Letter No. NRC-V10-10-007

August 5, 2010

United States Nuclear Regulatory Commission
Mr. Jonathon Rowley, Project Manager
M/S 12D2
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Subject: Nuclear Safety Related Qualification of the Tricon TMR Programmable Logic Controller (PLC) – Update to Qualification Summary Report Submittal and "Application for Withholding Proprietary Information from Public Disclosure" (TAC NO. ME2435)

References:

1. Letter, J. Polcyn (Invensys) to NRC, June 1, 2009, subject: NRC Safety Evaluation Report, "Review of Triconex Corporation Topical Reports 7286-545, Qualification Summary Report, and 7286-546, Amendment 1 to Qualification Summary Report, Revision 1", Letter No. NRC-V10-09-001.
2. Letter, B. Haynes (Invensys) to NRC, April 6, 2010, subject: Nuclear Safety Related Qualification of the Tricon TMR Programmable Logic Controller (PLC) – Update to Qualification Summary Report Submittal and "Application for Withholding Proprietary Information from Public Disclosure" (TAC NO. ME1906), Letter No. NRC-V10-10-003.
3. Letter, B. Haynes (Invensys) to NRC, April 9, 2010, subject: Nuclear Safety Related Qualification of the Tricon TMR Programmable Logic Controller (PLC) – Update to Qualification Summary Report Submittal and "Application for Withholding Proprietary Information from Public Disclosure" (TAC NO. ME1906), Letter No. NRC-V10-10-004.
4. Letter, B. Haynes (Invensys) to NRC, April 23, 2010, subject: Nuclear Safety Related Qualification of the Tricon TMR Programmable Logic Controller (PLC) – Update to Qualification Summary Report Submittal and "Application for Withholding Proprietary Information from Public Disclosure" (TAC NO. ME2435), Letter No. NRC-V10-10-005.
5. Letter, B. Haynes (Invensys) to NRC, April 23, 2010, subject: Nuclear Safety Related Qualification of the Tricon TMR Programmable Logic Controller (PLC) – Update to Qualification Summary Report Submittal and "Application for Withholding Proprietary Information from Public Disclosure" (TAC NO. ME2435), Letter No. NRC-V10-10-006.

In preparation for the NRC safety evaluation of the V10 Tricon TMR PLC, the staff visited Invensys at its Irvine, California, facility on January 21 and 22, 2010. As part of the information exchange that occurred, Invensys presented to the staff on various technical issues. The staff provided feedback on the technical presentations, and made a number of useful suggestions on the information the staff would need for the safety evaluation of the V10 Tricon TMR PLC. In Reference 2, Invensys committed to submitting the following documents to support the staff review:

(1) A revised topical report on the V10 Tricon TMR PLC, to include a redline-strikeout version that clearly annotates the differences between the V9 and V10 Tricon versions;

(2) An additional 54 technical documents pertaining to the V10 Tricon TMR PLC; during the January information exchange with NRC, the staff and Invensys performed a line-by-line review of the ISG6 table to finalize the list of documents to submit for the safety evaluation and identified these additional 54 documents required by the staff;

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(3) A whitepaper, NTX-SER-09-06 describing the process Invensys follows during the development of programmable logic devices, field programmable gate arrays (FPGAs), etc.; the document will address legacy development up to and including V10.5, as well as the process going forward to ensure recent NRC guidance on FPGA-based safety systems is incorporated into future Tricon releases;

(4) A revision to document SER Maintenance Process, NTX-SER-09-20, that clarifies and enhances the proposed SER maintenance process as compared to previous revisions of the paper;

(5) A revision to Tricon V9.5.3 to V10.2.1 Differences Document, NTX-SER-09-05, that provides additional clarity on product software configuration, structure, and development path;

(6) A revision to the Invensys ISG2 & ISG4 Compliance Paper, NTX-SER-09-10, that incorporates technical details into the discussion on conformance of the V10 Tricon TMR PLC communication features and protocols to the staff guidance on safety system communications;

(7) A Program Manual that will govern the Tricon TMR PLC nuclear system integration process, including nuclear application software development; this will be a revision to NTX-SER-09-21; and

(8) A revision to the Invensys Cyber Security Program Plan Licensing Topical Report (LTR) that will address anticipated regulatory changes as presented in Draft Guide-1249.

Items 1 thru 8 in the above list were enclosed in References 2, 3, 4, and 5. Invensys understands that the staff intends to formally accept the V10 Tricon application up to maintenance release V10.5.1, and that subsequent maintenance releases will not be included in the V10 Tricon TMR PLC safety evaluation.

Reference 5 discussed several open issues identified by the staff during the acceptance review as listed below. The open issues are addressed by Invensys in Enclosures 2 and 3 to this letter:

- Mapping of the Invensys FPGA development process to a software lifecycle that conforms to NRC guidance in BTP 7-14. To minimize the effort on requests for additional information, Invensys is providing Enclosure 2 that contains the next revision to the FPGA white paper, NTX-SER-09-06. The revision includes a new table that maps the Invensys FPGA development process to BTP 7-14 guidance.
- Invensys position regarding conformance of communications between a safety-related primary RXM and non-safety remote RXM chassis. A detailed discussion on how the RXM technology complies with the regulatory requirements is provided in Enclosure 3, Selected Topic 1. The V10 Tricon IO Bus is an internal system bus not subject to the same types of faults that would be exhibited on a computer network. Therefore, Invensys discusses the RXM technology from the perspective of IEEE Standards 603 and 7-4.3.2, as opposed to DI&C-ISG-04.
- Status of implementing the recommendations contained in the Critical Digital Review (CDR), Invensys document 9600164-539. Invensys has previously informed the staff that the open items have been addressed in accordance with our Appendix B program. Upon request by the staff, Invensys has included in Enclosure 3, Selected Topic 2, a cross reference between the recommendations contained in the CDR and the associated Invensys document(s) where they are implemented.
- Clarification of issues raised in the CDR regarding the TCM. During the V10 Tricon acceptance review the staff identified a number of issues contained in the CDR specific to the TCM. A tabulation of Invensys responses is contained in Enclosure 3, Selected Topic 3.
- Clarification regarding the V10 Tricon IO Bus. Specifically, the staff requested additional information on a particular function of the IO Bus between the 3008N main processors and an IO module(s) experiencing an error. Enclosure 3, Selected Topic 4 contains the detailed discussion.

Please find enclosed two CDs containing a document listed on Attachment 1 that was previously submitted on the NRC Letter indicated below. The file is being resubmitted to reflect additional information and clarifications. The file in Enclosure 2 supersedes in its entirety the document previously submitted as shown in the table below:

Table 1. Superseded files.

New File:	*Replaces Old File:*	*Old File Transmittal Letter*
[139R1_PLDDev_P.pdf]	*[139_PLDDev_P.pdf]*	*NRC-V10-10-004*

Invensys is also providing this letter as our "Application for Withholding" pursuant to the provisions of 10 CFR Part 2.390, Paragraph (b)(1). This submittal contains commercial strategic information proprietary to Invensys and customarily held in confidence. As previously identified in this letter, the proprietary material for which this withholding is requested has been specifically identified. In accordance with 10 CFR Part 2.390, Affidavit No. TCXNRC-10-05 accompanies this transmittal and sets forth the basis for which the identified proprietary information may be withheld from public disclosure. Accordingly, it is respectfully requested that the specified information which is proprietary to Invensys be withheld from public disclosure in accordance with 10 CFR Part 2.390.

Invensys has given its best effort to address all of the staff's comments and questions pertinent to the V10 Tricon TMR PLC to ensure an expeditious safety evaluation. However, we recognize that additional information may be required by the staff. We look forward to supporting the staff on this important effort.

Correspondence with regard to this transmittal should be directed to the following:

Mr. Brian Haynes
Project Manager
Invensys
15345 Barranca Parkway
Irvine, California 92618

If there are any questions on this submittal or any of its enclosures, please contact me at (949) 885-0778.

Sincerely,

Brian Haynes
Project Manager
Invensys

cc: Ms. Stacey Rosenberg, Branch Chief – NRR – CDs Only
Mr. William Kemper, Branch Chief – NRR – CDs Only
Mr. Steve Blair – Invensys – Letter Only
Mr. Andy Sykes – Invensys – Letter Only
Mr. Clayton Scott – Invensys – Letter Only
Mr. Paul Whitacre – Invensys – Letter Only
Mr. Richard Lilleston – Invensys – Letter Only
Attachment/Enclosures

ATTACHMENT 1
Enclosure Listing – CD 18 & 19 Content

Enclosure Description	*CD18**	*CD19*	*[filename] [size MB]*
Enclosure 1: - Affidavit #TCXNRC-10-05	X	X	*[143_Affidavit10_5.pdf] [0.2]*
Enclosure 2: Revision to Previously Submitted Document			
Triconex Development Processes for Programmable Logic Devices in Nuclear-Qualified Products – NTX-SER-09-06, Rev 1*	X	---	*[139R1_PLDDev_P.pdf] [3.0]*
Enclosure 3: Supplementary Information – Selected Topics			
Responses to Technical Issues - 8/3/10*	X	---	*[144_RAI_080310_P.pdf] [0.9]*
Responses to Technical Issues - 8/3/10**	X	X	*[145_RAI_080310_NP.pdf] [0.8]*

*) Document Contains Invensys Proprietary material

**) Non-proprietary version of Proprietary document (redacted)

Notes:
(a) CD#18 contains Proprietary Documents (among all files). CD#19 contains only Non-Proprietary Documents (Publicly Available).

(b) Non-Proprietary version of NTX-SER-09-06, Revision 1, not provided due to the predominantly proprietary content.

AFFIDAVIT No. TCXNRC-10-05
Re: Request for Withholding from Public Disclosure per 10CFR2.390

STATE OF CALIFORNIA)
) ss
COUNTY OF ORANGE)

I, Michael Kieu, being duly sworn, hereby say and depose:

1. I am Director of Safety and Critical Control Development at Invensys, and as such I have been specifically delegated the function of reviewing company proprietary information sought to be withheld from public disclosure in connection with the nuclear safety related qualification of the TRICON Programmable Logic Controller (PLC) system and am authorized to apply for its withholding on behalf of Invensys.

2. The information sought to be withheld is contained in the document(s) described below:

   (1) Triconex Development Processes for Programmable Logic Devices in Nuclear-Qualified Products – NTX-SER-09-06, Rev 1
   (2) Supplementary Information – Selected Topics – 8/3/10

   The indicated documents contain information considered to be proprietary. Proprietary material in the enclosed documents are indicated by brackets [ ] or other similar markings as required by 10CFR2.390(b)(1)(i)(B). As indicated in the associated Transmittal letter, non-proprietary versions of the documents are being provided, consistent with level of proprietary content.

   This information is documentation associated with ongoing upgrade and maintenance of qualification of the Tricon PLC. This will allow the NRC to verify compliance with current regulatory requirements in support of an update to the SER for the Tricon PLC System and associated Triconex Topical Report 7286-545-1-A.

3. I am making this affidavit in conformance with the provisions of 10CFR Part 2.390 of the Commission's regulations and in conjunction with the Invensys Triconex application for withholding accompanying this Affidavit.

4. I have personal knowledge of the criteria and procedures utilized by Invensys in designating information as a trade secret, privileged, or as confidential commercial or financial information. Some examples of categories of information which fit into the definition of proprietary information are:

   a) Information which discloses process, method, or apparatus, including supporting data and analyses, where prevention of its use by Invensys Triconex's competitors without license or contract from Invensys constitutes a competitive economic advantage over other companies in the industry.

b) Information, which if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.
c) Information which reveals cost or price information, production capacities, budget levels, or commercial strategies of Invensys, its customers, its partners, or its suppliers.
d) Information which reveals aspects of past, present, or future Invensys Triconex customer-funded development plans or programs, of potential commercial value to Invensys.
e) Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.
f) Information obtained through Invensys Triconex actions which could reveal additional insights into Nuclear safety related PLC equipment qualification processes and regulatory proceedings, and which are not otherwise readily obtainable by a competitor.

Information to be withheld is considered to be proprietary based on the reasons set forth in paragraphs 4 (a), (b), and (f) above.

5. This document describes the details of Triconex equipment which has undergone nuclear qualification testing. Product design and development details are also represented. Invensys Triconex is the first manufacturer of a PLC to fully implement the requirements set forth in the EPRI TR-107330, which has been endorsed by the Commission in an SER. Invensys Triconex has expended a significant amount of money and effort involving numerous contractors over a 12 year time period to develop and implement an ongoing successful approach to its qualification and test program. Information developed relating to test plans, approaches, equipment, specific problems encountered, licensing perspectives, and lessons learned has significant value because of the resources expended to successfully accomplish this process and the usefulness of this knowledge to potential competitors.

   Specific test data showing compliance with requirements and demonstrating technical capability of the equipment has substantial commercial value because it provides the basis for qualifying Triconex equipment to be sold for safety-related digital upgrades to nuclear plants. Existing options for digital upgrades in the nuclear industry are limited. We believe that ongoing successful nuclear qualification upgrades of the Invensys Triconex products, already well known in non-nuclear applications, will continue to give Invensys a competitive advantage in this field.

   Disclosure of information in these documents would cause substantial harm to the competitive position of the Invensys, as there are other competing companies who wish to develop, qualify, and sell digital control systems for safety related application in nuclear power plants. Competing firms could use our experience, successful approaches, and technical information to facilitate their own equipment qualification efforts and/or product design without compensating Invensys.

6. Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.
   (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Invensys.
   (ii) The information is of a type customarily held in confidence by Invensys and not customarily disclosed to the public. Invensys has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitute Invensys policy and provide the rational basis required.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10CFR Part 2.390, it is to be received in confidence by the Commission.

(iv) This information is not readily available in public sources.

(v) Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Invensys, because it would enhance the ability of competitors to provide similar design of PLC or qualify similar equipment using similar project methods, equipment, testing approach, contractors, or licensing approaches. As described in section 5, this information is the result of considerable expense to Invensys and has great value in that it will assist Invensys in providing Triconex digital upgrade equipment and services to a new, expanding markets not currently served by the company.

7. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

Michael Kieu
Director of Safety and Critical Control Development
Invensys

Sworn to and subscribed before me

this 5 day of Aug., 2010

Notary Public

V. MATHESON
COMM. # 1862131
NOTARY PUBLIC-CALIFORNIA
ORANGE COUNTY
My Comm. Expires AUG 21, 2013

RRS2

State of California
County of Orange
Subscribed and sworn to (or affirmed) before me
on this 5 day of Aug., 2010
by Michael Kieu,
proved to me on the basis of satisfactory evidence
to be the person(s) who appeared before me.
Signature (Seal)

Non -Proprietary copy per 10CFR2.390
- Areas of proprietary information have been redacted.
- Designation letter corresponds to Triconex proprietary policy categories (Ref. transmittal number NRC-V10-09-001, Affidavit, Section 4.)

Supplementary Information –

Selected Topics

Responses to technical issues 08/03/2010

Reference NRC Letter No. NRC-V10-10-007

1. **Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis**
2. **CDR Recommendations**
3. **Clarification of issues raised in the CDR regarding the TCM**
4. **Clarification of V10 Tricon IO Bus**

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Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis

Responses to technical issues 08/03/2010
Reference NRC Letter No. NRC-V10-10-007

Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis
Responses to technical issues 08/03/2010
Reference NRC Letter No. NRC-V10-10-007

The NRC has requested additional information on conformance to staff guidance on safety-to-nonsafety communications of certain configurations of the V10 Tricon.

Invensys document NTX-SER-09-10, "Tricon Applications in Nuclear Reactor Protection Systems – Compliance with NRC Interim Guidance ISG-2 & ISG-4," describes the V10 Tricon conformance to Interim Staff Guidance on communications between safety and non-safety systems contained in DI&C-ISG-04 (ISG-04). The staff has identified some concerns with NTX-SER-9-10 Section 2, *V10 Tricon Chassis Configurations*, and 3.2, *V10 Tricon Communications – Safety-to-Nonsafety Communications*, regarding proposed safety-to-nonsafety V10 Tricon architectures. Figure 1, below, taken from NTX-SER-09-10, shows a safety-related Main Chassis connected to a safety-related Primary RXM Chassis, which is, in turn, connected to a non-safety Remote RXM Chassis. The staff has requested clarification on how the configuration depicted in the figure meets ISG-04. Specifically, the staff has asked for clarification on the communications isolation, and impact on the safety function upon worst-case failure of the non-safety RXM chassis and/or input/output (IO) module in the non-safety RXM chassis.

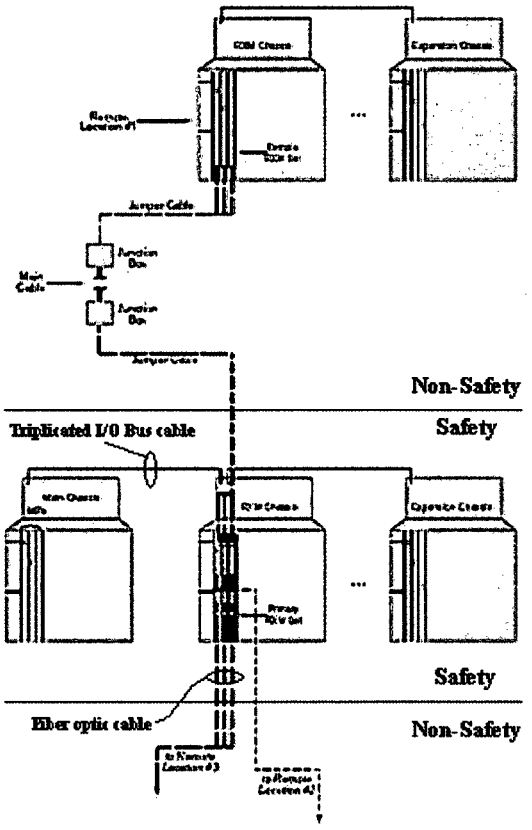

Figure 1 - Safety-Related System with Non-Safety Remote Location (Figure 3 in NTX-SER-09-10)

The Invensys response addresses the staff's concerns by highlighting the conclusions from the V9 Tricon safety evaluation that are relevant to the staff's "delta review" of the V10 Tricon, and by discussing compliance of the V10 Tricon to the applicable regulatory requirements. The discussion below builds upon technical information in Section 2.1 of Invensys document NTX-SER-09-10. Additional technical

details are provided as necessary. Supporting Invensys technical documents will be provided to the staff or made available for audit, as appropriate.

Precedence The staff reviewed the RXM technology as part of the V9 Tricon safety evaluation. The relevant excerpts from the V9 Tricon safety evaluation report (SER), ADAMS Accession Number ML013470433, are as follows (emphasis added):

> "2.1.1.3 Remote Extender Chassis
>
> "The remote extender chassis are similar to the expansion chassis, but are used for remote locations (up to several miles away), rather than locally. As such, each remote extender chassis has remote extender modules (RXMs) that serve as repeaters or extenders of the Tricon PLC I/O bus to allow communications with the main chassis and expansion chassis. The RXMs are single-mode fiber optic modules that allow the expansion chassis to be located up to 7.5 miles away from the main chassis. Each RXM module has separate transmit and receive cabling ports, requiring two unidirectional fiber optic cables (one to transmit and one to receive), for each module. Since the RXM modules are connected by fiber optic cables and not electrical cables, they provide ground loop isolation and immunity against electrostatic and electromagnetic interference, *and they can be used as 1E-to-non-1E isolators between a safety-related main chassis and a non safety-related expansion chassis.* The Tricon PLC remote extender chassis uses the same type of power supplies as the main chassis, and has the same dual and redundant power bus arrangement.
>
> "4.1.3.8 Class 1E to Non-1E Isolation Testing
>
> "During electrical isolation testing, the Tricon PLC test system was mounted in open instrument racks. No additional electrical protection devices were used on the I/O interfaces. At least one point on each I/O module was monitored for proper operation, and the communications modules were exercised through interfaces with external monitoring devices. Operability and prudency testing was performed following electrical isolation testing to demonstrate acceptable operation.
>
> "*The Tricon PLC test system used a fiber optic link to connect two of the expansion chassis to the system's main chassis. Triconex has demonstrated by analysis that the fiber optic cables provide electrical isolation between the main chassis and the fiber optically linked expansion chassis.* The basis for this conclusion is that since the fiber optic cables do not conduct electricity, they are incapable of transmitting electrical faults. In addition, the operability and prudency testing demonstrated that faults and failures of the fiber optic link do not degrade operation of the main chassis hardware...
>
> "*The staff determined that the Tricon PLC system design, which separates Class 1E modules from non-1E modules by the fiber optic link, has adequate electrical isolation*

Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis
Responses to technical issues 08/03/2010
Reference NRC Letter No. NRC-V10-10-007

> *between Class 1E and non-1E equipment and is suitable in this regard for safety-related use in nuclear power plants."*

The staff goes on to state in the V9 SER that the licensee must ensure the test voltages envelope the worst-case voltages at the site.

Since the time the V9 SER was issued in 2001, the RXM firmware has not been changed. As stated in the V9 SER, pages 18 and 22 show the firmware version number as 3310. This is the same version used for the V10 Tricon RXM modules. The differences between the RXM technology the staff approved for V9 and RXM technology the staff is currently reviewing for V10 lie in the hardware – the NRC-approved V9 RXM modules utilize single-mode fiber optic cables, whereas the V10 RXM modules utilize multi-mode fiber optic cables.

Regulatory Considerations IEEE Standard 603-1991 Clause 5.6, Independence, contains requirements to protect the safety system against the effects of design basis events and failures such that the safety system will perform its safety function when demanded. Specifically, IEEE Standard 603-1991 contains requirements for independence between:

- Redundant portions of a safety system;
- Safety systems and effects of design basis events;
- Safety systems and other systems, to include interconnected equipment, equipment in proximity to the safety systems, and the effects of single failures.

With regard to safety-related digital system utilizing software, IEEE Standard 7-4.3.2-2003, which was endorsed by the staff in Regulatory Guide 1.152, Revision 2, contains additional guidance on independence, specifically:

- Data communication between safety channels and between safety and non-safety systems; and
- Adequate barriers between safety and non-safety software on the same computer.

In the Standard Review Plan, NUREG-0800, Chapter 7, Appendix 7.1-C, the staff divided the independence requirements contained in IEEE Standard 603-1991 into three distinct facets, and identified review criteria for determining conformance:

1) Physical Independence;
2) Electrical Independence; and
3) Communications Independence.

In Appendix 7.1-D, the staff provided further clarification of adequate software barriers and data communications independence.

The Invensys response will explain how the proposed architecture in Figure 1 meets the independence requirements in IEEE Standard 603-1991 (i.e., Physical, Electrical, and Communications Independence), as well as describe software barriers inherent in the V10 Tricon RXM technology.

Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis
Responses to technical issues 08/03/2010
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Physical Independence The V10 Tricon comprises a Main Chassis, and, depending on how many I/O points are needed, an Expansion Chassis. If distances between the Main Chassis and the Expansion Chassis exceed the capability of the standard 9000-series copper cable, then a remote expansion chassis, or RXM Chassis, will be utilized. NTX-SER-9-10 gives more detail on the various V10 Tricon chassis.

In Figure 1 a safety-related Main, RXM, and Expansion Chassis are shown. Connected to the safety-related RXM Chassis via fiber-optic cables are a non-safety-related RXM and Expansion Chassis (connected via a 9000-series copper cable). In accordance with IEEE Standard 603-1991 and guidance in Chapter 7 of the SRP, the requirements for physical independence are satisfied by physical separation of safety- and nonsafety-related equipment in their respective chassis, as well as by distance. By definition, the RXM Chassis is utilized when the remote I/O is separated from the Main Chassis at a distance exceeding the capability of the 9000-series copper cable (greater than 100 feet). Therefore, the non-safety remote RXM Chassis would typically be located at a distance that would ensure compliance with the physical separation requirements of IEEE Standard 603. The Primary RXM would always be safety-related to maintain traceability to the V10 Tricon nuclear qualification, thus the Primary RXM and Main Chassis would not be subject to the separation criteria.

Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis
Responses to technical issues 08/03/2010
Reference NRC Letter No. NRC-V10-10-007

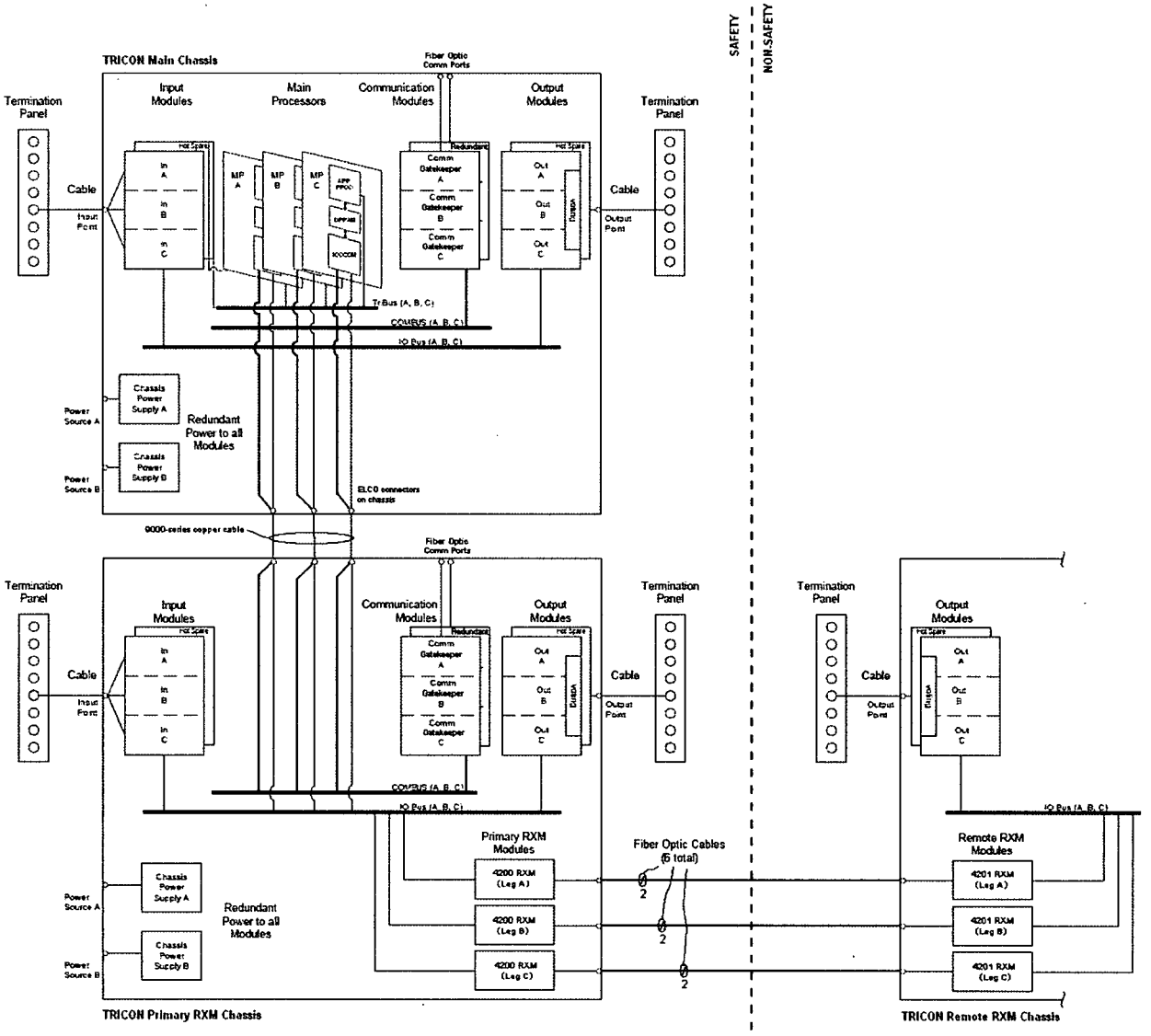

Figure 2 - System Block Diagram: Safety-Related Main and Primary RXM with Non-Safety Remote RXM

Figure 2, a more detailed version of Figure 4 in NTX-SER-09-10, shows the V10 Tricon system bus architecture for the case under consideration, i.e., safety-related Main and Primary RXM Chassis and nonsafety-related Remote RXM Chassis. The safety-to-nonsafety demarcation is represented by the vertical dashed line: on the left side are the safety-related Main Chassis and Primary RXM Chassis; on the right side is the non-safety Remote RXM Chassis. It is physically possible to have multiple Remote RXM Chassis connected to a single Primary RXM, or multiple Primary RXM Chassis connected to a single Main Chassis (up to a maximum of 14 expansion chassis). For simplicity, Figure 2 shows a single safety-related Primary RXM Chassis connected to a single non-safety Remote RXM Chassis. (It should be noted

that a "primary" RXM Chassis and a "remote" RXM Chassis are physically the same, with the difference being where in the chain a given chassis is located.)

The Primary RXM Chassis is connected to the Main Chassis using a 9000-series copper cable. If a TCM is in the Primary RXM Chassis, then a 9001 copper cable connects the Primary and Main Chassis, otherwise a 9000 copper cable is used. The 9001 copper cable contains the extra wiring for transmitting network communications between the Primary RXM Chassis and the Main Chassis. Because the RXM 4200-series modules extend only the system internal I/O Bus, a TCM cannot be used in any Remote RXM Chassis.

Figure 2 provides a clearer picture of the physical separation between the safety and non-safety portions of the proposed architecture.

Independence between Redundant Portions of a Safety System The V10 Tricon is a triple-modular-redundant system. Therefore, for the configuration in Figure 2, the safety-related Primary RXM Chassis will have three 4200 RXM modules with fiber optic connections to the non-safety 4201 RXM modules in the non-safety Remote RXM Chassis, with one 4200-4201 RXM module pair for each leg of the I/O Bus (Legs A, B, and C). Each 4200-4201 RXM module pair requires two multi-mode fiber optic cables (one for transmitting and one for receiving I/O Bus data), for a total of six fiber optic cables between RXM Chassis. A 4200 RXM module can support connections to three 4201 RXM modules, which means a Primary RXM Chassis can support fiber optic connections with up to three Remote RXM Chassis. The fiber optic connections provide ground loop isolation and immunity against electrostatic and electromagnetic interference, and the Invensys V10 Equipment Qualification Program has qualified the 4200-series RXM modules for safety related use, as documented in Invensys report 9600164-545, "Equipment Qualification Summary Report (EQSR)."

For nuclear applications, often redundant channels and trains are required to meet stringent nuclear safety requirements. For example, reactor protection systems may comprise four redundant trains, Train A, B, C, and D, with two-out-of-four voting. When composed of V10 Tricon controllers, there would effectively be twelve separate processing legs, three in each Train that would then vote amongst each other to obtain the two-out-of-four trip logic. The independence requirements for redundant portions of a safety system apply at the Train level, meaning Train A, B, C, and D are required to be isolated and independent from each other. Though internal to the V10 Tricon each leg is isolated from the other two, this is not governed by the overarching independence requirement.

This particular aspect of independence is applicable to plant-specific implementations of the V10 Tricon. NTX-SER-09-10 discusses this issue in greater detail.

Electrical Independence Each Tricon chassis type has dual-redundant power supplies. For the configuration shown in Figure 2, the safety-related Main and Primary RXM Chassis would be powered from safety-related power sources A and B, and the nonsafety-related remote RXM Chassis (though not explicitly shown) would be powered from nonsafety power sources. The Tricon can accept either AC or DC power sources. The actual configuration would be plant-specific, and would thus be the responsibility of the Licensee. However, the V10 Tricon in its various configurations satisfies the requirements for electrical independence.

If a particular Licensee implementation requires sharing of data between redundant trains, appropriate isolation would be utilized (e.g., safety-related opto-isolators). However, train-level configurations

utilizing the Tricon are plant-specific and thus the responsibility of the Licensee. NTX-SER-09-10 discusses interdivisional communications in greater detail.

a, b

Communications Independence Figure 3 shows the relationship between the RXM modules and the system for a *single leg* of I/O (Leg A, B, or C). The demarcation between safety and non-safety equipment is the dashed line: above the line is the safety-related Primary RXM Chassis with the safety-related portion of the IO Bus shown by the block "Primary I/O Bus" in the upper-left portion of the figure. This represents the Primary RXM Chassis backplane I/O bus that would transfer data to/from I/O modules inserted into the safety-related Primary RXM Chassis. Recall that the Primary I/O Bus is connected to the Main Chassis via the 9000-series copper cable (shown in Figure 2) at the Primary RXM Chassis panel connectors. Ultimately this goes to the IOCCOM processors on the associated 3008N MPs (Legs A, B, and C).

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Each RXM module extends one leg of the triplicated I/O Bus by operating as an active repeater of the I/O Bus messages. Each RXM module is connected to one leg, with three RXM modules installed to assure continued operation in the event of any failure of a single leg. The data on the I/O Bus is repeated onto the extended (fiber optic) I/O bus on a per-leg basis. Each leg operates completely independently of the others. Those messages that are intended for a specific RXM on a given leg will be responded to by the addressed RXM. These messages will also be relayed to all portions of the system *within the leg*, but will be ignored by all other modules. It should be noted that, as depicted in Figure 2, the I/O Bus is separated into command and response busses to eliminate erroneous messaging/interaction between I/O modules. All I/O Bus interactions are between the IOCCOM master and an I/O module slave.

a, b

Software Barriers The RXM modules utilize firmware in the master and slave CPUs, and the HDL for the PAL-based communication multiplexer. The firmware and HDL netlist are loaded onto the RXM module at the time of manufacture, and subsequently tested at the board level prior to installation into an integrated system. The safety-related RXM modules (in this case the safety-related Primary 4200 RXM modules) are dedicated in accordance with the Invensys Appendix B program for use in safety-related applications. Invensys document NTX-SER-10-14, "Tricon V10 Conformance to Regulatory Guide 1.152," describes the manufacturing process for Tricon modules. The 4200 and 4201 RXM modules have been qualified by Invensys for use in nuclear safety-related applications, as documented in the EQSR. The firmware (Revision 3310) has previously been approved by the NRC for safety-related use in nuclear power plants in the V9 SER, as explained previously. For the configuration shown in Figure 2, the 4200 RXM modules in the Primary RXM would be safety-related, while the 4201 RXM modules in the Remote RXM would be nonsafety-related. Because the firmware is loaded onto individual RXM modules, the barrier in this case is physical separation. The firmware is running on separate safety and non-safety processors on separate RXM modules, thereby satisfying the barrier requirement.

The same is true of the firmware for the embedded IOCCOM processors on the safety-related 3008N MP modules. The firmware for the IOCCOM is distinctly different from the RXM firmware, and is loaded onto a physically separate 3008N MP module. The IOCCOM, as described in other Invensys documentation provided to the staff in support of the V10 Tricon safety evaluation, provides one communication barrier. NTX-SER-09-10 provides additional detail on the IOCCOM and IO Bus operation. Essentially, the IOCCOM issues command messages (originating from the embedded application processor on the 3008N MP) to the IO modules, and any responses that do not meet format requirements and timing requirements are rejected (e.g., CRC, data type, message length, sequence number). If the IOCCOM receives a response message from an unrecognized IO module, the message is ignored. The combination of physical separation between the safety-related IOCCOM firmware and nonsafety-related Remote RXM module firmware and communication isolation provided by the IOCCOM satisfies the independence requirements.

An additional barrier is established in the application program executing on the embedded 3008N MP through strict adherence to Invensys guidance and procedures. Invensys document NTX-SER-09-21, Nuclear System Integration Program Manual, (NSIPM) governs the development process[1] for nuclear

[1] The Invensys Quality Assurance (QA) Program and implementing procedures have been assessed by several organizations, such as the NRC (during the V9 safety evaluation and subsequent inspections, the latest of which was 2008), and audits by Invensys Tricon development process and QA program satisfy the requirements of 10 CFR Part 50 Appendix B and BTP 7-14.

safety-related systems starting at the conceptual phase through testing phase and into delivery. Invensys documents 9700097-007, Safety Considerations Guide for Tricon V9-V10 Systems, and 9600164-545, V10 Tricon Application Guide, Appendix B, both contain guidance to the application engineer on programming of fault-handling algorithms for IO faults. Specialized Tricon library function blocks are available specifically for ensuring proper operation of safety-critical IO. The Application Guide also contains guidance for the application engineer on proper handling of both safety-critical and non-safety critical IO in application programs.

For the configuration shown in Figure 2, the safety function will not depend upon the non-safety IO points. However, the safety-related application program functions that handle the non-safety IO residing on the non-safety RXM Chassis and modules would be developed, tested, and maintained equivalent to safety-related functions, consistent with IEEE Std 603 and 7-4.3.2 and in conformance with guidance from the staff. Adhering to Invensys procedures and application guidance during development of application code for nuclear safety-related systems and following the NSIPM process will ensure the application program will be designed, implemented, tested, and maintained in accordance with NRC requirements for safety-related software in nuclear power plants.

Summary description of the IO Bus There are three 3008N MPs in the system and three legs in each IO module. There are three independent IO buses that connect each 3008N MP with one leg of an IO Module. The IO bus implements a serial master-slave protocol where the master (IOCCOM processor on the 3008N MP module) polls the slave (a leg in an IO module). The IO Bus is a closed system that is configured at design time. Messages are single threaded, which means a response message from an IO module for a given command message from the IOCCOM must be received or timed out *before* the next command message is issued. Commands from the IOCCOM processor are addressed to a specific IO module or may be broadcast to all IO modules. An IO Module's leg must respond only to messages that are addressed to it. However, a spare module's leg may listen to command messages and responses from its active partner but it will not respond.

The communication between the 3008N MP and the IO module uses a serial, asynchronous, RS485 master/slave protocol at 375 Kbps. The RS485 frame contains eleven bits, including a start bit. Multiple frames comprise a single command message from the 3008N MP to the IO module. Table 1 shows the format of IO message commands.

a, b

Failure Modes and Effects Analysis A Failure Modes and Effects Analysis (FMEA) was performed on the V10 Tricon system in accordance with the applicable requirements of EPRI TR-107330 Section 6.4.1. In general, the techniques of ANSI/IEEE Std. 352-1987 were used in the analysis. The results of the FMEA are documented in Invensys document 9600164-531, "Failure Modes and Effects Analysis for the Tricon Version 10.2 Programmable Logic Controller." The FMEA addressed failures of major components and at the module level. The approach was appropriate because sub-components in the Tricon modules are triple-redundant, and no single failure of an individual subcomponent can impact the ability of the Tricon to perform its safety-related functions, where *safety-related function* was defined as the ability of the safety system to perform a safe shutdown function. In addition, the Tricon self-diagnostic features have been specifically designed to detect and alarm failures of sub-components within each module. Extensive testing has been performed on each module to validate that the diagnostics detect all possible single failures within each module.

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The FMEA tabulation in Table 3 is an extension of the FMEA in 9600164-531 that postulates credible failures of the non-safety Remote RXM Chassis as shown in Figure 2. The approach identified the mechanisms that could cause the failure modes, and evaluated the consequences of the failures on the operation of the safety-related portion of the configuration (i.e., safety-related 3008N MPs and Primary RXM chassis and IO modules). Because of the architecture of the Tricon, failure mechanisms that affect a single leg of the triple redundant system generally have no effect on system operation. Therefore, the FMEA considered (1) failure mechanisms that are recognized as being highly unlikely but that could affect multiple components, and (2) the coincident occurrence of otherwise single failures (i.e., multiple failures). Multiple-failure scenarios include failures of all three non-safety Remote RXM modules due to software common mode failure, loss of all power, fire, floods, or missiles. These types of multiple-failure scenarios are recognized as being very unlikely, but are included to describe system behavior in the presence of severe failures and to provide guidance for application design.

Scenarios involving credible failures of non-safety IO modules in the Remote RXM Chassis were not specifically assessed because:

1) The safety-related application program executing on the 3008N MPs would be developed and tested using a process for developing safety-related software under an approved Appendix B program to ensure loss of non-safety IO process data would not cause loss of safety function;
2) Hardware single failure of non-safety remote RXM Chassis and IO modules and related hardware (e.g., termination panels in the cabinet) would be detected and alarmed; a review of the overall FMEA for the V10 Tricon in 9600164-531 confirms this; and
3) Catastrophic failures of the non-safety IO modules are bounded by the various scenarios in Table 3; for example, in accordance with EPRI TR-107330, Section 4.6.4, the maximum credible voltage transient (up to 600Vac and 250Vdc) on the input of a non-safety remote IO module could lead to an open IO bus in the non-safety Remote RXM Chassis, which is one of the scenarios analyzed in Table 3.

The tabulation provides the following data for each failure:

- Affected Components
- Failure Mode
- Failure Mechanism
- Effect on the safety-related Tricon Inputs and Outputs
- Effect on operability of the safety-related Main and Primary Remote RXM Chassis

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Table 3 - Failure Modes and Effects Analysis for Tricon V10.2 TMR Programmable Logic Controller – Cable and Non-Safety Remote RXM Module and Chassis Failures

Affected Components	Failure Mode	Failure Mechanism	Effect on PLC Inputs and Outputs	Effect on PLC Operability
NON-SAFETY REMOTE RXM MODULE-RELATED FAILURES				
1) Model 4201-3; Non-Safety Remote Extender Module (RXM), Multimode Fiber Optics (set of 3 modules)	Loss of all three non-safety RXM modules	Fire; flood; missiles; Software common mode failure	Input signals in affected non-safety RXM chassis will not be read. Non-safety analog and digital outputs fail low.	Safety-Related Main and Primary RXM Chassis continue to operate, with loss of non-safety I/O function in the failed non-safety Remote RXM chassis as noted and all downstream non-safety chassis assemblies. Safety-Related 3008N MP diagnostics will detect and flag non-safety Remote RXM communications fault.
2) Model 4201-3; Non-Safety Remote Extender Module (RXM), Multimode Fiber Optics (set of 3 modules)	Loss of one or two non-safety RXM modules	Electronics or software failure	None	Safety-Related Main and Primary RXM Chassis continue to operate via intact non-safety Remote RXM module(s). Safety-Related 3008N MP diagnostics will detect and flag non-safety Remote RXM module fault.
NON-SAFETY REMOTE RXM CHASSIS POWER SUPPLY-RELATED FAILURES				
1) Non-Safety RXM Chassis power supply: Model 8310 – 120Vac/Vdc Model 8311 – 24Vdc Model 8312 – 230Vac	Loss of one non-safety power supply output	Electronic component or fuse failure	None	Safety-Related Main and Primary RXM Chassis continue operation. Non-Safety Remote RXM Chassis continues to operate via the redundant non-safety Remote RXM Chassis power supply. Safety-Related 3008N MP diagnostics will detect and flag board fault on the non-safety Remote RXM Chassis power supply. Fault alarm via safety-related Main Chassis Power Module alarm circuit.

Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis
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Affected Components	Failure Mode	Failure Mechanism	Effect on PLC Inputs and Outputs	Effect on PLC Operability
2) Non-Safety RXM Chassis power supply: Model 8310 – 120Vac/Vdc Model 8311 – 24Vdc Model 8312 – 230Vac	Non-Safety power supply outputs fail (both non-safety power supplies fail)	Electronic component or fuse failure	All outputs fail low on all modules in affected non-safety Remote RXM Chassis.	Safety-Related Main and Primary RXM Chassis continue operation. Safety-Related 3008N MP diagnostics will detect and flag board fault in the non-safety Remote RXM Chassis. Fault alarm via safety-related Main Chassis Power Module alarm circuit.
NON-SAFETY REMOTE RXM CHASSIS-RELATED FAILURES				
1) Non-Safety Remote RXM Chassis power supply rails	Both rails fail open or short to ground	Electrical power transient; fire; flood; missiles	Non-Safety input signals will not be read. Non-Safety analog and digital outputs fail low for shorted rails, and fail low at and past the failure points for open rails.	Safety-Related Main and Primary RXM Chassis continue to operate, with loss of non-safety I/O function in the failed non-safety Remote RXM Chassis as noted and all downstream non-safety chassis assemblies. Safety-Related 3008N MP diagnostics will detect and flag power rail fault in the non-safety Remote RXM Chassis. Fault alarm via safety-related Main Chassis Power Module alarm circuit.
2) Non-Safety Remote RXM Chassis power supply rails	One rail fails open or shorts to ground	Electrical power transient and/or Motherboard insulation failure	None	Safety-Related Main and Primary RXM Chassis continue operation. Non-Safety Remote RXM Chassis continues operation via the redundant non-safety Remote RXM Chassis power supply. Safety-Related 3008N MP diagnostics will detect and flag power rail fault in the non-safety Remote RXM Chassis. Fault alarm via the safety-related Main Chassis Power Module alarm circuit.

Clarification of Safety-Related Primary RXM to Non-Safety-Related Remote RXM Chassis
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Affected Components	Failure Mode	Failure Mechanism	Effect on PLC Inputs and Outputs	Effect on PLC Operability
3) Non-Safety Remote RXM Chassis I/O Bus	All buses open or short to ground	Electrical power transient; fire; flood; missiles	Non-Safety input signals will not be read. Non-Safety analog and digital outputs fail low for shorted rails, and fail low at and past the failure points for open rails.	Safety-Related Main and Primary RXM Chassis continue to operate, with loss of non-safety I/O function in the failed non-safety Remote RXM Chassis as noted and all downstream non-safety chassis assemblies. Safety-Related 3008N MP diagnostics will detect and flag power rail fault in the non-safety Remote RXM Chassis. Fault alarm via safety-related Main Chassis Power Module alarm circuit.
4) Non-Safety Remote RXM Chassis I/O Bus	One or two buses open or short to ground	Electrical power transient and/or motherboard insulation failure	None	Safety-Related Main and Primary RXM Chassis continue to operate via intact I/O bus(es). Safety-Related 3008N MP diagnostics will detect and flag I/O bus fault.
PLC CABLE-RELATED FAILURES				
3) Model 4200-3 to Model 4201-3; Safety-Related Primary RXM to Non-Safety Remote RXM, Multi-mode Fiber Optics (set of 6 fiber optic cables)	Loss of all three RXM transmit or receive cables	Fire; flood; missiles	Input signals in affected non-safety Remote RXM Chassis will not be read. Analog and digital outputs fail low.	Safety-Related Main and Primary RXM Chassis continue to operate, with loss of I/O function in the failed non-safety Remote RXM Chassis as noted. Safety-Related 3008N MP diagnostics will detect and flag non-safety Remote RXM communications fault.
4) Model 4200-3 to Model 4201-3; Safety-Related Primary RXM to Non-Safety Remote RXM, Multi-mode Fiber Optics (set of 6 fiber optic cables)	Loss of one or two RXM transmit or receive cables	Fire or cable cut	None	Safety-Related Main and Primary RXM Chassis continue to operate via intact RXM fiber optic cable(s). Safety-Related 3008N MP diagnostics will detect and flag non-safety Remote RXM communications fault.

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Status of Recommendations for Triconex Action as documented in CDR

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Status of MPR Recommendations for Triconex Action as documented in CDR (Ref: Critical Digital Review 9100164-539)

a, b

Action Item	CDR Page	CDR Section	Description/Text Excerpt	Status O/C*	Action Taken to Satisfy Recommendation	Resolution Reference
1	12, 64, 108	2.2, 4.5.3, Table B-2 (5.3)	recommends that Triconex create a process for accepting and documenting the acceptance methods and criteria used to accept commercial grade software for use in the TCM in particular and the TRICON in general.	C	ARR 793 written to document the condition and track completion of actions. - Process for accepting the SW for TCM is DPE per EDM 76.00. - Generic process for Tricon is development of new EDM procedure.	Ref ARR 793, Action 6484 Ref ARR 793, Action 6483
2	12, 64, 108	2.2, 4.5.3, Table B-2 (5.3)	recommends that Triconex Quality Assurance document the Triconex evaluation of the quality processes.	C	Per ARR 793, a vendor evaluation has been performed on ver.	Ref ARR 793, Action 6481, 6482.
3	12, 64, 108	2.2, 4.5.3, Table B-2 (5.3)	also recommends that Triconex Quality Assurance consider if any additional evaluation is needed to document the acceptance of the other commercial third-party software provided by and embedded in the TCM...	C	ARR 793 evaluated the condition and concluded that are the only SW items of concern.	Ref ARR 793, Action 6420
4	53	3.4.2	(last bullet) It is recommended that Triconex strongly consider enhancing the "Compare to Last Download" function, or adding an additional function, to perform a thorough byte-by-byte comparison of the user application in TriStation with the application that has been downloaded to the TRICON.	C	Additional Guidance for Compare after download incorporated into Application Guide	Ref Topical Report 7286-545-1, Rev 3, App B, section 6.4.C

*) O=Open (unreviewed or unresolved)
C=Closed (Action completed or Captured & tracked by QA program)

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Clarification of Issues Raised in the CDR Regarding the TCM

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Clarification of Tricon V10 IO Bus

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Clarification of Tricon V10 IO Bus
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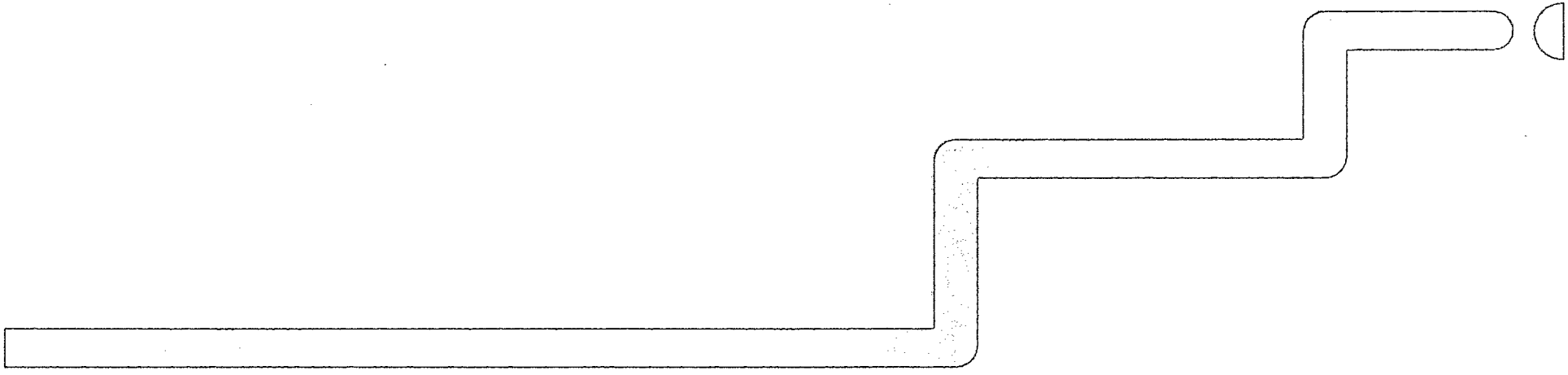
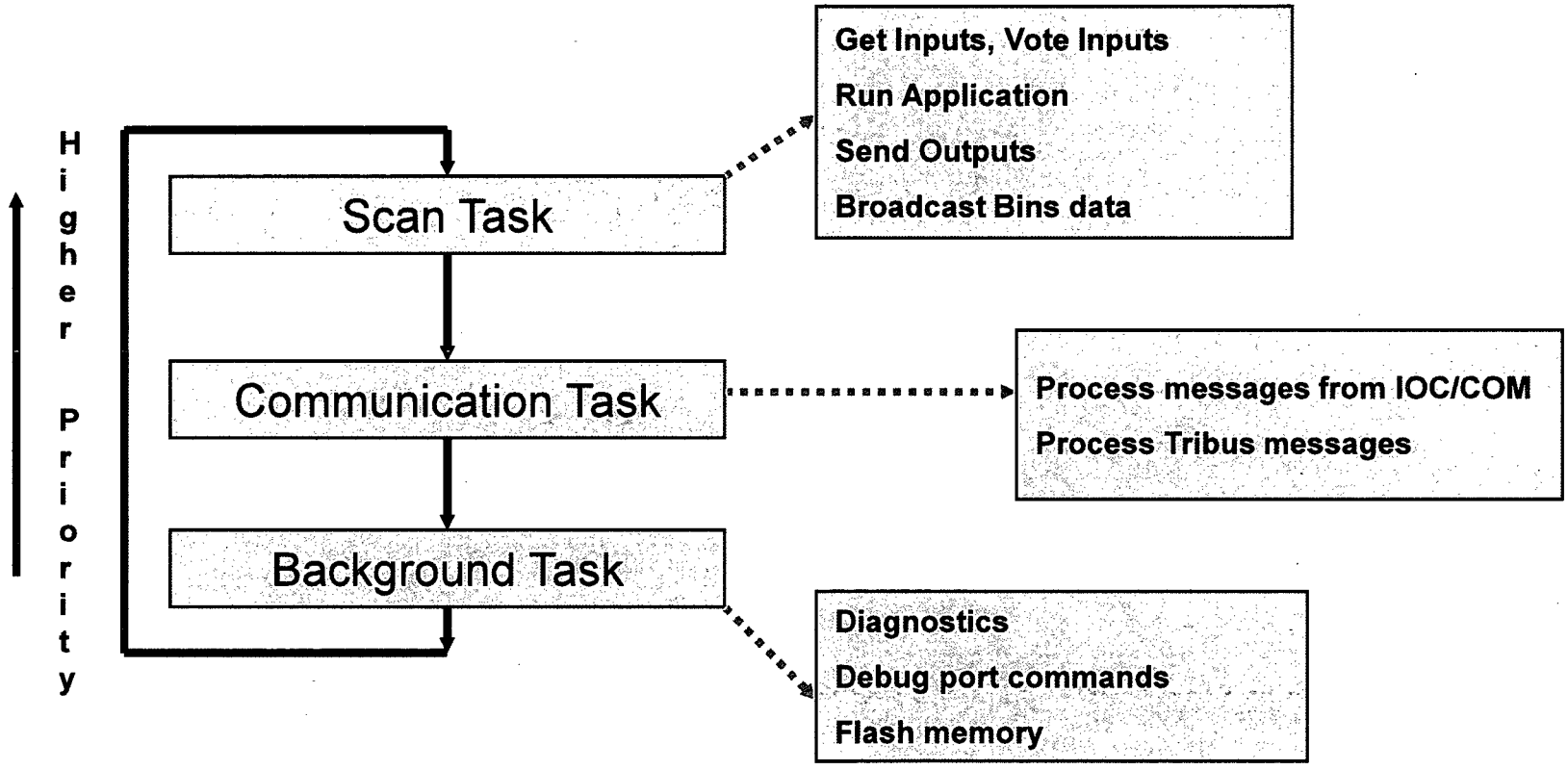
ATTACHMENT – Tricon Scan Timing

Tricon Scan Timing



Scanloop

- Consists of three tasks.



Scan Task

- Get clock calendar
- Get Inputs from IOCCOM via Dual Port RAM (DPRAM)
- Tribus transfer (Inputs, status, page of memory, outputs from last scan)
- Vote Inputs
- Execute Control Program (application)
- Send Outputs (Copy outputs into IOCCOM via DPRAM)
- Communication broadcast (Put bins in DPRAM)
- EOS sync

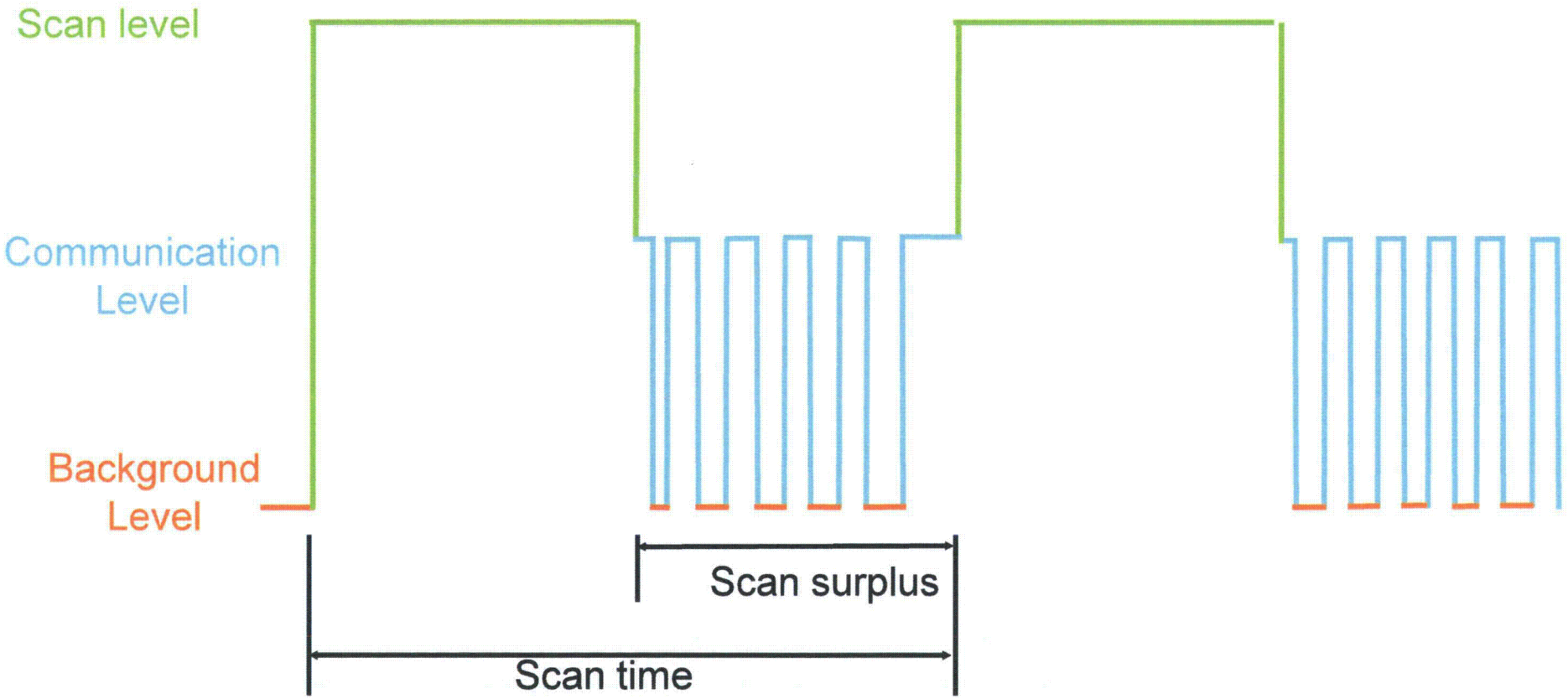
Communication Task

- Process communication messages from IOCCOM and Communication modules. These messages are received by the IOCCOM and put in the Dual Port RAM (DPRAM)
- Process Communication messages from Tribus
- Minimum time allocated ≈ 2.5 milliseconds (5 milliseconds total for this task and background task)
- During scan surplus, the communication task runs every 10 milliseconds

Proprietary – Withhold from Public Disclosure per 10CFR2.390

a, b

Task Scheduling



Proprietary – Withhold from Public Disclosure per 10CFR2.390

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Proprietary – Withhold from Public Disclosure per 10CFR2.390

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Proprietary – Withhold from Public Disclosure per 10CFR2.390

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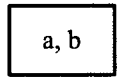

Proprietary – Withhold from Public Disclosure per 10CFR2.390

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Proprietary – Withhold from Public Disclosure per 10CFR2.390

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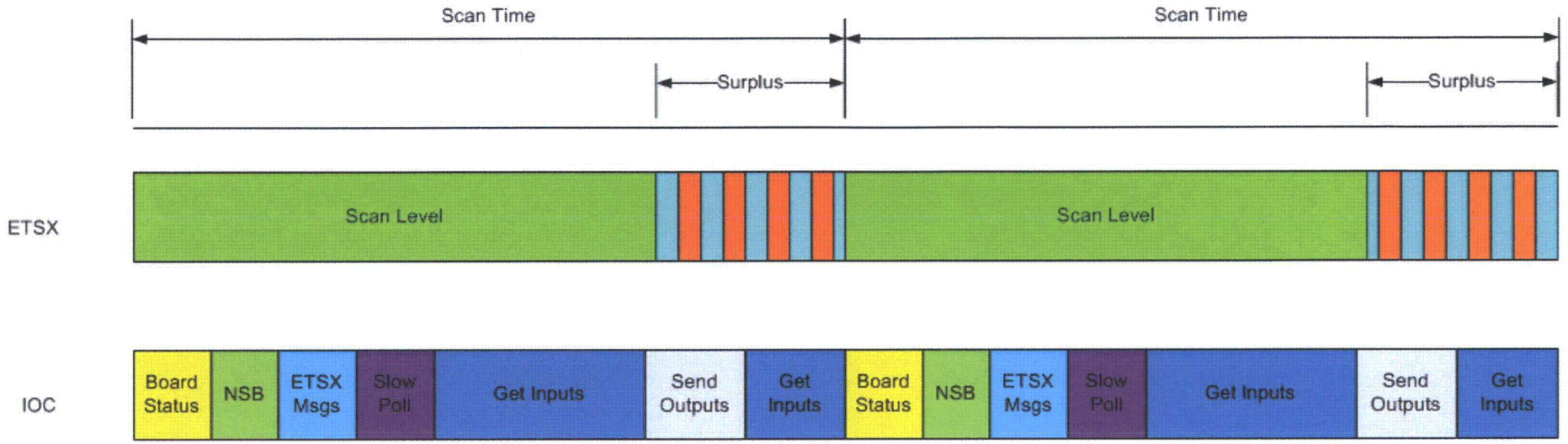
Tricon Scan



Legend

ETSX COM

ETSX Background