NSTX-U Interface Control Plan

NSTX-U-PLAN-038-00
6/11/2019

Peter Dugan Digitally signed by Peter Dugan
Date: 2019.06.14 12:14:24
-04'00'

Prepared By: P. Dugan

Stefan Gerhardt Digitally signed by Stefan Gerhardt
DN: cn=Stefan Gerhardt, o=Physics, ou=PPPL, email=sgerhard@pppl.gov, c=US
Date: 2019.06.14 12:32:01 -04'00'

Reviewed By: S. Gerhardt, Systems Integration

Yuhu Zhai Digitally signed by Yuhu Zhai
Date: 2019.06.14 13:27:38
-04'00'

Reviewed By: Y. Zhai, Project Engineer

Richard J. Hawryluk Digitally signed by Richard J. Hawryluk
Date: 2019.06.14 14:48:08 -05'00'

Approved by: R. Hawryluk, NSTX-U Project Director

Record of Revisions

Date	Version	Brief Description of Changes
6/11/19	Rev 0	Initial Release

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References

[1] NSTX-U-RQMT-GRD-001, NSTX-U General Requirements Document
[2] NSTX-U-RQMT-SRD-002, NSTX-U SRD - Magnets
[3] NSTX-U-RQMT-SRD-003, NSTX-U SRD - Plasma Facing Components
[4] NSTX-U-RQMT-SRD-004, NSTX-U SRD - Vacuum Vessel and Internal Hardware
[5] NSTX-U-RQMT-SRD-005, NSTX-U SRD – Auxiliary Systems
[6] NSTX-U-RQMT-SRD-006, NSTX-U SRD – Power Systems
[7] NSTX-U-RQMT-SRD-007, NSTX-U SRD – Heating Systems
[8] NSTX-U-RQMT-SRD-008, NSTX-U SRD –Real-Time Control and Protection
[9] NSTX-U-RQMT-SRD-009, NSTX-U SRD – Central Instrumentation and Control
[10] NSTX-U-RQMT-SRD-010, NSTX-U SRD – Test Cell
[11] NSTX-U-RQMT-SRD-011, NSTX-U SRD – Diagnostics
[12] NSTX-U-RQMT-SRD-012, NSTX-U SRD – Operations and Safety Systems
[13] ENG-064 "Interface Control"

1. Introduction

Interface Control is one of the critical components of systems integration. It identifies areas where different organizations collaborate to ensure that designs meet general high-level system requirements.

An interface from the standpoint of system development is defined as a boundary between major subsystems, system elements, and/or organizations responsible for executing system elements. The interface point is the physical or logical connection that occurs between these boundaries.

The NSTX-U is developed by executing designs of systems and subsystems as defined in the System Breakdown Structure (SBS). The SBS provides at least five levels of functional decomposition. In addition, an Organizational Breakdown Structure (OBS) defines the organizational structure of the program. The OBS consists of Responsible Engineers (REs). Cognizant Individuals are included in many cases when a single RE is responsible for multiple interfaces. These SBS elements when integrated, assembled, verified, and validated form the NSTX-U system.

Note: The methods described in this document are consistent with PPPL procedure ENG-064 *Interface Control*.

2. Scope

The scope of this plan is to:

- Establish and document the interface methods and attributes at the summary level in System Requirements Documents
- Define a process for establishing the technical agreements through interface control documents (ICDs) between Responsible Engineers to document the functional and physical characteristics required to implement the interface.

3. Interface Management - the GRD, Interface Sheet, and SRDs

The NSTX-U system uses several tiers of requirements documents, i.e., General Requirements Documents (GRD), Systems Requirements Documents (SRD), and Requirements Documents (RD) in compliance with ENG-50 Job Requirements Documentation & Control. The GRD states that interfaces be addressed and follow a specific format developed including the fields identified below for interface identification in the SRDs as shown in Table 1.

The SRDs provide detailed requirements for the subsystems and system components. The SRDs includes requirements for various system elements included in the SBS. As a result, interface summary tables are included for each system element.

Table 1: *SRD interface table format as specified in the GRD*

Interfacing SBS	Interfacing System	Type of Interface	Interface Boundary	Interface Description	Required Interface Documentation
(the SBS # of the interfacing system)	(describe the system to which the interface is made)	(see table below)	(Precise description of the physical interface between systems)	(numerical values if possible or reference to the source of values)	(Types of documents that must be produced)

Within the summary table, “Interfacing SBS” is the interfacing system SBS #, while “Interfacing System” is the system element that require interfacing. “Type of Interface” is the interface type (see Table 2). The “Interface Boundary” and “Interface Description” provide the details of the interface. Lastly, the “Required Interface Documentation” is required to determine how the interface will be documented, e.g., drawings, calculations, or design models.

The Requirements Documents (RD) identify very specific requirements depending on the purpose of the RD. As such, interfaces may or may not be identified. For example, RD Inner-PF Coil Interfaces to Coil Support Designs and Cooling Systems, NSTX-U-RQMT-RD-012-00 focus completely on interface requirements including vertical loads, side loads, preloads, thermal loads, and flow.

As a common source of information for interface information for the SRDs and ICD, all interfaces are managed in a single interface sheet called the NSTXU_SBS+OBS+Interfaces. This spreadsheet provides the SBS, OBSs, interface type, interface boundary, and interface description. Use of this table ensures that each interface is described the same way in each of the two SRDs where it appears. There are currently over 1,000 interfaces identified in the Interface Sheet.

The enumerated interface types specified in the GRD and used in the Interface Sheets and SRDs are as shown in Table 2.

***Table 2**: Interface type enumerated type as specified in the GRD*

Structural	Vacuum
Spatial	Eddy/Halo Current
Location	Gas
Wall/Floor Penetration	Fluid
Electrical Signal	Diagnostic
Ethernet	Thermal
Fiber Optic	Electrical Power
Software	Plasma

In order to quickly view and manage interfaces, a physical and functional interface diagram is developed sometimes; this is referred to as an N^2 diagram. The physical and functional interface diagram provides a brief overview of the system at a glance as shown in Figure 1. It allows one to see a summary of all the interfaces in a single view. Note that the matrix is not symmetric about the main diagonal; the interfaces are organized in a clockwise fashion so that the system in the row provides input to the system in the column [13].

Plasma Facing Components	Me,Th, Pe		Me,Th, Va,Pe						Me	Me	Me, Pe		Me			
	In-Vessel Structure	Me,Di, Pe			Th			Me,Th, Pe	Me		Me, Di, Pe			Di		
		Vacuum Vessel Structure			Me,Va	Me, Va	Me	Me, Th, Pe	Me	Me,Va	Me,Di, Va		Si	Di,Si		
		Va	Centerstack Structure			Va, Th	Me, Gf	Me	Me	Me				Di		
		Me	Me, Th, Ep	Magnets				Me			Di		SI	Di		
Si		Me, Va			Heating Systems		Gf	Th		Me		Gf, Si	Si	Si	Si	
					Si, Va, Me, Sw, Gf	Vacuum Pumping System		Si	Si	Gf, Si	Si		Si,Va	Si	Si	
				Gf,Si			Coolant System	Gf				Gf,Sw	Si, Sw	Si		
	Th, Gf	Ep,Di, Th, Va	Ep, Gf, Th, Pe		Si		Si	Bakeout System						Me	Si, Me	
			Gf,Va	Gf,Va	Ep	Gf,Si			Gas Delivery System	Me	Va		Si,Sw	Si	Si	
		Gf	Si			Si,Gf,Va			Gf	Wall Conditioning System			Si,Sw	Si	Si	
		Me,Va	Me,Va	Me	Me	Gf,Si	Gf			Va, Ep	Diagnostics		Si,Sw	Si	Si	Si
				Ep	Ep	Ep	Ep	Ep	Ep	Ep	Ep	Power Systems	Si	Ep, Si	Ep, Si, Di, Gf	Ep
					Si					Me, Si	Si		Centralized Instrumentation and Control	Si, Me		
										Sw		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

***Figure 1:** Physical and logical interface diagram (N^2 diagram). See Table 4 for an explanation of the definitions*

The "N" in an N2 diagram is the number of subsystems for which interfaces are identified. The N^2 diagram is developed where the row is the output and the column is the input. The method for population of the table is flexible and is not required to be symmetric. For example Figure 2 shows a mechanical interface for the Outboard Divertor (OBD), part of the In-Vessel Structure and the Plasma Facing Components. In this case, there are multiple mechanical loads between the two interfaces. However, only one interface needs to be selected. In this case, the PFC to In-Vessel Structure was selected as the all loads will be considered in calculations and the design.

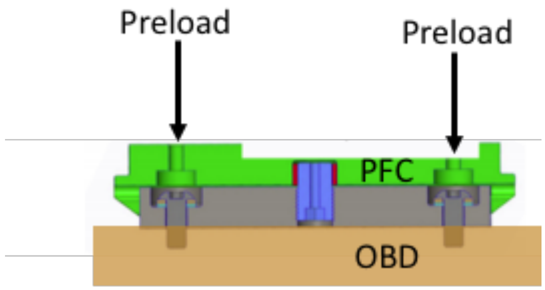

***Figure 2**. PFC to OBD Interface*

In order to make the physical and functional diagram manageable, the N2 diagram starts with level-3 of the SBS and adjusts to provide a single view of the NSTX-U. The interfaces start on the top left with the Plasma Facing Components and works out until all major elements are addressed and ends with test cell components generally the facility and egress cable trays. Table 3 provides a mapping of each subsystem to the SBS; the full SBS mapping is available on the engineering web-site. Notice how the SBS is provided from Level 2 to Level 5 in this table; decomposition below this level is used for QA purposes but is not considered in the interface program.

***Table 3**. SBS mapping used labeling all components on NSTX-U*

Subsystem	SBS#
Plasma Facing Components	1.1.1.1
In Vessel Structures (OBD, Passive Plates, NB Armor)	1.1.1.2
Vacuum Vessel Structures	1.1.2
Center Stack Structure	1.1.3.3.6-1.1.3.3.13
Magnets	1.1.3.3.1-1.1.3.3.5, 1.1.3.4, 1.1.3.5
Heating Systems	1.2
Vacuum Pumping System	1.3.2
Coolant System	1.3.2
Bakeout System	1.3.3
Gas Delivery System	1.3.4
Wall Conditioning System	1.3.5
Diagnostics	1.4
Power Systems	1.5
Centralized Instrumentation and Control	1.6
Integrated Machine Operations	1.7.3
Operations and Safety Systems	1.7.3.1, 1.7.3.2, 1.7.3.7-1.7.3.10, 1.8.1.1.3
D-Site Location (Test Cell)	1.8.1

4. Interface Management - Interface Control Documents

The Interface Control Document (ICD) is the method for documenting and managing physical interfaces between subsystems and system elements. Drawings, analyses, and calculations are critical to system design. These drawings and calculations take precedence in establishing the details of interface design and implementation. The ICD will make extensive use of references to existing relevant drawings, analyses, and calculations in defining the interfaces. Note: based on the current practice, drawings and calculations are not typically released until the FDR is completed.

ICD generation is the responsibility of the REs and systems engineer. The ICDs are living documents and will mature as the designs mature. An ICD may be comprised of multiple system elements, but there will generally be an ICD for each of the interfacing pairs of systems from Table 3. Each element will have their own interfaces defined in the ICD. Each component will be individually identified within the ICD. There is no limit on the number of interfaces that can be defined in a single Interface Control Document, within the construct that each ICD covers the interactions between only two systems.

The ICDs use interface abbreviations for the various the Interface Types, so as to streamline the depiction in the Physical and Logical interfaces. Table 4 provides the mapping of the abbreviations/interface categories to the interface types addressed in the ICDs.

***Table 4**. Interface types and codes*

Abbreviation	Interface Category	Interface Type
Me	Mechanical	Structural (S)
		Spatial (Sp)
		Location (L)
		Wall/Floor Penetration (Wp)
Ep	Electrical Power	Electrical Power
Si	Signal	Electrical Signal
		Ethernet
		Fiber Optic
Di	Diagnostic	Diagnostic
Gf	Gas/Fluid	Gas (G)
		Fluid (F)
Va	Vacuum	Vacuum
Sw	Software	Software
Th	Thermal	Thermal
Pe	Plasma/Eddy/Halo Current	Plasma (P)
		Eddy/Halo Current (E)

Each ICD is created using a template. The template includes scope, responsibilities, and section that align to interface types in Table 4. Each section includes default tables as shown Figure 3. The identifier a concatenation of the SBS elements, up to level-5, and an interface type code selected from Table 4. It also includes a description of the interface. The references provide a reference to a section number as well as source of the documentation.

For each interface identified, there is an option for interface notes. These notes are not part of the formal interface, but notes that may provide relevant information. Each interface is identified follow the following format: "ICD-"Prefix followed by three letter code for the subsystems followed by a sequence number for example: [ICD-PFC-CSS-1]. Annex A provides potential attributes to be collected for each interface type.

Identifier	Interface	References

Figure 3*. Default Interface boundary Table*

ICDs are created at PDR and updated through FDR. Signatures on the ICDs should be signed at the FDR or soon after as the drawings are signed. After ICDs are approved, the REs will not alter a design affecting the interface without the knowledge and approval of the affected REs.

ICDs will be posted on the NSTX-U Systems Engineering Web page and filed in the document management system.

As designs progress into final design and beyond, additional interfaces may be defined and documented in either new ICDs or modifications to existing ICDs. Should modifications to existing ICDs be identified as part of the design evolution process, these changes will be processed through revisions.

In rare instances, engineering errors, specification anomalies, or manufacturing tolerance problems result in interface incompatibilities that may not be discovered until after interface agreements are complete. These incompatibilities may be uncovered as part of interface verification (prototype fit checks, subsystem assembly, or testing). If this occurs, the impact must be assessed and rectified by both affected REs. ICDs will be updated accordingly.

In the unlikely event that REs cannot agree on an interface, the Project Engineer, in consultation with project management, will intervene and provide direction on interface resolution.

Annex A Typical Attributes

Interface Type	Attributes
Structural	Interface Location
	Mechanics of load path (Bolted, welded, keyed, pinned)
	Pre-load/Torque requirements
	Interface loads
Spatial	Positioning and alignment to other components
	Absolute or relative positioning
	Metrology monuments or other alignment facilitating features
	Critical clearances/tolerances/gaps not already specified in drawings
Electrical Power	Location, e.g., bus bar, outlets
	Expected connectors or connection features
	Power AC/DC Voltage and Current ranges
Signal	Physical Interface (e.g., Ethernet, cable pairs, RS-232)
	Connector pin-outs (if applicable0
	Processing temporal limits
	Signaling protocols
Software	APIs between software components
	Other Software interfaces
Diagnostic	Components application (Welded, glued)
	Special features (tapped holes)
	Electrical Isolation
	Connection type and name
Gas/Fluid	Type of Fluid/Gas
	Maximum Allowable Working pressure (MAWP)
	Flow Rates
	Components (Hoses/Connectors
Vacuum	Flange Name/Location
	Flange and Seal Size
	Seal Type
Thermal	Thermal ranges at the interface
	Heat flow and expected thermal conductivity
	Thermal Expansion
Plasma/Halo/ Eddy Currents	Heat fluxes from the plasma
	Currents injected at the interface, including potential information such as current magnitude and spatial distribution
	Eddy currents driven by plasma flux changes (both plasma motion and rapid changes in the plasma current)