 - Question 4 (a):

[

]

Framatome Inc. will revise Section 8.2.2 of the TR to state that the Framatome Inc. Quality Assurance Program controls, such as supplier audits, source surveillance, receipt inspection, and testing, are relied upon for product acceptance. These activities ensure that procured items satisfy procurement document requirements and provide verification of the effectiveness of supplier quality controls. These updates will ensure compliance with Criterion II and Criterion VII.

Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Revised Section 8.2.2 of the TR to add the statement above on September 29, 2025 (below is a screenshot of the change made to the TR).

8.2.2 Control of Purchased Materials, Items, and Services

The Framatome Inc. Quality Assurance Program, Section 7, governs control of purchased safety-related materials, items, and services including source evaluation and selection, source inspection, and receiving inspection in accordance with regulatory and contract requirements. This Section complies with Section VII of 10 CFR Part 50, Appendix B, "Control of Purchased Material, Equipment, and Services" and Requirement 7, "Control of Purchased Items and Services," ASME NQA-1 2015.

Control of purchased safety-related materials, items, and services is in accordance with written procedures and instructions. The Quality and Performance organization audits the capability of suppliers of safety-related materials, items, and services and maintains a list of approved suppliers.

Acceptability of suppliers of safety-related materials, items, or services are based on the following items:

- An evaluation of their QA Program to 10 CFR Part 50, Appendix B and ASME NQA-1 to determine the capability to supply materials, items, or services meeting procurement document requirements.
- A survey/audit of the supplier's facility.

Framatome Inc. Quality Assurance Program controls, such as supplier audits, source surveillance, receipt inspection, and testing, are relied upon for product acceptance. These activities ensure procured items satisfy procurement document requirements and provide verification of the effectiveness of supplier quality controls.

"b. Incorporate into the TR a description of the specific activities performed by Framatome Inc. to place Framatome SAS and Framatome GmbH on their approved supplier's list to issue purchase orders for safety-related procurement of the TXS Compact platform."

Framatome Inc. Response to RAI 10688 - Question 4 (b):

Supplier qualification audits of Framatome SAS and GmbH have been completed. Conditions of approval are currently in place pending corrective action closure.

Upon completion, Framatome Inc. will update its approved suppliers list and revise TR Section 8.3 to reflect the updated status. These updates will ensure compliance with Criterion II and Criterion VII.

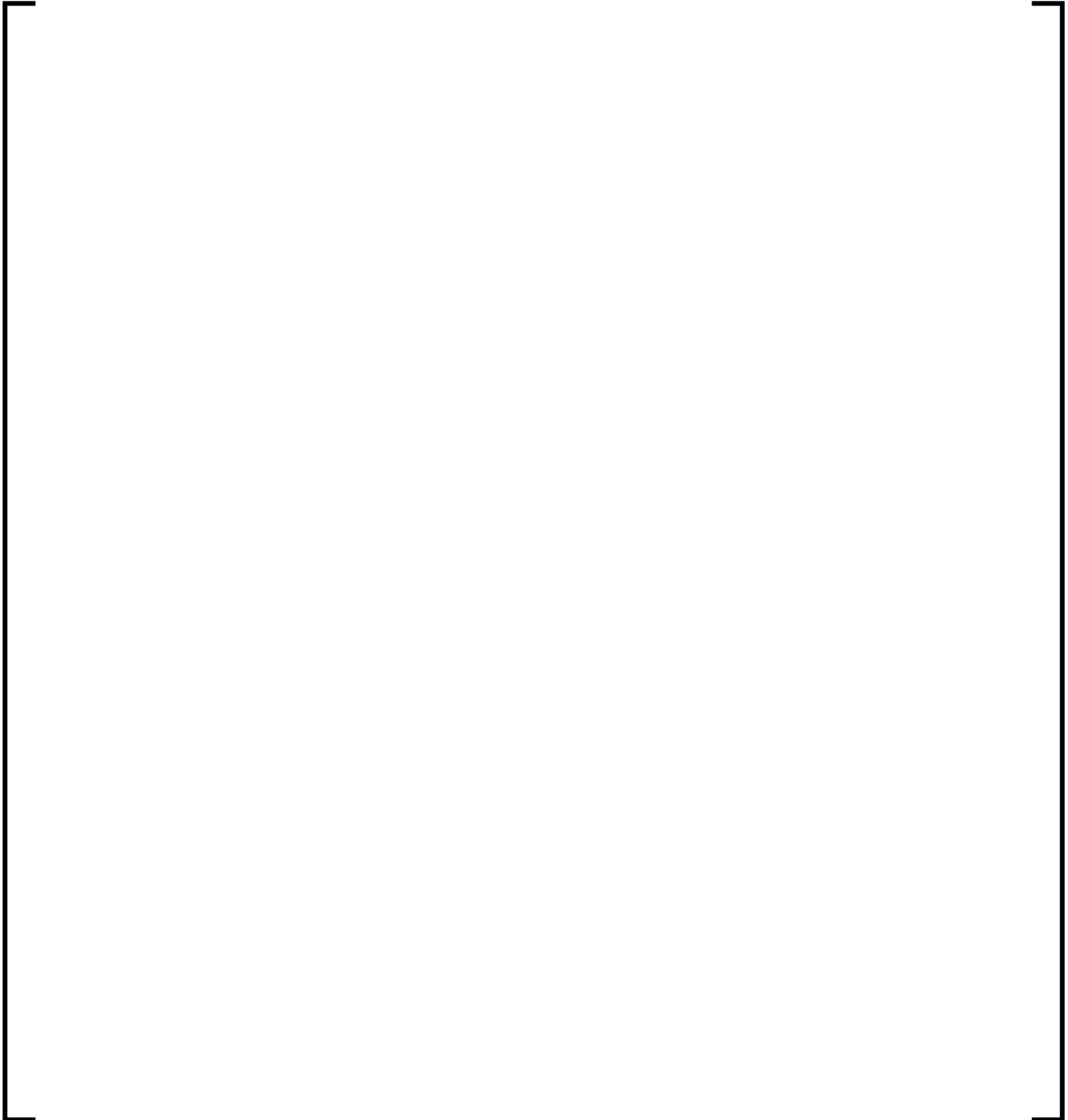
Tracking of this change is being maintained by the Project Manager (see Question 1).

Status – Revised Section 8.3 of the TR to address the qualification status as noted above.

[

]

(below is a screenshot of the change made to the TR).



Framatome Inc. Response to RAI 10688 - Question 4 (c):

[

]

Status – No further action required.

“d. Provide the results of the gap analysis performed to address audit findings on gaps between the Framatome SAS and Framatome GmbH’s QA program and procedures and Appendix B to 10 CFR Part 50 and the impact on completed activities affecting quality for the versions of TXS Compact Modules referenced in the TR.”

Framatome Inc. Response to RAI 10688 - Question 4 (d):

[

]

[

]

Status – Revised Section 8.3 of the TR to address the impact assessment for all Audit Findings on previously performed activities as well as current activities on October 3, 2025 (below is a screenshot of the change made to the TR).





January 21, 2026
NRC:26:005

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

**Response to Request for Additional Documents to Support the Review of
ANP-10357P, Revision 0, "TXS Compact Platform Topical Report"**

Ref. 1: Letter: Gayle Elliott (Framatome Inc.) to Document Control Desk (NRC),
"Request for Review and Approval of ANP-10357P, Revision 0, 'TXS
Compact Platform Topical Report'," NRC:24:015, August 2, 2024,
ML24218A280.

In Reference 1, Framatome Inc. (Framatome) requested NRC review and approval of Topical Report ANP-10357P, Revision 0, "TXS COMPACT PLATFORM" for referencing in licensing actions. The NRC has determined that three additional documents must be docketed to complete the review. The requested documents are enclosed with this letter.

Framatome considers the material contained in the enclosures to be proprietary to the extent that a redacted version would be of no value to the public. As required by 10 CFR 2.390(b), an affidavit is enclosed to support withholding of information from public disclosure.

There are no regulatory commitments within this letter or its enclosures.

If you have any questions related to this information, please contact Mr. Nathan Hottle, Deputy Director, Licensing & Regulatory Affairs, by telephone at (434) 832-3864, or by e-mail at Nathan.Hottle@framatome.com.

Sincerely,

Gayle Elliott, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: N. Otto
Project 728

Enclosures:

- 1 D02-ARV-01-233-823, Rev. A (38-9403159-000), TXS Compact – Documentation of Environmental (EMC, Climatic, Seismic) Type Testing (PROPRIETARY)
- 2 51-9389344-000, TXS Compact Gap Analysis (PROPRIETARY)
- 3 TA-B-25-006119-V2 (38-9403160-000), Tests to demonstrate behavior over time – TXS Compact (PROPRIETARY)
- 4 Affidavit



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 4, 2026

Ms. Gayle Elliott, Director
Licensing and Regulatory Affairs
Framatome Inc.
3315 Old Forest Road
Lynchburg, VA 24501

SUBJECT: THE U.S. NUCLEAR REGULATORY COMMISSION STAFF'S REVISED
SCHEDULE FOR REVIEW OF FRAMATOME'S ANP-10357P, REVISION 0,
"TXS COMPACT PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)

Dear Ms. Elliott:

By letter dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), and supplemented by letters dated June 30, July 22, July 30, and August 14, 2025, and January 16, 2026 (ML25188A147, ML25203A340, ML25212A178, ML25226A234, and ML26020A270), Framatome, Inc. (Framatome) submitted Topical Report (TR) ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report," for U.S. Nuclear Regulatory Commission (NRC) staff's review and approval. The NRC staff accepted the TR for review on October 7, 2024 (ML24256A027) and provided an initial review schedule. Since the acceptance, the NRC staff conducted an audit on March 31 - April 4, 2025 (ML24352A156), issued requests for additional information (RAIs)-10636, 10637, 10638, and 10688 (ML25161A164, ML25160A110, ML25160A168, and ML25178A444). Framatome provided a response to all the NRC staff's RAIs in letter dated July 30, 2025 (ML25212A178).

The NRC staff also conducted a public meeting with Framatome on September 19, 2025 (ML25262A196) to discuss the responses to RAI-10688 related to quality assurance (QA) aspect of the TR review. Subsequent to the public meeting, there was a government shutdown from October 1 - November 12, 2025, which delayed a planned December 2025 QA audit. The NRC conducted the QA related audit on January 5 - 9, 2026 (ML25344A021) to confirm corrective actions to address the NRC staff's observations from March 31 - April 4, 2025, regulatory audit was adequately implemented, and to verify proposed TR changes of the RAI-10688 responses.

Due to schedule impacts from the government shutdown, revisions to RAI-10688 responses, additional time needed to review a significant number of docketed documents, and change to the planned QA audit date, the NRC staff is revising the planned completion dates of the draft and final safety evaluations (SEs), which will be April 30 and June 12, 2026, respectively. This planned final SE date assumes that the proprietary review of the draft SE and resolution of any edits will be done in a timely manner. The revised schedule is provided in the enclosure.

The NRC staff are also aware of interests from Duke Energy Carolinas, LLC (ML24115A243) and Florida Power and Lighting Company (ML25335A060) in the use of this TR for nuclear plant application. The changes to the schedule have been discussed with Nathan Hottle at Framatome.

If you have any questions regarding this revised schedule and letter, please contact me at 301-415-6695 or via email at Ngola.Otto@nrc.gov.

Sincerely,

/RA/

Ngola A. Otto, Project Manager
Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No.: 99902041

Enclosure:
Revised Schedule

Revised Schedule

<u>Milestone</u>	<u>Current Date</u>	<u>Revised Date</u>
Initial Submittal	August 2, 2024	-----
Acceptance	October 1, 2024	-----
Conduct Audit #1 (In-person)	March 31 - April 4, 2025	-----
Issue Requests for Additional Information (RAIs)-10636, 10637, 10638 (Set #1)	June 13, 2025	-----
Issue RAI-10688 (Set #2)	June 16, 2025	-----
Response to RAI Set #1 and #2	July 30, 2025	-----
Conduct Audit #2 (Virtual)	December 2025	January 5 - 9, 2026
Revised Response to RAI Set #2	-----	January 16, 2026
Issue Draft Safety Evaluation (SE)	February 20, 2026	April 30, 2026
Issue Final SE	April 30, 2026	June 12, 2026

Enclosure

SUBJECT: THE U.S. NUCLEAR REGULATORY COMMISSION STAFF'S REVISED
SCHEDULE FOR REVIEW OF FRAMATOME'S ANP-10357P, REVISION 0,
"TXS COMPACT PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)
DATED FEBRUARY 4, 2026

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NCarte, NRR

MLi, NRR

MDiazMaldonado, NRR

ARivera-Varona, NRR

ADAMS Accession No.: ML26014A091***via eConcurrence****NRR-106**

OFFICE	NRR/DORL/LLPB/PM*	NRR/DORL/LLPB/LA*	NRR/DEX/EICB/BC (A)
NAME	NOtto	DHarrison	SDarbali
DATE	1/20/2026	1/27/2026	1/28/2026
OFFICE	NRR/DRO/IQVB/BC *	NRR/DORL/LLPB/BC	NRR/DORL/LLPB/PM*
NAME	DBollock	DMarcano	NOtto
DATE	1/29/2026	2/4/2026	2/4/2026

OFFICIAL RECORD COPY



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 16, 2026

Gayle Elliott, Director
Licensing and Regulatory Affairs
Framatome Inc.
3315 Old Forest Road
Lynchburg, VA 24501

SUBJECT: REPORT REGARDING JANUARY 5 THROUGH JANUARY 9, 2026,
REGULATORY AUDIT FOR FRAMATOME INC. ANP-10357P, REVISION 0,
"TXS COMPACT PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)

Dear Gayle Elliott:

By letter dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML24218A280), Framatome, Inc. submitted Topical Report (TR) ANP-10357P, Revision 0, "TXS COMPACT Platform Topical Report", for U.S. Nuclear Regulatory Commission (NRC) staff's review. The NRC staff conducted a virtual regulatory audit (ML25344A019) on January 5 to 9, 2026, to obtain additional information needed to complete the review of TR ANP-10357P, Revision 0. The main purpose of the audit was to confirm details of the TR changes made to address request for additional information responses and corrective actions from the March 31 to April 4, 2025 (ML25154A653), audit observations. The results of the audit will support the NRC staff's safety evaluation for TR ANP-10357P, Revision 0. The proprietary and non-proprietary audit reports are enclosed.

If you have any questions, please contact me at (301) 415-6695 or via e-mail at Ngola.Otto@nrc.gov regarding this letter.

Sincerely,

/RA/

Ngola A. Otto, Project Manager
Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 99902041

Enclosures:

1. Audit Report (Proprietary)
2. Audit Report (Nonproprietary)

NOTICE: Enclosure 1 to this letter contains Proprietary Information. When this letter is separated from Enclosure 1, this letter is DECONTROLLED.

SUBJECT: REPORT REGARDING JANUARY 5 THROUGH JANUARY 9, 2026,
REGULATORY AUDIT FOR FRAMATOME INC. ANP-10357P, REVISION 0,
"TXS COMPACT PLATFORM TOPICAL REPORT" (EPID L-2024-TOP-0029)
DATED MARCH 16, 2026

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EXTERNAL DISTRIBUTION:

Nathan.Hottle@framatome.com

ADAMS Accession Nos.:

ML26064A008 (Package)

ML26064A023 (Letter)

ML26064A025 (Audit Report - Proprietary)

ML26064A024 (Audit Report - Nonproprietary)

e-Concurrence case: 20260304-70011

REGULATORY AUDIT REPORT REGARDING
JANUARY 5 THROUGH JANUARY 9, 2026, AUDIT
FRAMATOME INC. ANP-10357P, REVISION 0,
“TXS COMPACT PLATFORM TOPICAL REPORT”
PROJECT NO. 728
EPID L-2024-TOP-0029

1.0 BACKGROUND

By application dated August 2, 2024 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24218A279), Framatome, Inc. submitted Topical Report (TR) ANP-10357P, Revision 0, “TXS Compact Platform Topical Report,” for U.S. Nuclear Regulatory Commission (NRC) staff’s review and approval. The TXS Compact Platform is based on a field programmable gate array (FPGA) technology and includes different module options that are designed for implementation in safety-related instrumentation and control (I&C) system applications in nuclear power plants (NPPs). During the March 31 to April 4, 2025, audit (ML25154A653), the NRC staff observed issues related to quality assurance (QA) program implementation for the design and development of TXS COMPACT platform, in which the NRC staff issued Request for Additional Information (RAI) 10688 for Framatome Inc. to address the observed issues and gaps in the information documented in the TXS COMPACT platform topical report. In addition, Framatome SAS¹, the designer and developer of the TXS COMPACT platform, created a corrective action report to address one issue observed by the NRC staff during the regulatory audit. On July 30, 2025, Framatome Inc. submitted its response to the NRC staff’s RAI 10688 (ML25212A176), and subsequently, the NRC staff held a public meeting on September 18, 2025 (ML25246C344) to discuss these RAI responses.

On January 5 to January 9, 2026 (ML25344A019), the NRC staff conducted a virtual audit of Framatome Inc. to confirm that the (1) details and draft markups to the topical report adequately support the RAI response, and (2) the corrective actions implemented to address the NRC staff’s observations during the March 31 to April 4, 2025, regulatory audit were adequately implemented.

Per the NRC staff’s request, a list of reference documents was available on the Framatome online portal to support the audit, and additional documents were added to facilitate responses to the NRC staff’s questions. The NRC staff’s informational needs requests were addressed by Framatome representatives during the audit.

¹ Framatome SAS (Société par actions simplifiée) based in France is owned by Électricité de France (EDF) Group (80.5%) and Mitsubishi Heavy Industries (MHI - 19.5%)

2.0 **REGULATORY AUDIT OBJECTIVES**

The overall objectives and goals for the audit are provided below.

- Assess Framatome Inc.'s procurement and supplier oversight activities of Framatome SAS and Framatome GmbH².
- Assess the relationship among the Framatome Inc. QA Program, Framatome Integrated Management System Manual, TXS QA Plan for TXS Compact Automation System (AS) FPGA, TXS Compact Engineering and Service Tools QAP, and TXS Compact Quality Management Plan to understand how the requirements of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," are met.

Those who participated in the audit are listed below.

Name	Title	Affiliation
Deanna Zhang	Senior Reactor Operations Engineer	NRC
Liam O'Donoghue	Reactor Operations Engineer	NRC
Jack Zhao	Senior Electronics (Digital I&C) Engineer	NRC
Ngola Otto	Project Manager	NRC
Norbert Carte	Senior Electronics (Digital I&C) Engineer	NRC
Gayle Elliott	Director of Licensing & Regulatory Affairs	Framatome Inc.
Mehdi El Ouafi	Director Strategic Development & Industrialization	Framatome Inc.
Hayder Haouaneb	Project Leader	Framatome SAS
Mark Harvey	Director, Quality, Performance and Operational Support	Framatome Inc.
Nathan Hottle	Framatome Licensing	Framatome Inc.
Ronda Lane	Framatome Licensing	Framatome Inc.
Brian McMahon	Application Engineer	Framatome Inc.
Matthieu Nobre	Supplier & Processes Manager	Framatome SAS
Stephane Nouketchessi Simo	Qualification and Licensing Engineer	Framatome SAS
Al Pitts	Quality Manager	Framatome Inc.

² Framatome GmbH, based in Erlangen, Germany is a wholly owned subsidiary of Framatome SAS in France.

3.0 **REGULATORY AUDIT BASES**

Regulations relevant to the audit and NRC staff's review of the TR are applicable criteria Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, including:

- Criterion III, "Design Control," which requires, in part, that quality standards be specified and that design control measures shall provide for verifying or checking the adequacy of design.
- Criterion IV, "Procurement Document Control," which requires, in part, that procurement documents to be include applicable regulatory requirements, design bases, and other requirements which are necessary to assure adequate quality are suitably included or referenced in the documents for procurement of material, equipment, and services.
- Criterion V, "Instructions, Procedures, and Drawings," requires, in part, that activities affecting quality shall be prescribed by "documented ...procedures... of a type appropriate to the circumstances...."
- Criterion VII, "Control of Purchased Material, Equipment, and Services," addresses control of purchased material, equipment, and services.
- Criterion XVI, "Corrective Actions," which requires, in part, that conditions adverse to quality are promptly identified and corrected.

4.0 **DISCUSSION**

The audit provided the NRC staff with the opportunity to:

1. Review the results of Framatome SAS implementation of corrective actions to address the NRC staff's observations on commercial grade dedication (CGD) of [[
]] from the NRC staff's 2025 audit.
2. Review the completed commercial grade survey (CGS) reports for [[
]].
3. Discuss with Framatome staff the revisions to the CGD plan for [[
]].
4. Discuss with Framatome staff [[
]].
5. Review and discuss with Framatome Inc. staff the draft markups to the Framatome TXS Compact TR.

The NRC staff had an observation regarding Framatome Inc.'s conclusions made in the draft TR regarding [[

]] when the final CGD reports were not complete until after the NRC staff raised a question about the CGD report status. Framatome Inc. staff acknowledged the NRC staff's observations.

5.0 CONCLUSION

The NRC staff's audit objectives were accomplished through discussions with the Framatome technical experts and engineers, document review, and verification of CGD results. More specifically, the NRC staff confirmed that 1) Framatome SAS implemented the corrective actions to address the NRC staff's observations from the NRC staff's audit in March 31 to April 4, 2025, and 2) draft RAI responses and TR markups appropriately reflect the activities and corrective actions completed.

No regulatory decisions were made during the audit.

Summary of Change Pages for
ANP-10357, Revision 0

Topical Report Section	Description of Change(s)
1.0	Editorial changes shared during January 5-9, 2026 remote audit.
1.1	Changes in response to RAI 10688 Question 3(a).
2	Editorial changes shared during January 5-9, 2026 remote audit.
3	Editorial changes shared during January 5-9, 2026 remote audit.
4	Updates to reflect the status of the project as of the Jan 5-9, 2026 remote audit. Changes were shared during the audit.
5	Editorial changes shared during January 5-9, 2026 remote audit.
6	Editorial changes shared during January 5-9, 2026 remote audit.
6.3	Changes in response to RAI 10688 Question 3(c).
8.1	Changes in response to RAI 10688 Question 1.
8.2	Changes in response to RAI 10688 Questions 2(a) and 2(b).
8.2.1	Changes in response to RAI 10688 Questions 3(b) and 3(c).
8.2.2	Changes in response to RAI 10688 Question 4(a).
8.3	Changes in response to RAI 10688 Questions 4(b) and 4(d).
8.4	Changes in response to RAI 10688 Question 2(d).
9	Editorial changes shared during January 5-9, 2026 remote audit.
10	Editorial changes shared during January 5-9, 2026 remote audit.
11	Updates to reflect the status of the project as of the January 5-9, 2026 remote audit. Changes were shared during the audit.
12	Updates to reflect the status of the project as of the January 5-9, 2026 remote audit. Changes were shared during the audit.