PRINCETON
PLASMA PHYSICS
LABORATORY

ENG-064 - ICD - INTERFACE CONTROL DOCUMENT

Centralized Instrumentation & Control - Integrated Machine Operations Interface Control Document

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National Spherical Torus eXperiment Upgrade

National Spherical Torus Experiment Upgrade

Interface Control Document

CENTRALIZED INSTRUMENTATION & CONTROL : INTEGRATED MACHINE OPERATIONS

NSTX-U-CIC-IMO-ICD-0

Revision 0
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Change Record

Revision	Date	Description of Change
0	February 6, 2020	Initial Release

References

[1] GENERAL REQUIREMENTS DOCUMENT, NSTX-U-RQMT-GRD-001-01

[2] SYSTEM REQUIREMENTS DOCUMENT, CENTRAL INSTRUMENTATION AND CONTROL, NSTX-U-RQMT-SRD-009-00

[3] SYSTEM REQUIREMENTS DOCUMENT, Real-time Control and Protection, NSTX-U-RQMT-SRD-008-00

[4] SYSTEM REQUIREMENTS DOCUMENT, Diagnostics, NSTX-U-RQMT-SRD-011-01

[5] NSTX-U Machine Instrumentation, NSTX-U-RQMT-RD-008-03

[6] User's Manual, Plasma Current (Ip) Calculator, AE4547

1. Purpose

This document describes the various interfaces between the following subsystems: Centralized Instrumentation & Control and the Integrated Machine Operations. The interface locations and boundaries that connect the Centralized Instrumentation & Control to the Integrated Machine Operations are identified based on different interface types.

2. Scope

The Central Instrumentation and Control consists of Control I/O, Plant Control and Monitoring, Timing and Synchronization System, Data I/O systems, and Data Archiving Systems. The Integrated Machine Operations consists of the Machine Instrumentation, Digital Coil Protection System, Shorted Turn Protection, and the Ip Calculator. The scope of this document addresses any defined interfaces between these identified system elements.

3. Responsibilities

The interfaces are managed between the following organizations:

- Centralized Instrumentation & Control
- Real Time Control & Protection
- Diagnostics
- Systems Engineering and Integration

4. Interfaces

Interface requirements in the following sections are identified with a requirement number, ICD followed by a number [ICD-CIC-IMO-X] where X is a sequential count beginning with 001, CIC represents Centralized Instrumentation & Control and IMO represents Integrated Machine Operations. There is also a unique identifier for all interfaces in the format [#####-#####-X]. The identifier is a concatenation of two level 5 WBS values and the interface type. This is followed by an interface description and a list of references. References provide evidence pertaining to interfaces include but are not limited to drawings, calculations, or specifications. Reference also includes a reference to a paragraph that identifies the set of interface definitions.

4.1. Interface Types

The top-level interface types are defined in Table 1. Within each heading there are sub-headings to address any special sub-elements that need consideration. For example, the Mechanical has four sub-elements that need to be addressed: Structural, Spatial, Location, and Wall/Floor Penetration. For those interface types with sub-interfaces there are corresponding sub-sections.

Table 1. Interface Types

Heading	Abbreviation	Name
4.2	Me	Mechanical
4.3	Ep	Electrical Power
4.4	Si	Signal
4.5	Di	Diagnostics
4.6	Gf	Gas/Fluid
4.7	Va	Vacuum
4.8	Sw	Software
4.9	Th	Thermal
4.10	Pe	Plasma/Eddy/Halo Current

Table 2 provides the N2 Diagram identifying all the interfaces for NSTX-U while Table 3 provides the specific details of the interface.

Table 2. N2 Diagram Interface types

Plasma Facing Components	Me,Th, Pe		Me,Th, Va,Pe						Me	Me	Me, Pe		Me			
	In-Vessel Structures	Me,Di, Pe			Th			Me,Th, Pe	Me		Me, Pe			Di		
		Vacuum Vessel Structure			Me,Va	Me, Va	Me	Me, Th, Pe	Me	Me,Va	Me,Di, Va		Si	Di, Me		
		Va	Centerstack Structures			Va, Th	Me, Gf	Me	Me					Di		
		Me	Me, Th, Ep	Magnets				Me			Di		SI	Di	Me	
Si		Me, Va			Heating Systems		Gf	Th		Me		Si	Si	Si	Si, Me, Di	
					Si, Va, Me, Sw, Gf	Vacuum Pumping System		Si	Si	Si	Si		Si,Va	Si	Si	
				Gf,Si			Coolant System	Gf				Gf,Sw	Si, Sw	Si	Si	
	Th, Gf	Ep,Di, Th, Va	Ep, Gf, Th, Pe		Si		Si	Bakeout System							Si, Me	
			Gf,Va			Me, Gf,Si			Gas Delivery System	Gf	Va		Si,Sw	Si	Si, Me	
		Gf				Si,Gf,Va			Me	Wall Conditioning System			Si,Sw		Me	
		Me,Va	Me,Va	Me	Me	Gf,Si	Gf			Va, Ep	Diagnostics		Si,Sw	Si	Si, Me	Si
				Ep	Ep	Ep	Ep	Ep	Ep	Ep	Ep	Power Systems	Ep,Si	Ep, Si	Si, Me,Di, Ep	Ep
					Si					Me, Si	Si		Centralized Instrumentation and Control	Si, Me		
												Si	Si,Sw	Integrated Machine Operations		
								Ep							Operations & Safety Systems	
Me		Me	Me	Me	Me	Me		Me	Me	Me	Me	Me	Me	Me	Me, Ep	D-Site Locations (Test Cell

Table 3. Callout

Centralized Instrumentation and Control	Si, Me
Si, Sw	Integrated Machine Operations

The remainder of this document addresses each of the interfaces. Note the template includes a paragraph heading for each interface and a table for each interface type. In the event there is no interface, the table will remain blank with a blank row.

The following paragraphs in Section 4 address each of the interfaces, and Section 5 addresses any off-project interfaces. Off-project interfaces are those external interfaces that interact with the NSTX-U system.

4.2. Mechanical Interfaces

This paragraph addresses any type of mechanical interfaces that include a structural, spatial, location dependent interfaces or areas where penetrations into a wall or floor are required. These are identified independently as interface parameters will likely be different.

4.2.1. Structural Interfaces

This identifies any interfaces between system elements that require a structural interface. This could be based on various forces placed on the system and by the system.

Identifier	Interface	References
N/A		]

4.2.2. Spatial Interface

This identifies any interfaces between the system elements pertaining to spatial restrictions or constraints.

Identifier	Interface	References
1.6.1.4-1.7.3-Sp	Installed in control Room racks with correct spacing using Unit Measure standards	See Paragraph 4.2.2.1, Drawing AE1072

4.2.2.1. Rack – Unit Measure Standards

Interface Notes:

- Interface was verified by on-site walkthrough. Standard Equipment width with U's.
- Each rack has an identified ground category.
- There are shared physical spaces between CI&C and IMO in the Diagnostic Room (DARM), Gas Injection System (GIS) racks, Class3 &4 Racks in the NSTX-U Test Cell, 138' Neutral Beam area and FCPC Junction Area. These spaces all use Standard Units as defined in ICD-CIC-IMO-001.

ICD-CIC-IMO-001: The IMO components, e.g., computers are placed in rack locations as identified in Drawing AE1072 for the FCC. These are standard commercial racks that allow standard equipment to include computers to be mounted and installed in place. Equipment in these racks are marked and are measured in the industry standard of “U“s where 1U equals 1.75-inches.

ICD-CIC-IMO-002: The IMO components, e.g., computers are placed in rack locations as identified in Figure 1 in the DARM. These are standard commercial racks that allow computers to be mounted and installed in place. Also, note that there are insulators between the racks.

Figure 1. Existing Racks in the DARM

4.2.3. Location Interfaces

This identifies any interfaces between the system elements that have any particular dependencies on element location or location constraints.

Identifier	Interface	References
N/A		

4.2.4. Wall/Floor Penetration Interfaces

This identifies any interfaces between the system elements any penetrations or modifications to the wall or floor of the D-Site building.

Identifier	Interface	References
N/A		

4.3. Electrical Power Interfaces

This identifies any interfaces between the system elements requiring AC, DC, rectification or power conditioning.

Identifier	Interface	References
N/A		

4.4. Signal Interfaces

This identifies any interfaces between the system elements and signals that are used to either send or receive control information or data. It explicitly includes the type of physical interface such as Ethernet or Fiber Optic or any specific protocols.

Identifier	Interface	References

1.6.2.1-1.7.3.4.1-Si	Some **Data I/O signals** from the instrumentation, e.g., Fiber Optic Strain, Temperature, and Displacement Measurements system will have their signals digitized	See Paragraph 4.4.1, Drawing AE1117
1.6.1.1-1.7.3.6.5-Si	Control I/O system used to provide **DCPS** I/O functionality from Plant Control and Monitoring (EPICS) via the Hardware Interface	See Paragraph 4.4.2, AE4005, AE4572
1.6.1.3-1.7.3-Si	**Timing & Sync Signals** to I**ntegrated Machine Operations**	See Paragraph 4.4.3,
1.7.3.6.5-1.6.1.1-Si	**Pulse Timing** of the **Digitizer (SAD)** in Junction Area	See Paragraph 4.4.4,
1.7.3.6.5-1.6.1.3-Si	**Sampling clock** & Clock events for digitizers at digital input to **DCPS. DCPS fault and watchdog timer output digitized by CI&C Plant Control and Monitoring DAQ system.**	See Paragraph 4.4.5, AE4557, AE4005 SHT. 51
1.7.3.6.9-1.6.1.1-Si	The data from the **Shorted Turn Protection** system are archived in **MDSplus** following the discharge. STP als received timing signals from the CI&C central clock and timing system. STP **fault and watchdog timer output digitized by CI&C Plant Control and Monitoring DAQ system.**	See Paragraph 4.4.6, AE1002
1.7.3.6.8-1.6.1.3-Si	**Pulse events** (Start, T0, End) At connector on **Ip Calculator** Chassis	See Paragraph 4.4.7, AE4036
1.7.3.6.8-1.6.1.1-Si	Data from **Ip Calculator** is digitized for archival in MDSplus	See Paragraph 4.4.8, AE4036, AE1002
1.7.3.5.1-1.6.1.3-Si	**PDP Timer** receives **trigger pulse**	See Paragraph 4.4.9, 4FD086
1.7.3.4.1-1.6.1.3-Si	**Timing markers and triggers** delivered to **instrumentation**, e.g., Fiber Optic Strain, Temperature, and Displacement Measurements systems	See Paragraph 4.4.10, DC1920

1.7.3.4.5-1.6.2.2.1-Si	The **TF twist instrumentation** sends data to the **MDSplus servers** via the Ethernet	See Paragraph 4.4.11, 4BA137, 4BA138, AE1002
1.6.1.1-1.7.3.4.5-Si	Connection to cameras used for camera control and data acquisition	See Paragraph 4.4.12

4.4.1. Data I/O - F/O Strain Sensor

Interface Notes:

- Rack in Test Cell provides a fiber optic converter to send data over the network.

ICD-CIC-IMO-003: The signals are sent over Fiber Optic connections between the sensor components in the test cell via a fiber optic patch panel FOPP that resides in Rack CTC-EE-495 to equipment in the DARM rack CDAR-EE-724 as Shown in Figure 1. Drawing AE1117 contains the components of that rack. There is hardware: CDAQ, Timing Modules, and servers that are used to process the data included in this rack.

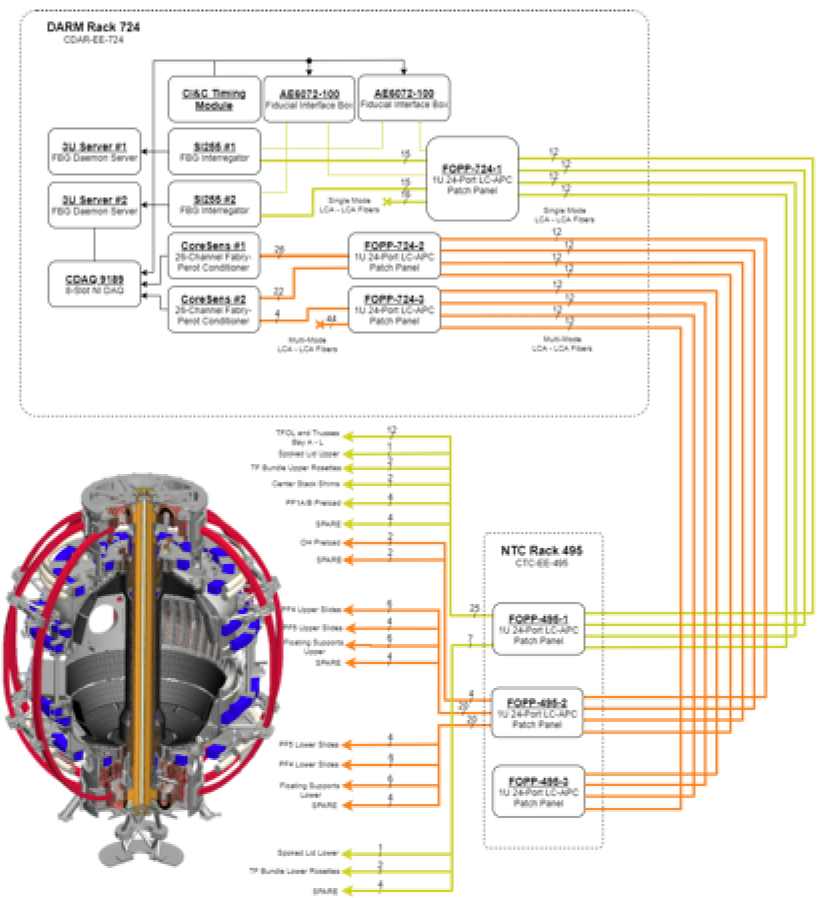

Figure 1. Cable Fiber Optic run

ICD-CIC-IMO-004: The Fiber Bragg Grating system will provide, from its interrogator laser systems, peak measurement values streamed over Ethernet to I&C servers which will archive to the MDSplus system and provide data to be monitored by the EPICS system.

4.4.2. Data I/O - DCPS I/O

ICD-CIC-IMO-005: DCPS control signals are routed from the DCPS Auto-Tester computer to the DCPS side panel and signals are routed from the DCPS Real-Time Computer in the Junction area as shown in drawing AE4005 SHT. 51. The interface is between the Control I/O system and Digitizer (dtacq). The data is sent to EPICs as shown in the center of Figure 2 from the data connections.

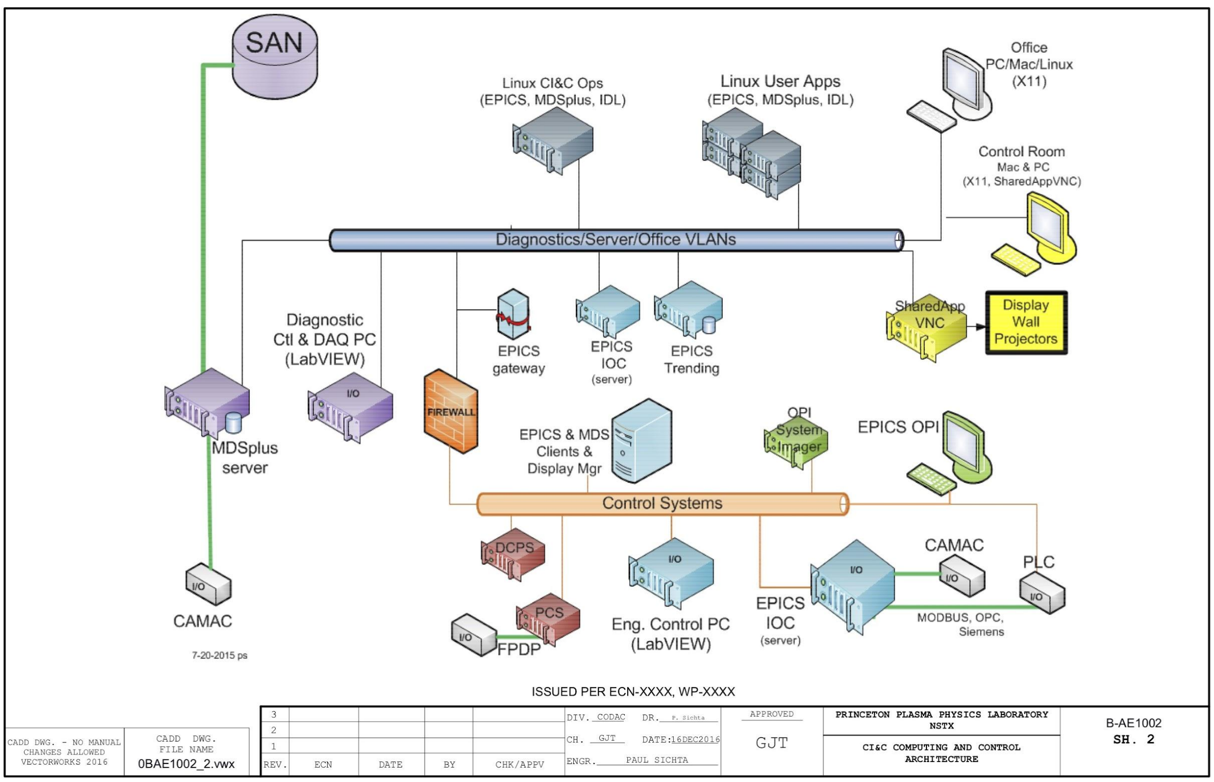

Figure 2. CI&C Computing and Control Architecture

ICD-CIC-IMO-006: DCPS control signals are routed from the DCPS Auto-Tester computer to the DCPS side panel and signals are routed from the DCPS Real-Time Computer in the FCC via a CAMAC H313 U-Port as shown in drawing AE4572 SHT. 1. The data is sent to EPICs as shown in the center of Figure 2 from the data connections.

ICD-CIC-IMO-007: The interface between EPICS in FCC with real-time computer(s) (PCS-RT3, PCS-RT4, Warthog over Ethernet)

ICD-CIC-IMO-007: Signals are routed using 3-Pin LEMO connectors as shown in drawing AE4005 SHT. 51.

4.4.3. Data I/O - Integrated Machine Operations

ICD-CIC-IMO-008: Timing signals are provided as a 1MHz Clock Signal, the Real TIme Control & protection IMO systems provide their own clocking signal of 5Khz. The clocks are synchronized via counts and timestamps to ensure that the various system clocks remain.

ICD-CIC-IMO-009: The timing signals are provided by RCIM and Facility Clock. In the FCC, the interface is between clock and FPDP in FCC VME Crate.

4.4.4. Data I/O - Digitizer (SAD)

ICD-CIC-IMO-010: The connections to the SAD occur via the RCIM Interface, and the DCPS expansion Chassis as shown in Drawing AE4572 SH. 108

4.4.5. Data I/O - DCPS Sampling Clock

ICD-CIC-IMO-011: Timing signals are provided as a 1MHz Clock Signal, the Real TIme Control & protection IMO systems provide their own clocking signal of 5Khz. The clocks are synchronized via counts and timestamps to ensure that the various system clocks remain.

ICD-CIC-IMO-012: The timing signals are provided by RCIM and Facility Clock. In the FCC, the interface is between clock and FPDP in FCC VME Crate.

4.4.6. Shorted Turn - MDS Plus

ICD-CIC-IMO-013: The DCPS Autotester sends data over the FPDP network for use by the STP system, which in turn archives both the current and voltage measurements obtained by data tables. These tables are used to prove the function of the STP. The current & voltage data is written to the appropriate STP tree in all occurrences, (Test, Ops, Dev & Auto configurations)) for both synchronous and asynchronous modes. The MDS Plus system architecture is provided as Figure 4.

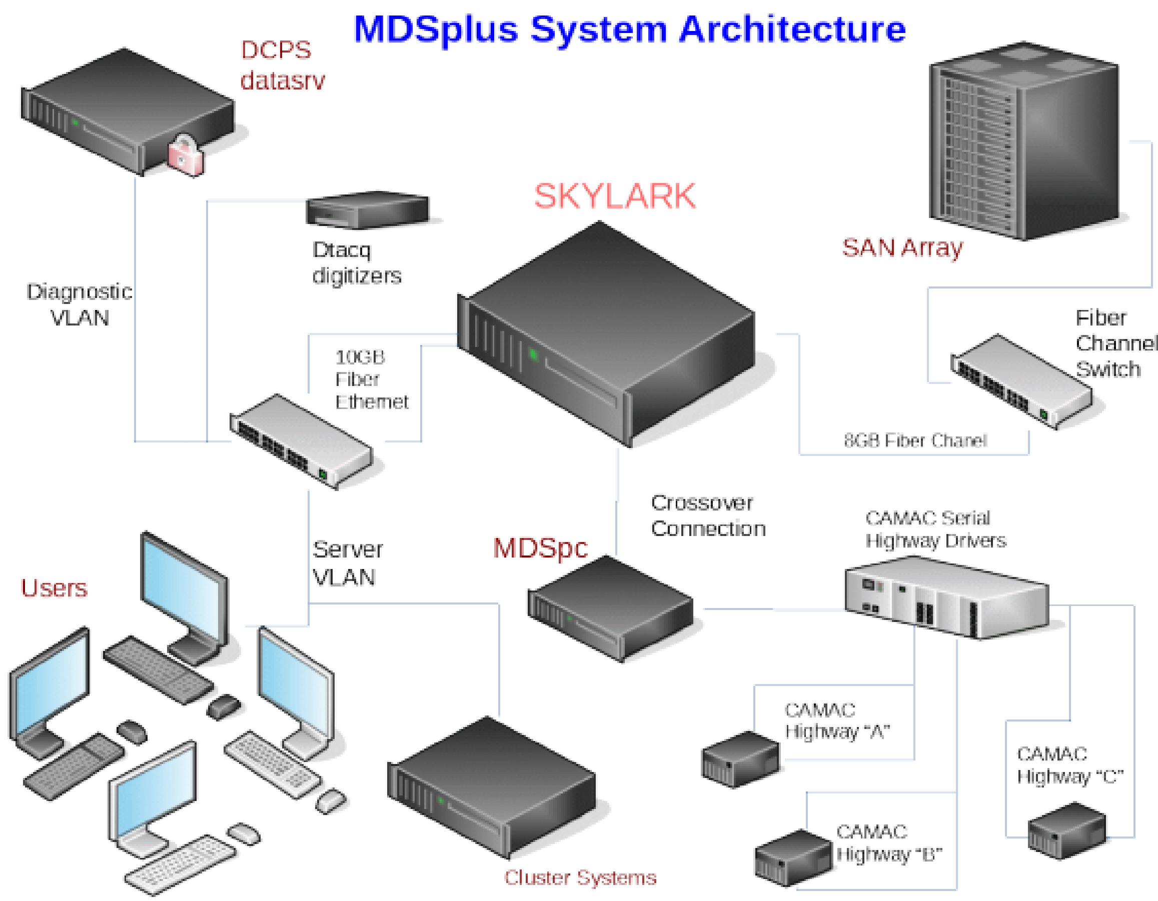

Figure 4. MDSplus Systems Architecture

4.4.7. Data I/O - Ip Calculator

ICD-CIC-IMO-014: IP Calculator Timing pulse are identified in Section 1.5 of Ref 6.

ICD-CIC-IMO-015: The IP Calculator uses a 3-Pin LEMO connector.

4.4.8. MDSPlus - Ip Calculator Digitized

ICD-CIC-IMO-016: The data I/O sends data over the network for access to the MDSplus server as contained in Drawing AE1002 Sheet 2 as shown on the left side of Figure 2 and Figure 4.

4.4.9. Data I/O - PDP Timer

ICD-CIC-IMO-017: The PDP Timer receives a trigger from 404A to the P/O connector P1- C as shown in drawing 4FD086.

ICD-CIC-IMO-018: A 1uS square wave pulse is used as the trigger as shown in drawing 4FD086.

ICD-CIC-IMO-019: A coaxial connector is used for the 404A pulse signal as shown in drawing 4FD086.

4.4.10. Markers and Timers - Strain Gauges

ICD-CIC-IMO-020: The reconfigurable timing uni) (RTU) is used to generate a timing signal for the strain gauges. In addition, there are two Piezo Buzzer Triggers. While the triggers do not necessarily provide timing input. Rather, to align data and provide a trigger to the data acquisition Daemon a single FBG strain sensor is attached to a Piezo buzzer which is driven by an RTU synchronized to the NSTX-U facility clock.

4.4.11. MDSplus - TF Twist Gauges

ICD-CIC-IMO-021: The data I/O send data over the network for access to the MDSplus server as contained in Drawing AE1002 Sheet 2 as shown on the left side of Figure 2 and Figure 4.

4.4.12. Data I/O - TF Twist Camera

ICD-CIC-IMO-022: The data from the Camera will be sent to the Data I/O system and captured. This will be accomplished by sending data over I/O ports using a standard camera format such as MP-4. The data will be processed using labview to create a point. This data will be sent to MDSplus.

4.5. Diagnostic Interfaces

This identifies any interfaces between the system elements with any instrumentation or diagnostic equipment to collect performance data.

Identifier	Interface	References
N/A		

4.6. Gas/Fluid Interfaces

This paragraph has two different types of interfaces: Gas and Fluid.

4.6.1. Gas Interfaces

This identifies any interfaces between the system elements that use any type of gas (e.g., He).

Identifier	Interface	References
N/A		

4.6.2. Fluid Interfaces

This identifies any interfaces between the system elements that use any type of fluid (e.g., ionized water).

Identifier	Interface	References
N/A		

4.7. Vacuum Interfaces

This identifies any interfaces between the system elements that pertain to the Vacuum.

Identifier	Interface	References
N/A		

4.8. Software Interfaces

This identifies any interfaces between the system elements that use software that may exchange interfaces with other software components. This includes application programming interfaces (APIs) or any other exchange of information between different software applications.

Identifier	Interface	References
1.7.3.4.1-1.6.2.2-Sw	Some element of the **instrumentation**, e.g., e.g., Fiber Optic Strain, Temperature, and Displacement Measurements system will directly input **data** to MDSplus	See Paragraph 4.8.1
1.7.3.6.6-1.6.2.2-Sw	**DCPS Software** Outputs: **Archived data**, including data that is used for shot restores, is archived in the MDSplus database	See Paragraph 4.8.2
1.7.3.6.9-1.6.2.2-Sw	Data is **archived** to MDSplus by the **shorted turn system**	See Paragraph 4.8.3
1.7.3.6.4-1.6.2.2-Sw	Data from the DCPS Autotester is directly archived in MDSplus	See Paragraph 4.8.4

4.8.1. Instrumentation – Data archive

ICD-CIC-IMO-023: The Fiber Bragg Grating sensors and temperature are configured by an application called Enlight. This provides the proper configuration data for both the strain sensors as well as the temperature sensors.

ICD-CIC-IMO-024: The MDSplus uses message serialization and deserialization to write to the MDS plus tree. The MDSplus provide their own APIs. The FPGs are stored under the Raw data branch of the MDSplus tree as shown in Figure 5. The sensors are defined under the FBG_Config, FBGSignals Branches. Trending data is stored under Eng_Trend.

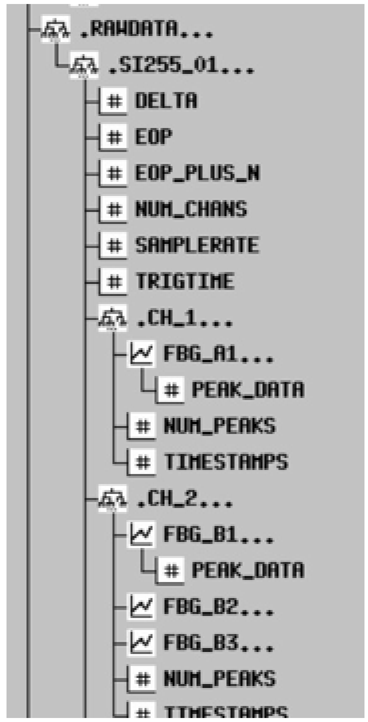

Figure 5. Sample Fiber Bragg Grating Sensor data

ICD-CIC-IMO-025: The Fabry-Perot sensors will voltage data will be read by Labview and stored as raw voltages. Calculations are performed within MDSplus.

4.8.2. DCPS - Parameter Input, Data Archive & Event Signaling

ICD-CIC-IMO-026: The MDSplus uses message serialization and deserialization to write to the MDS plus tree. The MDSplus provide their own APIs. (there is a template class in the SW that allows an event and data interface. The MDSplus provide their own APIs. DCPS interfaces with the MDSplus servers to await SW based event signals to coordinate actions with other operational and visualization tasks.

ICD-CIC-IMO-027: The MDSplus data is archived to a SAN as shown in the top-left hand side of Figure 2. To enable speed of processing the SAN network uses the Fibre Channel communication standard.

4.8.3. Shorted Turn Protection Systems –Parameter input & Data Archive

IICD-CIC-IMO-028: The MDSplus uses message serialization and deserialization to write to the MDS plus tree. The format of the tree is provided in Figure 6. The MDSplus provide their own APIs. There is a template class in the SW that allows an event and data interface.

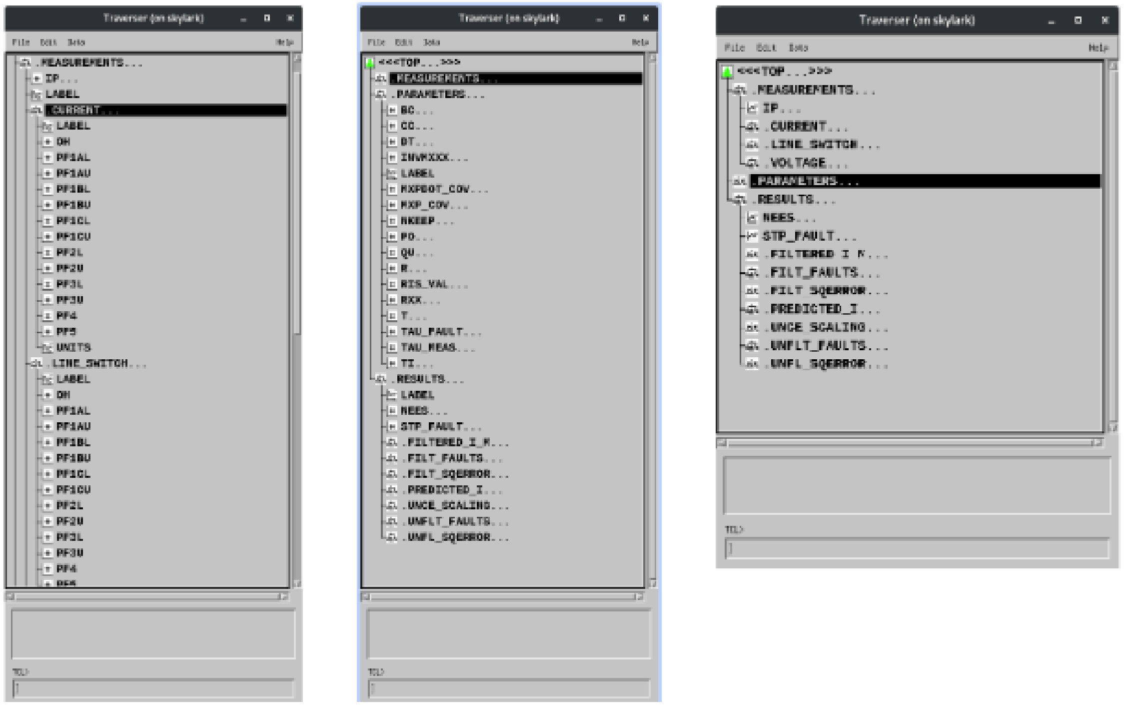

Figure 6. STP MDSplus Structure

4.8.4. DCPS Autotester- Data Archival & Event signaling

ICD-CIC-IMO-029: The MDSplus uses message serialization and deserialization to write to the MDS plus trees (DCPS_ Auto, DCPS_Test, DCPS_Dev, DCPS_Ops). The MDSplus provide their own APIs. DCPS interfaces with the MDSplus serverssrevers to await SW based event signals to coordinate actions with other operational and visualization tasks.

4.9. Thermal Interfaces

This identifies any interfaces between the system elements that pertain to Thermal characteristics.

Identifier	Interface	References
N/A		

4.10. Plasma Interfaces

This paragraph has two different types of interfaces: Plasma and Eddie/Halo Current.

4.10.1. Plasma Interfaces

This identifies any interfaces between the system elements with the Plasma.

Identifier	Interface	References
N/A		

4.10.2. Eddy/Halo Current Interfaces

This identifies any interfaces between the system elements with the Eddie/Halo Currents.

Identifier	Interface	References
N/A		

5. Off-Project Interfaces

The off-project interfaces are components that are not specifically part of the NSTX-U system. They may include external systems and interfaces where the program has little control on part of the interface. They are provided for completeness.

There are no external interfaces.