Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
General	GRD	GRD General Requirements							Ver. Method							
General	GRD	1	GRD- 4.1.1.a	General: Field Directions and Coordinates	1	1.1	The NSTX-U device shall be oriented so that the axis of the TF inner bundle points towards the ceiling of the NSTX-U Test Cell (NTC).				X				Metrology will be used to verify the orientation	
General	GRD	2	GRD- 4.1.1.b	General: Field Directions and Coordinates	2	1.1	A right hand coordinate system (R,ϕ,Z) shall be established so that: ● Positive Z has an origin at the machine midplane and points toward the NTC ceiling ● Positive R has an origin at the center of the TF bundle and points outward ● Positive ϕ has an origin along a line pointing towards the north wall4, directly between thecenterlines of Bays A and L, increasing in a counterclockwise direction when viewing from above.			X				All calculations and other documents will verify that the right coordinate system is implemented		
General	GRD	3	GRD- 4.1.1.c	General: Field Directions and Coordinates	3	1.1	The plasma current shall be positive in this coordinate system (i.e. counter clockwise when viewed from above)			X				All models and other documents will verify that the positive coordinate systems is used		
General	GRD	4	GRD- 4.1.1.d	General: Field Directions and Coordinates	4	1.1	The toroidal field shall be negative in this coordinate system (i.e. clockwise when viewed from above)			X				All models and other documents will verify that the negative coordinate systems is used		
General	GRD	5	GRD- 4.1.1.e	General: Field Directions and Coordinates	5	1.1	The coils shall have as their baseline directions the values in Table 4.1.1-1.	Table 4.1.1-1.		X						
General	GRD	6	GRD- 4.1.1.f	General: Field Directions and Coordinates	6	1.1	The 12 bays are given nominal angle definitions as in Table 4.1.1-2. Actual bay positions may differ slightly due to fabrication tolerances, and bay letters should be used only in a reference sense.	Table 4.1.1-2			X				Bays are identified in nearly all doc umentstion to include drawings	
General	GRD	7	GRD- 4.1.2.a	General: Baseline Operations Scenarios	7	1.1	Nominal plasma current (I p) waveform for engineering design purposes shall consist of linear ramp-up from zero to 2MA at a rate of 2MA/sec, flat top (constant 2MA) with duration up to 5.0 sec, and linear ramp-down from 2MA to zero at a rate of 1MA/sec [15]. Total duration 2/2 + 5 + 2/1 = 8.0 sec, with an ESW time of 6 seconds (Figure 4.1.2-1). This waveform is referred to as the “Long Pulse Partial Inductive” (LPPI) waveform. The “Short Pulse Full Inductive” (SPFI) waveform is similar, but with a flat-top duration of only 2.5 seconds	Figure 4.1.2-1	X				Nearly all calculations use the same basline values these values			
General	GRD	8	GRD- 4.1.2.c	General: Baseline Operations Scenarios	8	1.1	Plasma scenarios and the OH coil evolution shall be designed so that the frictional interaction between the OH coil and the TF inner leg bundle is acceptable. This is accomplished by keeping the bulk average temperature of the OH coil (T OH)) always greater than that of the TF inner leg bundle (T TF,inner).			X						
General	GRD	9	GRD- 4.1.2.d	General: Baseline Operations Scenarios	9	1.1	The coil protection systems shall have mechanisms to enforce T OH >T TF,inner .			X						
General	GRD	10	GRD- 4.1.3.a	General: Auxiliary Heating Input Power	10	1.3	For engineering purposes, the HHFW system shall be assumed to deliver a maximum of 4 MW to the plasma for 5 s.			X				Subsystem is existing and not being modified as part of recovery scope		

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Category	**Filter**	**SEQ. #**	**Req't ID**	**Subsystem Name**	**Sub-Count**	**SBS**	**Requirement**	**Figure Ref.**	**Anal**	**Demo**	**Insp**	**Test**	**Analysis Artifacts**	**Demonstration Artifacts**	**Inspection Artifacts**	**Test Artifacts**
General	GRD	11	GRD- 4.1.3.b	General: Auxiliary Heating Input Power	11	1.3	For engineering purposes each NBI beam line shall be assumed to deliver a maximum power to the plasma as indicated in Table 4.1.3-1.	Table 4.1.3-1.		X				Subsystem is existing and not being modified as part of recovery scope		
General	GRD	12	GRD- 4.1.3.c	General: Auxiliary Heating Input Power	12	1.3	The total combined auxiliary heating power will be that deliverable from the HHFW plus one NBI beamline (9 MW), or two beamlines (10 MW), for 5 seconds 5			X				Subsystem is existing and not being modified as part of recovery scope		
General	GRD	13	GRD- 4.1.4.a	General: Pulse Duty Factor	13	1.1	At the full rated pulse length, the repetition period shall be 2400 sec, but upgradeable to 1200 sec. via modification and upgrades to components outside the tokamak core. Therefore, all components in the tokamak core shall be designed for the 1200 sec. repetition rate.		X				Calculations addressing the time requirmenets address 1200 second intravals unless otherwide specified e.g., power Cable limitation			
General	GRD	14	GRD- 4.1.4.b	General: Pulse Duty Factor	14	1.1	Plasma pulses with shorter duration may be performed at a more rapid rate, consistent with the cooling of the coils and in-vessel components.					X				Will occur during experimental tests
General	GRD	15	GRD- 4.1.5.a	General:Heat Removal Capabilities	15	1.1	The average power load to the PFCs and VV is summarized in Table 4.1.5-1.	Table 4.1.5-2.	X							
General	GRD	16	GRD- 4.1.5.b	General:Heat Removal Capabilities	16	1.1	The minimum heat removal capabilities from the divertors of the device shall be based on a 30% radiation fraction, with a 50/50 up-down power split and an 80/20 out/in power split. Therefore, the heat removal capability shall be as per Table 4.1.5-2.	Table 4.1.5-2								
General	GRD	17	GRD- 4.1.5.c	General:Heat Removal Capabilities	17	1.1	The heat removal capability of the first wall shall be determined by the high radiation fraction scenario of Table 4.1.5-3.	Table 4.1.5-3								
General	GRD	18	GRD- 4.1.5.d	General:Heat Removal Capabilities	18	1.1	The radiated power in tables 4.1.5-2 and 4.1.5-3 shall be taken as uniformly radiated from within the 95% plasma boundary in Section 4.1.2.	tables 4.1.5-2 and 4.1.5-3								
General	GRD	19	GRD- 4.1.5.d'	General:Heat Removal Capabilities	19	1.1	Any in-vessel cooling loops shall follow the following guidelines [17] ● If made from single-walled tubing, then water cannot be used following the introduction of any lithium into the machine. Any tubes used in this fashion should be isolated from water supply and pumped out to 1x10 -3 torr before lithium introduction. ● If cooling loops can be formed with double wall tubing or other secondary barrier to the vacuum, then water cooling may be used during lithium operations. These cases require a system or program to positively verify on a daily basis that both barriers are intact. If either barrier is found to be compromised, then the system shall be taken out of service. Design should carefully guard against common mode failures that may simultaneously compromise both barriers.									

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
General	GRD	20	GRD- 4.1.6a	General:Shot Spectrum	20	1.1	For engineering purposes, the number of NSTX-U pulses, after implementing the Center Stack Upgrade, shall be assumed to consist of a total of 20,000 pulses based on the pulse spectrum given in Table 4.1.6-1.	Table 4.1.6-1		X				All of the fatigue analyses consider a shot spectum of 20,000 shots		
General	GRD	21	GRD- 4.1.7.a	General:Field Errors and Component Alignment	21	1.1	Manufacturing and assembly tolerances shall be provided in the appropriate SRD or RD.		X				RD-11 provides the critical assembly tolerances for alignment of the			
General	GRD	22	GRD- 4.1.8.a	General:Static EM Loads	22	1.1	The DPSS [15,16] establishes minimum static electromagnetic loads. Derived loads using other codes is permitted if the loads are verified to be greater than or equal to those established by the DPSS.		X							
General	GRD	23	GRD- 4.1.8.b	General:Static EM Loads	23	1.1	All static electromagnetic loads shall be computed from prescribed coil currents in the DPSS.		X							
General	GRD	24	GRD- 4.1.9.a	General: Disruption Requirements	24	1.1	NSTX-U plasma facing components, internal hardware (PFC tiles, passive plates, outboard divertor, neutral beam armor, cooling systems, shutters, etc), CSC, VV, and RF antenna shall be designed to withstand the forces and loads due to plasma disruption.		X				All Relevant calculation			
General	GRD	25	GRD- 4.1.9.b	General: Disruption Requirements	25	1.1	The loads shall be calculated as described in Ref. [18]. NSTX-U-RQMT-RD-003-00, NSTX-U Disruption Requirement		X				All relevant analyses use the appropriate disruption requirements			
General	GRD	26	GRD- 4.2.1.1.a	General: General Design Guidelines	26	1.1	Table 3.1-1 of the original NSTX Project GRD [2] is repeated as Table 4.2.1.1-1 and shall apply to theRecovery Project and all subsequent design.	Table 4.2.1.1-1	X							
General	GRD	27	GRD- 4.2.1.2.a	General: Failure Mode Effects Analysis	27	1.1	The FMEA which was prepared for the original NSTX Project and revised during the Upgrade project shall be updated, including an analysis of all changes implemented by the Recovery Project and redesign.		X				New document/process addressing FMECAs has been developed			
General	GRD	28	GRD- 4.2.1.2.b	General: Failure Mode Effects Analysis	28	1.1	Failure probabilities shall be quantified based on engineering judgment per the General Design Guidelines Table 4.2.1.1-1. Failure consequences shall be quantified based on engineering judgment per Table 4.2.1.2-1.	Table 4.2.1.1-1, Table 4.2.1.2-1.								
General	GRD	29	GRD- 4.2.1.3.a	General: Structural Design	29	1.1	All NSTX-U mechanical design shall follow the NSTX-U structural design criteria [19]. NSTX-CRIT-0001-02, NSTX Structural Design Criteria		X				At design reviews, all mechanical analyses consist of an allowable that is generated from the structural design criteria report.			
General	GRD	30	GRD- 4.2.1.3.b	General: Structural Design	30	1.1	All designs shall maintain the midplane symmetry of the device to the greatest extent possible		X				Part of the MC S FDR design			
General	GRD	31	GRD- 4.2.1.3.c	General: Structural Design	31	1.1	Toroidally continuous passive structures shall be minimized to the extent that other design constraints permit, and shall be made of high resistivity materials (316 SS, Inconel) where compatible with component function.		X	X			Designs removed jumpers addressed as part of the passive plate plate - FDR design addresses Jumpers to add a current path to the plate and the vessel	Passive Plates, OBD and other compoenents are not being redesigned		
General	GRD	32	GRD- 4.2.2.1.a	General: Materials Selection	32	1.1	Magnetic permeability of components shall be as defined in Ref. [20] NSTX-U-RQMT-RD-010-00, NSTX-U Magnetic Permeability Requirements		X				Nearly all calculations address magnetic permeability			

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
General	GRD	33	GRD- 4.2.2.2.a		33	1.1	All materials utilized within the primary vacuum boundary shall be on the PPPL Vacuum Committee approved list, or shall be approved by the committee.		X	X			IVPS FDR design	Components not chnages will be demonstrated		
General	GRD	34	GRD- 4.2.2.2.b	General: Materials Selection	34	1.1	All materials utilized within the primary vacuum boundary shall be designed to withstand the anticipated temperatures during plasma and bakeout operation. See Section 6.3.3.	Section 6.3.3.	X			X	Manufacturers data sheets			REC-176-00 Outgassing Test on Halo Current I
General	GRD	35	GRD- 4.2.2.1.c	General: Materials Selection	35	1.1	All viton O-ring seals shall be maintained at a temperature lower than 180 deg C during any operational or bakeout scenario.		X				Manufacturers data sheets			
General	GRD	36	GRD- 4.2.2.1.e	General: Materials Selection	36	1.1	All materials with line of sight exposure to the lithium evaporators or otherwise determined to be at risk to exposure to lithium films shall be approved for use under that condition.									
General	GRD	37	GRD- 4.2.3.a	General: Electrical Isolation and Grounding	37	1.1	The NSTX-U vacuum vessel shall be single-point grounded during operations. There shall be a mechanism to open the ground connection for testing purposes. When opened, the vessel vacuum vessel isolation shall be rated to withstand a one minute AC hipot test at 2 kV AC rms.					X				Hi-Pot Tests conducted
General	GRD	38	GRD- 4.2.3.b	General: Electrical Isolation and Grounding	38	1.1	Where sensors are installed inside the vacuum vessel, any associated instrumentation rack shall be electrically referenced to the vacuum vessel. Those racks shall be electrically isolated from structures, and on their AC power feed, with isolation rated to withstand a one minute AC hipot test at 2 kV AC rms.				X	X			28 March PFC diagnostics FDR mentioned the design called for the use of the common ground from track to vessel. Use of existing CWDs to verify grounding.	Hipot tests will be conducted
General	GRD	39	GRD- 4.2.3.c	Electrical Isolation and Grounding	39	1.1	All instrumentation originating from the test cell should be isolated prior to exiting the test cell boundary. The isolation shall be rated to withstand a one minute DC hipot test at 5kV. Examples of this isolation include optical and/or magnetic (isolation transformer) means. If this isolation cannot be achieved, then the equipment outside the test cell boundary shall be placed under access control as part of the primary test cell access control system				X	X			28 March PFC diagnostics FDR mentioned the design called for the use of the common ground from track to vessel. Use of existing CWDs to verify grounding.	Hipot tests will be conducted
General	GRD	40	GRD- 4.2.3.d	Electrical Isolation and Grounding	40	1.1	With the exception of dedicated grounding bus, components which are in mechanical contact with the vacuum vessel shall be electrically isolated from the vacuum vessel. The isolation shall be rated to withstand a one minute AC hipot test at 2 kV AC rms.			X				Part of the existing design		
General	GRD	41	GRD- 4.2.3.e	Electrical Isolation and Grounding	41	1.1	Conducting loops of area greater than 0.2 m 2 formed by metallic structures within a radius of 3 meters from the centerline of the torus shall be broken by insulating breaks, unless specific exception is granted. The insulation shall be rated to withstand a one minute AC hipot test at 2 kV AC rms.			X		X				Hi-Pot tests

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General	GRD	42	GRD- 4.2.4.a	General	42	1.1	Individual vacuum system components have a bench leak rate no greater than 1x10 -9 standard cubic centimeters per second (sccs) air equivalent as measured by a Helium Mass Spectrometer Leak Detector (HMSLD). The total aggregate leak rate for the NSTX-U Vacuum vessel/vacuum system shall not exceed 1x10 -5 sccs air equivalent.		X	X		X	IVPS FDR drawings showed venting through vacuum exhaust line MCS - Vacuum Calculations NSTXU_1-1-3-3_CALC_103			Testing as part of Vacuum pump down
General	GRD	43	GRD- 4.2.4.b	General	43	1.1	b. All vacuum systems with exposure to NSTX-U machine vacuum shall exhaust through the D-Site vent stack via the NSTX-U vacuum exhaust line.		X	X		X	IVPS FDR drawings showed venting through vacuum exhaust line			Testing as part of Vacuum pump down
General	GRD	44	GRD- 5.c	General: SRD	44	1.1	As per the NSTX-U QA Plan [22] and relevant engineering procedures, SRDs shall be reviewed by therelevant Responsible Engineers (REs), technical authorities, the NSTX-U Project Engineer, and ProjectManager and approved by the Chief Engineer, and accepted Project Director.				X				Signature Blocks and Signatures on SRDs	
General	GRD	45	GRD- 5.d	SRD General	45	1.1	For each SBS element in the SRD, the following sections shall be used to articulate the requirement: •Functions •Materials and Design Requirements •Configuration Requirements & Essential Features •Baseline Performance and Operational Requirements •Upgrade Performance and Operational Requirements •Interfaces				X				The SRDs follow this format.	
General	GRD	46	GRD- 5.f	SRD General	46	1.1	The "Type of Interface" column shall have one of the entries in Table 5-3.	Table 5-3.			X				The SRDs follow this format.	
Magnets	Magnets	**Magnets**														PTP
Magnets	Magnets	47	GRD- 6.1.3.1.1.a'	Outer and Inner PF Coils	1	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	The PF coils shall provide field nulling for plasma initiation and shall provide equilibrium and shape control during ramp-up, ramp-down, and flat-top..			X		X		Initial operations of the NSTX-U		
Magnets	Magnets	48	GRD- 6.1.3.1.1.a	Outer and Inner PF Coils	2	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Unless otherwise specified, all PF coils, when separately and singularly energized, shall be capable of supplying 100% of their rated ampere-turns, including any engineering headroom, in the form of a linear ramp-up, flat top, and linear ramp-down waveform synchronized with the Ip waveform given in section 4.1.2.			X		X		Outer Coils are not being modified as part of recovery; PF 4 re-aligned to meet requirements		Full power testing prior to installation. PTP & ISTP
Magnets	Magnets	49	GRD- 6.1.3.1.1.b	Outer and Inner PF Coils	3	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	For engineering purposes, the nominal design requirement for all components and systems shall be based on the load combination of coil currents up to 100% of their ampere-turns, with either polarity of OH current at 100% of its ampere-turns and with Ip=0 or ≠ 0, shall be allowable.		X			X	NSTXU-CALC-131-09-00			ISTP Phases II, III, & IV

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Magnets	Magnets	50	GRD- 6.1.3.1.1. b'	Outer and Inner PF Coils	4	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	In the event that this design requirement cannot be satisfied without significant cost impact and/or technical risk, exception may be taken. In this case the design requirement may be reduced from the assumption of maximum possible currents to the OH current distributions derived from the range of plasma equilibria specified by the physics requirements, including any applied headroom. The derivation shall be based on the nominal equilibria currents but adjusted for the post-disruption current distribution.			X				Outer of Coils are not being modified as part of recovery		PTP & ISTP on coil activation
Magnets	Magnets	51	GRD- 6.1.3.1.1. b''	Outer and Inner PF Coils	5	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	In the event that this design requirement cannot be satisfied without significant cost impact and/or technical risk, exception may be taken. In this case: the relationship between the design-driving quantity and the PF/OH/TF currents and the plasma current shall be determined and described by an algorithm to be used in the real-time coil protection system (see section 6.7.3.5) as appropriate.			X				Outer of Coils are not being modified as part of recovery		
Magnets	Magnets	52	GRD- 6.1.3.1.2. a	Outer and Inner PF Coils	6	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	The PF magnets shall consist of the Outer of coils (PF2a, 2b, 3a,3b,4b,4c, and PF5) and the Inner of coils (PF1a, PF1b, PF1c), as listed in Table 6.1.3.1.2.-1.	Table 6.1.3.1.2.-1.			X			Outer of Coils are not being modified as part of recovery		
Magnets	Magnets	53	GRD- 6.1.3.1.2. b	Outer and Inner PF Coils	7	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	The PF coils listed in Table 6.1.3.1.2-1 shall be connected in series groups with independent current control as indicated in Table 6.1.3.1.2-2.	Table 6.1.3.1.2-2.		X	X			Outer of Coils are not being modified as part of recovery		
Magnets	Magnets	54	GRD- 6.1.3.1.2. c	Outer and Inner PF Coils	8	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Structural design of coils and their supports shall accommodate any combination of PF, OH, and TF coil currents up to 100% of their ampere-turns, with either polarity of OH current at 100% of its ampere-turns and with I P =0 or ≠ 0 except where this is judged impractical and special exception is taken. See 6.1.3.1.1e.		X	X		X		Outer of Coils are not being modified as part of recovery		Magnet Acceptance testing
Magnets	Magnets	55	GRD- 6.1.3.1.2. d	Outer and Inner PF Coils	9	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	The coil system winding packs boundaries shall be nominally symmetric about the midplane.				X				Metrology	
Magnets	Magnets	56	GRD- 6.1.3.1.2. e	Outer and Inner PF Coils	10	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Turn counts, turn layouts, maximum currents, maximum voltages, required action integrals, and other numerical parameters for the of coils shall be provided in the DPSS				X				Included in the Design Point Spreadsheet (DPSS) NSTXU_1_CALC_100	
Magnets	Magnets	57	GRD- 6.1.3.1.2. f	Outer and Inner PF Coils	11	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Cooling for the of coils shall be provided consistent with a 1200 sec repetition period, or a 2400 sec repetition period upgradeable to a 1200 sec repetition period w/o modification of the coils.		X			X	DPSS provides the minimum cooling flow rates NSTXU_1_CALC_100			Cooling rate testing during Prototype testing

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Magnets	Magnets	58	GRD- 6.1.3.1.2.g	Outer and Inner PF Coils	12	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Electrical insulation design for the of coil, including turn insulation, ground insulation, as well as strike and creep distances of leads and fittings shall be conservatively designed based on a one minute DC hipot test voltage of 2E+1kV. For coils configured with two wire connections, E shall correspond to the maximum power supply line-to-line DC voltage. For coils configured in three-wire configurations, E shall correspond to the sum of the line-to-line DC voltages.		X	X		X	Calculations	Outer of Coils are not being modified as part of recovery		Prototype Testing and acceptance testing
Magnets	Magnets	59	GRD- 6.1.3.1.2.h	Outer and Inner PF Coils	13	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	All series coil connections indicated in Table 6.1.3.1.2-2 shall result in current flow which is equal in magnitude, and in the same ϕ direction, in the series connected coils.	Table 6.1.3.1.2-2	X	X				Outer of Coils are not being modified as part of recovery		
Magnets	Magnets	60	GRD- 6.1.3.1.2.I	Outer and Inner PF Coils	14	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	The outer coils shall be supported from the vacuum vessel.			X	X			Outer of Coils are not being modified as part of recovery	Spection as part of reassmebly	
Magnets	Magnets	61	GRD- 6.1.3.1.2.j	Outer and Inner PF Coils	15	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Structural support of the of coils shall allow for axial & radial thermal expansion while ensuring that the coils remains centered and restrained against vertical motion when subject to electromagnetic loads.			X				Outer of Coils are not being modified as part of recovery		
Magnets	Magnets	62	GRD- 6.1.3.1.2.k	Outer and Inner PF Coils	16	1.1.3.1 1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	All aspects of the coils design shall be compatible with NSTX-U operation with plasma current and toroidal field in either ϕ direction					X				ISTP Phase IV Accelerator Research Operations
Magnets	Magnets	63	GRD- 6.1.3.2.1.a	TF outer and inner legs	17	1.1.3.2 1.1.3.3.1	Toroidal field (B t) shall be 1.0T at R 0 =0. 9344m, maintained constant for the full 5.0 s duration of the LPPI plasma current flat-top based on the nominal I p waveform, as given in Fig. 6.1.3.2.1-1 and Table 6.1.3.2.1-1 [15]. The TF waveform for the SPFI scenario is given in Fig. 6.1.3.2.1-1 and Table 6.1.3.2.1-2		X	X		X	NSTXU_1_CALC_100			PTP and ISTP racheting tests
Magnets	Magnets	64	GRD- 6.1.3.2.2.a	TF outer and inner legs	18	1.1.3.2 1.1.3.3.1	Structural design of TF coils and their supports shall accommodate any combination of PF OH, and TF coil currents up to 100% of their ampere-turns, with either polarity of OH current at 100% of its ampere-turns and with I P =0 or ≠ 0 except where this is judged impractical and special exception is taken. See 6.1.3.1.1e.		X	X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	65	GRD- 6.1.3.2.2.b	TF outer and inner legs	19	1.1.3.2 1.1.3.3.1	Final values for turn counts, turn layouts, maximum currents, maximum voltages, required action integrals, and other numerical parameters for the TF coil shall be provided in the DPSS.		X		X		NSTXU_1_CALC_100		Verify data is in DPSS	
Magnets	Magnets	66	GRD- 6.1.3.2.2.c	TF outer and inner legs	20	1.1.3.2 1.1.3.3.1	Cooling for the TF coil shall be provided consistent with a 1200 sec repetition period.		X							
Magnets	Magnets	67	GRD- 6.1.3.2.2.d	TF outer and inner legs	21	1.1.3.2 1.1.3.3.1	Electrical insulation design for the TF coil, including turn insulation, ground insulation, as well as strike and creep distances of leads and fittings shall be conservatively designed based on a one minute DC hipot test voltage of 2E+1kV. For the TF coils, E shall correspond to the maximum power supply line-to-line DC voltage.			X		X		Subsystem is existing and not being modified as part of recovery scope		Hi-pot tests
Magnets	Magnets	68	GRD- 6.1.3.2.2.e	TF outer and inner legs	22	1.1.3.2 1.1.3.3.1	The outer TF legs shall be supported from the vacuum vessel.			X				Subsystem is existing and not being modified as part of recovery scope		

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Magnets	Magnets	69	GRD- 6.1.3.2.2.f	TF outer and inner legs	23	1.1.3.2 1.1.3.3.1	The inner-TF legs shall be supported as part of the CS assembly.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	70	GRD- 6.1.3.2.2.g	TF outer and inner legs	24	1.1.3.2 1.1.3.3.1	Demountable joints shall be provided between the TF outer legs and TF inner legs to allow removal/replacement of the Center Stack assembly.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	71	GRD- 6.1.3.2.2.h	TF outer and inner legs	25	1.1.3.2 1.1.3.3.1	Structural support of the TF inner leg shall allow for axial thermal expansion and restraint against electromagnetic loads.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	72	GRD- 6.1.3.2.2.i	TF outer and inner legs	26	1.1.3.2 1.1.3.3.1	Structural support of the TF outer leg shall allow for thermal expansion and restraint against electromagnetic loads.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	73	GRD- 6.1.3.2.2.j	TF outer and inner legs	27	1.1.3.2 1.1.3.3.1	All aspects of the TF coil design shall be compatible with NSTX-U operation with plasma current and toroidal field in either ϕ direction.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	74	GRD- 6.1.3.3.1.a	Ohmic Heating Solenoid	28	1.1.3.3.2	The OH coil shall provide loop voltage for plasma initiation, ramp-up, sustainment, and ramp-down, consistent with the plasma current waveform in Fig. 4.1.2-1.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	75	GRD- 6.1.3.3.1.b	Ohmic Heating Solenoid	29	1.1.3.3.2	The breakdown loop voltage shall be >=4.2 volts for >= 0.02 seconds			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	76	GRD- 6.1.3.3.2.a	Ohmic Heating Solenoid	30	1.1.3.3.2	Structural design of OH coil and its supports shall accommodate any combination of of, OH, and TF coil currents up to 100% of their ampere-turns, with either polarity of OH current at 100% of its ampere-turns and with I P =0 or ≠ 0 except where this is judged impractical and special exception is taken. See 6.1.3.1.1e.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	77	GRD- 6.1.3.3.2.b	Ohmic Heating Solenoid	31	1.1.3.3.2	Final values for turn counts, turn layouts, maximum currents, maximum voltages, required action integrals, and other numerical parameters for the OH coil shall be recorded in the DPSS.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	78	GRD- 6.1.3.3.2.c	Ohmic Heating Solenoid	32	1.1.3.3.2	Cooling for the OH coil shall be provided consistent with a 1200 sec repetition period.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	79	GRD- 6.1.3.3.2.d	Ohmic Heating Solenoid	33	1.1.3.3.2	Electrical insulation design for the OH coil, including turn insulation, ground insulation, as well as strike and creep distances of leads and fittings shall be conservatively designed based on a hipot test voltage of 2E+1. For the OH coil, E shall correspond to the maximum power supply line-to-line DC voltage.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	80	GRD- 6.1.3.3.2.e	Ohmic Heating Solenoid	34	1.1.3.3.2	Structural support of the OH coil shall allow for axial thermal expansion while ensuring that the coil is constrained to allowable levels when subject to electromagnetic loads.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	81	GRD- 6.1.3.3.2.f	Ohmic Heating Solenoid	35	1.1.3.3.2	The OH coil shall be supported as part of the CS assembly			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	82	GRD- 6.1.3.3.2.g	Ohmic Heating Solenoid	36	1.1.3.3.2	All aspects of the OH coil design shall be compatible with NSTX-U operation with plasma current and toroidal field in either ϕ direction.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	83	GRD- 6.1.3.5.2.a	Bus bar systems	37	1.1.3.4	Thermal capacity of coil bus runs shall be consistent with the action integrals of the coils to which they are attached.		X	X			Bus Bar PDR & FDR	Subsystem is existing and not being modified as part of recovery scope		

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Magnets	Magnets	84	GRD- 6.1.3.5.2.d	Bus bar systems	38	1.1.3.4	All aspects of the bus bar design shall be compatible with NSTX-U operation with plasma current and toroidal field in either ϕ direction.		X	X			Bus Bar PDR & FDR	Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	85	GRD- 6.1.3.6.2.a	Resistive Wall Mode Coils	39	1.1.3.5	The RWM coils shall consist of six coils mounted at the vessel midplane, each producing radial field.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	86	GRD- 6.1.3.6.2.a'	Resistive Wall Mode Coils	40	1.1.3.5	The coils shall fit in the opening between the of-5 supports, and shall as a group toroidally span the full vessel.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	87	GRD- 6.1.3.6.2.b	Resistive Wall Mode Coils	41	1.1.3.5	The coils shall be independently fed, allowing the application of even-n or odd-n fields depending on power supply connections.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	88	GRD- 6.1.3.6.2.c	Resistive Wall Mode Coils	42	1.1.3.5	They shall be sized to support a 6 kA-turn pulsed rating with the 1200 s duty cycle.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	89	GRD- 6.1.3.6.2.d	Resistive Wall Mode Coils	43	1.1.3.5	All aspects of the RWM coil design shall be compatible with NSTX-U operation with plasma current and toroidal field in either ϕ direction.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	90	MAG- 1.b	General	1	1.1.3	Any and all constraints on the simultaneous current distribution in the TF, PF, and OH coils, and the plasma, besides the individual peak coil current ratings, shall be explicitly identified as an outcome of the design process.		X				Included in the DPSS			
Magnets	Magnets	91	MAG- 2.a	General	2	1.1.3	"Permeability requirements are as per Ref. [2], while mechanical design shall be governed by the NSTX-U Structural Design Criteria"		X				Permeability of copper for magnets			
Magnets	Magnets	92	MAG- 2.c	General	3	1.1.3	Up-down symmetry of the vessel and magnets shall be a feature of the design to the greatest extent possible.				X				Metrology to measure the symmetry of the magnet location	
Magnets	Magnets	93	MAG- 2.c'	General	4	1.1.3	Symmetry deviations greater than 0.5 cm shall be approved by Project Physics.				X				Metrology to measure the symmetry of the magnet location	
Magnets	Magnets	94	MAG- 2.d	General	5	1.1.3	Toroidally continuous passive structures shall be minimized to the extent that other design constraints permit		X				FDR design			
Magnets	Magnets	95	MAG- 2.d'	General	6	1.1.3	Toroidally continuous passive structures shall be made of high resistivity materials where possible.		X				FDR design			
Magnets	Magnets	96	MAG- 2.f	General	7	1.1.3	Final values for turn counts, turn layouts, maximum currents, maximum voltages, required action integrals, and other numerical parameters for the coils shall be recorded in the revision controlled Design Point Spreadsheet	Design Point Spreadsheet	X				Updated In the Design Point Spreadsheet			
Magnets	Magnets	97	MAG- 2.g	General	8	1.1.3	All coil designs shall allow for operation of the toroidal field in either direction, and of the plasma current in either direction.			X		X		Subsystem is existing and not being modified as part of recovery scope		Initial operations PTP and ISTP
Magnets	Magnets	98	MAG- 2.h	General	9	1.1.3	All coils shall be fabricated from copper conductor with internal cooling channel sized to support a 1200 second repetition period.		X				Thermal Analysis			
Magnets	Magnets	99	MAG- 2.i	General	10	1.1.3	Water fitting materials shall be compatible with deionized water service.		X	X			Research on commercial fittings FDR design review	Demonstrate operations		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Magnets	Magnets	100	MAG- 2.j	General	11	1.1.3	Operational scenarios for coils shall accommodate any combination of PF, OH, and TF coil currents up to 100% of their ampere-turns, with either polarity of OH current at 100% of its ampere-turns and with I P =0 or ≠ 0 except where this is judged impractical and special exception is taken as per Section 6.1.3.1.1e of the General Requirements Document		X				DPSS			Load testing
Magnets	Magnets	101	MAG- 2.k	General	12	1.1.3	20000 full power pulses shall be used as the fundamental design basis. The shot spectrum from the GRD may be used only if that proves impractical.		X				All Coil and bus bar related calculations consider the results of fatigue of the 20K shots			
Magnets	Magnets	102	MAG- 2.m	General	13	1.1.3	Brazes on coils shall meet requirements of PPPL procedure Eng-037	Procedure Eng-037			X					
Magnets	Magnets	103	MAG- 3.3.a	Outer PF Coils	1	1.1.3.1	The outer PF magnets shall consist of four pairs of water-cooled copper coils designated as of 2a/2b, 3a/3b, 4b/4c, and 5a/5b.				X					
Magnets	Magnets	104	MAG- 3.3.a'	Outer PF Coils	2	1.1.3.1	The pairs shall be symmetric about the horizontal mid-plane of the NSTX-U device. All coils of 1a/1b/1c are part of the Inner of subsystem, SBS 1.1.3.3.3.			X	X			Subsystem is existing and not being modified as part of recovery scope	Metrology as applicable	
Magnets	Magnets	105	MAG- 3.3.b	Outer PF Coils	3	1.1.3.1	Coils identified on the S-1 spheromak as EF coils #1, #2 and #3 shall be used for the outer of coils PF2, PF3, and PF4 on NSTX-U.				X			Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	106	MAG- 3.3.c	Outer PF Coils	4	1.1.3.1	PF5 shall be the new coil fabricated for NSTX.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	107	MAG- 3.3.d	Outer PF Coils	5	1.1.3.1	The outer of coils shall be mechanically supported by the vacuum vessel structure			X	X			Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	108	MAG- 3.3.d'	Outer PF Coils	6	1.1.3.1	The support mechanism shall be compatible with the vacuum vessel thermal expansion during bakeout and operations, as well as coil thermal expansion and electromagnetic loads. Outer coil support systems are described in Ref. [8].			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	109	MAG- 3.3.e	Outer PF Coils	7	1.1.3.1	The outer coils shall be connected in series groups as indicated in Table 3.3-1.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	110	MAG- 3.3.f	Outer PF Coils	8	1.1.3.1	All series coil connections shall result in current flow which is equal in magnitude, and in the same ϕ direction, in the upper and lower coils.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	111	MAG- 3.4.a	Outer PF Coils	9	1.1.3.1	The outer of coils shall be capable of supplying 100% of their rated ampere-turns in the form of a linear ramp-up, flat top, and linear ramp-down waveform synchronized with the I p waveform. See Ref. [1] for the plasma current waveform.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	112	MAG- 3.3.b	Outer PF Coils	10	1.1.3.1	The outer of coils shall be able to conduct the pulse currents once every 1200 seconds.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	113	MAG- 3.3.c	Outer PF Coils	11	1.1.3.1	Each series group of outer of coils shall be able to operate with the terminal voltages indicated in table 2-1.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	114	MAG- 3.3.d	Outer PF Coils	12	1.1.3.1	Outer of coils must satisfy a hipot voltage of 2E+1. Any coils connected in a three-wire configuration shall have E as the sum of the maximum terminal voltages of the coils which share the central connection to FCPC.					X		Subsystem is existing and not being modified as part of recovery scope		Hi-Pot Tests
Magnets	Magnets	115	MAG- 3.3.d'	Outer PF Coils	13	1.1.3.1	If connected with a two-wire connection, then E shall be the maximum terminal-to-terminal voltage.			X				Subsystem is existing and not being modified as part of recovery scope		

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Magnets	Magnets	116	MAG- 3.3.e	Outer PF Coils	14	1.1.3.1	All upper and lower of coil pairs, with the exception of the PF4's and PF5's, shall have separate control of the current in the upper and lower coils.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Magnets	117	MAG- 3.3.f	Outer PF Coils	15	1.1.3.1	Pf-3U and of-3L shall be capable of bipolar operation with ampacity and voltage to null the leakage flux from the OH coil for a full 24 kA precharge while also transitioning to the confining polarity sufficiently quickly following breakdown.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Outer TF	118	MAG- 4.3.a	TF Outer Legs	1	1.1.3.2	NSTX-U shall use the TF outer legs fabricated for NSTX, with remanufacture of coils of similar design as necessary to replace any deemed not reliable.		X	X			Spatial Clearance Issue between coil and leg Leg Modified in NSTXU_1-1-2_CALC_101	Subsystem is existing and not being modified as part of recovery scope		
Magnets	Outer TF	119	MAG- 4.3.c	TF Outer Legs	2	1.1.3.2	The outer TF coils shall be supported from the NSTX-U vacuum vessel.				X				Already in place need to formally verify	
Magnets	Outer TF	120	MAG- 4.3.d	TF Outer Legs	3	1.1.3.2	Demountable joints shall be provided between the TF outer legs and TF inner legs to allow removal/replacement of the Center Stack assembly.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Outer TF	121	MAG- 4.4.a	TF Outer Legs	4	1.1.3.2	The baseline design of the outer legs of the TF coils shall be capable of producing the toroidal fields as given in Figure 4.4-1. Here, LPPI refers to a "Long Pulse Partial Inductive" scenario, while "SPFI" refers to a short pulse full inductive scenario. These are specified numerically in Tables 4.4-1 and 4.4-2.		X	X			DPSS	Subsystem is existing and not being modified as part of recovery scope		
Magnets	Outer TF	122	MAG- 4.4.c	TF Outer Legs	5	1.1.3.2	The TF coils shall be able to supply the pulse currents required to produce the fields given in Tables 3.4-1 and 3.4-2 once every 1200 seconds.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	123	MAG- 4.4.d	TF Outer Legs	6	1.1.3.2	Outer TF coils must satisfy a hipot voltage of 2E+1. Here, E shall be the maximum terminal-to-terminal voltage of 1012 V. Numerical values are provided in Table 2-1.					X				Hipot Tests
Magnets	Inner TF	124	MAG- 5.3.a	TF Inner Legs	1	1.1.3.3.1	The TF magnet shall consist of a 36 turn inner leg bundle connected in series with the existing 12 outer legs, each of which has three turns.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	125	MAG- 5.3.b	TF Inner Legs	2	1.1.3.3.1	The inner legs of the TF coils shall consist of tightly-nested fully-bonded copper conductors. The utilization of cross sectional area shall be optimized to maximize the conductor cross sectional area and minimize the radial build of the center stack assembly.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	126	MAG- 5.3.c	TF Inner Legs	3	1.1.3.3.1	Structural support of the TF coil shall allow for axial thermal expansion while ensuring that the coil remains centered when subject to electromagnetic loads.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	127	MAG- 5.3.d	TF Inner Legs	4	1.1.3.3.1	The water cooling for each inner leg shall be in series with the associated outer leg, with the outer leg receiving the cooling water first.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	128	MAG- 5.4.a	TF Inner Legs	5	1.1.3.3.1	The TF inner legs shall be designed to, in concert with the outer legs, produce the toroidal field evolution described in Fig. 4.4-1 and Tables 4.4-1 and 4.4-2.			X				Subsystem is existing and not being modified as part of recovery scope		

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Magnets	Inner TF	129	MAG- 5.4.b	TF Inner Legs	6	1.1.3.3.1	Cooling shall be provided consistent with a 1200 sec repetition period, or a 2400 sec repetition period upgradeable to a 1200 sec repetition period without modification to the coil.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	130	MAG- 5.4.c	TF Inner Legs	7	1.1.3.3.1	Electrical insulation design for the TF inner legs, including turn insulation, ground insulation, as well as strike and creep distances of leads and fittings shall be conservatively designed based on a hipot test voltage of 2E+1, for both coil-to-ground and inter-turn tests.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	131	MAG- 5.4.c'	TF Inner Legs	8	1.1.3.3.1	E shall correspond to the maximum power supply line-to-line DC voltage. Numerical values are provided in Table 3.4.1.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Inner TF	132	MAG- 5.4.d	TF Inner Legs	9	1.1.3.3.1	The TF turn-to-turn transitions shall include features to minimize stray field due to net toroidal turn. Alternatively it may be demonstrated that the field error due to turn-to-turn transitions can be nullified to a magnitude less than 1 gauss anywhere between $R_0 - a \le r \le R_0 + a$, z=0.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	133	MAG- 6.3.a	OH Solenoid	1	1.1.3.3.2	The OH coil shall consist of a solenoid surrounding the inner legs of the TF coil.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	134	MAG- 6.3.a'	OH Solenoid	2	1.1.3.3.2	The utilization of cross sectional area shall be optimized to maximize the conductor cross sectional area and minimize the radial build of the center stack assembly.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	135	MAG- 6.3.b	OH Solenoid	3	1.1.3.3.2	The height of the OH coil shall be maximized within the available envelope to maximize the flux linkages with the plasma and minimize the stray fields during plasma initiation.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	136	MAG- 6.3.c	OH Solenoid	4	1.1.3.3.2	Structural support of the OH coil shall allow for axial thermal expansion while ensuring that the stresses remain within allowables when subject to electromagnetic loads.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	137	MAG- 6.3.d	OH Solenoid	5	1.1.3.3.2	An array of thermocouples shall be mounted to the OH coil, to assess temperature excursions during normal operations and bakeout				X					
Magnets	OH	138	MAG- 6.3.e	OH Solenoid	6	1.1.3.3.2	The surface of the new OH coil shall be provided with a ground plane of sufficient conductivity to serve as an electrostatic shield while limiting induced currents.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	139	MAG- 6.3.e'	OH Solenoid	7	1.1.3.3.2	Suitable ground plane leads shall be provided for a ground connection on both the upper and lower ends of the coil.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	140	MAG- 6.3.f	OH Solenoid	8	1.1.3.3.2	A vertical array of flux loops shall be mounted on the OH coil outside the ground plane			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	141	MAG- 6.3g	OH Solenoid	9	1.1.3.3.2	The OH lead shall utilize a coaxial design to minimize net force and field error.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	142	MAG- 6.4.a	OH Solenoid	10	1.1.3.3.2	The OH coil shall be designed to operate with a maximum terminal to terminal voltage of 6077 volts, and a current limit of +/- 24 kA.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	143	MAG- 6.4.c	OH Solenoid	11	1.1.3.3.2	Electrical insulation design for the OH coil, including turn insulation, ground insulation, as well as strike and creep distances of leads and fittings shall be conservatively designed based on a hipot test voltage of 2E+1.			X				Subsystem is existing and not being modified as part of recovery scope		

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Magnets	OH	144	MAG- 6.4.c'	OH Solenoid	12	1.1.3.3.2	For the OH coil, E shall correspond to the maximum power supply line-to-line DC voltage. Numerical values are provided in Table 2-1.			X	X			Subsystem is existing and not being modified as part of recovery scope		
Magnets	OH	145	MAG- 6.4.e	OH Solenoid	13	1.1.3.3.2	The current evolution of the OH coil shall be such that the condition T OH >T TF is maintained.			X	X			Subsystem is existing and not being modified as part of recovery scope	FMECA addresses ensuring that is this the case	
Magnets	Inner PF	146	MAG- 7.3.a	Inner PF Coils: All Coils	1	1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	The inner-of coils shall consist of three upper and lower coil pairs, denoted of-1a, of-1b, and of-1c.				X				Procurement and Inspection on installation	
Magnets	Inner PF	147	MAG- 7.3.b	Inner PF Coils: All Coils	2	1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Coils shall be fabricated from conductors with embedded cooling channels.				X				On drawings and inspected for assembly	
Magnets	Inner PF	148	MAG- 7.3.c	Inner of Coils: All Coils	3	1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Cooling holes shall be sized to permit a 1200 second repetition rate at the stated current levels and ESW.		X				Drawings DC11109, 11110, 1117S; DPSS			
Magnets	Inner PF	149	MAG- 7.3.d	Inner of Coils: All Coils	4	1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Coils shall be designed with turn-to-turn and turn-to-ground insulation with significant (>x10) margin on expected operating voltages, including fault cases.		X			X	FDR Presentations			Inner PF Prototype Evaluation Report for design verification (NSTX-U-REC-040) Acceptance Testing on production coils
Magnets	Inner PF	150	MAG- 7.3.e	Inner of Coils: All Coils	5	1.1.3.3.3 1.1.3.3.4 1.1.3.3.5	Coils shall be designed and manufactured in a fashion that facilitates turn-to-turn insulation testing before final installation					X				Inner PF Prototype Evaluation Report for design verification (NSTX-U-REC-040) Acceptance Testing on production coils
Magnets	Inner PF	151	MAG- 7.3.f	Inner of Coils: PF-1a	6	1.1.3.3.3	The centroid of the coil shall be at R=0.325, Z=+/- 1.591.				X				Metrology	
Magnets	Inner PF	152	MAG- 7.3.f'	Inner of Coils: PF-1a	7	1.1.3.3.3	Deviation on order of 1.0 cm in radial or vertical position shall be allowed in consultation with Project Physics.				X				Metrology	
Magnets	Inner PF	153	MAG- 7.3.g	Inner of Coils: PF-1a	8	1.1.3.3.3	Each of-1a coil shall have the following diagnostics mounted outside the ground insulation, but underneath any support slings or structures [4]: ● Four flux loops ● Two thermocouples				X	X			Flux Loops included in design	Diagnostics will checkout the flux loops
Magnets	Inner PF	154	MAG- 7.3.h	Inner of Coils: PF-1b	9	1.1.3.3.4	The centroid of the coil shall be at R=0.400, Z=+/- 1.804.				X				Metrology	
Magnets	Inner PF	155	MAG- 7.3.h'	Inner of Coils: PF-1b	10	1.1.3.3.4	Deviation on order of 1.0 cm in radial or vertical position shall be allowed in consultation with Project Physics.				X				Metrology	
Magnets	Inner PF	156	MAG- 7.3.i	Inner of Coils: PF-1b	11	1.1.3.3.4	Each of-1b coil shall have the following diagnostics mounted outside the ground insulation, but underneath any support slings or structures [4]: ● Two flux loops ● Two thermocouples				X	X			Flux Loops included in design	Diagnostics will checkout the flux loops
Magnets	Inner PF	157	MAG- 7.3.j	Inner of Coils: PF-1c	12	1.1.3.3.5	Toroidally continuous passive structures shall be minimized to the extent that other design constraints permit				X					
Magnets	Inner PF	158	MAG- 7.3.k	Inner of Coils: of-1c	13	1.1.3.3.5	Each PF-1c coil shall have the following diagnostics mounted outside the ground insulation, but underneath any support slings or structures [4]: ● Two flux loops ● At least two thermocouples				X				Flux Loops included in design and d	Diagnostics will checkout and test the flux loops on Bench and part of PTP
Magnets	RWM	159	MAG- 8.3.a	RWM Coils	1	1.1.3.5	The RWM coils shall be formed from six approximately rectangular window-pane coils, located at the vessel midplane, and conformal to the vessel outer wall.			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Magnets	RWM	160	MAG- 8.3.b	RWM Coils	2	1.1.3.5	RWM coils shall be mounted outside the vessel, and may be mechanically restrained against the vessel.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	RWM	161	MAG- 8.3.b'	RWM Coils	3	1.1.3.5	Provision for relative expansion due to both coil operational Ohmic heating and vessel bakeout shall be made if the coils are mounted to the vessel.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	RWM	162	MAG- 8.3.c	RWM Coils	4	1.1.3.5	The area of the RWM coils shall be approximately 2.4 m 2 ,			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	RWM	163	MAG- 8.3.c'	RWM Coils	5	1.1.3.5	the areas of opposing coils shall be matched to within 5%.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	RWM	164	MAG- 8.3.d	RWM Coils	6	1.1.3.5	The RWM coils shall be capable of individual power feeds, or opposing coils should be capable of series or anti-series connections			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	RWM	165	MAG- 8.3.c'	RWM Coils	7	1.1.3.5	Electrical insulation design for the RWM coils, including turn insulation, ground insulation, as well as strike and creep distances of leads and fittings shall be conservatively designed based on a hipot test voltage of 2E+1.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	RWM	166	MAG- 8.3.c''	RWM Coils	8	1.1.3.5	For the RWM coil, E shall correspond to the maximum power supply line-to-line DC voltage. Numerical values are provided in Table 2-1.	Table 2-1.		X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	RWM	167	MAG- 8.4.a	RWM Coils	9	1.1.3.5	The coils shall be capable of 6 kA-turn operations, for 5 seconds, every 1200 seconds.		X	X						
Magnets	Bus Bar	168	MAG- 9.1.a	Bus Bar Systems	1	1.1.3.4	Bus bar systems shall provide electrical connections from coil terminals to the cabling from FCPC.				X	X			PCTS provides the location to interconnect all magnets with the Bus Bar System	PTP & ISTP
Magnets	Bus Bar	169	MAG- 9.3.a	Bus Bar Systems	2	1.1.3.4	The OH current feed shall be coaxial in design.				X					
Magnets	Bus Bar	170	MAG- 9.3.b	Bus Bar Systems	3	1.1.3.4	RWM current feeds shall allow individual feeds, or opposing coils should be capable of series or anti-series connections, with less than three hours to reconfigure the connections.			X				Subsystem is existing and not being modified as part of recovery scope		
Magnets	Bus Bar	171	MAG- 9.3.c	Bus Bar Systems	4	1.1.3.4	Current feeds to at the top of the machine shall accommodate the thermal growth of the casing during bakeout and of the TF inner bundle during bakeout and plasma operations		X				"NSTXU_1-1-3-4_CALC_100 PF1AU&1BU Bus Analysis NSTXU_1-1-3-4_CALC_101PF1AL&1BL Bus Analysis NSTXU_1-1-3-4_CALC_102 PF1CU Bus Analysis NSTXU_1-1-3-4_CALC_103 PF1CL Bus Analysis"			
Magnets	Bus Bar	172	MAG- 9.3.d	Bus Bar Systems	5	1.1.3.4	Grounding switches shall be installed in the test cell to enable grounding of all coil systems.			X				The grounding switches are existing components and once connected correct operation will be demonstrated		
Magnets	Bus Bar	173	MAG- 9.3.e	Bus Bar Systems	6	1.1.3.4	Structures shall be built to support bus runs to the midplane and upper level of the machine.				X			Bus Tower is existing and runs the conduit		

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Magnets	Bus Bar	174	MAG- 9.4.b	Bus Bar Systems	7	1.1.3.4	Thermal capacity of coil bus runs shall be consistent with the action integrals of the coils to which they are attached.		X				Lead with Bus Bars NSTX-U-CALC-55-10 PF-1cU Leads and Busbars NSTX-U-CALC-131-02 PF-1cL Leads and Busbar NSTX-U-CALC-55-08 NSTXU_1-1-3-4_CALC_100 PF1AU&1BU Bus Analysis NSTXU_1-1-3-4_CALC_101PF1AL&1BL Bus Analysis NSTXU_1-1-3-4_CALC_102 PF1CU Bus Analysis NSTXU_1-1-3-4_CALC_103 PF1CL Bus Analysis			
Magnets	Bus Bar	175	MAG- 9.4.d	Bus Bar Systems	8	1.1.3.4	Electrical insulation design for bus runs shall be conservatively designed based on a hipot test voltage equal to the hipot voltage of the coil to which they are attached. Numerical values are provided in Table 2-1.	Table 2-1.		X		X	NSTXU_1-1-3-4_CALC_100 PF1AU&1BU Bus Analysis NSTXU_1-1-3-4_CALC_101PF1AL&1BL Bus Analysis NSTXU_1-1-3-4_CALC_102 PF1CU Bus Analysis NSTXU_1-1-3-4_CALC_103 PF1CL Bus Analysis			Inner PF Prototype Evaluation Report for design verification (NSTX-U-REC-040) Hi-Pot Tests
PFCs	PFCs	**Plasma Facing Components**														
PFCs	PFCs	176	GRD- 6.1.1.1.1.a	Plasma Facing Components	1	1.1.1.1	The Plasma Facing Component (PFC) tiles shall consist of carbon-based materials designed to absorb the heat, particle, and photon flux from the plasma and heating systems, to minimize the influx of impurities to the plasma, and to withstand the electromagnetic forces associated with plasma disruption.		X			X	SFW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, OBD12: NSTX-U-CALC-11-22-00, OBD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			Tests conducted on prototype tiles
PFCs	PFCs	177	GRD- 6.1.1.1.1.b	Plasma Facing Components	2	1.1.1.1	PFC tiles shall be installed on the Center Stack casing, divertors, passive plates, and neutral beam armor.		X	X			SFW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, OBD12: NSTX-U-CALC-11-22-00, OBD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00	Passive Plates PFCS and Neutral Beam Armor will use existing tiles. Not in scope for recovery project		
PFCs	PFCs	178	GRD- 6.1.1.1.2.a	Plasma Facing Components	3	1.1.1.1	Plasma facing components shall be formed from fine-grain isotropic graphite or carbon-carbon composites.		X				SFW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, OBD12: NSTX-U-CALC-11-22-00, OBD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	179	GRD- 6.1.1.1.2.b	Plasma Facing Components	4	1.1.1.1	Tile surfaces may be designed to be non-axisymmetric (e.g. shaped in the toroidal direction) to avoid leading edges to meet heat flux requirements. Shaping shall be in accordance with the field polarities listed in Section 4.1.1.		X				SFW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, OBD12: NSTX-U-CALC-11-22-00, OBD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			

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PFCs	PFCs	180	GRD- 6.1.1.1.2.c	Plasma Facing Components	5	1.1.1.1	PFC tiles shall be classified as “critical components” for design evaluation per the definition given in the Structural Design Criteria		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	181	GRD- 6.1.1.1.2.d	Plasma Facing Components	6	1.1.1.1	Tile design shall be based on accommodation of 10 MW input power for 5 seconds duration with a 2400 second repetition rate and the baseline cooling methods (radiation, conduction, and baseline levels of heat extraction with ex-vessel water or He).		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	182	GRD- 6.1.1.1.2.e	Plasma Facing Components	7	1.1.1.1	"Heat extraction capability shall be installed in the tokamak core to allow an upgrade to a 1200 second repetition rate without perturbation to the implemented core design. See Table 4.1.5-2."	Table 4.1.5-2.	X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			NSTXU_1-1-1-1-1_PLAN_100
PFCs	PFCs	183	GRD- 6.1.1.1.2.f	Plasma Facing Components	8	1.1.1.1	PFCs shall be designed to accommodate independent or concurrent i) bakeout and ii) glow discharge cleaning or boronization.		X				NSTX-U-CALC-10-6-00			
PFCs	PFCs	184	GRD- 6.1.1.1.2.h	Plasma Facing Components	9	1.1.1.1	Sufficient number of tiles shall be instrumented with thermocouples to confidently assess their temperature during plasma and bakeout modes of operations.		X		X		FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00 Drawings: ED-1471, 9D-11556		The requirements are included in this matrix and are separately addressed RD-03	
PFCs	PFCs	185	GRD-6.1.1.2.3.2.a	Neutral Beam Armor	10	1.1.1.1.7	The neutral beam armor shall be designed to accept at least a single case with full energy and duration beam impingement from both beam lines, for any power & duration case listed in Table 4.1.3-1.			X				Subsystem is existing and not being modified as part of recovery scope		
PFCs	PFCs	186	GRD-6.1.1.2.3.2.b	Neutral Beam Armor	11	1.1.1.1.7	The neutral beam armor shall be designed to withstand all loads during operation due to dead weight, thermal, and electromagnetic effects.			X				Subsystem is existing and not being modified as part of recovery scope		
PFCs	PFCs	187	GRD-6.1.1.2.3.2.c	Neutral Beam Armor	12	1.1.1.1.7	The neutral beam armor shall have provision to bake the plasma facing components.			X				Subsystem is existing and not being modified as part of recovery scope		
PFCs	PFCs	188	PFC-2.1.a	General	1	1.1.1.1	All PFCs in NSTX-Upgrade shall be made from either fine grain isotropic graphite, or from other carbon based materials, for instance carbon-carbon composites, here referred to as CFCs.		X		X		FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
PFCs	PFCs	189	PFC-2.1.b	General	2	1.1.1.1	The exception to this is the RF antenna guard which can be made from boron nitride. The RF antenna guard shall not be regarded as a surface on which it is acceptable to intentionally limit the plasma.			X				Subsystem is existing and not being modified as part of recovery scope		
PFCs	PFCs	190	PFC-2.1.c	General	3	1.1.1.1	For isotropic graphite and carbon-carbon composites, the brittle materials qualification shall be used, as per the structural design criterion [7], where PFCs are defined as critical components.		X			X	FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			Vendor Tests and Test reports
PFCs	PFCs	191	PFC-2.1.e	General	4	1.1.1.1	Non-ferritic materials should be used for all fasteners. SS316, A286, or Inconel are preferred. Magnetic permeability requirements shall be adhered to as per GRD [3]. 1	as per GRD [3]. 1	X		X		FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00 PFC drawings address all materials not in calculations			
PFCs	PFCs	192	PFC-2.2.a	General	5	1.1.1.1	Disruption mechanical and thermal loads shall be computed as per the NSTX-U Disruption Specification		X		X		FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00		RD-003 provides the disruption requirements	
PFCs	PFCs	193	PFC-3.1.a	Thermal and Shaping	6	1.1.1.1	The design scenarios described in sections below shall be qualified for repetition rate of ≤ 2400 second repetition rate with the base cooling. Baseline cooling is defined in Reference [9].		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	194	PFC-3.1.b	Thermal and Shaping	7	1.1.1.1	A 1200 second repetition rate shall be possible with application of additional cooling, but no modifications to the tokamak core.		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00 NSTX-U-CALC-10-6-00			

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PFCs	PFCs	195	PFC-3.1.c	Thermal and Shaping	8	1.1.1.1	Tiles shall be designed so that the peak surface temperature of the wetted top face, away from local peaks at the edges (as defined in 3.1-d), at the end of the pulse shall not exceed 1600 o C [10]; disruption heating need not be included in this consideration.		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00 NSTX-U-CALC-10-6-00			
PFCs	PFCs	196	PFC-3.1.d	Thermal and Shaping	9	1.1.1.1	For forward helicity, tiles shall be designed so that the edge temperatures of local surface features (e.g. access holes) or edge features of non-shaped tiles shall not exceed 2000 o C and meet 3.1-c at distance of 2 mm from the edge/feature ; disruption heating need not be included in this consideration.		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	197	PFC-3.1.e	Thermal and Shaping	10	1.1.1.1	Reversed helicity cases shall be held to the same temperature limit as edges (see 3.1-d).		X				BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00,			
PFCs	PFCs	198	PFC-3.1.i	Thermal and Shaping	11	1.1.1.1	When tile surface shaping (see 3.1-h) is utilized to prevent edge heating in forward helicity, edges across poloidal 3 gaps shall be shadowed to the maximum angle listed in tables in section 4 below.		X				BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00,			
PFCs	PFCs	199	PFC-3.1.l	Thermal and Shaping	12	1.1.1.1	Emissivity of 0.7 shall be used for calculations		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00 NSTX-U-CALC-10-6-00			
PFCs	PFCs	200	PFC-3.1.m	Thermal and Shaping	13	1.1.1.1	Designs for tile shaping features shall accommodate a reduction in fishscale angle consistent with a reduction in step height, Δd , of 0.003" over the their lifetime and still maintain shadowing.		X				BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00,			
PFCs	PFCs	201	PFC-3.2.a	Bakeout	14	1.1.1.1	All in-vessel graphite, including that used for PFCs, shall be capable of being baked to at least 350 C, with the note that the higher He inlet temperatures may result in some tiles exceeding this temperature by some 10s of degrees.		X				NSTU-X-CALC-10-6-00			
PFCs	PFCs	202	PFC-3.3.b	PFC Locations	15	1.1.1.1	The center radius of the IBDH/OBDR1 interface shall be at R=59.5 +/- 0.5 cm.		X		X		Part of drawing; radius identified			
PFCs	PFCs	203	PFC-3.3.d	PFC Locations	16	1.1.1.1	Regions on the casing and PFC mounting surfaces not protected from direct lines of sight shall be minimized. Any toroidally running gap wider than 1 mm must be evaluated and approved during the design review process.	x	X		X		FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			

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PFCs	PFCs	204	PFC-3.3.e	PFC Locations	17	1.1.1.1	PFC and mounting structure designs shall allow, coordinated with magnet and vessel structure adjustability, for sufficient positional adjustability to meet tolerances for PFCs relative to magnets, as described in Ref. [11] and derived documents.		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	205	PFC-3.3.f	PFC Locations	18	1.1.1.1	For each region, field lines impinging on PFCs at angles 1.5 times the maximum given in Tables 4.2.1-4.5.1 shall not impact fasteners or other metallic components used for securing tiles. Table 3.3.1	Tables 4.2.1-4.5.1	X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	206	PFC-3.4.a	Diagnostic	19	1.1.1.1	PFCs shall accommodate the following types of sensors : ● Langmuir probes ● Mirnov coils ● Rogowski coils ● Shunt tiles ● Thermocouples	x	X		X		FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	207	PFC-3.5.a	Install and Maintenance	20	1.1.1.1	No module or single component installed by a single person shall weigh more than 50 lbs, per OSHA recommendation, unless lifting and handling equipment and procedures are specially developed.		X				Extracted from drawings; defined during FDR presentation			
PFCs	PFCs	208	PFC-3.5.d	Install and Maintenance	21	1.1.1.1	The design shall be such that removal replacement of any tile shall not mandate the removal of the center-stack or outboard divertor copper/stainless structure.		X	X			Defined during FDR presentation			
PFCs	PFCs	209	PFC-3.5.e	Install and Maintenance	22	1.1.1.1	An assembly sequence shall be provided with the design that takes account of machine assembly (including CS insertion to the machine), wire management, and any industrial hygiene and health physics concerns.	x		X	X					
PFCs	PFCs	210	PFC-3.5.f	Install and Maintenance	23	1.1.1.1	No permanently installed component on the outboard divertor shall extend inside the radius of the main vessel flanges (R vessel_flange =23.625”),		X		X		Part of drawing; radius needs to be identified			
PFCs	PFCs	211	PFC-3.5.f'	Install and Maintenance	24	1.1.1.1	No permanently installed component on the CS shall extend more than ¼” beyond the radius of the CS horizontal flanges (R flange =21.875”, for R max =R flange +1/4 = 22.125”).		X		X		Part of drawing; radius needs to be identified			
PFCs	PFCs	212	PFC-3.6.a	In Vessel Gas Delivery	25	1.1.1.1	Two gas fuelling outlets shall be provided near the CS midplane for core fuelling.		X		X		Part of FDR package and ICD			
PFCs	PFCs	213	PFC-3.6.b	In Vessel Gas Delivery	26	1.1.1.1	One gas fuelling outlet shall be provided near the CSAS tiles on the upper portion of the CS for core fuelling.		X		X		Part of FDR package and ICD			
PFCs	PFCs	214	PFC-3.6.c	In Vessel Gas Delivery	27	1.1.1.1	Two gas fuelling outlets shall be provided near the corner of the row 1 tiles in the outboard divertor for divertor fuelling.		X		X		Part of FDR package and ICD			

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PFCs	PFCs	215	PFC-3.6.d	In Vessel Gas Delivery	28	1.1.1.1	Two gas fueling lines, with outlets near the upper and lower IBDH/IBDV interfaces, shall be provided for private flux region divertor fuelling.		X		X		Part of FDR package and ICD			
PFCs	PFCs	216	PFC-4.0.d	In Vessel Gas Delivery	29	1.1.1.1	To judge if PFCs satisfy requirements, heat fluxes shall be applied as described in Tables 4.2-1 through 4.5-1 over the given PFC surface, for the given angles of incidence for the listed duration. The effects of tile shaping, surface features (e.g. fish-scaling and bolt-holes), and fabrication and assembly tolerances enhance the nominal, axisymmetric, heat flux and should be included to satisfy requirements.	Tables 4.2-1 through 4.5-1	X				NSTX-U CALC-11-28-00 FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	217	PFC-4.0.d'	In Vessel Gas Delivery	30	1.1.1.1	This shall assume axisymmetric mounting surfaces and exclude heat flux enhancements due to coil misalignments and other non-axisymmetric magnetic effects (e.g. coil leads, bus work).		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	218	PFC-4.0.e	In Vessel Gas Delivery	31	1.1.1.1	To judge operational flexibility for PFCs that are shown to reach the temperature limit (defined in Section 3.1) prior to reaching the stress allowable (2.1-c), the magnitude of the heat flux, applied as per Tables 4.2-1 through 4.4-1, and resulting surface temperature that leads to the PFCs reaching their stress allowable shall also be estimated and included in design reports or calculations.	Tables 4.2-1 through 4.4-1	X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	219	PFC-4.1.a	CSFW	32	1.1.1.1.1	The radial step between adjacent tiles shall not exceed 0.035”. There is not an expectation that eccentricities in the casing itself will be compensated out by this tile installation.		X				Addressed in PFC drawings			
PFCs	PFCs	220	PFC-4.2.a	Horizontal Target	33	1.1.1.1.4	Heat flux requirements on this surface are given in Table 4.2-1.	Table 4.2-1.	X				IBDH: NSTX-U-CALC-11-18-00,			
PFCs	PFCs	221	PFC-4.3.a	Vertical Target	34	1.1.1.1	Heat flux requirements on the vertical target are as per Table 4.3-1.	Table 4.3-1.	X				BDV: NSTX-U-CALC-11-19-00,			
PFCs	PFCs	222	PFC-4.4.b	Outboard Divertor	1	1.1.1.1.5	The requirements so derived are shown in Tables 4.4-1 through 4.4-3 [4,6]	Tables 4.4-1 through 4.4-3 [4,6]	X				BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	223	PFC-4.4.c	Outboard Divertor	2	1.1.1.1.5	Field line impingement on metal components at diagnostic cut-outs shall be prevented by custom protective tile features.		X				BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	224	PFC-4.4.d	Outboard Divertor	3	1.1.1.1.5	Diagnostic cut-outs (defined in 4.4-f) for R4/R5 shall be included in the lower outboard divertor at Bays: B, C, E, F, G, H, I, J and K		X				OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	225	PFC-4.4.e	Outboard Divertor	4	1.1.1.1.5	Diagnostic cut-outs (defined in 4.4-f) for R4/R5 shall be included in the upper outboard divertor at Bays: B, C, D, E, F, G, H, I, J, K and L		X				OBD4: NSTX-U-CALC-11-16-00, BD5: NSTX-U-CALC-11-12-00,			

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PFCs	PFCs	226	PFC-4.4.g	Outboard Divertor	5	1.1.1.1.5	The diagnostic cutouts in general shall not intrude on the outboard diverter row-3 region.		X				OBD3: NSTX-U-CALC-11-14-00,			
PFCs	PFCs	227	PFC-4.4.i	Outboard Divertor	6	1.1.1.1.5	Specialized diagnostic cutouts facilitating the poloidal CHERS and related diagnostics shall be included between Bay-A and Bay-L in the lower and upper outboard divertor.		X				OBD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
PFCs	PFCs	228	PFC-4.5.a	CSAS	1	1.1.1.1.2	Heat fluxes for the CSAS are as per Ref. [6], and provided in Table 4.5-1.	Table 4.5-1	X				CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00			
PFCs	PFCs	229	PFC-4.6.a	Passive Plates	1	1.1.1.1.6	The passive plate PFCs shall be qualified to a normal heat flux implied by the 100% radiated power scenario from the GRD.			X				Subsystem is existing and not being modified as part of recovery scope		
PFCs	PFCs	230	PFC-4.8.a	NB Armor	1	1.1.1.1.7	The neutral beam armor shall tolerate radiative normal heat fluxes implied by the 100% radiated power scenario from the GRD.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	**Vacuum Vessel & Internal Hardware**														
VVIH	Passive Plates	231	GRD-6.1.1.2.1.1.a	Passive Plates	1	1.1.1.2.1	The passive plates shall consist of four rows of copper stabilizing plates, two above the midplane and two below the midplane.				X				The capability is existing and can be verified upon re-installation.	
VVIH	Passive Plates	232	GRD-6.1.1.2.1.1.b	Passive Plates	2	1.1.1.2.1	There shall be 12 copper plates per row.	6.1.1.2.1.2 Engineering Requirements			X				The capability is existing and can be verified upon re-installation.	
VVIH	Passive Plates	233	GRD-6.1.1.2.1.1.c	Passive Plates	3	1.1.1.2.1	The plate thickness shall be sized to accomplish stabilization of n=0 and n=1 plasma instabilities (here, n is the toroidal mode number).			X						
VVIH	Passive Plates	234	GRD-6.1.1.2.1.2.a	Passive Plates	4	1.1.1.2.1	The passive plates and their mounting structures shall be designed to withstand all loads during operation due to dead-weight, thermal gradient, and electromagnetic effects.		X				NSTXU_1-1-3-4_CALC_104	PF4 Bus Analysis		
VVIH	Passive Plates	235	GRD-6.1.1.2.1.2.b	Passive Plates	5	1.1.1.2.1	The passive plate brackets shall have provision to bake their carbon plasma facing components.			X				The passive plates are being re-used from a previous design and have been designed to address the Bakeout.		
VVIH	OBD	236	GRD-6.1.1.2.2.1.a	Outboard Divertor Structures	6	1.1.1.2.2	The outboard divertors shall provide a mechanical structure on which to mount plasma facing components that protect the lower and upper sections of the vacuum vessel from direct plasma impingement.			X						
VVIH	OBD	237	GRD-6.1.1.2.2.2.a	Outboard Divertor Structures	7	1.1.1.2.2	The outboard divertors shall be designed to withstand all loads during operation due to dead-weight,thermal, and electromagnetic effects.			X						
VVIH	OBD	238	GRD-6.1.1.2.2.2.b	Outboard Divertor Structures	8	1.1.1.2.2	The outboard divertors shall have provision to bake any carbon plasma facing components.		X	X			Global Analysis calculation considers the OBD	Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	239	GRD-6.1.1.2.3.1.a	Neutral Beam Armor	9	1.1.1.2.3	The neutral beam armor shall provide a mechanical structure on which to mount graphite plasma facing components that protect the vessel wall from direct impingement by the neutral beam			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	240	GRD- 6.1.2.1.a	Vacuum Vessel and Support Structure	10	1.1.2.1	The outer vacuum vessel shall, along with the Center Stack casing, provide the primary vacuum boundary.					X				Vacuum Pump tests
VVIH	VVIH	241	GRD- 6.1.2.1.b	Vacuum Vessel and Support Structure	11	1.1.2.3	The outer vacuum vessel shall provide the primary structural support of the outer TF legs and outer PF coils.			X				Subsystem is existing and not being modified as part of recovery scope		

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VVIH	VVIH	242	GRD- 6.1.2.1.c	Vacuum Vessel and Support Structure	12	1.1.2.1	The vacuum vessel shall support in-vessel components such as the neutral beam armor, the passive plates, the RF antenna, and the outboard divertors.		X	X			Passive Plate FDR addresses the structural suypoprt for the passive plate mpints that that are currently welded to teh vessel wall	Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	243	GRD- 6.1.2.2.a	Vacuum Vessel and Support Structure	13	1.1.2.1	The outer vacuum vessel and support structure shall be designed to withstand all loads during normal operation due to seismic loads, dead weight, vacuum, thermal, normal electromagnetic, and disruption electromagnetic.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	244	GRD- 6.1.2.2.b	Vacuum Vessel and Support Structure	14	1.1.2.1	The outer vacuum vessel and support structure shall be designed to withstand all loads during bakeout due to seismic loads, dead weight, vacuum, and thermal conditions.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	245	GRD- 6.1.2.2.c	Vacuum Vessel and Support Structure	15	1.1.2.1	The outer of and TF outer leg support structures shall have allowance for all thermal scenarios, including coil thermal expansion during operations and vessel thermal expansion during bakeout			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	246	GRD- 6.1.2.2.d	Vacuum Vessel and Support Structure	16	1.1.2.1	The Center Stack casing (CSC) shall be mechanically connected, but electrically isolated, at the upper interface between the CSC and the outer vacuum vessel. Insulation shall be designed to withstand a one minute AC hipot test at 2E+1=1kV AC rms.					X				Hi-Pot Testing Conducted to ensure system is
VVIH	VVIH	247	GRD- 6.1.2.2.e	Vacuum Vessel and Support Structure	17	1.1.2.1	The CSC and outer vacuum vessel shall not include any ceramic insulator feature at their lower interface (as was the case for the original versions of NSTX and NSTX-U).		X		X		MCS FDR lower cermic break removed from design		MCS FDR lower cermic break removed from design	
VVIH	VVIH	248	GRD- 6.1.2.2.f	Vacuum Vessel and Support Structure	18	1.1.2.1	The vacuum vessel shall accommodate two TFTR neutral beam lines at the desired tangency radii described in Section 6.2.4.2.	radii described in Section 6.2.4.2.		X	X			Subsystem is existing and not being modified as part of recovery scope	Once connected the connection will be inspected	
VVIH	Center Sta	249	GRD- 6.1.3.4.1.a	Center Stack Assembly and Ceramic Break	19	1.1.3.3	The Center Stack Assembly shall consist of the OH coil, TF inner legs, inner of coils and their supports,Center Stack Casing, ceramic break assembly, pedestal, and inboard PFC tiles.				X				Part of the Centyer Stack and MCS Design	
VVIH	Center Sta	250	GRD- 6.1.3.4.2.a	Center Stack Assembly and Ceramic Break	20	1.1.3.3	The Center Stack Assembly shall be designed in such a way that it can be extracted whole or in parts from the NSTX-U outer vessel.		X			X	Part of the CSC FDR - Drawings show lift points			
VVIH	Center Sta	251	GRD- 6.1.3.4.2.b	Center Stack Assembly and Ceramic Break	21	1.1.3.3	The pedestal shall support the CS assembly against gravity, and share in the transfer of seismic and electromagnetic loads.		X				NSTXU_1-1-3_CALC_100 Sections 11 & 12			
VVIH	Center Sta	252	GRD- 6.1.3.4.2.c	Center Stack Assembly and Ceramic Break	22	1.1.3.3.6	The CS casing shall provide structural support for PFCs which protect it, including against disruption loads. This support may be via intermediate structures.		X				NSTX-U-CALC-23-00 NSTX U-CALC-12-20-00			
VVIH	Center Sta	253	GRD- 6.1.3.4.2.d	Center Stack Assembly and Ceramic Break	23	1.1.3.3	The assembly shall include provision for bakeout of the inboard PFC tiles and for cooling during plasma operations, including electrical isolation at the upper mechanical interface to the vacuum vessel.		X				NSTX-U-CALC-23-00			
VVIH	Center Sta	254	GRD- 6.1.3.4.2.e	Center Stack Assembly and Ceramic Break	24	1.1.3.3	Appropriate thermal isolation shall be provided between coils in the Center Stack assembly and any components that achieve the bakeout temperature.		X				NSTX-U-CALC-10-6-01			

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VVIH	Center Sta	255	GRD- 6.1.3.4.2.f	Center Stack Assembly and Ceramic Break	25	1.1.3.3	All vacuum seals associated with the mechanical interface between the CS casing and the vacuum vessel shall use either i) double O-rings with pumped interspaces or ii) welded lip seals.		X			X	Part of the IVPS & MCS FDR			Vacuum Testing as part of pump down
VVIH	Center Sta	256	GRD- 6.1.3.4.2.f	Center Stack Assembly and Ceramic Break	26	1.1.3.3	The components of the CS assembly shall be composed of parts that can be lifted into place by the existing NSTX-U Test Cell crane. It is desired that these lifts be accomplished without perturbation tothe south shield wall.		X			X	Part of the CSC FDR			Lift procedures
VVIH	VVIH	257	VVIH- 2.b	General	1	1.1.2	Permeability requirements are as per the NSTX-U Magnetic Permeability Requirements [2], while mechanical design shall be governed by the NSTX-U Structural Design Criteria [3].		X				NSTX-U-CALC-23-00			
VVIH	VVIH	258	VVIH- 2.d	General	2	1.1.2.1	Up-down symmetry of the vessel shall be maintained to the greatest extent possible.		X		X		MCS FDR tolerance analysis		Reassmebly metrology	
VVIH	VVIH	259	VVIH- 2.e	General	3	1.1.2	Toroidally continuous passive structures shall be minimized to the extent that other design constraints permit, and shall be made of high resistivity materials where possible.			X				Design chnaged eliminating jumpers. Addressed during Passive Plate FDR.		
VVIH	VVIH	260	VVIH- 2.f	General	4	1.1.2	All viton O-rings shall be maintained under 180 deg C under all thermal scenarios (bakeout, plasma operations,...)		X				Manufacturers Spec, IVPS FDR			
VVIH	VVIH	261	VVIH- 2.g	General	5	1.1.2	All materials utilized within the primary vacuum boundary shall be designed to withstand the anticipated temperatures during plasma and bakeout operation.		X				Manufacturers Spec, Polar Region PDR, IVPS FDR			
VVIH	VVIH	262	VVIH- 2.h	General	6	1.1.2	All materials at risk of exposure to lithium films shall be approved for use under that condition.									
VVIH	VVIH	263	VVIH- 2.i	General	7	1.1.2	As noted in the GRD [1], all components shall be designed for of & TF coil currents up to 100% of their ampere-turns, with either polarity of OH current at 100% of its ampere-turns and with Ip=0 or ≠ 0. If this is not possible, excep on may be taken as per the GRD									
VVIH	VVIH	264	VVIH- 2.j	General	8	1.1.2	All pressure systems shall conform to PPPL standard ES-MECH-015. [7]									
VVIH	VVIH	265	VVIH- 2.l	General	9	1.1.2	Systems that are thermally cycled during bakeout shall be designed consistent with the guidance in Ref. [9] Auxiliary Systems		X				Thermal analysis is support of the MCS FDR			
VVIH	VVIH	266	VVIH- 3.2.b	Vacuum Vessel, Ports, and Vessel Legs	1	1.1.2.1	The VV & support structures shall be designed to withstand all loads during normal operation as described in Ref [3]. NSTX Structural Design Criteria		X	X			CSC and MCS FDRs provide the various system loads	Existing VV loads not changing nor being updated.		
VVIH	VVIH	267	VVIH- 3.2.c	Vacuum Vessel, Ports, and Vessel Legs	2	1.1.2.1	The VV & support structures shall be designed to withstand all loads during bakeout as described in Ref. [3]. NSTX Structural Design Criteria									
VVIH	VVIH	268	VVIH- 3.3.a	Vacuum Vessel, Ports, and Vessel Legs	3	1.1.2.1	The vacuum vessel shall be oriented so that the TF inner legs have a vertical orientation.		X	X	X		Alignment Tolerance Stack	Vacuum Vessel not chnaging more precision on Inner TF coiils and CSC alignment with vessel	Metrology	
VVIH	VVIH	269	VVIH- 3.3.c	Vacuum Vessel, Ports, and Vessel Legs	4	1.1.2.1	The vessel proper (cylinder and domes) shall be constructed of 304 stainless steel and have a nominal wall thickness of 5/8 inch.			X				Subsystem is existing and not being modified as part of recovery scope		

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VVIH	VVIH	270	VVIH- 3.3.c'	Vacuum Vessel, Ports, and Vessel Legs	5	1.1.2.1	Additional ports and features associated with the vessel shall by default be fabricated from 316 SS or materials of similar magnetic permeability [2], unless specific dispensation is given.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	271	VVIH- 3.3.d	Vacuum Vessel, Ports, and Vessel Legs	6	1.1.2.1	The cylindrical sec on of the vessel shall have a sufficient number of large ports and smaller ports to accommodate plasma heating, diagnostic and pumping configuration requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	272	VVIH- 3.3.e	Vacuum Vessel, Ports, and Vessel Legs	7	1.1.2.1	The cylindrical section shall include ports to accommodate the use of two TFTR Neutral Beam Injectors injecting at the device midplane.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	273	VVIH- 3.3.e'	Vacuum Vessel, Ports, and Vessel Legs	8	1.1.2.1	The first injector shall have tangency radii of R tan =[50,60,70] cm, while the second injector shall have tangency radii of R tan = [110,120,130] cm			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	274	VVIH- 3.3.f	Vacuum Vessel, Ports, and Vessel Legs	9	1.1.2.1	The lower dome of the outer section of the Vacuum Vessel shall be electrically grounded via three approximately toroidally symmetric connections to a single point connection to the facility ground, which is designed to permit opening for the purpose of testing of the integrity of electrical isolation between the Vacuum Vessel and other components and structures.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	275	VVIH- 3.3.f'	Vacuum Vessel, Ports, and Vessel Legs	10	1.1.2.1	Isolation shall be rated to withstand a one minute AC hipot test at 2kV rms.			X		X		Subsystem is existing and not being modified as part of recovery scope		Hi-pot Testing
VVIH	VVIH	276	VVIH- 3.3.f''	Vacuum Vessel, Ports, and Vessel Legs	11	1.1.2.1	Grounding connections shall have provision for monitoring for ground faults.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	277	VVIH- 3.3.g	Vacuum Vessel, Ports, and Vessel Legs	12	1.1.2.1	All vacuum vessel flanges shall provide a vacuum seal compatible with high vacuum (pressure < 2x10 -8 torr following bakeout) and bakeout conditions [9].			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	278	VVIH- 3.3.h	Vacuum Vessel, Ports, and Vessel Legs	13	1.1.2.3	The vacuum vessel support legs shall support the vacuum vessel and all components attached to the vessel including in-vessel structures, plasma facing components, TF outer legs, outer of coils, and other components mounted to the vessel.		X	X			MCS FDR provides teh supports from the pedestal to the center stack and inner coils	Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	279	VVIH- 3.3.j	Vacuum Vessel, Ports, and Vessel Legs	14	1.1.2.1	Three approximately toroidally symmetric connection points shall be provided at the top and bottom of the vacuum vessel.									
VVIH	VVIH	280	VVIH- 3.3.j'	Vacuum Vessel, Ports, and Vessel Legs	15	1.1.2.1	Connections shall be sized to carry the current for arbitrary duration during bakeout heating of the center stack casing.									
VVIH	VVIH	281	VVIH- 3.3.j''	Vacuum Vessel, Ports, and Vessel Legs	16	1.1.2.1	A total casing current of 8 kA shall be assumed for the purposes of design.		X				7KA and 8Ka have been used in the Global thermal Model			
VVIH	VVIH	282	VVIH- 3.3.h'	Vacuum Vessel, Ports, and Vessel Legs	17	1.1.2.1	If these electrical connections remain in place during operations, then their design shall accommodate loads during operations, including disruption loads									
VVIH	Passive Plates	283	VVIH- 4.2.a	Passive Plates	1	1.1.1.2.1	The passive plates shall be made of high strength copper material, i.e. CuCrZr.			X						

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VVIH	Passive Plates	284	VVIH- 4.3.a	Passive Plates	2	1.1.1.2.1	The passive plates shall consist of primary (closest to midplane) and secondary (furthest from midplane) groupings, one set above the midplane and one set below the midplane of the NSTX-U device.				X				The capability is existing and can be verified upon re-installation.	
VVIH	Passive Plates	285	VVIH- 4.3.b	Passive Plates	3	1.1.1.2.1	There shall be 12 passive plates per each of the four rows, for a total of 48 plates.				X				The capability is existing and can be verified upon re-installation.	
VVIH	Passive Plates	286	VVIH- 4.3.c	Passive Plates	4	1.1.1.2.1	Each plate shall be made up of a series of ½" thick conically shaped copper plates.				X				The capability is existing and can be verified upon re-installation.	
VVIH	Passive Plates	287	VVIH- 4.3.d	Passive Plates	5	1.1.1.2.1	The passive plates shall be mounted to brackets extending from the outer vacuum vessel cylinder, and will be located from machined surfaces on these brackets.		X	X			Passive Plate FDR ddresses the mounting fixures	Current passive plate welds are not being modified as part of recovery		
VVIH	Passive Plates	288	VVIH- 4.3.e	Passive Plates	6	1.1.1.2.1	The passive plates and their mounting structures shall be designed to withstand all loads during operation and bakeout as per Reference [3] NSTX Structural Design Criteria		X				FDR Analyses			
VVIH	Passive Plates	289	VVIH- 4.3.f	Passive Plates	7	1.1.1.2.1	The connections shall contain provisions to facilitate removal of individual plates for modification to accommodate access for future diagnostic upgrades.			X				Plates have already been removed and has been demonstrated. The reassembly will demonstrate assembly		
VVIH	Passive Plates	290	VVIH- 4.3.f'	Passive Plates	8	1.1.1.2.1	The passive plates shall be electrically connected to the vessel via their mounting structures.		X				FDR Copper Plate Analysis			
VVIH	Passive Plates	291	VVIH- 4.3.g	Passive Plates	9	1.1.1.2.1	The plates shall have a well defined and reliable route for currents to pass through the plates to their mounting structures, on both toroidal ends of the plate.		X				FDR Analyses related to next requirement			
VVIH	Passive Plates	292	VVIH- 4.3.h	Passive Plates	10	1.1.1.2.1	At least one electrical connection mechanism shall exist between the plate/bracket combination and the weld ears at each end of the plate to facilitate the requirement in g).		X				FDR Analyses			
VVIH	Passive Plates	293	VVIH- 4.3.l	Passive Plates	11	1.1.1.2.1	The plate support features shall be traced with SS tubing to facilitate bakeout of the PFCs on the passive plate surface.		X	X			FDR Analyses HE Tube Mounts Only			
VVIH	Passive Plates	294	VVIH- 4.3.m	Passive Plates	12	1.1.1.2.1	The nominal locations of the plate front surface shall be as in Table 4.3-1 and Figure 4.3-1. Deviations of up to 1 cm in the average radius are acceptable, with deviations of +/- 0.5 cm from that average allowed.	Table 4.3-1 and Figure 4.3-1	X	X	X		Passive Plate FDR design focuses on mounting hardware	The Passive plate locations exist and are not being modified as part of recovery	Inspect as part of system reassmebly	
VVIH	Passive Plates	295	VVIH- 4.4.a	Passive Plates	13	1.1.1.2.1	The trace tubing shall be rated for the temperature (450 C) and pressure (300 PSIG) of the bakeout helium system			X				Tubes already designed and installed to meet system requirements		
VVIH	OBD	296	VVIH- 5.1.a	Outboard Divertor Structures	1	1.1.1.2.2	This power handling surface shall be graphite tiles,			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	OBD	297	VVIH- 5.3.a	Outboard Divertor Structures	2	1.1.1.2.2	The outboard divertor area strike plates shall consist of segmented upper and lower toroidal ring assemblies, bridged by copper plates which are then covered by protective tiles.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	OBD	298	VVIH- 5.3.b	Outboard Divertor Structures	3	1.1.1.2.2	These ring assemblies shall be mounted, on the vacuum side, to the two vacuum vessel domes, concentric to the center stack.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	OBD	299	VVIH- 5.3.c	Outboard Divertor Structures	4	1.1.1.2.2	The outboard divertor plates shall be traced with stainless steel tubing for active temperature control during bakeout and, as a poten al future upgrade, during operation.			X				Subsystem is existing and not being modified as part of recovery scope		

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VVIH	OBD	300	VVIH- 5.3.d	Outboard Divertor Structures	5	1.1.1.2.2	There shall be standard cutouts in the ring and copper plate assemblies at each vertical dome port to allow for diagnostic views. Some diagnostics may need larger or customized cutouts.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	OBD	301	VVIH- 5.3.e	Outboard Divertor Structures	6	1.1.1.2.2	The dimension of the divertor top surface shall designed as in Table 5.3-1	Table 5.3-1		X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	OBD	302	VVIH- 5.3.f	Outboard Divertor Structures	7	1.1.1.2.2	The outboard divertors and trace tubing shall be designed to withstand all loads during operation as elaborated in Ref. [3].			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	OBD	303	VVIH- 5.3.g	Outboard Divertor Structures	8	1.1.1.2.2	No permanently installed component on the outboard divertor shall extend inside the radius of the main vessel flanges (R vessel_flange =23.625"),			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	OBD	304	VVIH- 5.4.a	Outboard Divertor Structures	9	1.1.1.2.2	The trace tubing shall be rated for the maximum temperature (450 C) and pressure (300 PSIG) of the hot helium system.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	305	VVIH- 6.1.a	Neutral Beam Armor Mechanical Structures	1	1.1.1.2.3	This power handling surface shall be graphite tiles			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	306	VVIH- 6.3.a	Neutral Beam Armor Mechanical Structures	2	1.1.1.2.3	The armor mechanical structures shall be supported from the vessel wall.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	307	VVIH- 6.3.b	Neutral Beam Armor Mechanical Structures	3	1.1.1.2.3	The armor mechanical structures shall use the midplane port at Bay H for electrical and fluid or gas feedthroughs for the armor.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	308	VVIH- 6.3.c	Neutral Beam Armor Mechanical Structures	4	1.1.1.2.3	The armor mechanical structures shall have provision for mounting graphite tiles facing the plasma and neutral beam.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	309	VVIH- 6.3.d	Neutral Beam Armor Mechanical Structures	5	1.1.1.2.3	The armor mechanical structures shall have provision to allow the MSE-LIF diagnostic neutral beam to pass through into the plasma.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	310	VVIH- 6.3.e	Neutral Beam Armor Mechanical Structures	6	1.1.1.2.3	The armor shall be traced with stainless steel tubing for active temperature control during bakeout and operation.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	311	VVIH- 6.3.f	Neutral Beam Armor Mechanical Structures	7	1.1.1.2.3	The armor shall be designed to withstand all loads during operation as described in Ref [3]. NSTX Structural Design Criteria			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	312	VVIH- 6.4.a	Neutral Beam Armor Mechanical Structures	8	1.1.1.2.3	Armor shall be designed to absorb a full duration and full energy or full power pulse from all ion sources simultaneously, without damage to the vessel or underlying metallic structures. The beam energy vs. voltage is described in the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	313	VVIH- 6.4.b	Neutral Beam Armor Mechanical Structures	9	1.1.1.2.3	Trace tubing shall facilitate bakeout of the PFC tiles on the armor to > 300 C.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	NB Armor	314	VVIH- 6.4.c	Neutral Beam Armor Mechanical Structures	10	1.1.1.2.3	Trace tubing used in the neutral beam armor heating/cooling loops shall be rated for the maximum temperature and pressure of the hot helium system (450 C & 300 PSI).			X				Subsystem is existing and not being modified as part of recovery scope		

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VVIH	In-Vessel I	315	VVIH- 7.3.a	In-Vessel Heating/Cooling Tubing	1	1.3.3.1.3	The in-vessel heating/cooling tubes shall interface to the hot helium vessel feedthroughs [9].			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	In-Vessel I	316	VVIH- 7.3.b	In-Vessel Heating/Cooling Tubing	2	1.3.3.1.3	Trace tubing shall convey hot helium to the following structures, for purposes of elevating their temperature to bake out PFC tiles1: ● Primary passive plate brackets ● Secondary passive plate brackets ● Outboard divertor structures		X	X			Helium tubing structural design NSTXU_1_1_1_2_1_CALC_051 Helium Tube Structural Analysis	Subsystem is existing and not being modified as part of recovery scope.		
VVIH	In-Vessel I	317	VVIH- 7.4.a	In-Vessel Heating/Cooling Tubing	3	1.3.3.1.3	Tubing shall be rated for the maximum temperature and pressure of the hot helium system (450 C and 300 PSI).		X				NSTX-U-CALC-10-6-00 NSTX-U Center Stack Casing Heating/Cooling Final Design Review, Heat Transfer Tube (HTT) and Heat Transfer Plate (HTP), Oct. 24, 2018			
VVIH	In-Vessel I	318	VVIH- 7.4.b	In-Vessel Heating/Cooling Tubing	4	1.3.3.1.3	Tubing shall accommodate all load cases during operations and bakeout as described in Ref. [3].		X				NSTX-U-CALC-10-7-00, NSTX-U-CALC-12-25-00, NSTX-U Center Stack Casing Heating/Cooling Final Design Review, Heat Transfer Tube (HTT) and Heat Transfer Plate (HTP), Oct. 24, 2018			
VVIH	In-Vessel I	319	VVIH- 7.4.c	In-Vessel Heating/Cooling Tubing	5	1.3.3.1.3	Tubes shall be leak-tight as per GRD.		X		X		HTT/HTP FDR		Part of reassembly	
VVIH	VVIH	320	VVIH- 8.3.a	Vessel, Passive Plate, Outboard Divertor and In-Vessel Tubing Thermocouples	1	1.1.2.2	The vessel thermocouples shall be electrically isolated from the vessel.		X			X	PFC Diagnostics FDR			Verify design through test
VVIH	VVIH	321	VVIH- 8.3.b	Vessel, Passive Plate, Outboard Divertor and In-Vessel Tubing Thermocouples	2	1.1.2.2	Within the constraints provided by the physical features and geometry of the vessel, the vessel thermocouples shall be uniformly distributed on the vessel surface.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	VVIH	322	VVIH- 8.3.c	Vessel, Passive Plate, Outboard Divertor and In-Vessel Tubing Thermocouples	3	1.1.2.2	The passive plate thermocouples shall be located on the back sides of selected plates (facing away from the plasma)			X				Subsystem is existing and not being modified as part of recovery scope. Drawing ED1471 provides cabling for the Diagnostics including passive plates. Also athe passive plate design review a presentation was prepared that stated that the new thermocouple PFC designs is ready for use.		
VVIH	VVIH	323	VVIH- 8.3.d	Vessel, Passive Plate, Outboard Divertor and In-Vessel Tubing Thermocouples	4	1.1.2.2	Outboard divertor thermocouples shall be installed on selected Cu components of the divertor in a way that does not interfere with the PFC tiles.		X	X			MCS FDR for Inner PF coils	Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	324	VVIH- 9.1	Coil Support Structures	1	1.1.2.3	The function of the coil support structures shall be to support the coils off of the vacuum vessel.			X				Subsystem is existing and not being modified as part of recovery scope		

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VVIH	Coils Supp	325	VVIH- 9.1.a	Coil Support Structures	2	1.1.2.3	The function of the coil support structures shall be to support the coils off of the vacuum vessel. In particular, they shall provide support for the outer legs of the TF coils against all loads (electromagnetic, seismic, other)			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	326	VVIH- 9.1.b	Coil Support Structures	3	1.1.2.3	The function of the coil support structures shall be to support the coils off of the vacuum vessel. In particular, they shall:provide support for the outer of coils (Pf-5, Pf-4, Pf-3, and Pf-2) against all loads (electromagnetic, seismic, other)			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	327	VVIH- 9.3.1.a	Coil Support Structures: TF Outer Legs	4	1.1.2.3.1	The TF outer legs shall be supported by i) systems of trusses and tie-bars, located above and below the midplane and connected to the vacuum vessel, and ii) the umbrella structures.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	328	VVIH- 9.3.1.b	Coil Support Structures: TF Outer Legs	5	1.1.2.3.1	The supports for the TF outer legs shall accommodate thermal scenarios during bakeout with < 1 day used to field modify the supports both before and after the bake.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	329	VVIH- 9.3.1.c	Coil Support Structures: TF Outer Legs	6	1.1.2.3.1	The supports for the TF outer legs shall accommodate thermal scenarios and EM loads during operations, as described in Ref. [3].			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	330	VVIH- 9.3.1.d	Coil Support Structures: TF Outer Legs	7	1.1.2.3.1	All aspects of the TF coil support shall be compatible with NSTX-U operation with plasma current and toroidal field in either ϕ direction.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	331	VVIH- 9.3.2.a	Coil Support Structures: TF Outer Coils	8	1.1.2.3.2	Structural support of the of coils shall restrain against vertical motion when subject to electromagnetic loads, while also providing required radial restraints.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	332	VVIH- 9.3.2.a'	Coil Support Structures: of Outer Coils	9	1.1.2.3.2	Structural support of the of coils shall restrain free body motion of the coil due to all EM loads.			X				Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	333	VVIH- 9.3.2.b	Coil Support Structures: of Outer Coils	10	1.1.2.3.2	The outer Pf mounting structures shall designed with allowance for the range of coil and vessel thermal scenarios, including bakeout and plasma operations, ensuring that the coils remain centered.		X	X			PF4/5 Realignment FDRs	Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	334	VVIH- 9.3.2.c	Coil Support Structures: of Outer Coils	11	1.1.2.3.2	The PF-4 and PF-5 coils shall be restrained from radial thermal growth at two opposing locations, allowing an n=2 deformation under thermal growth. The toroidal angle of one restraint shall coincide with the lead block of the coil to inhibit coil motion near the leads.		X	X			PF4/5 Realignment FDRs	Subsystem is existing and not being modified as part of recovery scope		
VVIH	Coils Supp	335	VVIH- 9.3.2.d	Coil Support Structures: of Outer Coils	12	1.1.2.3.2	All aspects of the of coil support shall be compatible with NSTX-U operation with plasma current and toroidal field in either ϕ direction.					X				Initial Experimental Tests
VVIH	Center Sta	336	VVIH- 10.2.b	CS Casing Assembly, Pedestal, and Ceramic Breaks	1	1.1.3.3.6	Lateral displacements at the top of the CS due to toroidally asymmetric halo currents shall be restrained, either in the base thermal case or the fully ratcheted case, via transfer to the outer vessel.		X				NSTX-U-CALC-12-30-00 NSTX-U-CALC-23-00			
VVIH	Center Sta	337	VVIH- 10.2.b'	CS Casing Assembly, Pedestal, and Ceramic Breaks	2	1.1.3.3.6	Provisions shall be made to restrain CS lateral motion due to EM loads. Restraints must accommodate CS thermal growth and vertical displacements due to EM loads.		X				NSTX U-CALC-12-23-00			

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VVIH	Center Sta	338	VVIH- 10.2.c	CS Casing Assembly, Pedestal, and Ceramic Breaks	3	1.1.3.3.6	Any part which will achieve the full bakeout temperature while exposed to atmosphere shall be made from a material which can tolerate this combination of temperature and environment.		X				NSTX-U-CALC-23-00			
VVIH	Center Sta	339	VVIH- 10.3.1.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Assembly	1	1.1.3.3.6	No permanently installed component on the CS shall extend more than ¼" beyond the radius of the CS horizontal flanges (R flange =21.875", for R max =R flange +1/4 = 22.125"). Any exceptions to these rules must be granted by the NSTX-U Project Engineer or Construction Manager.		X				NSTX U-CALC-133-37-00			
VVIH	Center Sta	340	VVIH- 10.3.1.c	CS Casing Assembly, Pedestal, and Ceramic Breaks: Assembly	2	1.1.3.3.8	The PF1c/insulating ring assemblies, both upper and lower, shall be removable without removing the Center Stack.		X	X			MCS Design FDR	Reassembly		
VVIH	Center Sta	341	VVIH- 10.3.1.d	CS Casing Assembly, Pedestal, and Ceramic Breaks: Assembly	3	1.1.3.3.7	The pedestal design shall allow it to be removed with the Center Stack temporarily supported from above.			X	X					
VVIH	Center Sta	342	VVIH- 10.3.1.e	CS Casing Assembly, Pedestal, and Ceramic Breaks: Assembly	4	1.1.3.3.7	The mating of the OH/TF magnet assembly to the casing shall include provision to adjust the position and tilt of the magnet assembly within the casing within travel allowed by existing geometry.		X	X	X		Part of MCS Design presented at FDR. Shims of different sizes will be used to adjust the TF/OH magnet assembly to meet shift and tilt requirements in RD-11 for the TF innner legs.	Demonstarted during Re-assembly	Verify through inspection that the coils can be adjusted	
VVIH	Center Sta	343	VVIH- 10.3.2.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Coil Thermal Isolation	5	1.1.3.3.7	The center stack casing shall include an air gap and/or insulating material in the annular region surrounding the OH and inner-of coils for the purpose of thermal and electrical isolation between the coil and the casing.		X				NSTX U-CALC-133-37-00			
VVIH	Center Sta	344	VVIH- 10.3.2.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Coil Thermal Isolation	6	1.1.3.3.2-1.1.3.3.5	Thermal isolation shall be designed to protect the OH coil, of-1a coils, of-1b coils, and surrounding magnetics diagnostics from excess temperatures due to heat influx from bakeout and from normal operations.		X				NSTX-U-CALC-10-6-01			
VVIH	Center Sta	345	VVIH- 10.3.3.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Ceramic Insulator Assembly	7	1.1.3.3.8	The NSTX-U device shall have only a single ceramic insulator between the outer vacuum vessel and the Center Stack casing.		X				Part of the Design updated in drawings			
VVIH	Center Sta	346	VVIH- 10.3.3.a'	CS Casing Assembly, Pedestal, and Ceramic Breaks: Ceramic Insulator Assembly	8	1.1.3.3.8	The design shall locate this single ceramic insulator at the top of the machine.			X				Included in models and drawings		

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VVIH	Center Sta	347	VVIH- 10.3.3.c	CS Casing Assembly, Pedestal, and Ceramic Breaks: Ceramic Insulator Assembly	9	1.1.3.3.8	The ceramic insulator should be suspended between double O-rings. This suspension should be designed such that no deflection, thermal, EM, or otherwise, can result in unacceptable loading of the insulator as per the structural design criterion. Mechanical clamping of the ceramic insulator shall not "bottom out" the metal flange to ceramic gap under any conditions.		X				Included as part of the MCS FDR			
VVIH	Center Sta	348	VVIH- 10.3.4.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Vacuum Seal	10	1.1.3.3.6	No single elastomer seals shall be used on the primary seals between the CS assembly and the outer vacuum vessel. Acceptable vacuum seal technologies include: ● Double viton O-rings with pumped interspaces ● Metal seals with a secondary seal (viton or metal) and pumped interspace ● Welded lip seals		X			X	Part of the MCS FDR			Leak Tests
VVIH	Center Sta	349	VVIH- 10.3.4.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Vacuum Seal	11	1.1.3.3.6	Provision shall be made to leak-check all primary vacuum seals that interface the Center Stack casing to the outer vessel before full machine pump-down.		X			X	Part of the MCS FDR			Leak Tests
VVIH	Center Sta	350	VVIH- 10.3.5.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Electrical Considerations	12	1.1.3.3.6	The center stack casing shall have three electrical connections top and bottom sized for passing of the bakeout current (8 kA total for design purposes). They should be toroidally aligned to the connections on the outer vessel.		X		X		Part of the CSC FDR and the pending Bakeout Bus Design reviews			
VVIH	Center Sta	351	VVIH- 10.3.5.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Electrical Considerations	13	1.1.3.3.6	If these electrical connections remain in place during operations, then their design shall accommodate loads during operations, including disruption loads.		X							
VVIH	Center Sta	352	VVIH- 10.3.6.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Heating and Cooling	14	1.1.3.3.6	The center stack casing shall tolerate the full range of bakeout temperatures (300 C minimum to 350 C maximum average over the full casing).		X				Part of the MCS FDR Thermal Analyses being conducted			
VVIH	Center Sta	353	VVIH- 10.3.6.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Heating and Cooling	15	1.1.3.3.9 1.1.3.3.10	Provision shall be made via heating/cooling features to heat or cool the horizontal and vertical inner divertor targets, at both the CS top and bottom. Water may be used for cooling if outside the primary vacuum boundary; gas cooling must be used used if the features are on the vacuum side and do not have other secondary containment.		X				NSTX-U-CALC-10-6-00 HTP: NSTX U-CALC-12-26-00 HTT:NSTX U-CALC-12-23-00			
VVIH	Center Sta	354	VVIH- 10.3.6.c	CS Casing Assembly, Pedestal, and Ceramic Breaks: Heating and Cooling	16	1.1.3.3.6	The center stack casing shall accommodate the passage of a current in the Z direction for the purpose of resistive heating as a source of heat during the bakeout mode.		X				NSTX-U-CALC-10-6-01			

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VVIH	Center Sta	355	VVIH- 10.3.6.d	CS Casing Assembly, Pedestal, and Ceramic Breaks: Heating and Cooling	17	1.1.3.3.6	The center stack casing shall have compliant features (bellows) to accommodate the differential thermal expansion between the vacuum vessel and the casing for the full range of potential thermal differentials, including bakeout and operations scenarios.		X				NSTX U-CALC-CC-12-19 -00			
VVIH	Center Sta	356	VVIH- 10.3.6.e	CS Casing Assembly, Pedestal, and Ceramic Breaks: Heating and Cooling	18	1.1.3.3.6	These bellows shall be electrically protected from ohmic heating and electromagnetic loads during bakeout and operations, including disruption loads. [12]		X				NSTX U-CALC-12-29-0			
VVIH	Center Sta	357	VVIH- 10.3.7.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Coil Supports	19	1.1.3.3.11 1.1.3.3.12	The PF-1a and -1b coils shall be constrained by support structures that have the following features: ● Minimal toroidal conductivity of metallic components ● Thermal isola on from hot surface during operations and bakeout scenarios. ● Support which maintains the coil centered position against radial, sideways, and vertical loads from all static and dynamic load cases. ● Ability to adjust coil radial positions within geometric constraints, and with any toroidal phase.		X				Part of the MCS FDR			
VVIH	Center Sta	358	VVIH- 10.3.7.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Coil Supports	20	1.1.3.3.8	PF1c shall be in a reentrant flange that forms the vacuum boundary, accommodating the mandrel-less approach to manufacture. The assembly shall: ● have provision for maintaining the centered position of the coils while providing adequate stiffness to overcome any non-axisymmetric radial load, ● provide the ability to adjust the coil radial positions within geometric constraints, and with any toroidal phase.		X				Part of the MCS FDR			
VVIH	Center Sta	359	VVIH- 10.3.7.c	CS Casing Assembly, Pedestal, and Ceramic Breaks: Coil Supports	21	1.1.3.3.6	Structural support of the OH coil shall allow for axial thermal expansion while ensuring that the coil motion is constrained to allowable levels when subject to electromagnetic loads.		X	X			Cenerstack and MCS FDRs	Subsystem is existing and not being modified as part of recovery scope		
VVIH	Center Sta	360	VVIH- 10.3.7.e	CS Casing Assembly, Pedestal, and Ceramic Breaks: Coil Supports	22	1.1.3.3.11 1.1.3.3.12	Designs for inner-PF coil supports shall apply the required coil preloads.		X			X	Part of the MCS FDR ; NSTXU_1-1-3_CALC_100 Sections 2, 3, 4, & 9 Only the PF-1 a&b have required preloads			MCS Risk Reduction testing prior to FDR
VVIH	Center Sta	361	VVIH- 10.3.7.h	CS Casing Assembly, Pedestal, and Ceramic Breaks: Coil Supports	23	1.1.3.3.11 1.1.3.3.12	For coils where pre-load is required, sensors shall be installed to monitor that preload.		X		X		Interface Control Documents identify the sensors that will be included to capture that data		Verify during installation	

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VVIH	Center Sta	362	VVIH- 10.3.9.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Lateral Load Bearing Structures	24	1.1.3.3.13	These lateral load bearing structures shall have designs that do not risk the seating of O-rings or place load on the ceramic insulators.		X				Part of the MCS FDR NSTXU_1-1-3_CALC_100 Section 6			
VVIH	Center Sta	363	VVIH- 10.3.10.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Pedestal	25	1.1.3.3.7	The pedestal shall be designed to handle all loads associated with the support of the center column, including but not limited to dead weight, EM vertical loads, and global torques.		X				Part of the MCS FDR, NSTXU_1-1-3_CALC_100 Sections 11&12			
VVIH	Center Sta	364	VVIH- 10.3.10.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Pedestal	26	1.1.3.3.7	The pedestal shall be designed to accommodate the access of auxiliary components (cooling hose, instrumentation cabling as appropriate, etc.) to the CS assembly.		X	X	X		Part of the MCS FDR; Many of the access points are addressed in the appropriate ICDs.	Pedestal design isn't changing significantly	Verify during re-assembly	
VVIH	Center Sta	365	VVIH- 10.3.10.c	CS Casing Assembly, Pedestal, and Ceramic Breaks: Pedestal	27	1.1.3.3.8	Pedestal design shall have features which provide adjustment of the TFOH bundle and the CS Assembly.		X	X	X		Part of the MCS FDR Presentations will allow for shimms to make fine adjustments of the TF-OH Bundle from the pedestal	Demonstrated as part of reassambly	Metrology and reassembly alignment	
VVIH	Center Sta	366	VVIH- 10.4.1.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Electrical	28	1.1.3.3.6	The casing electrical insulation with respect to ground shall be designed for a 2 kV rms high-pot test voltage of duration 1 minute.					X				Hi-Pot Testing
VVIH	Center Sta	367	VVIH- 10.4.2.a	CS Casing Assembly, Pedestal, and Ceramic Breaks: Heating And Cooling	29	1.1.3.3.8 1.1.3.3.11 1.1.3.3.12	Structures should be designed so that i) coil ground insulation does not exceed 140 °C and ii) any glass reinforced plastic/laminate material does not exceed its rated service or operation temperature. These criteria shall apply under any possible thermal scenario (operations, bakeout, etc.).		X				NSTX-U-CALC-10-6-01 -- FDR Chit to clearly identify compliance to requirement. Thremal modeling presentation shows that the lower PF-1c with a loss of cooling strats with a temerature of >140 deg C and does not reach 140 deg C for ~40 minutes. Need to revalidate. CHit written to dteremnine if the 150 deg C was ground insulation or G-10.			
VVIH	Center Sta	368	VVIH- 10.4.2.b	CS Casing Assembly, Pedestal, and Ceramic Breaks: Heating And Cooling	30	1.1.3.3.2 1.1.3.3.3 1.1.3.3.4	The insulation or design features protecting the OH and PF-1a/b/c coils from the any elevated temperature metallic structures (casing, coil housings, etc) should provide at least 1 hour response time against the temperature limits noted in 10.4.3a following a coil loss of cooling condition during bakeout or operations.		X				NSTX-U-CALC-10-6-01 -- FDR Chit to clearly identify compliance to requirement; Calculation to be finalized - Calculation			
Auxiliary	Auxiliary	**Auxiliary Systems (Vacuum Pumping, Cooling Water, Bakeout, Gas Delivery, Wall Conditioning)**														
Auxiliary	VPS	369	GRD - 6.3.1.1.a	Vacuum Pumping System	1	1.3.1	The Vacuum Pumping System shall provide the required high vacuum environment for plasma operations.		X	X			IVPs FDR	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	370	GRD - 6.3.1.1.a'	Vacuum Pumping System	2	1.3.1	"It shall pump the vessel from atmosphere to base vacuum, exhaust the spent plasma constituents after each pulse"		X	X			IVPs FDR	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	371	GRD - 6.3.1.1.a''	Vacuum Pumping System	3	1.3.1	"It shall pump the vessel from atmosphere to base vacuum, exhaust the spent plasma constituents after each pulse"			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	VPS	372	GRD - 6.3.1.1.b	Vacuum Pumping System	4	1.3.1	The Vacuum Pumping System shall be equipped a Residual Gas Analyzers (RGA) that can be operated during both glow discharge cleaning and normal high vacuum conditions.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	373	GRD - 6.3.1.1.c	Vacuum Pumping System	5	1.3.1	The vacuum pumping system shall have a capability to evacuate the inter-spaces on double O-ring seals		X				NSTX-U-CALC-33-04-00			
Auxiliary	VPS	374	GRD - 6.3.1.2.a	Vacuum Pumping System	6	1.3.1	The roughing pump(s) shall be capable of evacuating the vacuum vessel from atmosphere to 1x10 -3 Torr in less than 4 hours.			X		X		Subsystem is existing and not being modified as part of recovery scope		Pump Down Verification Tests
Auxiliary	VPS	375	GRD - 6.3.1.2.b	Vacuum Pumping System	7	1.3.1	The TVPS shall be capable of achieving a base pressure of 2x10 -8 Torr following bakeout, excluding fueling gas.			X		X		Subsystem is existing and not being modified as part of recovery scope		Pump Down Verification Tests
Auxiliary	VPS	376	GRD - 6.3.2.1.a	Cooling Water Systems	8	1.3.2	The CWS shall provide deionized cooling water to the TF coil, of coil, OH coil and bus work, as well as selected additional components, with parameters to support a 1200 second repetition rate.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	377	GRD - 6.3.2.2.a	Cooling Water Systems	9	1.3.2	All coil, vessel, and bus-work cooling paths shall be individually monitored and interlocked for flow and temperature on the outlet side. Other paths may also be monitored and interlocked in this fashion.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	378	GRD - 6.3.2.2.c	Cooling Water Systems	10	1.3.2	The CWS configuration for the OH coil shall minimize layer-to-layer temperature differences during cooldown.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	379	GRD - 6.3.2.2.f	Cooling Water Systems	11	1.3.2	Where multiple flow path are mechanically bonded (for instance, the TF inner legs, the OH coil), loss of flow in one path shall result in termination of flow in all other paths.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	380	GRD - 6.3.2.2.h	Cooling Water Systems	12	1.3.2	The capability shall exist to display alarms and remove the power supply permissive under low-flow or high temperature conditions.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	381	GRD - 6.3.3.1.a	Bakeout Heating and Cooling Systems	13	1.3.3	The bakeout system shall include means for heating the full volumes of the carbon PFCs to the required temperatures for an indefinite period while maintaining the vacuum vessel and components connected thereto to temperatures within their temperature ratings.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	382	GRD - 6.3.3.2.a	Bakeout Heating and Cooling Systems	14	1.3.3	The volume of all carbon PFCs shall be heated to >300 deg C during bakeout.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	383	GRD - 6.3.3.2.b	Bakeout Heating and Cooling Systems	15	1.3.3	The average measured temperature of PFCs over a given region (CSFW, OBD, PPPs, SPPs, IBDH, IBDV, etc.) shall not exceed 350 deg C.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	384	GRD - 6.3.3.2.c	Bakeout Heating and Cooling Systems	16	1.3.3	The temperature of the vacuum vessel surfaces shall be heated to > 115 deg C during bakeout.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	385	GRD - 6.3.3.2.d	Bakeout Heating and Cooling Systems	17	1.3.3	The average measured temperature of the vacuum vessel surface shall not exceed 160 deg C.			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	Bakeout	386	GRD - 6.3.3.2.e	Bakeout Heating and Cooling Systems	18	1.3.3	Bakeout heating systems shall be designed to heat the vacuum vessel and PFCs to the required temperature in 48 hours.		X	X			NSTXU_1-3-3-2-1_CALC_101 Bakeout Bu	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	387	GRD - 6.3.3.2.f	Bakeout Heating and Cooling Systems	19	1.3.3	After completion of bakeout, the machine shall be cooled down to an operation temperature (nominally room temperature) in less than 24 hours.		X	X			NSTXU_1-3-3-2-1_CALC_101 Bakeout Bu	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	388	GRD - 6.3.4.1.a	Gas Delivery and Injection Systems	20	1.3.4	The gas delivery and injection system shall provide the following operational fueling capabilities: a. Prefill - maintain a low fill pressure on order of 10 -5 Torr before the discharge b. Low field side injection - inject gas with pulse width modulated piezo valves on the outer vessel once the discharge has been initiated, for core plasma fueling c. High field side injection - Inject gas from the high field side for increased fueling efficiency. d. Divertor injection - Inject gas into the divertor region.		X	X			Private Flux FDR	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	389	GRD - 6.3.4.2.a	Gas Delivery and Injection Systems	21	1.3.4	The gas delivery system (GDS) shall provide a means to connect gas cylinders to gas injection valves on the machine.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	390	GRD - 6.3.4.2.b	Gas Delivery and Injection Systems	22	1.3.4	For baseline operations, the gas injection system (GIS) shall provide at least three piezoelectric valves on the Vacuum Vessel for low field side injection, with independent control of the fueling gas in each injector.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	391	GRD - 6.3.4.2.c	Gas Delivery and Injection Systems	23	1.3.4	For baseline operations, the GIS shall provide three injectors on the CS. Two shall have orifices located near the midplane, and one shall have an orifice located near the CSAS tiles.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	392	GRD - 6.3.4.2.d	Gas Delivery and Injection Systems	24	1.3.4	The GIS shall provide four divertor injectors, two on the center stack and two on the lower outboard divertors.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	393	GRD - 6.3.5.1.a	Wall Conditioning Systems	25	1.3.5	There shall be a glow discharge conditioning (GDC) system installed, capable of cleaning the PFC and vessel wall surfaces in zero-field conditions via bombardment of ions formed during the glow process.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	394	GRD - 6.3.5.1. a'	Wall Conditioning Systems	26	1.3.5	This system shall consist of ionizing filaments, electrodes, power supplies, gas delivery and control system components. Some of these components may be shared with other systems.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	395	GRD - 6.3.5.1.b	Wall Conditioning Systems	27	1.3.5	These shall be a system to “boronize” the vacuum vessel inner surface with deuterated Trimethylboron. This system may share components with other systems.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	396	GRD - 6.3.5.2.a	Wall Conditioning Systems	28	1.3.5	The NSTX shall be equipped to provide glow discharge cleaning (GDC) mode with DC glow for indefinitely long periods, as well as between discharges.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	397	GRD - 6.3.5.2.b	Wall Conditioning Systems	29	1.3.5	The system shall have at least two electrodes, biased relative to the vacuum vessel, and physically separated to provide a more uniform glow discharge.			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	WCS	398	GRD - 6.3.5.2.c	Wall Conditioning Systems	30	1.3.5	The system shall provide pre-ionization filaments near each electrode, and each filament location shall have redundant filaments.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	399	GRD - 6.3.5.2.d	Wall Conditioning Systems	31	1.3.5	The system shall function with either standard GDC with Ne, Ar, He or D 2 , or with the boronization system.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	400	GRD - 6.4.2.a	Wall Conditioning Systems	32	1.3.5	All diagnostics shall be compatible with the full range of bakeout and operations temperatures, with any required additional cooling implemented in a way that is consistent with other GRD requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	401	GRD - 6.4.2.b	Wall Conditioning Systems	33	1.3.5	All diagnostics shall be compatible with the full range of operations electromagnetic load cases, including disruption loads.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	402	AUX- 2.1.b	Vacuum Pumping System (VPS)	1	1.3.1	The NSTX-U torus vacuum pumping system (TVPS) shall perform the following functions: · Roughdown of the NSTX-U device from atmosphere to base pressure. · Provide a high vacuum environment compatible with the NSTX-U experimental program. · Remove plasma exhaust and fuelling/GDC gas between discharges. · Minimize and maintain impurity levels as required. · Provide analytical capability for monitoring and control of machine vacuum condition. · Provide pumping and control of pressure for Glow Discharge Cleaning (GDC) and boronization modes. · Be compatible with, and provide pumping for vacuum vessel bakeout. · Provide appropriate safety interlocks for personnel and equipment safety.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	403	AUX- 2.1.c	Vacuum Pumping System	2	1.3.1	A separate vacuum system shall be used to provide intermediate vacuum for sealing locations utilizing double O-ring seals with pumped interspace; this system will be called the Interspace Vacuum Pumping System within this document (IVPS).		X				IVPS FDR			
Auxiliary	VPS	404	AUX- 2.1.d	Vacuum Pumping System	3	1.3.1	The system shall provide for remote actuation of torus interface valves (TIVs) and shutters.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	405	AUX- 2.1.e	Vacuum Pumping System	4	1.3.1	The dedicated vacuum control PLC shall provide centralized control over the TVPS, IVPS, shutter and TIV control system, and wall conditioning systems, and provide HMI capability.		X	X			IVPS FDR	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	406	AUX- 2.1.f	Vacuum Pumping System	5	1.3.1	A dedicated cooling water system shall provide cooling water to those vacuum pumps that require continuous cooling water.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	407	AUX- 2.1.g	Vacuum Pumping System	6	1.3.1	A system shall be provided to control the position of movable diagnostic probes, including position and TIV interlocking.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	408	AUX- 2.2.a	Vacuum Pumping System	7	1.3.1	Magnetic and vacuum materials shall be as described in the NSTX-U GRD [		X	X			IVPS FDR	Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	VPS	409	AUX- 2.2.b	Vacuum Pumping System	8	1.3.1	The design of the vacuum system shall be compatible with PPPL standard ES-MECH-15	compatible with PPPL standard ES-MECH-15	X	X			IVPS FDR	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	410	AUX- 2.2.c	Vacuum Pumping System	9	1.3.1	The system shall be designed to facilitate a 1200 s repetition rate.		X	X			IVPS FDR	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	411	AUX- 2.2d	Vacuum Pumping System	10	1.3.1	All vacuum pumping systems with exposure to NSTX-U machine vacuum shall exhaust through the D-Site vent stack via the NSTX-U vacuum exhaust line.		X	X			IVPS FDR drawings show the venting of applicaitons	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	412	AUX- 2.3.1.a	VPS TVPS	11	1.3.1.1	The TVPS shall consist of a pair of water-cooled turbo molecular (momentum transfer) pumps and at least one positive displacement mechanical pump.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	413	AUX- 2.3.1.b	VPS TVPS	12	1.3.1.1	Turbomolecular pumps, as well as the RGA and vacuum vessel pressure gauges shall be located on, or close to the vacuum vessel to maximize conductance. Here, “close” is defined by meeting the performance requirements in the following section.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	414	AUX- 2.3.1.b'	VPS TVPS	13	1.3.1.1	All components shall be capable of operation in the stray magnetic field close to the NSTX-U device.		X	X			IVPS FDR drawings show the venting of applicaitons	Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	415	AUX- 2.3.1.c	VPS TVPS	14	1.3.1.1	Service ports, strategically located on the vacuum system shall be provided to facilitate maintenance and leak checking.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	416	AUX- 2.3.1.d	VPS TVPS	15	1.3.1.1	Pressure gauges capable of monitoring pressure from atmosphere to high vacuum shall be located on the vacuum vessel or appropriate appendages.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	417	AUX- 2.3.1.e	VPS TVPS	16	1.3.1.1	Redundant Residual Gas Analyzers (RGA) capable of discriminating gas species shall be employed.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	418	AUX- 2.3.1.f	VPS TVPS	17	1.3.1.1	The RGA shall function in both high vacuum configuration, and higher pressure situations such as GDC and bakeout.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	419	AUX- 2.3.1.g	VPS TVPS	18	1.3.1.1	Capability for monitoring and remote control of machine vacuum system components from the control room shall be provided.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	420	AUX- 2.3.1.h	VPS TVPS	19	1.3.1.1	Provisions shall be made to bring the vacuum system up to atmospheric pressure using dry gaseous nitrogen or argon			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	421	AUX- 2.3.1.i	VPS TVPS	20	1.3.1.1	All exhaust gases from TVPS shall be directed to the facility elevated exhaust stack.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	422	AUX- 2.3.1jj	VPS TVPS	21	1.3.1.1	Pumping systems, pressure gauges, and RGAs shall be electrically isolated from the vessel as per GRD.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	423	AUX- 2.3.2.a	VPS IVPS	22	1.3.1.7	The IVPS shall consist of a dry vacuum pump, with manifolding to provide adequate conductance connections between the pumps and the double O-ring locations on the machine.		X				NSTX-U-CALC-33-04-00			
Auxiliary	VPS	424	AUX- 2.3.2.b	VPS IVPS	23	1.3.1.7	All exhaust gases from IVPS shall be directed to the facility elevated exhaust stack.		X				NSTX-U-CALC-33-04-00			
Auxiliary	VPS	425	AUX- 2.3.2.c	VPS IVPS	24	1.3.1.7	Capability for monitoring and remote control of the iVPS from the control room shall be provided.		X				NSTX-U-CALC-33-04-00			

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Auxiliary	VPS	426	AUX- 2.3.3.a	VPS Vacuum PLC	25	1.3.1.4	The Vacuum PLC shall be designed to control all vacuum pumps, pneumatic TIVs & shutters, all pneumatic and solenoid valves in the gas delivery and injection system (SBS 1.3.4), and the functions of the GDC and dTMB systems (SBS 1.3.5).			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	427	AUX- 2.3.3.b	VPS Vacuum PLC	26	1.3.1.4	The design should have an HMI with control from remote locations including the control room and bottle rack.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	428	AUX- 2.3.3.c	VPS Vacuum PLC	27	1.3.1.4	The design of the Vacuum PLC I/O capability shall be designed with expansion as a critical consideration.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	429	AUX- 2.3.4.a	VPS Shutter and TIV Control System	28	1.3.1.3	The shutter and TIV control system shall provide remote control and status information for all pneumatic shutters and TIVs on NSTX-U.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	430	AUX- 2.3.4.b	VPS Shutter and TIV Control System	29	1.3.1.3	The system shall be synchronized to the NSTX-U central clock and provide preset configurations for all shutters and TIVs, i.e. plasma operations, GDC, etc.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	431	AUX- 2.3.4.a	VPS Probe Drive Control System	30	1.3.1.5	The probe drive control system shall provide the capability to remotely monitor and control the positions of movable probes on NSTX-U (LITER, MAPP, etc.).			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	432	AUX- 2.3.4.b	VPS Probe Drive Control System	31	1.3.1.5	The system shall have capabilities to prevent the closure of torus isolation valves on an inserted probe, and to prevent the insertion of the probe into a closed TIV..			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	433	AUX- 2.4.1.a	VPS TVPS	32	1.3.1.1	The roughing pump(s) shall be capable of evacuating the vacuum vessel from atmosphere to 1x10 -3 Torr in less than 4 hours.			X		X		Subsystem is existing and not being modified as part of recovery scope		Vacuum Pumpdown acceptance tests
Auxiliary	VPS	434	AUX- 2.4.1.b	VPS TVPS	33	1.3.1.1	The TVPS shall be capable of achieving a base pressure of 2x10 -8 Torr, excluding fuelling gas, after the vacuum vessel has been baked out.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	435	AUX- 2.4.1.c	VPS TVPS	34	1.3.1.1	The system shall be capable of evacuating plasma gas loads and establishing an adequate pressure between machine pulses on a 1200 s cycle, including the impact of inter-shot GDC periods.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	436	AUX- 2.4.1.d	VPS TVPS	35	1.3.1.1	The high vacuum pressure sensing elements shall provide one or more signals to the real-time control system. The latency between a change in the vessel pressure and the change voltage output should be less than 100ms.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	437	AUX- 2.4.1.e	VPS TVPS	36	1.3.1.1	The RGA system shall be able to scan and provide resolution of 1x10 -11 Torr partial pressure for masses 1 to 60.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	438	AUX- 2.4.1.f	VPS TVPS	37	1.3.1.1	The vacuum system shall be capable of supporting GDC mode of operation as described in Section 5 of this SRD.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	439	AUX- 2.4.1.g	VPS TVPS	38	1.3.1.1	The mechanical pump backing system shall be capable of maintaining less than 2 Torr at the exhaust of the TMPs under all conditions such as GDC and TMB operations.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	440	AUX- 2.4.1.h	VPS TVPS	39	1.3.1.1	The mechanical pumps shall be capable of evacuating the NSTX-U vacuum vessel from atmosphere to 5 x 10 -2 Torr,			X		X		Subsystem is existing and not being modified as part of recovery scope		Vacuum Pumpdown acceptance tests

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Auxiliary	VPS	441	AUX- 2.4.1.h'	VPS TVPS	40	1.3.1.1	shall be capable of backing the turbomolecular pumps during operation and GDC..			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	VPS	442	AUX- 2.4.2.a	VPS IVPS	41	1.3.1.7	The IVPS shall be designed to provide vacuum pressures of 5x10 -2 Torr at the inlet ports to the interspaces in a dead-ended configuration.		X				Calculation from FDR		NSTX-U-CALC-33-04-00	
Auxiliary	VPS	443	AUX- 2.4.1.a	VPS Upgrade Performance	42	1.3.1	The IVPS shall be designed such that expansion to additional interspaces can be accommodated. These may include, but not be limited to, diagnostic seals or seals on the neutral beam ducts.									
Auxiliary	VPS	444	AUX- 2.4.1.d	VPS Upgrade Performance	43	1.3.1	The vacuum controls shall provide an interface with Plant I&C to allow remote monitoring and control requests, data trending, and distributed display of system information.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	445	AUX- 3.1.a	Cooling Water System (CWS)	1	1.3.2	The cooling water system shall provide continuous cooling for the coil systems, the power supply systems, the component cooling system, and the heating systems that support NSTX-U.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	446	AUX- 3.1.b	Cooling Water System (CWS)	2	1.3.2	The cooling water system shall provide flow and temperature interlocks for specific circuits.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	447	AUX- 3.2.a	Cooling Water System (CWS)	3	1.3.2	The design of the cooling water system shall be compatible with PPPL standard ES-MECH-15			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	448	AUX- 3.3.1.a	Cooling Water System (CWS)	4	1.3.2	The cooling water system shall utilize existing equipment located in the D-site Pump Room.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	449	AUX- 3.3.1.a'	Cooling Water System (CWS)	5	1.3.2	The primary cooling water pump, heat exchanger and tank shall not infringe on the space in the NSTX-U test cell.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	450	AUX- 3.3.1.b	Cooling Water System (CWS)	6	1.3.2	The conductivity of the deionized water shall be monitored to verify it is within acceptable limits			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	451	AUX- 3.3.1.c	Cooling Water System (CWS)	7	1.3.2	All materials in the cooling water system shall be selected for operation in deionized water.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	452	AUX- 3.3.1.d	Cooling Water System (CWS)	8	1.3.2	A low flow signal shall be available for each flow path; this sensor shall be on the outlet side of the coil or component in each path.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	453	AUX- 3.3.1.e	Cooling Water System (CWS)	9	1.3.2	An outlet water temperature measurement shall be available for each flow path.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	454	AUX- 3.3.1.f	Cooling Water System (CWS)	10	1.3.2	A dedicated processor or PLC shall receive flow and temperature inputs and provide data to the central I&C system, indicating the status of each individual flow path (outlet water temperature, flow status).			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	455	AUX- 3.3.1.f'	Cooling Water System (CWS)	11	1.3.2	Magnet energization shall be disallowed if corresponding flows or temperatures are not in the allowed ranges.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	456	AUX- 3.3.1.g	Cooling Water System (CWS)	12	1.3.2	Valves and pumps shall be controlled locally and from the D site pump room.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	457	AUX- 3.3.1.h	Cooling Water System (CWS)	13	1.3.2	Activation of the NTC Emergency Stop buttons shall signal the water systems PLC to shut down any operating pumps delivering fluid flow to the NTC.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	458	AUX- 3.3.1.h'	Cooling Water System (CWS)	14	1.3.2	This interlock shall serve as an equipment protection measure in the event of a fluid leak and is not intended to provide life-safety protection.			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	CWS	459	AUX- 3.3.1.i	Cooling Water System (CWS)	15	1.3.2	To improve operations efficiency, authorized remote control from the Plant Control and Monitoring system for specific pumps, valves, or settings shall be provided.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	460	AUX- 3.3.2.a	CWS OH and Inner-of Coil Cooling	16	1.3.2.1	Two high pressure booster pumps shall be configured as a primary unit and an emergency backup (redundant system) and supply boosted pressure to the OH and inner-of cooling water supply circuit.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	461	AUX- 3.3.2.b	CWS OH and Inner-of Coil Cooling	17	1.3.2.1	Provision shall be made in the OH cooling circuit to adjust the flow such that all of the 8 parallel paths have a similar evolution of the water outlet temperature following a pulse.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	462	AUX- 3.3.2.c	CWS OH and Inner-of Coil Cooling	18	1.3.2.1	Provision shall be made in the OH cooling circuit to provide a variable inlet water temperature over the range 12-100 C, in order to reduce the cooling wave thermal stresses.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	463	AUX- 3.3.2.c'	CWS OH and Inner-of Coil Cooling	19	1.3.2.1	The system shall be externally controllable, and have a mechanism to match the coil inlet water temperature at the end of the pulse to the temperature of the coil.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	464	AUX- 3.3.2.d	CWS OH and Inner-of Coil Cooling	20	1.3.2.1	Loss of flow in any one OH circuit shall result in flow being terminated in all OH circuits.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	465	AUX- 3.3.2.e	CWS OH and Inner-of Coil Cooling	21	1.3.2.1	Loss of flow in any one (or more) TF water circuit shall result in flow being terminated in all OH circuits.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	466	AUX- 3.3.2.f	CWS OH and Inner-of Coil Cooling	22	1.3.2.1	Provision shall be made to connect potable water to the OH and inner-of coils within 45 minutes of NTC access if a power loss event occurs during bakeout operations and backup power does not function properly.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	467	AUX- 3.3.3.a	CWS TF Coil	23	1.3.2.1	The TF inner legs shall be fed with water that has previously been passed through the TF outer legs, functioning as a pre-heater.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	468	AUX- 3.3.3.b	CWS TF Coil	24	1.3.2.1	Loss of flow in any one TF circuit shall result in flow being terminated in all TF circuits and OH circuits.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	469	AUX- 3.4.a	CWS Baseline Performance & Operational Requirements	25	1.3.2	For coils where the exit cooling water temperature may exceed 100°C the water pressure shall be maintained at the pressure required to prevent boiling.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	470	AUX- 3.4.b	CWS Baseline Performance & Operational Requirements	26	1.3.2	The deionized water conductivity shall be less than or equal to 0.2 µmho/cm			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	471	AUX- 3.4.c	CWS Baseline Performance & Operational Requirements	27	1.3.2	The cooling water system shall provide chilled deionized cooling water to the following components in Tables 3.4-1 through 3.4-3.	Tables 3.4-1 through 3.4-3.		X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	472	AUX- 3.4.d	CWS Baseline Performance & Operational Requirements	28	1.3.2	Flow rates, temperature ranges, and similar information for coil circuits shall be found in the design point spreadsheet			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	473	AUX- 3.4.e	CWS Baseline Performance & Operational Requirements	29	1.3.2	The coil cooling water inlet temperature shall be at least 2 ° C above the NTC dew point			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	CWS	474	AUX- 3.4.f	CWS Baseline Performance & Operational Requirements	30	1.3.2	The cooling water system shall also provide deionized water to the Field Coil Power Conversion water distribution system.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	CWS	475	AUX- 3.4.g	CWS Baseline Performance & Operational Requirements	31	1.3.2	The cooling water system flow switches shall be augmented by the installation of parallel flow measurement instrumentation as indicated in Table 3.4-1 through 3.4-3	Table 3.4-1 through 3.4-3		X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	476	AUX- 4.1.a	Bakeout System	1	1.3.3	The assembled vessel shall have a heating system with in situ bakeout for the vessel and PFC tiles. During this procedure, the gases absorbed and diffused within the vessel material are released and subsequently removed from the vessel by the Torus Vacuum Pumping System.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	477	AUX- 4.1.b	Bakeout System	2	1.3.3	A vacuum vessel heating/cooling system shall provide for heating the vessel during the bakeout mode of operation, and in an upgrade mode cooling the vessel during long pulse operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	478	AUX- 4.2.b	Bakeout System	3	1.3.3	Permeability requirements are as per Ref [4], while mechanical design shall be governed by the NSTX-U Structural Design Criteria			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	479	AUX- 4.2.c	Bakeout System	4	1.3.3	The design of the various bakeout systems shall be compatible with PPPL standard ES-MECH-15			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	480	AUX- 4.2.d	Bakeout System	5	1.3.3	For purposes of design, the bakeout system shall assumed to be operated 24 hours per day, 7 days a week, in 3 week increments, once per year, for a 20 year lifecycle. It may be assumed that multiple (3) start-stop cycles occur during each annual operations period. Note that the actual duration of any individual bakeout will be determined by the evolution of the vacuum parameters during that bakeout.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	481	AUX- 4.3.c	Bakeout High Temperature Helium System	6	1.3.3	All piping, feedthroughs, valves, and similar for the helium system shall be qualified for the maximum helium temperature of 450°C and pressure of 300 PSIG .			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	482	AUX- 4.3.d	Bakeout High Temperature Helium System	7	1.3.3	He shall be fed into the vacuum chamber via the 8" flanges located ~53" above and below the midplane at Bays D, H, and L/A.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	483	AUX- 4.3.f	Bakeout High Temperature Helium System	8	1.3.3	Flow throttling valves and instrumentation shall be installed at each feedthrough to assess and adjust the flow balance for the system.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	484	AUX- 4.3.g	Bakeout Ex-Vessel Heating System	9	1.3.3	Heating/cooling coils shall be mounted on the vacuum vessel exterior. High temperature water will be circulated through the coils, at a pressure sufficient to prevent the water transitioning to steam.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	485	AUX- 4.3.h	Bakeout Ex-Vessel Heating System	10	1.3.3	Appropriate controls and interlocks shall be made to prevent and mitigate loss-of-pressure accident scenarios.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	486	AUX- 4.3.i	Bakeout CS DC Heating System	11	1.3.3	Provision shall be made to pass DC current down the center-stack casing, in order to heat the casing and therefore the tiles affixed to it.			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	Bakeout	487	AUX- 4.3.i	Bakeout CS DC Heating System	12	1.3.3	This shall include electrical connections to the vessel connection points to facilitate this injection, and the installation of appropriate DC power supply(s).			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	488	AUX- 4.3.j	Bakeout Control	13	1.3.3	A PLC or similar control system shall be used to coordinate the operation of the various systems. The PLC shall provide for remote operation of the bakeout systems.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	489	AUX- 4.3.k	Bakeout Control	14	1.3.3	The PLC shall provide interlock capability for the safe operation of the heating system. System-level required interlocks include: ● Loss of flow in any coil or vessel cooling path. ● Loss of functionality of any of the three individual systems ● Emergency stop near NSTX-U and near any remotely located equipment. ● Excessive vacuum vessel pressure or failure of TVPS ● PLC failures			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	490	AUX- 4.3.l	Bakeout Other	15	1.3.3	The bake out heating system and procedures shall insulate personnel from heated surfaces.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	491	AUX- 4.4.a	Bakeout Baseline Performance & Operational Requirements	16	1.3.3	The external vacuum vessel heating paths shall bring the vacuum vessel to >115 deg C bakeout temperature within 48 hrs;			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	492	AUX- 4.4.a'	Bakeout Baseline Performance & Operational Requirements	17	1.3.3	this minimum limit shall apply to all measurement locations on the vessel surface.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	493	AUX- 4.4.b	Bakeout Baseline Performance & Operational Requirements	18	1.3.3	The average temperature of the vessel skin shall be maintained at a value less than 160 deg C.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	494	AUX- 4.4.c	Bakeout Baseline Performance & Operational Requirements	19	1.3.3	The internal vacuum vessel heating paths and DC current heating system shall bring all carbon tiles to the specified bake out temperature of >300 deg C within 48 hrs.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	495	AUX- 4.4.d	Bakeout Baseline Performance & Operational Requirements	20	1.3.3	The average temperature of PFCs over a given region (CSFW, OBD, PPPs, SPPs, etc.) shall not exceed 350 deg C.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	496	AUX- 4.4.c'	Bakeout Baseline Performance & Operational Requirements	21	1.3.3	The port covers shall not exceed 150 degrees centigrade.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	497	AUX- 5.1.a	Gas Delivery and Injection (GD&I) System	1	1.3.4	The Gas Delivery System (GDS) shall provide the following functions: ● Provide means of routing gas from gas cylinders to injectors on or near the machine. ● Provide instrumentation and control for gas injection ● Provide remotely controlled pump/purge capabilities			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	GDS	498	AUX- 5.1.b	GD&I Gas Delivery System (GDS)	2	1.3.4	The Gas Injection System (GIS) shall provide the following functions ● Provide gas delivery control to the vacuum chamber via piezo electric valves ● Provide gas delivery control to the vacuum chamber via puff valves ● Provide gas for GDC via the systems noted in the previous bullets if required ● Provide gas injection via various research-specific injectors (divertor gas injectors, massive gas injections, supersonic gas injection, etc.) ● Provide in-vessel lines for delivery of gas from the injector to desired location.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	499	AUX- 5.2.a	GD&I Gas Delivery System (GDS)	3	1.3.4	The design of the gas delivery and injection system shall be compatible with PPPL standard ES-MECH-15.	PPPL standard ES-MECH-15.		X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	500	AUX- 5.3.a	GD&I Gas Delivery System (GDS)	4	1.3.4	The GDS shall have a bottle bank allowing different gasses to be routed to different injectors on the machine.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	501	AUX- 5.3.b	GD&I Gas Delivery System (GDS)	5	1.3.4	The GDS shall minimize or eliminate of explosive mixtures in the system piping and hardware.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	502	AUX- 5.3.c	GD&I Gas Delivery System (GDS)	6	1.3.4	The GDS shall have remote operation of system via the vacuum PLC and HMI.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	503	AUX- 5.3.d	GD&I Gas Delivery System (GDS)	7	1.3.4	The GDS system shall be grounded to building steel.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	504	AUX- 5.3.e	GD&I Gas Delivery System (GDS)	8	1.3.4	The GDS shall include a dedicated vacuum pump and vent all exhaust gas to the D-site stack.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	505	AUX- 5.3.f	GD&I Gas Delivery System (GDS)	9	1.3.4	The GDS shall provide an interface with Plant Control and Monitoring to allow gas types, pressure gauges,valve positions, and other relevant readings to be acquired, centrally-displayed, and archived.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	506	AUX- 5.3.a'	GD&I Gas Injection System (GIS)	10	1.3.4	The GIS shall have three gas injection points on the outer vacuum vessel utilizing piezo-electric valves.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	507	AUX- 5.3.b'	GD&I Gas Injection System (GIS)	11	1.3.4	This system shall include in-vessel tubing to route gas to the orifice locations. Further details are provided in Ref. [2]			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	508	AUX- 5.3.b''	GD&I Gas Injection System (GIS)	12	1.3.4	The GIS shall have three injection points on the center column, composed of one near the ends of the CS First Wall (CSFW), and two near the midplane, utilizing puff valves.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	509	AUX- 5.3.c'	GD&I Gas Injection System (GIS)	13	1.3.4	The GIS shall have two injection points on the lower outboard divertor, in the vicinity of the Row 1 tiles.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	510	AUX- 5.3.c''	GD&I Gas Injection System (GIS)	14	1.3.4	These shall use piezo valves for injection control, and have in-vessel tubes to route gas to the orifice locations. Further details are provided in Ref. [7,8]			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	511	AUX- 5.3.d'	GD&I Gas Injection System (GIS)	15	1.3.4	The GIS shall have two injection ports, located at or near the interface of the inboard horizontal and vertical divertor targets, one each at the the top and bottom of the device			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	GDS	512	AUX- 5.3.d''	GD&I Gas Injection System (GIS)	16	1.3.4	These shall use piezo valves for injection control, and may utilize in-vessel tubes for gas delivery. Further details are provided in Ref. [7,8]			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	513	AUX- 5.3.e'	GD&I Gas Injection System (GIS)	17	1.3.4	All GIS valves shall have the injection timing controlled by the plasma control system.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	514	AUX- 5.3.f'	GD&I Gas Injection System (GIS)	18	1.3.4	The jitter on the timing of puff valve opening shall be less than 5 ms.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	515	AUX- 5.3.g	GD&I Gas Injection System (GIS)	19	1.3.4	The GIS shall have electrical isolation of all piezo or puff valves from the vacuum vessel or CSC as per the GRD.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	516	AUX- 5.3.h	GD&I Gas Injection System (GIS)	20	1.3.4	Designs shall ensure the low-pressure conditions do not occur in ceramic insulators where high voltage conditions may arise during a plasma discharge.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	GDS	517	AUX- 5.3.i	GD&I Gas Injection System (GIS)	21	1.3.4	The GIS shall include valve drivers and electronics to interface to the plasma control system the vacuum system PLC, and the facility clock system			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	518	AUX- 6.1.d	Wall Conditioning Systems (WCS)	22	1.3.5	A system shall be provided to purge NSTX-U with inert gas (Argon) in the event of a vacuum breach during LiTER operations.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	519	AUX- 6.2.a	WCS Argon Purge System	23	1.3.5	The design of the glow discharge system, the dTMB system, the LITER system, and the vessel purge system shall be compatible with PPPL standard ES-MECH-15.	PPPL standard ES-MECH-15.		X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	520	AUX- 6.3.1.a	WCS GDC System	24	1.3.5.1	The following features shall be incorporated into the GDC design:2 or more in-vessel probes on approximately opposite sides of the chamber which act as the anode. These may be mounted to the vacuum vessel wall or mounted on probe drives.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	521	AUX- 6.3.1.b	WCS GDC System	25	1.3.5.1	The following features shall be incorporated into the GDC design: Power supply for the anode probes.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	522	AUX- 6.3.1.c	WCS GDC System	26	1.3.5.1	The following features shall be incorporated into the GDC design:Instrumentation and control for operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	523	AUX- 6.3.1.d	WCS GDC System	27	1.3.5.1	The GDC shall be remotely configurable and operable.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	524	AUX- 6.3.1.e	WCS GDC System	28	1.3.5.1	The GDC shall be capable of operating with helium and other gases.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	525	AUX- 6.3.1.f	WCS GDC System	29	1.3.5.1	The GDC system shall be capable of steady state operation, as well as between-discharge operations.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	526	AUX- 6.3.1.g	WCS GDC System	30	1.3.5.1	The GDC system shall be interlocked with the Hardwired Interlock System to prevent operation with personnel in the test cell.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	527	AUX- 6.3.1.h	WCS GDC System	31	1.3.5.1	The GDC system shall provide pre-ionization filaments near each electrode, and each filament location shall have redundant filaments.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	528	AUX- 6.3.1.i	WCS GDC System	32	1.3.5.1	The GDC voltage, current, and other relevant readings shall be acquired, centrally-displayed, and archived via the Plant Monitoring and Control system			X				Subsystem is existing and not being modified as part of recovery scope		

[redacted]

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Auxiliary	WCS	529	AUX- 6.3.2.a	WCS dTMB System	33	1.5.3.2	The following features shall be incorporated into the dTMB system: Dedicated gas cabinet controlled under 1 ATM to prevent gas leaking outside of the cabinet.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	530	AUX- 6.3.2.b	WCS dTMB System	34	1.5.3.2	The following features shall be incorporated into the dTMB system: dTMB leakage detection in gas cabinet with normal, warning and alarm levels and annunciations.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	531	AUX- 6.3.2.c	WCS dTMB System	35	1.5.3.2	The following features shall be incorporated into the dTMB system: A dedicated vacuum pump capable of evacuating any section of the gas delivery system, and a He backfill system			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	532	AUX- 6.3.2.d	WCS dTMB System	36	1.5.3.2	The following features shall be incorporated into the dTMB system: Synchronization of the gas control with the operation of the GDC system.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	533	AUX- 6.3.2.e	WCS dTMB System	37	1.5.3.2	The following features shall be incorporated into the dTMB system: Treatment of the exhaust gas with nitrogen dilution to control the toxic gas in exhaust line at a safe level .			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	534	AUX- 6.3.2.f	WCS dTMB System	38	1.5.3.2	The following features shall be incorporated into the dTMB system: A coaxial dTMB delivery line between gas cabinet and vacuum vessel TIV. Outer jacket filled with above 1 ATM helium and pressure monitored for any gas leakage.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	535	AUX- 6.3.2.g	WCS dTMB System	39	1.5.3.2	The following features shall be incorporated into the dTMB system: Automated switch between pure helium plasma and dTMB plasma without plasma interruption.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	536	AUX- 6.3.2.h	WCS dTMB System	40	1.5.3.2	The following features shall be incorporated into the dTMB system: Distributed dTMB injection ports on vacuum vessel for uniform boron coating.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	537	AUX- 6.3.2.i	WCS dTMB System	41	1.5.3.2	The following features shall be incorporated into the dTMB system: Mass flow rate of dTMB and Helium should be controlled by a Mass Flow Controller(MFC).			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	538	AUX- 6.3.2.j	WCS dTMB System	42	1.5.3.2	The following features shall be incorporated into the dTMB system: A battery backup design allows controlled shut down of the dTMB gas delivery during loss of regular power.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	539	AUX- 6.3.2.k	WCS dTMB System	43	1.5.3.2	The following features shall be incorporated into the dTMB system: Provision for GDC using either dTMB or helium.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	540	AUX- 6.3.2.l	WCS dTMB System	44	1.5.3.2	The dTMB system shall be capable of initiating a boronization session with 1 hour of starting.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	541	AUX- 6.3.3.a	WCS LITER System	45	1.3.5.3	Two LiTERs shall be mounted on the upper dome of the vacuum vessel at nominally opposite toroidal angles, enabling approximately uniform coverage of the lower divertor.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	542	AUX- 6.3.3.b	WCS LITER System	46	1.3.5.3	The LiTER evaporation center line shall be aimed toward the middle of the lower divertor			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	543	AUX- 6.3.3.c	WCS LITER System	47	1.3.5.3	When LiTER system is isolated from vacuum vessel by TIV valve, LiTER probe shall be capable of being pumped down to 10 -7 torr via a pump cart			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Auxiliary	WCS	544	AUX- 6.3.3.d	WCS LITER System	48	1.3.5.3	Liquid lithium filling shall be conducted in argon environment			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	545	AUX- 6.3.3.e	WCS LITER System	49	1.3.5.3	A fully automated and interlocked linear motion system shall be designed to move the lithium reservoir in and out of the NSTX-U vacuum vessel during operation			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	546	AUX- 6.3.3.f	WCS LITER System	50	1.3.5.3	A shutter shall be installed in order to block lithium evaporation during plasma operation or other times when evaporation to the PFC surfaces is not desired			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	547	AUX- 6.3.3.g	WCS LITER System	51	1.3.5.3	The lithium coating process through LiTER shall be fully automated via the LiTER control system, TVPS PLC system and Plant Monitoring and Control (EPICS) system			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	548	AUX- 6.3.4.a	WCS Argon Vessel Purge System	52	1.3.4.4	The vessel purge system shall have sufficient capability to bring the NSTX-U vessel fully up to atmospheric pressure with argon or other inert gas, following detection of a leak during LiTER operations.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	549	AUX- 6.3.4.b	WCS Argon Vessel Purge System	53	1.3.4.4	The control system for the vessel purge system shall have access to both LiTER status information, the vessel pressure, and TIV status.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	550	AUX- 6.3.4.c	WCS Argon Vessel Purge System	54	1.3.4.4	The vessel purge system shall not activate until both the NB TIVs are closed.4			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	551	AUX- 6.3.4.d	WCS Argon Vessel Purge System	55	1.3.4.4	The vessel purge system shall not activate unless at least one LiTER is both at temperature and has its TIV open as one of the interlock requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	552	AUX- 6.3.4.e	WCS Argon Vessel Purge System	56	1.3.4.4	The vessel purge system shall use the pressure signals from all three vessel capacitance manometers in order to guard against false positives.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	553	AUX- 6.3.4.f	WCS Argon Vessel Purge System	57	1.3.4.4	The argon from the Vessel Purge System shall enter the machine at the bottom of the vessel.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	554	AUX- 6.3.4.g	WCS Argon Vessel Purge System	58	1.3.4.4	A separate vessel vent at the upper portion of the vessel shall be provided, allowing excess argon to exit the top of the machine when the Vessel Purge System is triggered.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	555	AUX- 6.4.b	Wall Conditioning Systems (WCS)	59	1.3.5	The GDC system shall be capable of regulating the vessel pressure to 3 mTorr pressure with less than 25% amplitude variation.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	556	AUX- 6.4.c	Wall Conditioning Systems (WCS)	60	1.3.5	Each LiTER shall hold approximately 80 grams of lithium			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	557	AUX- 6.4.d	Wall Conditioning Systems (WCS)	61	1.3.5	The LiTER shall provide Li deposition rates of 5-70 mg/min while the vacuum vessel pressure is in the 10 -8 torr range			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	558	AUX- 6.4.e	Wall Conditioning Systems (WCS)	62	1.3.5	The vessel purge system shall be capable of bringing the NSTX-U vessel from base vacuum to atmospheric pressure of Argon or other inert gas within 15 minutes of trigger.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	WCS	559	AUX- 6.4.f	Wall Conditioning Systems (WCS)	63	1.3.5	For the purposes of triggering the vessel purge system, a leak shall be declared when the vessel pressure exceeds 8 torr.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	Power	**Power Systems**														

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Power	AC	560	GRD - 6.5.1.a	AC Power Systems	1	1.5.1	The AC Power Systems shall provide all electrical power required for the NSTX facility.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	561	GRD - 6.5.2.1.1.a	TF Power Conversion System	2	1.5.2.1 1.5.3.1	TF power supplies shall supply current to the TF coils to produce a toroidal field (B_t) ≤ 1.0T at R_0 =0.9344m, maintained constant for the full 5.0s duration of plasma current flat-top based on the nominal I_p waveform given in section 4.1.2. Corresponding flat top coil current is 129.8kA.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	562	GRD - 6.5.2.1.2.a	TF Power Conversion System	3	1.5.2.1 1.5.3.1	Baseline repetition period shall be 2400s.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	563	GRD - 6.5.2.1.2.b	TF Power Conversion System	4	1.5.2.1 1.5.3.1	Waveforms for current rise and fall, including L/R decay in case of a fault, shall be coordinated with design of the TF coil in terms of heating.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	564	GRD - 6.5.2.1.2.c	TF Power Conversion System	5	1.5.2.1 1.5.3.1	Redundant measurements of the TF coil currents shall be provided with accuracy of 0.2% (magnitude of DC measurement error at full rated current).			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	565	GRD - 6.5.2.1.2.d	TF Power Conversion System	6	1.5.2.1 1.5.3.1	Current during flat top shall be regulated to within 0.5%.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	566	GRD - 6.5.2.1.2.e	TF Power Conversion System	7	1.5.2.1 1.5.3.1	Bus links or other means shall be provided in order that the current in the TF magnets can be driven in either direction. The polarity reversal procedure shall require 4 hours or less.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	567	GRD - 6.5.2.1.2.f	TF Power Conversion System	8	1.5.2.1 1.5.3.1	Additional parameters regarding the TF power conversion system are specified in the DPSS			X				Subsystem is existing and not being modified as part of recovery scope		
Power	OH	568	GRD - 6.5.2.2.1.a	OH Power Conversion Sys	9	1.5.2.2 1.5.3.2	The OH circuit shall provide four quadrant operation over a current range of +/- 24 kA, and a voltage range of +/- 6 kV.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	OH	569	GRD - 6.5.2.2.2.a	OH Power Conversion Sys	10	1.5.2.2 1.5.3.2	The OH circuit shall be bipolar (current supplied in both directions during a pulse).			X				Subsystem is existing and not being modified as part of recovery scope		
Power	OH	570	GRD - 6.5.2.2.2.b	OH Power Conversion Sys	11	1.5.2.2 1.5.3.2	Baseline repetition period shall be 1200 s.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	OH	571	GRD - 6.5.2.2.2.c	OH Power Conversion Sys	12	1.5.2.2 1.5.3.2	Redundant measurements of the OH coil currents shall be provided with accuracy of 0.2% (magnitude of DC measurement error at full rated current).			X				Subsystem is existing and not being modified as part of recovery scope		
Power	OH	572	GRD - 6.5.2.2.2.d	OH Power Conversion Sys	13	1.5.2.2 1.5.3.2	Bus links or other means shall be provided in order that the connection between the power supplies and coils can be established in either direction. The polarity reversal procedure shall require 4 hours or less.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	PF	573	GRD - 6.5.2.3.1.a	PF Power Conversion System	14	1.5.2.3 1.5.3.3	The of power systems shall provide current and voltage to the of-1a through of-5 coils at levels defined by the DPSS [15] and the magnets SRD [5].	DPSS [15] and the magnets SRD [5]		X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	PF	574	GRD - 6.5.2.3.2.a	PF Power Conversion System	15	1.5.2.3 1.5.3.3	In the base configuration, the PF1C, PF1B, and PF3 circuits shall be bipolar (current supplied in both directions during a pulse). Other of circuits shall be unipolar, with no design choices being made to preclude an upgrade to bipolar operations.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	PF	575	GRD - 6.5.2.3.2.b	PF Power Conversion System	16	1.5.2.3 1.5.3.3	Baseline repetition period shall be 1200 s.									

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Power	PF	576	GRD - 6.5.2.3.2.c	PF Power Conversion System	17	1.5.2.3 1.5.3.3	Bus links or other means shall be provided in order that the connection between the power supplies and coils can be established in either direction.									
Power	PF	577	GRD - 6.5.2.3.2.c'	PF Power Conversion System	18	1.5.2.3 1.5.3.3	The polarity reversal procedure shall require 4 hours or less.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	PF	578	GRD - 6.5.2.3.2.d	PF Power Conversion System	19	1.5.2.3 1.5.3.3	Redundant measurements of the of coil currents shall be provided with accuracy of 0.2% (magnitude of DC measurement error at full rated current).			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	579	GRD - 6.5.2.4.a	Switching Power Amplifiers	20	1.5.3.4	The RWM coils shall be powered by bipolar switching power amplifiers (SPAs), capable of frequency response 0 - 100Hz.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	580	GRD - 6.5.2.4.b	Switching Power Amplifiers	21	1.5.3.4	The SPAs shall be capable of providing at least 3.3 kA for at least six seconds into either a single or series connected pair of RWM coils.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	DC	581	GRD - 6.5.3.1.a	DC Systems	22	1.5.2 1.5.3	The DC systems shall connect the AC/DC converters in FCPC to the Power Cable Termination Structure (PCTS) in the NTC.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	DC	582	GRD - 6.5.3.1.b	DC Systems	23	1.5.2 1.5.3	These systems shall consist of disconnect and grounding switches, power cables, DC current transducers, and ground fault detection			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	DC	583	GRD - 6.5.3.2.a	DC Systems	24	1.5.2 1.5.3	The TF, OH, and each of circuits shall be equipped with disconnect switches to isolate the power supply systems from the connections to the magnets.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	DC	584	GRD - 6.5.3.2.b	DC Systems	25	1.5.2 1.5.3	In addition, no-load grounding switches shall be provided to ground the terminals of the connections to the magnets.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	DC	585	GRD - 6.5.3.2.c	DC Systems	26	1.5.2 1.5.3	These ground and disconnect switches shall be interlocked with test cell access control.									
Power	DC	586	GRD - 6.5.3.2.d	DC Systems	27	1.5.2 1.5.3	The baseline repetition period of the DC systems shall be 2400s, upgradeable to 1200s.									
Power	Power	587	PWR - 2.0.a	General	1	1.5	The baseline Power Systems shall be designed to produce a maximum of 50 pulses per 24 hour period									
Power	Power	588	PWR - 2.0.b	General	2	1.5	Routine NSTX-U operation shall be assumed to consist of 30 pulses per day, 5 days per week, 3 weeks per month, 9 months per year. Non-operating times are available for maintenance.				X					
Power	AC	589	PWR - 3.3.a	AC Power Systems	1	1.5.1	All input power shall be derived from the 138kV service coming into the laboratory.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	590	PWR - 3.3.d	AC Power Systems	2	1.5.1	PPPL's pulsing affects other PPPL loads which derive power from the 138kV system as well, some of which (such as computer systems) are voltage sensitive. For that reason the dynamic voltage variation at PPPL's 138 kV bus (on pulsing) shall be held to +/-3% or better. The composite loads imposed by NSTX-U and the remainder of PPPL need to be accommodated, as well as fault transients due to short circuits, load sheds etc.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	591	PWR - 3.3.e	AC Power Systems	3	1.5.1	The utility system per unit impedance data given in the Table 3.3-1 (100 MVA base apparent power, 138 kV base voltage) shall be utilized for voltage drop and short circuit calculations			X				Subsystem is existing and not being modified as part of recovery scope		

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Category	**Filter**	**SEQ. #**	**Req't ID**	**Subsystem Name**	**Sub-Count**	**SBS**	**Requirement**	**Figure Ref.**	**Anal**	**Demo**	**Insp**	**Test**	**Analysis Artifacts**	**Demonstration Artifacts**	**Inspection Artifacts**	**Test Artifacts**
Power	AC	592	PWR - 3.3.g	AC Power Systems	4	1.5.1	Standard Auxiliary Power Systems services shall be as follows: • Service voltages (3-phase) 13.8kV, 4.16kV, 480V, 208V • Service voltages (single phase) 120V			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	593	PWR - 3.4.1.e	AC Power Systems	5	1.5.1	Voltage variations at PPPL's 138 kV bus, under unusual and fault conditions (such as load shed or short circuit) shall be limited to less than +/-10%.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	594	PWR - 3.4.1.f	AC Power Systems	6	1.5.1	Harmonic content of the line current at PPPL's 138 kV bus shall not exceed that of a 12 pulse rectifier, i.e.: harmonic: 11th 13th 23rd 25th rms % of fundamental: 9 7.5 4.5 4			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	595	PWR - 3.4.1.g	AC Power Systems	7	1.5.1	Operation at full rating shall not be restricted to any particular time of day.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	596	PWR - 3.4.1.h	AC Power Systems	8	1.5.1	Experimental power loads from other machines at PPPL shall be assumed inactive or not coincident with NSTX-U.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	597	PWR - 3.4.1.h'	AC Power Systems	9	1.5.1	However, the auxiliary systems loads from other experiments at the laboratory shall be considered coincidental, including those due to D-site.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	598	PWR - 3.4.2.a	AC Power Systems	10	1.5.1	Experimental power shall be taken nominally through one of the two D-site Motor-Generator (MG) units.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	599	PWR - 3.4.2.a'	AC Power Systems	11	1.5.1	The only exceptions shall be the HHFW system, for which the sources are located at C-site, and the NBI auxiliaries (decel, arc, filament, and magnet supplies) which are fed by the S2 bus at D-site.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	600	PWR - 3.4.2.b	AC Power Systems	12	1.5.1	When the experimental power load is such that the total composite load required by NSTX-U can be supplied directly by the grid, the configuration of the AC systems shall permit operation directly from the grid without the use of the MG set.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	601	PWR - 3.4.2.b'	AC Power Systems	13	1.5.1	Therefore the AC input to the TF, OH, and of converters, and the AC input to NBI equipment, shall each be separately connectable either to the MG set or to the grid.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	602	PWR - 3.4.2.c	AC Power Systems	14	1.5.1	Capability for testing of the experimental power equipment when supplied directly from the grid shall be possible within the limits of the grid.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	603	PWR - 3.4.2.f	AC Power Systems	15	1.5.1	For the case when operation is entirely from the grid, peak S1 bus power shall be limited to 120 MVA and 50 MVAR.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	AC	604	PWR - 3.4.2.i	AC Power Systems	16	1.5.1	Any combination of pulsed load and repetition period with $\int i^2(t)dt$ less than or equal to that described by the nominal loading scenario shall be possible, as long as the repetition period is not less than the minimum NSTX-U repetition period and as long as the peak active and reactive power demands do not exceed the nominal maximum values given in Table 3.4.2-1.			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Power	TF	605	PWR - 4.1.a	TF AC/DC Converters and DC Systems	1	1.5.2.1 1.5.3.1	The of/OH Power Conversion System shall provide a variable current in the of and OH magnet circuits during an NSTX-U discharge based on a reference firing angle signal provided in real time.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	606	PWR - 4.3.a	TF AC/DC Converters and DC Systems	2	1.5.2.1 1.5.3.1	The TF Power Conversion System shall include all equipment necessary to power the TF coils			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	607	PWR - 4.3.a'	TF AC/DC Converters and DC Systems	3	1.5.2.1 1.5.3.1	This shall include all equipment from the AC input power interface through to the DC bus connections to the magnets, including converter transformers, thyristor converters, DC cable, DC bus, disconnect switches and bus links, and all associated monitoring, control, and protection equipment.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	608	PWR - 4.3.b	TF AC/DC Converters and DC Systems	4	1.5.2.1 1.5.3.1	Bus links or other means shall be provided in order that the current in the TF magnets can be driven in either direction. The polarity reversal procedure shall require 4 hours or less/			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	609	PWR - 4.3.c	TF AC/DC Converters and DC Systems	5	1.5.2.1 1.5.3.1	No-load disconnect switches shall be provided to isolate the TF Power Conversion System from the connections to the TF magnets.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	610	PWR - 4.3.c'	TF AC/DC Converters and DC Systems	6	1.5.2.1 1.5.3.1	In addition, no-load grounding switches shall be provided to ground the terminals of the connections to the TF magnets			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	611	PWR - 4.3.c''	TF AC/DC Converters and DC Systems	7	1.5.2.1 1.5.3.1	These switches shall be interlocked with test cell access control.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	612	PWR - 4.3.d	TF AC/DC Converters and DC Systems	8	1.5.2.1 1.5.3.1	The TF power system shall be capable of accepting a reference firing angle from the real time data stream and producing the appropriate voltage from that firing angle.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	613	PWR - 4.3.e	TF AC/DC Converters and DC Systems	9	1.5.2.1 1.5.3.1	The TF Power Conversion System shall include protection to avoid the delivery of current which would overheat the TF magnets, assuming that their coolant conditions are nominal.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	614	PWR - 4.3.f	TF AC/DC Converters and DC Systems	10	1.5.2.1 1.5.3.1	Redundant measurements of TF current shall be provided.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	615	PWR - 4.3.g	TF AC/DC Converters and DC Systems	11	1.5.2.1 1.5.3.1	The TF power system shall be grounded via high resistance connections at the (+) and (-) coil terminals.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	616	PWR - 4.3.g'	TF AC/DC Converters and DC Systems	12	1.5.2.1 1.5.3.1	A ground fault protection system shall be used in conjunction with the grounding scheme to detect grounds within the TF circuit and terminate the discharge upon excessive ground current.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	617	PWR - 4.3.h	TF AC/DC Converters and DC Systems	13	1.5.2.1 1.5.3.1	The TF power system equipment and bus system external to the test cell shall be totally enclosed so that access can be maintained around the operating equipment without danger to the personnel.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	618	PWR - 4.3.i	TF AC/DC Converters and DC Systems	14	1.5.2.1 1.5.3.1	Branch currents, line-to-ground voltages, ground currents, and other rectifier signals shall be digitized for post-shot inspection.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	619	PWR - 4.3.j	TF AC/DC Converters and DC Systems	15	1.5.2.1 1.5.3.1	For each parallel branch in the TF circuit, each active rectifier shall be in series with a permanently bypassed rectifier.			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Power	TF	620	PWR - 4.3.k	TF AC/DC Converters and DC Systems	16	1.5.2.1 1.5.3.1	TF rectifiers shall be interfaced to the Hardwired Interlock System (HIS) in a fashion to prevent operations when when the test cell is potentially occupied.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	621	PWR - 4.3.l	TF AC/DC Converters and DC Systems	17	1.5.2.1 1.5.3.1	TF rectifiers shall be interlocked to prevent operations when test cell ground switches are closed.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	622	PWR - 4.4.a	TF AC/DC Converters and DC Systems	18	1.5.2.1 1.5.3.1	Two basic waveform sets shall be considered for the TF coil. The "Long Pulse Partial Inductive" (LPPI) is described in the GRD, and provides the long flat-top scenario. The "Short Pulse Full Inductive (SPFI)" case provides a simpler waveform, in support of shorter plasma discharges. Current and voltage cases for these two scenarios are provided in Figures 4.4-1 and 4.4-2			X		X		Subsystem is existing and not being modified as part of recovery scope		PTP-ECS-039 Dummy Load Testing
Power	TF	623	PWR - 4.4.d	TF AC/DC Converters and DC Systems	19	1.5.2.1 1.5.3.1	The Equivalent Square Wave (ESW) is the time duration of a constant current (equal to the current required to produce the required magnetic field) for which the ∫i 2 (t)dt produces the maximum allowable coil temperature rise under adiabatic conditions.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	624	PWR - 4.4.d'	TF AC/DC Converters and DC Systems	20	1.5.2.1 1.5.3.1	The current waveform in actual operation shall have an ∫i 2 (t)dt which is less than or equal to that given by the ESW.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	625	PWR - 4.4.d''	TF AC/DC Converters and DC Systems	21	1.5.2.1 1.5.3.1	The TF power supply system shall be capable of driving the coil current through the trajectories in Tables 3.4-1 and 3.4-2.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	626	PWR - 4.4.d'''	TF AC/DC Converters and DC Systems	22	1.5.2.1 1.5.3.1	The ∫i 2 (t)dt of the resultant waveform shall be within the specified limit.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	TF	627	PWR - 4.4.d''''	TF AC/DC Converters and DC Systems	23	1.5.2.1 1.5.3.1	In case of a fault the TF power supply shall shut down in such a way that the maximum ∫i 2 (t)dt of the pre-fault and post-fault current waveform does not exceed the maximum value given Table 4.4-4.			X				Subsystem is existing and not being modified as part of recovery scope		
Power	OH/PF	628	PWR - 5.1.a	OH and PF AC/DC Converters and DC Systems1	1	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	The of/OH Power Conversion System shall provide a variable current in the of and OH magnet circuits during an NSTX-U discharge based on a reference firing angle signal provided in real time.		X	X			Calc-53-08-00 (Current Limiting Reactor Sizing)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	629	PWR - 5.1.b	OH and PF AC/DC Converters and DC Systems1	2	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	The OH power supply shall: ● precharge the OH coil ● produce sufficient loop voltage to initiate the plasma ● ramp up the plasma current ● hold the plasma current at the requested value ● ramp down the plasma current			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	630	PWR - 5.1.c	OH and PF AC/DC Converters and DC Systems1	3	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	The of power supplies shall: ● Energize selected of coils to provide fields that null the OH linkage flux. ● Energize simultaneously all of coils to control the plasma equilibrium from plasma current ramp-up, through the plasma current flat-top, through plasma current ramp-down, and then return all coil currents to zero.	NSTX U-CALC-53-04	X	X			Calc-53-08-00 (Current Limiting Reactor Sizing)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Power	OH/PF	631	PWR - 5.3.a	OH and PF AC/DC Converters and DC Systems1	4	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	The of/OH Power Conversion System shall include all of the equipment necessary to power the of and OH coils. This includes all equipment from the primary terminals of the converter transformers through to the DC bus connections to the magnets, consisting of phase controlled thyristor converters, disconnect switches and bus links, and all associated monitoring, and protection equipment.		X	X			Calc 53-07-00 (Power Cabling Heating), Calc-53-08-00 (Current Limiting Reactor Sizing)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	632	PWR - 5.3.b	OH and PF AC/DC Converters and DC Systems1	5	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	The of coils shall be connected in series groups in separate circuits with independent current control as indicated in Table 5.3-1.	Table 5.3-1.	X	X			Calc-53-08-00 (Current Limiting Reactor Sizing)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	633	PWR - 5.3.c	OH and PF AC/DC Converters and DC Systems1	6	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	All series coil connections indicated in Table 5.3-1 shall result in current flow which is equal in magnitude, and in the same ϕ direction, in the series connected coils.	Table 5.3-1.	X	X			Calc-53-08-00 (Current Limiting Reactor Sizing)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	634	PWR - 5.3.e	OH and PF AC/DC Converters and DC Systems1	7	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	Bus links or other means shall be provided in order that the current in the OH & of magnets can be driven in either direction. The polarity reversal procedure shall require 4 hours or less.		X	X			Calc-53-08-00 (Current Limiting Reactor Sizing)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	635	PWR - 5.3.f	OH and PF AC/DC Converters and DC Systems1	8	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	No-load disconnect switches shall be provided to isolate the OH and of Power Systems from the connections to the magnets.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	636	PWR - 5.3.f'	OH and PF AC/DC Converters and DC Systems1	9	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	In addition, no-load grounding switches shall be provided to ground the terminals of the connections to the OH and of magnets.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	637	PWR - 5.3.g	OH and PF AC/DC Converters and DC Systems1	10	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	Disconnect and grounding switches shall be interlocked with test cell access control.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	638	PWR - 5.3.h	OH and PF AC/DC Converters and DC Systems1	11	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	Redundant measurements of each OH and of current shall be provided.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	639	PWR - 5.3.i	OH and PF AC/DC Converters and DC Systems1	12	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	Dummy load, and system of bus links permitting connection into of/OH power system circuits, shall be provided. Load ampacity should permit a brief flat top at full baseline of/OH current.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	640	PWR - 5.3.j	OH and PF AC/DC Converters and DC Systems1	13	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	Each power supply in the OH and of power system shall be grounded via high resistance connections at the (+) and (-) coil terminals.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	641	PWR - 5.3.j'	OH and PF AC/DC Converters and DC Systems1	14	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	A ground fault protection system shall be used in conjunction with the grounding scheme to detect grounds within the circuits and terminate the discharge upon excessive ground current.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	642	PWR - 5.3.k	OH and PF AC/DC Converters and DC Systems1	15	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	The OH and of power system equipment and bus system external to the test cell shall be totally enclosed so that access can be maintained around the operating equipment without danger to the personnel.	QC		X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Power	OH/PF	643	PWR - 5.3.l	OH and PF AC/DC Converters and DC Systems1	16	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	Branch currents, ground currents, line-to-ground voltages, and other rectifier signals shall be digitized for post-shot inspection.	QC		X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	644	PWR - 5.3.m	OH and PF AC/DC Converters and DC Systems1	17	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	In-line spare rectifiers shall be provided for the OH and of circuits to the extent that it is practical to do so.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	645	PWR - 5.3.n	OH and PF AC/DC Converters and DC Systems1	18	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	OH and of rectifiers shall be interfaced to the Hardwired Interlock System (HIS) in a fashion to prevent operations when when the test cell is potentially occupied.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	646	PWR - 5.3.o	OH and PF AC/DC Converters and DC Systems1	19	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	OH and of rectifiers shall be interlocked to prevent operations when test cell ground switches are closed.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	647	PWR - 5.4.c	OH and PF AC/DC Converters and DC Systems1	20	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	In order to satisfy NSTX-U plasma equilibria requirements the of/OH circuit ampacities and capabilities shall at minimum match the parameters in Table 5.4-2. RMS currents are rounded up to the nearest kiloampere.	Table 5.4-2	X	X			Calc 53-07-00 (Power Cabling Heating)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	OH/PF	648	PWR - 5.4.d	OH and PF AC/DC Converters and DC Systems1	21	1.5.2.2 1.5.3.2 1.5.2.3 1.5.3.3	Voltage requirements for the of coil shall be as Table 5.4-3.	Table 5.4-3	X	X			Calc 53-07-00 (Power Cabling Heating)	All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	649	PWR - 6.3.a	Switching Power Amplifiers	1	1.5.3.4	The SPA system shall have at least six independently controllable power supplies.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	650	PWR - 6.3.b	Switching Power Amplifiers	2	1.5.3.4	DC charging power shall be provided by a spare TRANSREX section.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	651	PWR - 6.3.c	Switching Power Amplifiers	3	1.5.3.4	Disconnect switches shall be provided between the TRANSREX supply and the SPA, enabling the systems to be isolate from each other.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	652	PWR - 6.3.d	Switching Power Amplifiers	4	1.5.3.4	No-load disconnect switches shall be provided to isolate the SPA Power Systems from the connections to the RWM coil.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	653	PWR - 6.3.d'	Switching Power Amplifiers	5	1.5.3.4	In addition, no-load grounding switches shall be provided to ground the terminals of the connections to the RWM coils.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	654	PWR - 6.3.e	Switching Power Amplifiers	6	1.5.3.4	Disconnect and grounding switches shall be interlocked with test cell access control.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	655	PWR - 6.3.f	Switching Power Amplifiers	7	1.5.3.4	Redundant measurements of each power supply current shall be provided.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	656	PWR - 6.3.g	Switching Power Amplifiers	8	1.5.3.4	Each power supply in the SPA system shall be grounded via high resistance connections at the (+) and (-) coil terminals.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	657	PWR - 6.3.h	Switching Power Amplifiers	9	1.5.3.4	A ground fault protection system shall be provided, with capability to terminate the pulse if a ground is detected.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	658	PWR - 6.3.i	Switching Power Amplifiers	10	1.5.3.4	Overcurrent, overtime, and I 2 t protection shall be provided			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Power	SPA	659	PWR - 6.3.j	Switching Power Amplifiers	11	1.5.3.4	The SPA/RWM power system equipment and bus system external to the test cell shall be totally enclosed so that access can be maintained around the operating equipment without danger to the personnel.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	660	PWR - 6.3.k	Switching Power Amplifiers	12	1.5.3.4	The SPA current output shall be controlled from the plasma control system.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	661	PWR - 6.3.l	Switching Power Amplifiers	13	1.5.3.4	Sufficient SPA signals shall be digitized to aid in troubleshooting. These include but are not limited to the current reference for each supply or subunit, any enable/status bits, the voltage on the SPA capacitor banks and the bank charging current.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	662	PWR - 6.3.m	Switching Power Amplifiers	14	1.5.3.4	The SPA systems shall be interfaced to the Hardwired Interlock System (HIS) in a fashion to prevent operations when when the test cell is potentially occupied.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Power	SPA	663	PWR - 6.3.n	Switching Power Amplifiers	15	1.5.3.4	The SPA systems shall be interlocked to prevent operations when test cell ground switches are closed.			X				All of Power Systems except of-1b is existing and not being modified as part of recovery scope		
Heating	Heating	**Heating Systems(NBI, PCH, HHFW)**														
Heating	HHFW	664	GRD - 6.2.1.1.a	High Harmonic Fast Wave System	1	1.2.1	The HHFW system shall deliver 4 MW of power to the plasma for 5 seconds, every 1200 seconds.			X		X		Subsystem is existing and not being modified as part of recovery scope		PTP
Heating	HHFW	665	GRD - 6.2.1.2.a	High Harmonic Fast Wave System	2	1.2.1	The HHFW system shall utilize RF power produced by the six existing Tokamak Fusion Test Reactor (TFTR) Ion Cyclotron Range of Frequencies (ICRF) sources.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	666	GRD - 6.2.1.2.b	High Harmonic Fast Wave System	3	1.2.1	The HHFW system shall utilize a twelve strap antenna mounted on the vacuum vessel wall in the gap between the upper and lower passive stabilizing plates. The antenna shall be arranged toroidally between the NSTX-U vacuum vessel mid-plane ports.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	667	GRD - 6.2.1.2.c	High Harmonic Fast Wave System	4	1.2.1	Each current strap shall include a backplane, a Faraday shield, and a local (bumper) limiter structure.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	668	GRD - 6.2.1.2.d	High Harmonic Fast Wave System	5	1.2.1	The antenna shall be compatible with bakeout and glow discharge modes of operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	669	GRD - 6.2.1.2.e	High Harmonic Fast Wave System	6	1.2.1	The twelve antennas shall be capable of operating at frequencies in the range of 30MHz to 40MHz.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	670	GRD - 6.2.1.2. e'	High Harmonic Fast Wave System	7	1.2.1	All RF generators operating at any single frequency shall be phase locked to provide control over the wavenumber spectrum excited in the plasma at that frequency.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	671	GRD - 6.2.1.2.f	High Harmonic Fast Wave System	8	1.2.1	Switches shall be provided to isolate HHFW power from the NSTX test cell. These switches shall be interlocked with the test cell access control system.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	672	GRD - 6.2.1.2.g	ECH Pre-Ionization	9	1.2.3	Antenna structures shall be qualified for the full disruption loads specified in Ref. [18]. NSTX-U-RQMT-RD-003-00, NSTX-U Disruption Requirements			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	673	GRD - 6.2.3.1.a	ECH Pre-Ionization	10	1.2.3	The EC system shall provide microwave RF power in the electron cyclotron range of frequencies for preionization.			X		X		Subsystem is existing and not being modified as part of recovery scope		System test part of PTP

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Heating	ECH	674	GRD - 6.2.3.2.a	ECH Pre-Ionization	11	1.2.3	One EC launcher shall be installed at an outboard location in the Vacuum Vessel to direct the microwave radiation toward the desired absorption location.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	675	GRD - 6.2.3.2.b	ECH Pre-Ionization	12	1.2.3	The launcher shall have a vacuum window connecting it to the external transmission system.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	676	GRD - 6.2.3.2.c	ECH Pre-Ionization	13	1.2.3	The system shall provide >20 kW of power, for a duration >20 msec, every 1200 seconds.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	677	GRD - 6.2.3.2.d	ECH Pre-Ionization	14	1.2.3	The EC power shall be interlocked to the test cell access control system.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	678	GRD - 6.2.4.1.a	Neutral Beam Injection	15	1.2.4	Two beamlines, with three ion sources each, shall be installed on NSTX-U at Bays A and K.			X		X		Subsystem is existing and not being modified as part of recovery scope		System test part of PTP
Heating	NBI	679	GRD - 6.2.4.2.a	Neutral Beam Injection	16	1.2.4	The neutral beam system shall use the TFTR-era beamlines, ion-sources, cryo-systems, and control. Modernizations for these systems shall be undertaken as appropriate.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	680	GRD - 6.2.4.2.b	Neutral Beam Injection	17	1.2.4	The beamlines shall be isolated from NSTX-U primary vacuum by torus isolation valves.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	681	GRD - 6.2.4.2.c	Neutral Beam Injection	18	1.2.4	One beamline shall inject through Bay A, and shall have beam tangency radii of R tan of 50, 60, and 70 cm.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	682	GRD - 6.2.4.2.d	Neutral Beam Injection	19	1.2.4	One beamline shall inject through Bay K, and shall have beam tangency radii of R tan of 110, 120, and 130 cm.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	683	GRD - 6.2.4.2.e	Neutral Beam Injection	20	1.2.4	Beam delivered power per beamline shall be as per Table 4.1.3-1.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	684	HEAT- 2.0.b	General	1	1.2	Permeability requirements are as per Ref. [2], while mechanical design shall be governed by the NSTX-U Structural Design Criteria [3].			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	685	HEAT- 2.0.d	General	2	1.2	Up-down symmetry of the vessel shall be maintained to the greatest extent possible.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	686	HEAT- 2.0.e	General	3	1.2	All viton O-rings shall be maintained under 180 o C under all thermal scenarios (bakeout, plasma operations,...)			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	687	HEAT- 2.0.f	General	4	1.2	All materials utilized within the primary vacuum boundary shall be designed to withstand the anticipated temperatures during plasma and bakeout operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	688	HEAT- 2.0.g	General	5	1.2	All pressure systems shall comply with PPPL standard ES-MECH-015 [5].			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	689	HEAT- 2.0.h	General	6	1.2	All materials at risk of exposure to lithium films shall be approved for use under that condition.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	690	HEAT- 2.0.i	General	7	1.2	Electrical isolation from the vessel shall be as specified in the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	Heating	691	HEAT- 2.0.j	General	8	1.2	Electrical isolation for signals leaving the test cell shall be as specified in the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		

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Heating	NBI	692	HEAT- 3.3.1.a	Neutral Beams	1	1.2.4	There shall be two TFTR era neutral beamlines installed on NSTX-U, each of which has the full complement of beamline hardware including but not limited to: ● Source platform ● Ion sources ● Source isolation valves ● Neutralizers and gas injection ● Bending magnets ● Ion dumps ● A calorimeter ● Cryo-panels and LN 2 and LHe distribution manifolds ● A turbo-molecular pump			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	693	HEAT- 3.3.1.b	Neutral Beams	2	1.2.4	Each beamline shall have three ion sources.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	694	HEAT- 3.3.1.b'	Neutral Beams	3	1.2.4	Each beamline shall have three ion sources.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	695	HEAT- 3.3.1.c	Neutral Beams	4	1.2.4	The sources shall be denoted A,B, and C, with the A source on the left and C source on the right when facing the beamline from behind.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	696	HEAT- 3.3.1.d	Neutral Beams	5	1.2.4	The neutral beam system shall be configured to inject in the co- direction, i.e. parallel to the plasma current. As per the GRD, the base plasma current direction will be counterclockwise when viewed from above.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	697	HEAT- 3.3.1.e	Neutral Beams	6	1.2.4	Beamline #1 shall be configured such that the tangency radius of the sources [A,B,C] are R tan =[70, 60, 50] cm.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	698	HEAT- 3.3.1.f	Neutral Beams	7	1.2.4	Beamline #1 shall be configured to inject at Bay A.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	699	HEAT- 3.3.1.g	Neutral Beams	8	1.2.4	Beamline #2 shall be configured such that the tangency radius of the sources [A,B,C] are R tan =[130,120,110] cm.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	700	HEAT- 3.3.1.h	Neutral Beams	9	1.2.4	Beamline #2 shall be configured to inject at Bay K.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	701	HEAT- 3.3.1.i	Neutral Beams	10	1.2.4	Beamline components, with the exception of the drift ducts, shall be isolated from the NSTX-U primary vacuum by torus isolation valves (TIVs)			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	702	HEAT- 3.3.1.j	Neutral Beams	11	1.2.4	Drift ducts shall be provided to interface the beamline TIV to the main torus.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	703	HEAT- 3.3.1.k	Neutral Beams	12	1.2.4	Armor shall be placed in the drift ducts as appropriate to protect against heating from the neutral beam itself or any reionization in the duct.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	704	HEAT- 3.3.1.l	Neutral Beams	13	1.2.4	The beamlines shall be electrically isolated from the vacuum vessel as per the GRD.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	705	HEAT- 3.3.2.a	Neutral Beams	14	1.2.4	The vessel shall be protected with a beam armor acting as a back stop such that no beam may impinge on the vessel proper but rather will impinge on carbon tiles. (Specific requirements for the beam armor are provided in Ref. [6]).			X				Subsystem is existing and not being modified as part of recovery scope		

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Heating	NBI	706	HEAT- 3.3.2.b	Neutral Beams	15	1.2.4	During Source Conditioning Operations , the neutral beams are injected into the lowered calorimeter for shorter pulses. ● The beam is not interlocked to the plasma current. ● The calorimeter is in the lowered position ● The torus isolation valves can be open or closed			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	707	HEAT- 3.3.2.c	Neutral Beams	16	1.2.4	During Armor Conditioning Operations , the neutral beams are injected into the armor for 50ms as allowed by the plasma current interlock system. ● The beam is interlocked to the plasma current. ● The calorimeter is in the raised position ● The torus isolation valves are open			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	708	HEAT- 3.3.2.d	Neutral Beams	17	1.2.4	During Beam Aiming/ MSE Calibration Operations , the neutral beams are injected into the armor for longer durations (~0.5 s), under strict administrative control, as well as interlocks in Section 3.3.4. ● The beam is not interlocked to the plasma current. ● The calorimeter is in the raised position ● The torus isolation valves are open			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	709	HEAT- 3.3.3.a	Neutral Beams	18	1.2.4	Provision shall be made for control of the beam on/off status from the output stream of the plasma control system.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	710	HEAT- 3.3.3.b	Neutral Beams	19	1.2.4	Measurements of the ion source voltage and current shall be provided to the real time data stream on a per-source basis, and the formula for conversion to source power provided.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	711	HEAT- 3.3.3.c	Neutral Beams	20	1.2.4	Indicators of the two calorimeter positions shall be provided to the real time data stream			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	712	HEAT- 3.3.3.d	Neutral Beams	21	1.2.4	Measurements of the ion source voltage and current shall be archived in the MDS+ database at a sampling rate >5 kHz, and the formula for conversion to source power provided.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	713	HEAT- 3.3.3.e	Neutral Beams	22	1.2.4	Indicators of the two calorimeter positions shall be provided to the MDS+ database.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	714	HEAT- 3.3.3.f	Neutral Beams	23	1.2.4	A PLC or similar shall be provided for control of the NB systems and interface to other control systems			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	715	HEAT- 3.3.4.a	Neutral Beams	24	1.2.4	The neutral beams shall be interlocked to the plasma current signal, such that low plasma current ends the beam pulse after a pre-determined short delay of up to 50 msec, to avoid overheating of the neutral beam armor.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	716	HEAT- 3.3.4.b	Neutral Beams	25	1.2.4	The neutral beam accel high voltage shall be interlocked to the NSTX-U Hardwired Interlock System, preventing application of high voltage when the test cell is in a safe state (i.e. free access or controlled access [7]).			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	717	HEAT- 3.3.4.c	Neutral Beams	26	1.2.4	The neutral beam torus isolation valve position shall be interlocked to torus pressure.			X				Subsystem is existing and not being modified as part of recovery scope		

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Heating	NBI	718	HEAT- 3.3.4.d	Neutral Beams	27	1.2.4	An over-temperature condition on the neutral beam armor TCs shall prevent the next NB shot into the plasma or armor until reset by neutral beam operators.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	719	HEAT- 3.3.5.a	Neutral Beams	28	1.2.4	An over-temperature condition on the neutral beam armor TCs shall prevent the next NB shot into the plasma or armor until reset by neutral beam operators.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	720	HEAT- 3.3.5.b	Neutral Beams	29	1.2.4	Operation of any combination of three ion sources from the power grid shall be possible.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	721	HEAT- 3.4.a	Neutral Beams	30	1.2.4	Each beamline shall be capable of delivering power in the Plasma Operations mode as per Table 3.4-1.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	722	HEAT- 3.4.a'	Neutral Beams	31	1.2.4	the design shall not preclude voltage levels corresponding to powers exceeding 7.5 MW per beamline.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	NBI	723	HEAT- 3.4.b	Neutral Beams	32	1.2.4	The two beamlines shall be capable of delivering these powers simultaneously			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	724	HEAT- 4.2.b	High Harmonic Fast Wave Heating	1	1.2.1	The design and construction of the antenna, internal transmission line, and feed through shall be consistent with good vacuum practices.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	725	HEAT- 4.2.b'	High Harmonic Fast Wave Heating	2	1.2.1	All materials utilized within the primary vacuum boundary shall be on the PPPL Vacuum Committee approved list, or shall be approved by the committee.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	726	HEAT- 4.2.c	High Harmonic Fast Wave Heating	3	1.2.1	The antenna, feed through, and internal transmission line construction shall be consistent with good electrical practices at radio frequencies and high radio frequency voltages.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	727	HEAT- 4.3.1.a	High Harmonic Fast Wave Heating	4	1.2.1	The HHFW system shall utilize RF power produced by the six existing Tokamak Fusion Test Reactor (TFTR)-era Ion Cyclotron Range of Frequencies (ICRF) sources located at C-Site.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	728	HEAT- 4.3.1.b	High Harmonic Fast Wave Heating	5	1.2.1	"The The HHFW system shall utilize RF power produced by the six existing Tokamak Fusion Test Reactor (TFTR)-era Ion Cyclotron Range of Frequencies (ICRF) sources located at C-Site. HHFW system shall utilize RF power produced by the six existing Tokamak Fusion Test Reactor"			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	729	HEAT- 4.3.1.c	High Harmonic Fast Wave Heating	6	1.2.1	The set of six sources (and twelve antennas) shall be capable of operation at a frequency of 30 MHz.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	730	HEAT- 4.3.1.c'	High Harmonic Fast Wave Heating	7	1.2.1	All RF generators operating shall be phase locked to provide control over the wavenumber spectrum excited in the plasma at that frequency.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	731	HEAT- 4.3.1.d	High Harmonic Fast Wave Heating	8	1.2.1	Switches shall be provided to isolate HHFW power from the NSTX-U test cell. These switches shall be interlocked with the test cell access control system			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	732	HEAT- 4.3.1.d'	High Harmonic Fast Wave Heating	9	1.2.1	Both electrical and mechanical (Kirk Key) interlocks shall be provided. 4.3.2 Electrical			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	733	HEAT- 4.3.2.a	High Harmonic Fast Wave Heating	10	1.2.1	The antenna back-plane with attached Faraday shield shall be electrically connected to the vacuum vessel wall via a low inductance ground.			X				Subsystem is existing and not being modified as part of recovery scope		

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Heating	HHFW	734	HEAT- 4.3.2.b	High Harmonic Fast Wave Heating	11	1.2.1	The antenna straps shall be end fed, with a center ground to the antenna shield enclosure.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	735	HEAT- 4.3.2.b'	High Harmonic Fast Wave Heating	12	1.2.1	The ends shall be fed out of phase, so that a voltage null exists at the antenna mid-point ground location.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	736	HEAT- 4.3.2.c	High Harmonic Fast Wave Heating	13	1.2.1	Both the inner and outer conductors of the transmission line shall be electrically isolated from the vacuum vessel with a voltage rating of 2 kV AC rms.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	737	HEAT- 4.3.3.d	High Harmonic Fast Wave Heating	14	1.2.1	The antenna, internal transmission line, and feed through assemblies shall be compatible with glow discharge cleaning of the NSTX-U vessel and limiters.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	738	HEAT- 4.3.3.e	High Harmonic Fast Wave Heating	15	1.2.1	The current straps, back planes, Faraday shields, internal transmission lines and RF feedthroughs shall be bakeable to the same temperature as the outboard vacuum vessel wall, namely 150 o C.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	739	HEAT- 4.3.3.e'	High Harmonic Fast Wave Heating	16	1.2.1	They shall be designed to tolerate the significantly higher temperature (~350 o C) of adjacent components (passive plates, outboard diverters, etc.)			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	740	HEAT- 4.3.3.f	High Harmonic Fast Wave Heating	17	1.2.1	The dead load imposed onto the vacuum vessel includes the weight of the antenna assembly and bumper limiters. The dead load imposed on structures external to the vacuum vessel, including those sections of transmission line connected to the feed through and isolated from the remainder of the line by the mechanical isolation bellows, shall be adequately taken by external supports from the NSTX-U structure.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	741	HEAT- 4.3.3.f'	High Harmonic Fast Wave Heating	18	1.2.1	The dead load for the remainder of the transmission line run includes the transmission line itself with associated components including tees, decoupling loops, stubs, and line stretchers, shall be taken by the transmission line support system.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	742	HEAT- 4.3.3.f''	High Harmonic Fast Wave Heating	19	1.2.1	This support system shall accommodate motion of the vessel without undue stress to vacuum feedthroughs and similar components due to vacuum vessel vertical and radial motion.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	743	HEAT- 4.3.3.g	High Harmonic Fast Wave Heating	20	1.2.1	To provide reliability and provide a margin of safety the RF vacuum feedthrough shall withstand a pressure of 30 psi.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	744	HEAT- 4.3.3.h	High Harmonic Fast Wave Heating	21	1.2.1	The bumper limiter assembly shall accommodate a heat load of 1 MW/m 2 .			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	745	HEAT- 4.3.3.h'	High Harmonic Fast Wave Heating	22	1.2.1	The Faraday shield shall accommodate the heat load associated with line-of-site radiation and neutral particle flux from the plasma, along with RF losses as calculated for the detailed design.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	746	HEAT- 4.3.3.i	High Harmonic Fast Wave Heating	23	1.2.1	Design of the antenna assembly shall consider the electromagnetic loads induced during normal operation of the device as well as the electromagnetic loads induced during abnormal operating events.			X				Subsystem is existing and not being modified as part of recovery scope		

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Heating	HHFW	747	HEAT- 4.3.3.i'	High Harmonic Fast Wave Heating	24	1.2.1	Events such as disruptions, plasma control failures, power supply failures, bus opens or shorts, or magnetic faults shall be included in the design and associated disruption loads.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	748	HEAT- 4.3.4.a	High Harmonic Fast Wave Heating	25	1.2.1	Diagnostics, signal detection, and data recording for antenna strap current, voltage, and relative phase shall be included in the HHFW system.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	749	HEAT- 4.3.4.b	High Harmonic Fast Wave Heating	26	1.2.1	Diagnostics, signal detection and data recording for forward power, reverse power, and phase shall be included in the HHFW system.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	750	HEAT- 4.3.4.c	High Harmonic Fast Wave Heating	27	1.2.1	Features shall be provided for real time control (preprogrammed with feedback modification) of the relative antenna current strap phasing.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	751	HEAT- 4.3.4.d	High Harmonic Fast Wave Heating	28	1.2.1	Features shall be provided for real time control (preprogrammed with feedback modification) of the RF power.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	752	HEAT- 4.3.4.e	High Harmonic Fast Wave Heating	29	1.2.1	The HHFW system shall be equipped with a plasma current interlock.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	753	HEAT- 4.3.5.a	High Harmonic Fast Wave Heating	30	1.2.1	The HHFW system shall not be allowed to direct power into the test cell when the NSTX-U Hardwired Interlock System (HIS) is in a safe state (i.e. free access or controlled access [7]).			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	754	HEAT- 4.3.5.b	High Harmonic Fast Wave Heating	31	1.2.1	Systems shall detect and respond to excessive reflected power by blanking RF power for a duration of order msec.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	755	HEAT- 4.4.1.a	High Harmonic Fast Wave Heating	32	1.2.1	The HHFW system shall permit vacuum conditioning of the antenna at pulse lengths of up to 5 sec.			X		X		Subsystem is existing and not being modified as part of recovery scope		System test part of PTP
Heating	HHFW	756	HEAT- 4.4.1.b	High Harmonic Fast Wave Heating	33	1.2.1	Cooling shall be sufficient to maintain strap, Faraday shield, and limiter temperature at or below 350 o C during conditioning.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	757	HEAT- 4.4.1.c	High Harmonic Fast Wave Heating	34	1.2.1	RF power supplied during vacuum conditioning shall be sufficient to bring the 6 port cube voltages to a peak voltages of 35 kV if vacuum conditioning permits.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	758	HEAT- 4.4.2.a	High Harmonic Fast Wave Heating	35	1.2.1	The HHFW system shall be capable of delivering at least 4 MW of power to the NSTX-U plasma for 5 seconds, once every 1200 seconds.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	759	HEAT- 4.4.2.b	High Harmonic Fast Wave Heating	36	1.2.1	Strap cooling shall be sufficient to maintain strap temperature at or below 350 o C during operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	760	HEAT- 4.4.2.c	High Harmonic Fast Wave Heating	37	1.2.1	Strap-to-strap phase accuracy shall be equal or better than 5 degrees.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	HHFW	761	HEAT- 4.4.3.a	High Harmonic Fast Wave Heating	38	1.2.1	A mode shall exist for testing leakage from transmission lines.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	762	HEAT- 5.2.a	EC Preionization System	1	1.2.3	The design and construction of the window shall be consistent with good vacuum practices.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	763	HEAT- 5.2.a'	EC Preionization System	2	1.2.3	All materials utilized within the primary vacuum boundary shall be on the PPPL Vacuum Committee approved list, or shall be approved by the committee.			X				Subsystem is existing and not being modified as part of recovery scope		

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Heating	ECH	764	HEAT- 5.2.b	EC Preionization System	3	1.2.3	The launcher construction shall be consistent with good electrical practices at radio frequencies and high radio frequency voltages.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	765	HEAT- 5.3.1.a	EC Preionization System	4	1.2.3	One ECH launcher shall be installed at an outboard location in the Vacuum Vessel to direct the microwave radiation toward the desired absorption location. The launcher must be compatible with bakeout and glow discharge modes.			X		X		Subsystem is existing and not being modified as part of recovery scope		System test part of PTP
Heating	ECH	766	HEAT- 5.3.1.a'	EC Preionization System	5	1.2.3	The launcher shall have a vacuum window connecting it to the external transmission system. This window must have low electrical loss at microwave frequencies and satisfy the thermal and mechanical requirements for vacuum interfaces.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	767	HEAT- 5.3.1.b	EC Preionization System	6	1.2.3	The transmission system shall efficiently transport the microwave power from the RF sources to the vacuum window.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	768	HEAT- 5.3.1.b'	EC Preionization System	7	1.2.3	It shall consist of a waveguide and special components for power measurement.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	769	HEAT- 5.3.1.c	EC Preionization System	8	1.2.3	The RF source shall be located inside the test cell and will provide the microwave power.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	770	HEAT- 5.3.1.c'	EC Preionization System	9	1.2.3	It shall include local controls and interlocks.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	771	HEAT- 5.3.2.a	EC Preionization System	10	1.2.3	The launcher shall be electrically connected to the vacuum vessel wall via a low inductance ground			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	772	HEAT- 5.3.2.b	EC Preionization System	11	1.2.3	The transmission line shall be electrically isolated from the vacuum vessel with a voltage rating of 2 kV AC rms.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	773	HEAT- 5.3.3.a	EC Preionization System	12	1.2.3	The window shall be compatible with glow discharge cleaning of the NSTX-U vessel and limiters.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	774	HEAT- 5.3.3.b	EC Preionization System	13	1.2.3	The window and launcher assembly shall be bakeable to the same temperature as the outboard vacuum vessel wall, namely 150 o C.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	775	HEAT- 5.3.3.c	EC Preionization System	14	1.2.3	This support system for waveguides shall accommodate motion of the vessel without undue stress to vacuum feedthroughs, windows, and similar components due to vacuum vessel vertical and radial motion.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	776	HEAT- 5.3.3.d	EC Preionization System	15	1.2.3	To provide reliability and provide a margin of safety the vacuum window shall withstand a pressure of 30 psi.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	777	HEAT- 5.3.4.a	EC Preionization System	16	1.2.3	RF start/stop triggering shall be externally controlled.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	778	HEAT- 5.3.4.b	EC Preionization System	17	1.2.3	A launched power signal shall be digitized.			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	779	HEAT- 5.3.5.a	EC Preionization System	18	1.2.3	The ECH-PI system shall be interlocked to the NSTX-U Hardwired Interlock System (HIS), preventing operation when the test cell is in a safe state (i.e. free access or controlled access [7]).			X				Subsystem is existing and not being modified as part of recovery scope		

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Heating	ECH	780	HEAT- 5.3.5.b	EC Preionization System	19	1.2.3	The ECH-Pi system shall have additional interlocks necessary for self-protection (reflected power, cooling water, etc.)			X				Subsystem is existing and not being modified as part of recovery scope		
Heating	ECH	781	HEAT- 5.4.a	EC Preionization System	20	1.2.3	The ECH system shall be designed to deliver >5 kW for 10 ms.			X		X		Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	**Real Time Control and Protection**														
RTC&P	RTCP	782	GRD - 6.7.3.5.1.a	Real Time Control and Software Coil Protection Systems	1	1.7.3.6	The Digital Coil Protection System (DCPS) system shall be used when the allowances of section 6.1.3.1.1b are invoked.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	783	GRD - 6.7.3.5.1.b	Real Time Control and Software Coil Protection Systems	2	1.7.3.6	The DCPS system shall be able to compare coil current values to limits.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	784	GRD - 6.7.3.5.1.c	Real Time Control and Software Coil Protection Systems	3	1.7.3.6	The DCPS system shall be able to compare coil action calculation to limits.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	785	GRD - 6.7.3.5.1.d	Real Time Control and Software Coil Protection Systems	4	1.7.3.6	The DCPS system shall be able to enforce the limit of T OH >T TF .			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	786	GRD - 6.7.3.5.1.e	Real Time Control and Software Coil Protection Systems	5	1.7.3.6	The DCPS system shall be able to compute forces, moments, and stresses on individual coils and coil mounting structures, and compare to limits.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	787	GRD - 6.7.3.5.1.f	Real Time Control and Software Coil Protection Systems	6	1.7.3.6	The DCPS system shall have the ability to compute combinations of forces and compare to limits.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	788	GRD - 6.7.3.5.1.g	Real Time Control and Software Coil Protection Systems	7	1.7.3.6	The coil protection system shall have the capability to detect turn-to-turn and coil-lead arc faults, here referred to as the Shorted Turn Protection System			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	789	GRD - 6.7.3.5.1.h	Real Time Control and Software Coil Protection Systems	8	1.7.3.6	Both systems shall have the capability to declare an FCPC Level-1 fault if limit values are exceeded or a turn-to-turn or coil-lead arc is detected.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	790	GRD - 6.7.3.5.2.a	Real Time Control and Software Coil Protection Systems	9	1.7.3.6	There shall be at least two separate, redundant, instances of the Digital Coil Protection System operating during any discharge.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	791	GRD - 6.7.3.5.2.b	Real Time Control and Software Coil Protection Systems	10	1.7.3.6	There shall be at least one instance of the Shorted Turn Protection System operating during any discharge			X				Subsystem is existing and not being modified as part of recovery scope		

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RTC&P	RTCP	792	GRD - 6.7.3.5.1.a'	Real Time Control and Software Coil Protection Systems	11	1.7.3.6	A real-time plasma control system shall be installed, capable of closed loop control of the plasma current, shape, gas fuelling, heating systems, RWM coil currents, and other properties.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	793	GRD - 6.7.3.5.2.a'	Real Time Control and Software Coil Protection Systems	12	1.7.3.6	The system shall have a distributed input data stream for data relevant to plasma operation. Data shall be converted and packaged as necessary for transporting it.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	794	GRD - 6.7.3.5.2.b'	Real Time Control and Software Coil Protection Systems	13	1.7.3.6	The input data stream shall be continuously expandable			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	795	GRD - 6.7.3.5.2.c'	Real Time Control and Software Coil Protection Systems	14	1.7.3.6	The sampling rate of the input stream shall be >= 5 kHz.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	796	GRD - 6.7.3.5.2.d'	Real Time Control and Software Coil Protection Systems	15	1.7.3.6	The system shall have an output stream with control information of rectifier firing angles (for transrex rectifiers) or a current reference (for the SPAs), as well as for gas valve modulation, and neutral beam on/off.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	797	GRD - 6.7.3.5.2.f'	Real Time Control and Software Coil Protection Systems	16	1.7.3.6	The system shall have a real time computer interfacing to the data streams, capable of executing the required algorithms, and with the ability to add additional algorithms.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	798	GRD - 6.7.3.4.a	Pulse Duration and Period Timer	17	1.7.3.6	A system shall be provided to enforce a maximum on-duration of the FCPC rectifiers, as well as the minimum duration between pulses.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	799	GRD - 6.7.3.4.b	Pulse Duration and Period Timer	18	1.7.3.6	The two durations on this system shall be reconfigurable.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	800	RCP- 2.2.a	RT Data Stream	1	1.7.3.6.1	The System shall be designed to conform to electrical isolation requirements as defined in the GRD [1] Section 4.2.3 Part b and Part c.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	801	RCP- 2.2.b	RT Data Stream	2	1.7.3.6.1	A combination of industry standard and in-house designs shall be used to implement the NSTX-U Real-Time Data Stream.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	802	RCP- 2.2.d	RT Data Stream	3	1.7.3.6.1	When equipment must be designed in-house for a specific purpose, it shall conform to industry and PPPL engineering procedures defined for electronics (ENG-023 [3]) and software .	PPPL engineering procedures defined for electronics (ENG-023 [3]) and software		X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	803	RCP- 2.2.e	RT Data Stream	4	1.7.3.6.1	The use of material in construction of this system shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directives and other industry mandates.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	804	RCP- 2.3.a	RT Data Stream	5	1.7.3.6.1	The real-time input stream shall be capable of analog and digital inputs. Other input types may additionally be defined as needed for specific applications.			X				Subsystem is existing and not being modified as part of recovery scope		

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RTC&P	RTCP	805	RCP- 2.3.b	RT Data Stream	6	1.7.3.6.1	The real-time input stream shall have input modules distributed as necessary throughout the NSTX-U plant, with channel counts based on current needs as well as anticipated future demands of the evolving research program1.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	806	RCP- 2.3.c	RT Data Stream	7	1.7.3.6.1	The input data stream shall have modules or mechanisms to identify timing, i.e. timestamps or time markers.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	807	RCP- 2.3.d	RT Data Stream	8	1.7.3.6.1	The input data stream shall be provided to the primary real-time control system.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	808	RCP- 2.3.e	RT Data Stream	9	1.7.3.6.1	An identical input data stream shall be provided to a secondary real-time control system used, for development and as hot-spare, without compromising the primary control system data input.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	809	RCP- 2.3.f	RT Data Stream	10	1.7.3.6.1	Modules of the input stream located in different rooms or test cell ground classes shall have electrical ground separation.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	810	RCP- 2.3.g	RT Data Stream	11	1.7.3.6.1	Locations for input modules shall include, but not necessarily be limited to, the locations in Table 2.3-1 and Table 2.3-2.	Table 2.3-1 and Table 2.3-2.		X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	811	RCP- 2.3.a'	RT Data Stream	12	1.7.3.6.1	The real-time output stream shall be capable of analog and digital outputs. Other output types may additionally be defined as needed for specific applications.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	812	RCP- 2.3.b'	RT Data Stream	13	1.7.3.6.1	The real-time output stream shall have output modules distributed as necessary throughout the NSTX-U plant, with channel counts determined as needed by the evolving demands of the research program.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	813	RCP- 2.3.c'	RT Data Stream	14	1.7.3.6.1	Modules of the output stream located in different rooms or test cell ground classes shall have electrical ground separation.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	814	RCP- 2.3.d'	RT Data Stream	15	1.7.3.6.1	Output channels shall be of sufficient quantity and distribution to control the actuators in Table 2.3-3.	Table 2.3-3		X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	815	RCP- 2.4.a	RT Data Stream	16	1.7.3.6.1	The input datastream shall deliver a full set of input data to each client system at a minimum of 5 kHz.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	816	RCP- 2.4.b	RT Data Stream	17	1.7.3.6.1	The output datastream shall deliver a full data set of commands to actuators at a minimum of 5 kHz.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	817	RCP- 3.2.a	RT Plasma Control Computer	1	1.7.3.6.2 1.7.3.6.3	The system shall use reliable, enterprise-class hardware components.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	818	RCP- 3.2.b	RT Plasma Control Computer	2	1.7.3.6.2 1.7.3.6.3	The operating environment shall provide deterministic, real-2 time behaviour.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	819	RCP- 3.3.a.a	RT Plasma Control Computer	3	1.7.3.6.2 1.7.3.6.3	The system shall have a mechanism for calibrating all input data. This may include Decoding the digitizer data to its respective voltage range,			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	820	RCP- 3.3.a.b	RT Plasma Control Computer	4	1.7.3.6.2 1.7.3.6.3	The system shall have a mechanism for calibrating all input data. This may include Conversion from electrical units to physics/engineering units (A, V, etc.)			X				Subsystem is existing and not being modified as part of recovery scope		

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RTC&P	Plasma Co	821	RCP- 3.3.a.c	RT Plasma Control Computer	5	1.7.3.6.2 1.7.3.6.3	The system shall have a mechanism for calibrating all input data. This may include Baseline subtraction, including a sloped baseline to account for integrator drift for magnetic sensors.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	822	RCP- 3.3.b	RT Plasma Control Computer	6	1.7.3.6.2 1.7.3.6.3	The system shall have a graphical user interface allowing the operator to configure the software and provide reference values, gain settings, and other input data.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	823	RCP- 3.3.c	RT Plasma Control Computer	7	1.7.3.6.2 1.7.3.6.3	The system shall be capable of executing heterogeneous algorithms based on the real time input data, operator inputs, and other configuration settings.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	824	RCP- 3.3.d	RT Plasma Control Computer	8	1.7.3.6.2 1.7.3.6.3	The system shall produce output commands for all configured output modules			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	825	RCP- 3.3.e	RT Plasma Control Computer	9	1.7.3.6.2 1.7.3.6.3	The system shall allow algorithms to deterministically exchange data.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	826	RCP- 3.3.f	RT Plasma Control Computer	10	1.7.3.6.2 1.7.3.6.3	The system shall allow the choice of which algorithm to execute from pre-defined groups on a per-cycle basis.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	827	RCP- 3.3.g	RT Plasma Control Computer	11	1.7.3.6.2 1.7.3.6.3	The system shall have the capability to switch which algorithm controls a given actuator or provides a given piece of data to a subsequent algorithm, based on either pre-determined changes in the algorithm sequence or as a result of detected events.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	828	RCP- 3.3.h	RT Plasma Control Computer	12	1.7.3.6.2 1.7.3.6.3	The system shall be capable of using multiple cores for algorithm execution.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	829	RCP- 3.3.i	RT Plasma Control Computer	13	1.7.3.6.2 1.7.3.6.3	The system shall be capable of restoring entire or partial pulse configurations from archive for inspection and running future pulses.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	830	RCP- 3.3.j	RT Plasma Control Computer	14	1.7.3.6.2 1.7.3.6.3	The system shall allow optional configuration settings to be automatically skipped when restoring from archive.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	831	RCP- 3.3.k	RT Plasma Control Computer	15	1.7.3.6.2 1.7.3.6.3	The system shall archive all input data in both raw and calibrated form.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	832	RCP- 3.3.l	RT Plasma Control Computer	16	1.7.3.6.2 1.7.3.6.3	The system shall archive all attempted output commands.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	833	RCP- 3.3.m	RT Plasma Control Computer	17	1.7.3.6.2 1.7.3.6.3	In the event of a full hardware failure, the system shall be recoverable in less than 4 hours.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	834	RCP- 3.3.n	RT Plasma Control Computer	18	1.7.3.6.2 1.7.3.6.3	The system shall restrict configuring designated algorithms to an administratively controlled list of authorized users.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	835	RCP- 3.3.o	RT Plasma Control Computer	19	1.7.3.6.2 1.7.3.6.3	Without assuming the role of other protection systems, the plasma control system shall enforce limits on operator inputs.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	836	RCP- 3.3.p	RT Plasma Control Computer	20	1.7.3.6.2 1.7.3.6.3	The system shall record all changes in pulse configuration with timestamp and user identity.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	837	RCP- 3.4.a	RT Plasma Control Computer	21	1.7.3.6.2 1.7.3.6.3	The system shall operate with a maximum 0.2 msec periodic. Some more complex numerical algorithms may require multiple cycles to complete execution.			X				Subsystem is existing and not being modified as part of recovery scope		

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RTC&P	Plasma Co	838	RCP- 3.4.b	RT Plasma Control Computer	22	1.7.3.6.2 1.7.3.6.3	The control system latency, including the input/output stream, as measured through the vertical control loop shall, be less than 800µs.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	839	RCP- 3.4.c.a	RT Plasma Control Computer	23	1.7.3.6.2 1.7.3.6.3	The system shall have capabilities for the simultaneous operation of the following control algorithms: Generation of firing angle and reference current commands for FCPC rectifiers and Switching Power Amplifiers (SPAs), based on input voltage and current requests.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	840	RCP- 3.4.c.b	RT Plasma Control Computer	24	1.7.3.6.2 1.7.3.6.3	The system shall have capabilities for the simultaneous operation of the following control algorithms: Real-time solution of the Grad-Shafranov equation, constrained by input data			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	841	RCP- 3.4.c.c	RT Plasma Control Computer	25	1.7.3.6.2 1.7.3.6.3	The system shall have capabilities for the simultaneous operation of the following control algorithms: Plasma boundary shape control in limited and diverted configuration, based on either magnetic sensor data alone or the equilibrium output from the Grad-Shafranov solver			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	842	RCP- 3.4.c.d	RT Plasma Control Computer	26	1.7.3.6.2 1.7.3.6.3	The system shall have capabilities for the simultaneous operation of the following control algorithms: Gas valve control, including pulse width modulation on piezo valves, based on either feed-forward control or feedback from real-time measurements			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	843	RCP- 3.4.c.e	RT Plasma Control Computer	27	1.7.3.6.2 1.7.3.6.3	The system shall have capabilities for the simultaneous operation of the following control algorithms: Neutral beam status control, based on either feed-forward commands or profile control algorithms			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	844	RCP- 3.4.c.f	RT Plasma Control Computer	28	1.7.3.6.2 1.7.3.6.3	The system shall have capabilities for the simultaneous operation of the following control algorithms: Analysis of 3D perturbations from magnetic sensors, and development of SPA current requests based on feedback operations on those perturbations.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	845	RCP- 3.4.c.g	RT Plasma Control Computer	29	1.7.3.6.2 1.7.3.6.3	The system shall have capabilities for the simultaneous operation of the following control algorithms: Lithium granule injector (LGI) status control, based on either feed-forward or feedback commands.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	846	RCP- 3.4.d	RT Plasma Control Computer	30	1.7.3.6.2 1.7.3.6.3	Additional algorithms shall be expected, and this list shall be used for conceptual guidance only.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	847	RCP- 3.4.e	RT Plasma Control Computer	31	1.7.3.6.2 1.7.3.6.3	The system shall be designed such that it satisfies the FMEA design criteria in the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	848	RCP- 3.4.e'	RT Plasma Control Computer	32	1.7.3.6.2 1.7.3.6.3	System failures shall be reduced to being an "Extremely unlikely Event" as defined in Table 4.2.1.1-1	Table 4.2.1.1-1 No table in document		X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Plasma Co	849	RCP- 3.5.a	RT Plasma Control Computer	33	1.7.3.6.2 1.7.3.6.3	The system shall be designed with the continued addition of algorithms anticipated. This may involve upgraded or additional hardware to support the required computation rate.			X				Subsystem is existing and not being modified as part of recovery scope		

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RTC&P	DCPS	850	RCP- 4.2.a	Digital Coil Protection	1	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The protection from mechanical stresses is provided by algorithms executing within the DCPS. The systems shall: The System shall be designed to conform to electrical isolation requirements as defined in the GRD [1] Section 4.2.3 Part b and Part c.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	851	RCP- 4.2.b	Digital Coil Protection	2	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The protection from mechanical stresses is provided by algorithms executing within the DCPS. A combination of industry standard and in-house designs shall be used to implement the DCPS.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	852	RCP- 4.2.c	Digital Coil Protection	3	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The protection from mechanical stresses is provided by algorithms executing within the DCPS. The systems shall: Where practical, equipment, communication protocols, and software will be utilized that is commercially available and supported by vendors or open source software communities.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	853	RCP- 4.2.d	Digital Coil Protection	4	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The protection from mechanical stresses is provided by algorithms executing within the DCPS. The systems shall: When equipment must be designed in-house for a specific purpose, it shall conform to industry and PPPL engineering procedures defined for electronics (ENG-023 [3]) and software.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	854	RCP- 4.2.e	Digital Coil Protection	5	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The protection from mechanical stresses is provided by algorithms executing within the DCPS. The use of material in construction of this system shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directives and other industry mandates.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	855	RCP- 4.2.f	Digital Coil Protection	6	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The protection from mechanical stresses is provided by algorithms executing within the DCPS. The systems shall: Be built using standard engineering practices for real-time systems			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	856	RCP- 4.3.1.a	Digital Coil Protection	7	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Two separate DCPS instances shall be installed and operated without allowing for degraded operation.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	857	RCP- 4.3.1.b	Digital Coil Protection	8	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Hardware systems associated with DCPS shall detect duty-cycle failures 3.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	858	RCP- 4.3.2.a	Digital Coil Protection	9	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall have as input data redundant measurements of the following currents: i. TF coil ii. OH coil iii. All of coils iv. Plasma.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	859	RCP- 4.3.2.b	Digital Coil Protection	10	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall adjudicate between the redundant measurements using a fail-safe, worst-case method.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	860	RCP- 4.3.2.c	Digital Coil Protection	11	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall convert the input data stream to the physics and engineering representation required by the algorithms.			X				Subsystem is existing and not being modified as part of recovery scope		

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	DCPS	861	RCP- 4.3.3.a	Digital Coil Protection	12	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall operate in tandem with the existing facility clock.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	862	RCP- 4.3.3.b.i	Digital Coil Protection	13	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall define two discrete states of active protection aligned with the facility clock: During a pulse			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	863	RCP- 4.3.3.b.ii	Digital Coil Protection	14	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall define two discrete states of active protection aligned with the facility clock: Between pulses			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	864	RCP- 4.3.4.a	Digital Coil Protection	15	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall perform deterministic, real-time calculations of algorithms necessary to protect the coils and their supports from mechanical and thermal failure outside their design limits meeting the requirements defined in [6] and [7]			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	865	RCP- 4.3.4.b.i	Digital Coil Protection	16	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall ensure that the coils are protected both between pulses and during pulses. There shall be no current allowed in any coil between pulses.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	866	RCP- 4.3.4.b.ii	Digital Coil Protection	17	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall ensure that the coils are protected both between pulses and during pulses. The system shall execute predefined protection algorithms during a pulse			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	867	RCP- 4.3.5.a	Digital Coil Protection	18	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Algorithms shall be configurable offline			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	868	RCP- 4.3.5.a.i	Digital Coil Protection	19	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Configuration shall include both the internal parameters of an algorithm along with the limits against which it is evaluated			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	869	RCP- 4.3.5.a.ii	Digital Coil Protection	20	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Configurations shall be secured from accidental or intentional tampering.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	870	RCP- 4.3.5.a.iii	Digital Coil Protection	21	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Configurations shall be validated and verified before use.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	871	RCP- 4.3.5.a.iv	Digital Coil Protection	22	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The user shall be able to add and modify algorithms through configuration changes to adapt to changing operational scenarios.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	872	RCP- 4.3.5.b.i	Digital Coil Protection	23	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	There shall be a single fault response for any declared fault resulting in, at a minimum, the following:Prevention of further plasma operations			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	873	RCP- 4.3.5.b.ii	Digital Coil Protection	24	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	There shall be a single fault response for any declared fault resulting in, at a minimum, the following:Deenergizing of all coils			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	874	RCP- 4.3.5.c.i	Digital Coil Protection	25	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall assert a fault within 1.0 ms following detection of any of the following conditions: Duty-cycle failure			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	DCPS	875	RCP- 4.3.5.c.ii	Digital Coil Protection	26	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall assert a fault within 1.0 ms following detection of any of the following conditions: Redundant input mismatch			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	876	RCP- 4.3.5.c.iii	Digital Coil Protection	27	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall assert a fault within 1.0 ms following detection of any of the following conditions: Any algorithm exceeding its configured limit			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	877	RCP- 4.3.5.d	Digital Coil Protection	28	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Faults shall be fail-safe.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	878	RCP- 4.3.5.e	Digital Coil Protection	29	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Faults shall require an operator action to clear.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	879	RCP- 4.3.6.a	Digital Coil Protection	30	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall archive at a minimum all calculation results, fault outputs, and necessary internal state.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	880	RCP- 4.3.6.b	Digital Coil Protection	31	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	Data archives shall be immutable once created.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	881	RCP- 4.3.7.a	Digital Coil Protection	32	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The online protection mechanisms shall be fail-safe.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	882	RCP- 4.3.7.b	Digital Coil Protection	33	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall allow fail-safe reconfiguration without compromising protection			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	883	RCP- 4.3.7.c	Digital Coil Protection	34	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall support offline testing using pulse archives or custom waveforms as input.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	884	RCP- 4.4.a	Digital Coil Protection	35	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall enforce the protections defined in section 4.3 with limit values tailored to a maximum latency of 1ms.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	885	RCP- 4.4.b'	Digital Coil Protection	36	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	The system shall be designed such that it satisfies the FMEA design criteria in the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	DCPS	886	RCP- 4.4.b'	Digital Coil Protection	37	1.7.3.6.4 1.7.3.6.5 1.7.3.6.6 1.7.3.6.7	System failures shall be reduced to being an "Extremely unlikely Event" as defined in Table 4.2.1.1-1	Table 4.2.1.1-1 No table in document		X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	STP	887	RCP- 5.2.a	Shorted Turn Protection System	1	1.7.3.6.9	The system shall have galvanic isolation from any coil or power supply terminals conforming to electrical isolation requirements as defined in the GRD [1] Section 4.2.3 Part b and Part c.	GRD [1] Section 4.2.3 Part b and Part c.	X							
RTC&P	STP	888	RCP- 5.3.1.a	Shorted Turn Protection System	2	1.7.3.6.9	The system shall have as input data redundant measurements of the following measurements: i. TF coil current and voltage ii. OH coil current and voltage iii. All of coils current and voltage iv. Plasma current		X			X	Shorted Turn CDR			Algorthmic and compoent testing

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	STP	889	RCP- 5.3.1.b	Shorted Turn Protection System	3	1.7.3.6.9	The system shall sample all inputs at a minimum of 5kHz.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	890	RCP- 5.3.1.c	Shorted Turn Protection System	4	1.7.3.6.9	The system shall adjudicate between the redundant measurements using a fail-safe, worst-case method.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	891	RCP- 5.3.1.d	Shorted Turn Protection System	5	1.7.3.6.9	The system shall convert the input data stream to the physics and engineering representation required by the algorithms.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	892	RCP- 5.3.1.e	Shorted Turn Protection System	6	1.7.3.6.9	The system shall have access to the plasma current data, from the plasma current Rogowski after compensation for vessel and linked-coil pickup.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	893	RCP- 5.3.1.f	Shorted Turn Protection System	7	1.7.3.6.9	The system shall take all configuration data from secure external input mechanisms. This may include: ● Circuit parameters ● Fault thresholds		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	894	RCP- 5.3.2.a.i	Shorted Turn Protection System	8	1.7.3.6.9	There shall be a single fault response signal for any declared fault. The declared fault shall result in, at a minimum, the following: Prevention of further plasma operations		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	895	RCP- 5.3.2.a.ii	Shorted Turn Protection System	9	1.7.3.6.9	There shall be a single fault response signal for any declared fault. The declared fault shall result in, at a minimum, the following: Deenergizing of all coils		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	896	RCP- 5.3.2.b	Shorted Turn Protection System	10	1.7.3.6.9	The system shall update its output signals at a minimum of 5kHz.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	897	RCP- 5.3.2.c.i	Shorted Turn Protection System	11	1.7.3.6.9	The system shall assert a fault within 1.0 ms following occurence of any of the following conditions: A coil fault / arc		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	898	RCP- 5.3.2.c.ii	Shorted Turn Protection System	12	1.7.3.6.9	The system shall assert a fault within 1.0 ms following occurence of any of the following conditions: Duty-cycle failure		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	899	RCP- 5.3.2.c.iii	Shorted Turn Protection System	13	1.7.3.6.9	The system shall assert a fault within 1.0 ms following occurence of any of the following conditions: Redundant input mismatch		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	900	RCP- 5.3.2.d	Shorted Turn Protection System	14	1.7.3.6.9	Faults shall be fail-safe.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	901	RCP- 5.3.2.d'	Shorted Turn Protection System	15	1.7.3.6.9	Any fault in the system itself shall result in the assertion of the fault response.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	902	RCP- 5.3.3.a	Shorted Turn Protection System	16	1.7.3.6.9	The system shall operate in tandem with the existing facility clock.		X	X			Shorted Turn CDR	Demonstrate the usage of the system clock		
RTC&P	STP	903	RCP- 5.3.3.b.i	Shorted Turn Protection System	17	1.7.3.6.9	The system shall define two discrete states of active protection aligned with the facility clock: During a pulse, i.e. in the time from the Start-Of-Pulse (SOP) event to the End-Of-Pulse (EOP) event		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	904	RCP- 5.3.3.b.ii	Shorted Turn Protection System	18	1.7.3.6.9	The system shall define two discrete states of active protection aligned with the facility clock: Between pulses, i.e. in the time from the EOP event to the SOP event.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	905	RCP- 5.3.4.a	Shorted Turn Protection System	19	1.7.3.6.9	The system shall archive all calculations, as well as its level-1 fault outputs.		X			X	Shorted Turn CDR			Algorthmic and compoent testing

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	STP	906	RCP- 5.4.c.i	Shorted Turn Protection System	20	1.7.3.6.9	The system shall be designed to detect electrical faults in the NSTX-U coil systems with minimum sensitivity sufficient to detect : terminal arcs on any NSTX-U coil system,		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	907	RCP- 5.4.c.ii	Shorted Turn Protection System	21	1.7.3.6.9	The system shall be designed to detect electrical faults in the NSTX-U coil systems with minimum sensitivity sufficient to detect : layer-to-layer faults on any of coil system, or the OH coil system,		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	908	RCP- 5.4.c.iii	Shorted Turn Protection System	22	1.7.3.6.9	The system shall be designed to detect electrical faults in the NSTX-U coil systems with minimum sensitivity sufficient to detect : arcs between individual flags on the TF coils,		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	909	RCP- 5.4.c.iv	Shorted Turn Protection System	23	1.7.3.6.9	The system shall be designed to detect electrical faults in the NSTX-U coil systems with minimum sensitivity sufficient to detect : faults within individual TF outer legs,		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	910	RCP- 5.4.c.v	Shorted Turn Protection System	24	1.7.3.6.9	The system shall be designed to detect electrical faults in the NSTX-U coil systems with minimum sensitivity sufficient to detect : arcs between individual water feeds on the OH coil.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	911	RCP- 5.4.d	Shorted Turn Protection System	25	1.7.3.6.9	The system shall have a nominal response time of 1.0 msec from the occurrence of the fault state to the reception of the fault signal at the HCS.		X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	STP	912	RCP- 5.4.e	Shorted Turn Protection System	26	1.7.3.6.9	The system shall be designed such that it satisfies the FMEA design criteria in the GRD [1].		X				Shorted Turn CDR			
RTC&P	STP	913	RCP- 5.4.e'	Shorted Turn Protection System	27	1.7.3.6.9	System failures shall be reduced to being an "Extremely unlikely Event" as defined in Table 4.2.1.1-1	Table 4.2.1.1-1 no table in document	X			X	Shorted Turn CDR			Algorthmic and compoent testing
RTC&P	Ip Calc	914	RCP- 6.2a	Ip Calculator	1	1.7.3.6.8	The System shall be designed to conform to electrical isolation requirements as defined in the GRD [1] Section 4.2.3 Part b and Part c.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	915	RCP- 6.2b	Ip Calculator	2	1.7.3.6.8	A combination of industry standard and in-house designs shall be used to implement the NSTX-U Plant Control I/O system.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	916	RCP- 6.2c	Ip Calculator	3	1.7.3.6.8	Where practical, equipment and software shall be utilized that is commercially available and supported by vendors.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	917	RCP- 6.2d	Ip Calculator	4	1.7.3.6.8	When equipment must be designed in-house for a specific purpose, it shall conform to industry and PPPL conventions for electrical, electronic, and software engineering.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	918	RCP- 6.2e	Ip Calculator	5	1.7.3.6.8	The use of material in construction of this system shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directives and other industry mandates.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	919	RCP- 6.2f	Ip Calculator	6	1.7.3.6.8	Redundancy shall be used for increased reliability.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	920	RCP- 6.3.a	Ip Calculator	7	1.7.3.6.8	The system shall process the signals from two plasma current (I P) Rogowski coils.			X				Subsystem is existing and not being modified as part of recovery scope		

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	Ip Calc	921	RCP- 6.3.b	Ip Calculator	8	1.7.3.6.8	The system shall compensate the signal by subtracting all linked currents from the Rogowski, as captured by the following equation IP = Irog – IV V – N1bUI1bU – N1bLI1bL – N1cUI1cU – N1cLI1cL IP : Plasma current Irog : Current measured by the Rogowski IV V : Toroidal Vacuum vessel current I1bU, I1bL, I1cU, I1cL : Currents in the coils of-1bU, of-1bL, of-1cU, of-1cL Number of turns in the coils of-1bU, of-N1bU, N1bL, N1cU, N1cL 1bL, of-1cU, of-1cL			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	922	RCP- 6.3.d	Ip Calculator	9	1.7.3.6.8	The vacuum vessel current shall be derived from a weighted sum of loop voltages, i.e. IV V = ΣαiV loop.i .			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	923	RCP- 6.3.d'	Ip Calculator	10	1.7.3.6.8	Eight flux loops on the CS assembly and 16 flux loops on the vacuum vessel, passive plates, and outboard divertors shall be used in this summation.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	924	RCP- 6.3.d''	Ip Calculator	11	1.7.3.6.8	The weights shall be αi shall be determined by project physics.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	925	RCP- 6.3.e	Ip Calculator	12	1.7.3.6.8	The system shall produce permissive signals to other systems by comparing the calculated plasma current against thresholds, where the thresholds shall be independently adjustable.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	926	RCP- 6.3.f	Ip Calculator	13	1.7.3.6.8	Internal failures of the system shall produce a system fault that prevents plasma operation.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	927	RCP- 6.3.g	Ip Calculator	14	1.7.3.6.8	External pulse timing information shall be provided by the facility clock.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	Ip Calc	928	RCP- 6.4.a	Ip Calculator	15	1.7.3.6.8	The system shall produce a low-gain and high-gain output for each Rogowski, with full-scale outputs of 10,000 kA for the low-gain and and 1000 kA for the high-gain output 6			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	929	RCP- 7.2.a	Pulse Duration and Period Timer	1	1.7.3.6 1.5.4	The System shall be designed to conform to electrical isolation requirements as defined in the GRD [1] Section 4.2.3 Part b and Part c.	as defined in the GRD [1] Section 4.2.3 Part b and Part c.		X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	930	RCP- 7.2.b	Pulse Duration and Period Timer	2	1.7.3.6 1.5.4	A combination of industry standard and in-house designs shall be used to implement the Pulse Duration Timer.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	931	RCP- 7.2.c	Pulse Duration and Period Timer	3	1.7.3.6 1.5.4	Where practical, equipment and software shall be utilized that is commercially available and supported by vendors.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	932	RCP- 7.2.d	Pulse Duration and Period Timer	4	1.7.3.6 1.5.4	When equipment must be designed in-house for a specific purpose, it shall conform to industry and PPPL conventions for electrical, electronic, and software engineering.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	933	RCP- 7.2.e	Pulse Duration and Period Timer	5	1.7.3.6 1.5.4	The use of material in construction of this system shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directives and other industry mandates.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	934	RCP- 7.3.a	Pulse Duration and Period Timer	6	1.7.3.6 1.5.4	The two durations t period and t allow shall be user configurable in the range from 0 seconds to 1999 seconds for t period and in the range from 0.0 seconds to 99.9 seconds for t allow .			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	935	RCP- 7.4.a	Pulse Duration and Period Timer	7	1.7.3.6 1.5.4	The PDP timer shall have three states: WAIT, ALLOW and INHIBIT			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	RTCP	936	RCP- 7.4.b	Pulse Duration and Period Timer	8	1.7.3.6 1.5.4	The PDP timer shall update the asserted state every 0.1 ms.			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	937	RCP- 7.4.c	Pulse Duration and Period Timer	9	1.7.3.6 1.5.4	The ALLOW state shall be true for a duration t allow following a pulse ('trigger pulse") from the facility clock, indicating the start of a shot			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	938	RCP- 7.4.d	Pulse Duration and Period Timer	10	1.7.3.6 1.5.4	The INHIBIT state shall be true, starting at time t allow after the trigger pulse, for a duration t period -t allow .			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	939	RCP- 7.4.e	Pulse Duration and Period Timer	11	1.7.3.6 1.5.4	The WAIT state shall be true after the end of INHIBIT and before the reception of the next trigger pulse			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	940	RCP- 7.4.f	Pulse Duration and Period Timer	12	1.7.3.6 1.5.4	The FCPC permissives shall only be enabled with ALLOW and not(INHIBIT) and not(WAIT)			X				Subsystem is existing and not being modified as part of recovery scope		
RTC&P	RTCP	941	RCP- 7.4.g	Pulse Duration and Period Timer	13	1.7.3.6 1.5.4	Trigger pulses shall be ignored during ALLOW and INHIBIT.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	**Central Instrumentation & Control**														
CI&C	CI&C	942	GRD - 6.6.1.a	Central I&C	1	1.6	The Central I&C system shall provide supervisory control and monitoring of the NSTX-U facility, including: ● Plant Control and Monitoring (asynchronous routine control and monitoring) ● Timing and synchronization (synchronization of triggered actions from master clock events) ● Data acquisition ● Data archiving ● Visual and audio monitoring and archiving of specific areas of the test cell ● Configuration of the NSTX-U control room and Fusion Control Center			X		X		Subsystem is existing and not being modified as part of recovery scope		Included as part of the PTP test
CI&C	CI&C	943	GRD - 6.6.2.a	Central I&C	2	1.6	"The NSTX-U Control Room shall be installed in the location previously occupied by the TFTR Control Room."			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	944	GRD - 6.6.2.b	Central I&C	3	1.6.2	The Central I&C systems shall include a data archival mechanism archiving all data from each discharge within 900 seconds of the end of pulse			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	945	GRD - 6.6.2.b'	Central I&C	4	1.6	It shall be possible to adjust the order in which data is collected.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	946	GRD - 6.6.2.c	Central I&C	5	1.6	This archival system shall allow on-line access to all NSTX and NSTX-U shot data, for users both at PPPL and off-site.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	947	GRD - 6.6.2.d	Central I&C	6	1.6.1	The Central I&C systems shall provide a system for distributed process control of the NSTX-U plant over the full 1200 second shot cycle, as well as during periods when no operations are occurring.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	948	GRD - 6.6.2.d'	Central I&C	7	1.6.1	This system shall have a graphical user interface accessible throughout the facility, with provision for continual expansion of the input and output capabilities.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	949	GRD - 6.6.2.e	Central I&C	8	1.6.1 1.6.2	The Central I&C systems shall provide a programmable clock system to synchronize events within the NSTX-U clock cycle.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	950	GRD - 6.6.2.f	Central I&C	9	1.6.1	The central I&C systems shall provide systems to monitor sounds and movement within the test cell.			X		X		Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	951	GRD - 6.6.2.f'	Central I&C	10	1.6.2	Images and sounds shall be archived for interrogation following the discharge.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	952	GRD - 6.6.2.g	Central I&C	11	1.6.1	The Central I&C system shall provide sixteen (16) electrically isolated, general purpose signal channels between the Junction Area and the control room.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	953	GRD - 6.6.2.g'	Central I&C	12	1.6.1	These signals shall be displayed in the control room in real-time.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	954	CIC- 1.a	General	1	1.6.1 1.6.2	For each of these functions Central Instrumentation and Control shall provide support, maintenance and upgrades : ● A physical interface to subsystems in other NSTX-U SBS areas as required, centralizing Plant Control Input/Output Interface including hardware (SBS 1.6.1.1) ● An integrated, distributed control and monitoring system of NSTX-U's engineering subsystems (SBS 1.6.1.2) ● Components of the timing and synchronization system which provides synchronized control of processes throughout the NSTX-U environment (SBS 1.6.1.3) ● A facility for research and operations staff with additional space for computing resources supporting machine operations. (SBS 1.6.1.4) ● Test cell audio/video equipment for visual monitoring of NSTX-U vessel components. (SBS 1.6.1.5) ● Mechanisms via which users can set up timing and control parameters and store them as well as calibration, configuration and experimental data (SBS 1.6.2.1) ● A secure yet accessible experimental data repository for both engineering data and physics data (SBS 1.6.2.2)			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	955	CIC- 1.c.a	General	2	1.6.1 1.6.2	Additional NSTX-U Central Instrumentation and Control systems or equipment may exist outside of this System Requirements Document in support of research and development of new capabilities. While not included in the SRD, these systems shall: Be in conformance with the CI&C SRD			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	956	CIC- 1.c.b	General	3	1.6.1 1.6.2	Additional NSTX-U Central Instrumentation and Control systems or equipment may exist outside of this System Requirements Document in support of research and development of new capabilities. While not included in the SRD, these systems shall: Conform with GRD [1] requirements			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	957	CIC- 1.c.c	General	4	1.6.1	Additional NSTX-U Central Instrumentation and Control systems or equipment may exist outside of this System Requirements Document in support of research and development of new capabilities. While not included in the SRD, these systems shall: When upgrading, being integrated with, or replacing existing SBS elements they shall comply with the Central Instrumentation and Control SRD.			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	958	CIC- 1.c.d	General	5	1.6.1 1.6.2	Additional NSTX-U Central Instrumentation and Control systems or equipment may exist outside of this System Requirements Document in support of research and development of new capabilities. While not included in the SRD, these systems shall: The format of this document, including interfaces specifications, is provided in the NSTX-U General Requirements Document [1].			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	959	CIC- 2.2.a	Plant Control Input/Output System	1	1.6.1.1	A combination of industry standard and in-house designs shall be used to implement the NSTX-U Plant Control I/O system. Commercially available equipment and software is preferred when supported by vendors or open-source software communities.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	960	CIC- 2.2.c	Plant Control Input/Output System	2	1.6.1.1	The use of material in construction of this system shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directives and other industry mandates.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	961	CIC- 2.3.a	Plant Control Input/Output System	3	1.6.1.1	Plant Control shall not provide system, machine or personnel protection and should not be considered a protection system.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	962	CIC- 2.3.b	Plant Control Input/Output System	4	1.6.1.1	The system shall provide analog input, digital input, analog output and digital output functionality as required by application.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	963	CIC- 2.3.c	Plant Control Input/Output System	5	1.6.1.1	The system shall provide and interface with the Timing and Synchronization system and provide timing signal inputs and outputs			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	964	CIC- 2.3.d	Plant Control Input/Output System	6	1.6.1.1	The system shall be capable of interfacing through I/O, networking, or software with non I&C system controls, such as Neutral Beams or Water Systems.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	965	CIC- 2.3.e	Plant Control Input/Output System	7	1.6.1.1	Some features of the system shall be capable of continuous operation as required.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	966	CIC- 2.3.f	Plant Control Input/Output System	8	1.6.1.1	The system shall be capable of interfacing directly with I/O points, or through industry standard networks.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	967	CIC- 2.3.g	Plant Control Input/Output System	9	1.6.1.1	Plant Control I/O data shall be archived either by a dedicated process control archiver system or to SBS element 1.6.2.1 when the data is specific to an NSTX or NSTX-U shot			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	968	CIC- 2.3.g'	Plant Control Input/Output System	10	1.6.1.1	Non-shot specific data shall be retained for a period of at least six months.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	969	CIC- 2.3.h	Plant Control Input/Output System	11	1.6.1.1	The system shall be physically distributed throughout the facility to simplify connectivity to monitored and controlled systems.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	970	CIC- 2.4.a	Plant Control Input/Output System	12	1.6.1.1	The Plant Control I/O System shall support NSTX-U physics configurations up to and including 13 seconds of acquisition as defined in GRD Section 4.1.2, to include critical data generated before and after the formation of the plasma.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	971	CIC- 2.4.b	Plant Control Input/Output System	13	1.6.1.1	As per the GRD [1], all instrumentation shall be isolated via optical and/or magnetic (isolation transformer) means prior to exiting the test cell boundary.			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	972	CIC- 2.4.c	Plant Control Input/Output System	14	1.6.1.1	The Plant Control I/O System shall support signal sampling rate of at least 1 Hz and be defined by the one of the following general categories: a. Analog Input: ■ The system design must accommodate 4-20 mA, 0 to +5 VDC, 0 to +10 VDC, +/-2.5 VDC, +/-5 VDC, +/-10 VDC, thermocouple, RTD, and strain gauge interfaces. b. Analog Output: ■ The system design must accommodate 4-20 mA, 0 to +5 VDC, 0 to +10 VDC, +/-2.5 VDC, +/-5 VDC, and +/-10 VDC interfaces. c. Digital Input: ■ The system design must accommodate TTL, contact, +5 VDC,+12 VDC and +24 VDC interfaces. d. Digital Output: ■ The system design must accommodate TTL, NIM, Relay, +5 VDC, +12 VDC and +24 VDC interfaces.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	973	CIC- 2.4d	Plant Control Input/Output System	15	1.6.1.1	The NSTX-U The Plant Control I/O System shall support existing CAMAC Data Acquisition component performance.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	974	CIC- 2.4d'	Plant Control Input/Output System	16	1.6.1.1	The tabulated data acquisition signals require sampling rates ranging from 100 Hz to 1 MHz and shall be used to meet interface requirements needed for engineering subsystems. These interfaces, are defined by one of the following general categories: a. Low Speed: ■ Data Acquisition signals requiring sample rates between 100 Hz and 2 KHz. b. Moderate Speed: ■ Data Acquisition signals requiring sample rates between 2 KHz and 100 KHz.fr c. High Speed: ■ Data Acquisition signals requiring sample rates between 100 KHz and 1 MHz.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	975	CIC- 2.4e	Plant Control Input/Output System	17	1.6.1.1	Additional Plant Control I/O System components that do not utilize existing CAMAC infrastructure shall support performance equal to or better than defined previously.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	976	CIC- 2.4.a	Plant Control Input/Output System	18	1.6.1.1	Upgrades to the current Plant Control I/O system performance shall be undertaken to reduce the archiving time to under 5 minutes after the plasma discharge completes.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	977	CIC- 2.4.b	Plant Control Input/Output System	19	1.6.1.1	The system shall be capable of incremental or modular upgrades to improve performance and satisfy future requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	978	CIC- 3.2.a	Plant Control and Monitoring System	1	1.6.1.2	The system shall use Enterprise or Industrial grade, commercially available computing equipment in its construction.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	979	CIC- 3.2.b	Plant Control and Monitoring System	2	1.6.1.2	The PCMS shall interface with the PPPL network infrastructure.			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	980	CIC- 3.3.a	Plant Control and Monitoring System	3	1.6.1.2	The PCMS shall not provide system, machine or personnel protection for system to which it interfaces and should not be considered a protection system.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	981	CIC- 3.3.d	Plant Control and Monitoring System	4	1.6.1.2	The design of the PCMS shall facilitate monitoring and control of the Control I/O System (SBS 1.6.1.1) by parties inside and outside of the NSTX-U control room (SBS 1.6.1.4).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	982	CIC- 3.3.e	Plant Control and Monitoring System	5	1.6.1.2	The PCMS shall provide process synchronization from the Timing and Synchronization System (SBS 1.6.1.3) events or process-specific conditions to NSTX-U subsystems.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	983	CIC- 3.3.f	Plant Control and Monitoring System	6	1.6.1.2	The PCMS shall function as the Control I/O data acquisition system and archive system configuration, sampling, acquisition, and display.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	984	CIC- 3.3.g	Plant Control and Monitoring System	7	1.6.1.2	The PCMS shall provide Historical Trending (continuous slow sampling, storage, and display).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	985	CIC- 3.3.h	Plant Control and Monitoring System	8	1.6.1.2	The PCMS shall provide alarm annunciation (hierarchical alarm display, notification, and logging).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	986	CIC- 3.3.i	Plant Control and Monitoring System	9	1.6.1.2	The PCMS shall provide access and system security, limiting access of “control points” to authorized users.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	987	CIC- 3.3.j	Plant Control and Monitoring System	10	1.6.1.2	The PCMS shall provide a uniform Human Machine Interface to access Process Data throughout the experimental complex.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	988	CIC- 3.4.a	Plant Control and Monitoring System	11	1.6.1.2	Trended PCMS data shall be maintained on-line for 30 days to support the display of historical trend data. After 30 days, data shall be stored off-line for archival purposes as needed.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	989	CIC- 3.4.b	Plant Control and Monitoring System	12	1.6.1.2	The NSTX-U PCMS shall support archiving existing CAMAC I/O points. Each existing I/O point, already interfaced to CAMAC I/O modules, requires a low scan rate (nominally 1 Hz).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	990	CIC- 3.4.c	Plant Control and Monitoring System	13	1.6.1.2	The NSTX-U PCMS shall support archiving existing CAMAC Data Acquisition channels.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	991	CIC- 3.4.c'	Plant Control and Monitoring System	14	1.6.1.2	The tabulated data acquisition signals require sampling rates ranging from 100 Hz to 1 MHz and shall be used to meet NSTX-U Engineering Data Acquisition requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	992	CIC- 3.4.d	Plant Control and Monitoring System	15	1.6.1.2	Human Machine Interfaces (HMI) shall be provided to engineering operators to interface with NSTX-U subsystems.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	993	CIC- 3.4.d'	Plant Control and Monitoring System	16	1.6.1.2	Each HMI shall utilize a common interaction tools such as trackballs, mice, touch-screens and keyboards.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	994	CIC- 3.4.d''	Plant Control and Monitoring System	17	1.6.1.2	Displays shall use color monitors or televisions, sized appropriately for viewing in their location.			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	995	CIC- 3.4.e	Plant Control and Monitoring System	18	1.6.1.2	A notification system shall be used to alert operators of the system status, alarming when the system is in an impaired state. Depending on the severity and systems affected by the alarm the, the PCMS may be used to inhibit further machine operation cycles. The PCMS is not considered to be a personnel or equipment protection system.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	996	CIC- 3.4.f	Plant Control and Monitoring System	19	1.6.1.2	The Baseline performance for IO, processing and controller capabilities shall be met or exceeded as outlined in table 2.4.1			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	997	CIC- 3.5.a	Plant Control and Monitoring System	20	1.6.1.2	The PCMS shall be upgradable to operate on replacement computing hardware as technologies evolve.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	998	CIC- 3.5.b	Plant Control and Monitoring System	21	1.6.1.2	The PCMS shall upgradable to support newer Control I/O hardware as legacy equipment is phased out and replaced with newer equipment.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	999	CIC- 3.5.c	Plant Control and Monitoring System	22	1.6.1.2	The PCMS shall be scalable to include additional I/O points and controllers			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1000	CIC- 3.5.d	Plant Control and Monitoring System	23	1.6.1.2	The number of supported PCMS Human Machine Interfaces shall be scalable to include additional Operator Interface HMI's.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1001	CIC- 4.2.a	Timing and Synchronization System	1	1.6.1.3	The System shall be designed to conform to electrical isolation requirements as defined in the GRD Section 4.2.3 Part c.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1002	CIC- 4.2.b	Timing and Synchronization System	2	1.6.1.3	A combination of industry standard and in-house designs shall be used to design and implement the NSTX-U Timing and Synchronization System.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1003	CIC- 4.2.d	Timing and Synchronization System	3	1.6.1.3	When equipment must be designed in-house for a specific purpose, it shall conform to industry and PPPL engineering procedures defined for electronics (ENG-023) and software (ENG-010).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1004	CIC- 4.2.a'	Timing and Synchronization System	4	1.6.1.3	The use of material in construction of this system shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directives and other industry mandates.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1005	CIC- 4.3.a	Timing and Synchronization System	5	1.6.1.3	The Synchronization System shall generate and distribute synchronous events (preprogrammed) to the NSTX-U subsystems.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1006	CIC- 4.3.a'	Timing and Synchronization System	6	1.6.1.3	Synchronous events shall prescribe a predefined schedule of occurrences to be initiated at preselected times prior to, during, and after each shot cycle or pulse.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1007	CIC- 4.3.d	Timing and Synchronization System	7	1.6.1.3	The NSTX-U Timing and Synchronization System shall be programmable via Human Machine Interface enabling the configuration of clock settings.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1008	CIC- 4.3.e	Timing and Synchronization System	8	1.6.1.3	The clock link shall supports at least 16 encoded "events" which can be used to signal actions to occur at desired times.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1009	CIC- 4.3.f	Timing and Synchronization System	9	1.6.1.3	The NSTX-U Timing and Synchronization System configuration and shot timing shall be archived to the Data archiving system			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
CI&C	CI&C	1010	CIC- 4.3.g	Timing and Synchronization System	10	1.6.1.3	The system shall provide digital input and digital output functionality as required by application.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1011	CIC- 4.4.a	Timing and Synchronization System	11	1.6.1.3	The NSTX-U Timing and Synchronization System shall provide repeatable timing and distributed encoded events to support "pulsed" plasma operations.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1012	CIC- 4.4.a	Timing and Synchronization System	12	1.6.1.3	The NSTX-U Timing and Synchronization System shall provide repeatable timing and distributed encoded events to support "pulsed" plasma operations.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1013	CIC- 4.4.b	Timing and Synchronization System	13	1.6.1.3	The NSTX-U Timing and Synchronization System shall provide a timing configuration resolution of one microsecond (µs) and an absolute accuracy across the experimental complex of < 25 µs.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1014	CIC- 4.4.c	Timing and Synchronization System	14	1.6.1.3	The NSTX-U Timing and Synchronization System shall utilize and conform to legacy TFTR Standard Timing Pulse [5] and legacy timing and synchronization module standards which are used to interface with NSTX-U engineering systems, diagnostics, and data acquisition equipment.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1015	CIC- 4.4.d	Timing and Synchronization System	15	1.6.1.3	The Facility clock link shall be distributed throughout the experimental complex at C-Site and D-Site.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1016	CIC- 4.4.d'	Timing and Synchronization System	16	1.6.1.3	The distribution network shall use a "star" topology, with the clock signal originating in the NSTX-U Control Room.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1017	CIC- 4.4.f	Timing and Synchronization System	17	1.6.1.3	The Clock Control System shall allow multiple authorization modes, to control who can operate the clock. Critical authorization modes that must be supported include those in Table 4.4-1.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1018	CIC- 4.5.a	Timing and Synchronization System	18	1.6.1.3	The Timing and Synchronization System shall be upgradable to support faster facility clock rates.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1019	CIC- 4.5.b	Timing and Synchronization System	19	1.6.1.3	The Timing and Synchronization System shall allow for the addition of network based timing and synchronization.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1020	CIC- 4.5.c	Timing and Synchronization System	20	1.6.1.3	The Timing and Synchronization System shall allow the modification or redefinition of encoded clock events.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1021	CIC- 5.2.a	NSTX-U Control Room And Fusion Control Center	1	1.6.1.4	Furniture used in the NSTX-U control room shall meet PPPL ergonomic directives as defined in ESHD 50008, Section 9, Chapter 9 [4].			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1022	CIC- 5.2.c	NSTX-U Control Room And Fusion Control Center	2	1.6.1.4	Access to the NSTX-U Control room and Fusion Control Center shall be restricted to authorized personnel and utilize Lab-wide security systems for access control.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1023	CIC- 5.2.d	NSTX-U Control Room And Fusion Control Center	3	1.6.1.4	The fire detection and suppression systems shall be built in accordance with PPPL facility requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1024	CIC- 5.2.e	NSTX-U Control Room And Fusion Control Center	4	1.6.1.4	The AC Power systems shall be built in accordance with PPPL facility requirements			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	1025	CIC- 5.3.a	NSTX-U Control Room And Fusion Control Center	5	1.6.1.4	The NSTX-U Control Room shall: Be installed in the location previously occupied by the TFTR Control Room.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1026	CIC- 5.3.b	NSTX-U Control Room And Fusion Control Center	6	1.6.1.4	The NSTX-U Control Room shall: Facilitate interaction among experimental physicists and operations personnel to promote an interactive work environment.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1027	CIC- 5.3.c	NSTX-U Control Room And Fusion Control Center	7	1.6.1.4	The NSTX-U Control Room shall: Provide racks to house NSTX-U operations computer systems and related development equipment			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1028	CIC- 5.3.d	NSTX-U Control Room And Fusion Control Center	8	1.6.1.4	The NSTX-U Control Room shall: Provide a cable tray system to economically and easily route power cables, signal cables and fiber optic cables.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1029	CIC- 5.3.e	NSTX-U Control Room And Fusion Control Center	9	1.6.1.4	The NSTX-U Control Room shall: Provide furniture to support the engineering and experimental physics activities.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1030	CIC- 5.3.f	NSTX-U Control Room And Fusion Control Center	10	1.6.1.4	The NSTX-U Control Room shall: Provide AC power distribution throughout the room from the electrical distribution panel provided.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1031	CIC- 5.3.g	NSTX-U Control Room And Fusion Control Center	11	1.6.1.4	The NSTX-U Control Room shall: Be secured and prevent access by unauthorized individuals.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1032	CIC- 5.3.h	NSTX-U Control Room And Fusion Control Center	12	1.6.1.4	The NSTX-U Fusion Control Center shall: Provide racks to house NSTX-U computer systems and related equipment			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1033	CIC- 5.3.i	NSTX-U Control Room And Fusion Control Center	13	1.6.1.4	The NSTX-U Fusion Control Center shall: Be secured and prevent access to unauthorized individuals.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1034	CIC- 5.3.j	NSTX-U Control Room And Fusion Control Center	14	1.6.1.4	The NSTX-U Fusion Control Center shall: Provide a cable tray system to route power cables, network cables, signal cables and fiber optic cables.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1035	CIC- 5.3.k	NSTX-U Control Room And Fusion Control Center	15	1.6.1.4	The NSTX-U Fusion Control Center shall: Provide sufficient cooling for equipment operating within.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1036	CIC- 5.3.l	NSTX-U Control Room And Fusion Control Center	16	1.6.1.4	The NSTX-U Fusion Control Center shall: Provide fire detection and suppression protection for equipment contained within.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1037	CIC- 5.3.m	NSTX-U Control Room And Fusion Control Center	17	1.6.1.4	The NSTX-U Fusion Control Center shall: Provide AC power sufficient for equipment operating within.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1038	CIC- 5.4.a	NSTX-U Control Room And Fusion Control Center	18	1.6.1.4	A large display of at least 9 square meters shall be provided in the control room to facilitate viewing experimental results and information.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1039	CIC- 5.4.a'	NSTX-U Control Room And Fusion Control Center	19	1.6.1.4	It shall be visible from the physics and engineering operations stations, and to the majority of other workstations.			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	1040	CIC- 5.4.c	NSTX-U Control Room And Fusion Control Center	20	1.6.1.4	An area for critical operations staff shall be provided and separated by visual boundaries.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1041	CIC- 5.5.a	NSTX-U Control Room And Fusion Control Center	21	1.6.1.4	The NSTX-U Control Room shall be capable of being reconfigured to accommodate changes in furniture and power requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1042	CIC- 5.5.b	NSTX-U Control Room And Fusion Control Center	22	1.6.1.4	The NSTX-U Fusion Control Center shall be capable of being reconfigured to accommodate changes in rack space and support system requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1043	CIC- 6.2.a	NSTX-U Test Cell Surveillance System	1	1.6.1.5	Camera, microphones, display and recording equipment shall be Commercial, Off the Shelf (COTS) in origin.			X		X		Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1044	CIC- 6.2.c	NSTX-U Test Cell Surveillance System	2	1.6.1.5	Cameras and their related equipment shall be rugged enough to be resilient to light physical damage resulting from normal movements of personnel and equipment in the area in which they are located.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1045	CIC- 6.2.d	NSTX-U Test Cell Surveillance System	3	1.6.1.5	Cameras shall be of an aim-able type in locations where a single view is insufficient to capture areas of interest.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1046	CIC- 6.2.e	NSTX-U Test Cell Surveillance System	4	1.6.1.5	Display equipment shall support viewing all relevant cameras simultaneously.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1047	CIC- 6.3.a	NSTX-U Test Cell Surveillance System	5	1.6.1.5	The NSTX-U Test Cell Surveillance System (TCSS) shall function within the magnetic and radiological environment of NSTX-U for at least one run year without requiring replacement due to degraded performance.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1048	CIC- 6.3.b	NSTX-U Test Cell Surveillance System	6	1.6.1.5	The TCSS shall record video, and optionally audio, from an adjustable, pre-selected time and cease recording at a preselected time.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1049	CIC- 6.3.c	NSTX-U Test Cell Surveillance System	7	1.6.1.5	The TCSS shall utilize existing network and other infrastructure wherever practical.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1050	CIC- 6.3.d	NSTX-U Test Cell Surveillance System	8	1.6.1.5	Data generated by the TCSS shall include metadata that describes when they were generated.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1051	CIC- 6.3.e	NSTX-U Test Cell Surveillance System	9	1.6.1.5	The audio portion of the TCSS shall be designed in such a way as to aid in determining the location of sounds recorded during a pulse. Cameras shall be deployed in such a way as to provide visible coverage of the majority of NSTX-U, including views above, below, and at the midplane.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1052	CIC- 6.3.f	NSTX-U Test Cell Surveillance System	10	1.6.1.5	The recorded content shall be archived in a format that can be viewed by common media playback software.			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	1053	CIC- 6.3.g	NSTX-U Test Cell Surveillance System	11	1.6.1.5	The archived data shall be retained until deemed unnecessary or obsolete.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1054	CIC- 6.3.h	NSTX-U Test Cell Surveillance System	12	1.6.1.5	The primary display and HMI equipment shall be placed in the NSTX-U Control Room.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1055	CIC- 6.3.i	NSTX-U Test Cell Surveillance System	13	1.6.1.5	Analog signal links between the junction area and the control room shall be electrically isolated.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1056	CIC- 6.3.j	NSTX-U Test Cell Surveillance System	14	1.6.1.5	The analog shall have the transmitting function in the junction area and receiving function in the control room.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1057	CIC- 6.3.k	NSTX-U Test Cell Surveillance System	15	1.6.1.5	The analog signal links shall have an input range appropriate for accepting signals from the DCCT Conditioning Circuits.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1058	CIC- 6.4.a	NSTX-U Test Cell Surveillance System	16	1.6.1.5	The TCSS shall monitor and record video at a frame rate of at least 30 Frames Per Second (FPS) in accordance with the National Television Standard Committee (NTSC) standard.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1059	CIC- 6.4.b	NSTX-U Test Cell Surveillance System	17	1.6.1.5	There shall be 16 channels in the analog links between the junction area and the control room.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1060	CIC- 6.5.a	NSTX-U Test Cell Surveillance System	18	1.6.1.5	The system shall be designed such that it shall be possible to add additional cameras and recorders.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1061	CIC- 7.2.a	Data Input/Output System	1	1.6.2.1	The Data I/O System shall be designed to meet the NSTX-U engineering requirements given in Section 6.6.2 Part b of the NSTX-U General Requirements Document (GRD),			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1062	CIC- 7.2.b	Data Input/Output System	2	1.6.2.1	The Data I/O System shall utilize existing CAMAC resources from the TFTR I&C system in order to reduce costs where possible.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1063	CIC- 7.2.c	Data Input/Output System	3	1.6.2.1	The Data I/O System shall interface with critical and non-critical Diagnostic systems to provide data acquisition, synchronization control and monitoring.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1064	CIC- 7.2.d	Data Input/Output System	4	1.6.2.1	When Data I/O equipment must be designed in-house for a specific purpose, it shall conform to industry and PPPL engineering procedures defined for electronics (ENG-023) and software (ENG-010).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1065	CIC- 7.2.e	Data Input/Output System	5	1.6.2.1	The Data I/O System shall interface with the Timing And Synchronization System (SBS 1.6.1.3) to provide hardware based triggering.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1066	CIC- 7.2.f	Data Input/Output System	6	1.6.2.1	The Data I/O system shall be physically distributed throughout the facility to simplify connectivity to monitored and controlled systems			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	CI&C	1067	CIC- 7.2.g	Data Input/Output System	7	1.6.2.1	The use of material in construction of the Data I/O System shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directives and other industry mandates.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1068	CIC- 7.3.a	Data Input/Output System	8	1.6.2.1	The Data I/O System shall not provide system, machine or personnel protection and should not be considered a protection system.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1069	CIC- 7.3.b	Data Input/Output System	9	1.6.2.1	The Data I/O System shall provide analog input, digital input, analog output and digital output functionality as required by application.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1070	CIC- 7.3.c	Data Input/Output System	10	1.6.2.1	The Data I/O System shall provide and interface with the Timing and Synchronization system and provide timing signal inputs and outputs.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1071	CIC- 7.3.d	Data Input/Output System	11	1.6.2.1	The Data I/O System shall be capable of receiving signals to initiate operation of I/O equipment for a specified period of time.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1072	CIC- 7.3.e	Data Input/Output System	12	1.6.2.1	The Data I/O System shall be capable of interfacing directly with I/O points, or through industry standard networks.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1073	CIC- 7.3.f	Data Input/Output System	13	1.6.2.1	The Data I/O System shall be physically distributed throughout the facility to simplify connectivity to diagnostic systems.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1074	CIC- 7.4.a	Data Input/Output System	14	1.6.2.1	Data acquisition equipment shall use differential signal inputs in environments where electronic noise causes interference such as the RF area and the NSTX-U Test Cell.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1075	CIC- 7.4.b	Data Input/Output System	15	1.6.2.1	Data acquired shall be available for offloading to the shot database with 60 seconds after recording completes.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1076	CIC- 7.4.c	Data Input/Output System	16	1.6.2.1	The Data I/O System shall support a 1200 second repetition rate, with all data archived within 900 seconds of the pulse ending.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	CI&C	1077	CIC- 7.5.a	Data Input/Output System	17	1.6.2.1	The Data I/O System shall be scalable to meet increased demands for performance and user load.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1078	CIC- 8.2.a	Data Archiving System	1	1.6.2.2	The design of the Central I&C Data Archiving System shall extend Section 8.2 to include control of diagnostic data acquisition systems, by parties outside of the NSTX control room (e.g. remote collaborators, physicists inside and outside of PPPL).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1079	CIC- 8.2.b	Data Archiving System	2	1.6.2.2	The Data Archiving System shall use Enterprise grade, commercially available computing equipment in its construction.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1080	CIC- 8.2.c	Data Archiving System	3	1.6.2.2	The Data Archiving System shall interface with the PPPL's Ethernet network infrastructure.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1081	CIC- 8.2.d	Data Archiving System	4	1.6.2.2	The Data Archiving System shall interface with a heterogenous mixture of hardware and software and their interface requirements.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1082	CIC- 8.2.e	Data Archiving System	5	1.6.2.2	The Data Archiving System shall adhere to the Lab-wide Information Technology Policy for short term backups of experimental data [6].			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1083	CIC- 8.2.e'	Data Archiving System	6	1.6.2.2	These backups shall be sent off-site for storage.			X				Subsystem is existing and not being modified as part of recovery scope		

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CI&C	Data Arch	1084	CIC- 8.2.f	Data Archiving System	7	1.6.2.2	Archiving of NSTX-U experiment data shall adhere to Lab policies for long term archival and records management [7].			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1085	CIC- 8.2.f'	Data Archiving System	8	1.6.2.2	In accordance with Level 2 Research. Data shall be retained for a period of 25 years after the experiment has ceased operation.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1086	CIC- 8.3.b	Data Archiving System	9	1.6.2.2	All experimental, calibration and configuration data acquired during machine operations from NSTX through NSTX-U shall be available for retrieval.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1087	CIC- 8.3.c	Data Archiving System	10	1.6.2.2	This system shall function as a means to backup NSTX-U experimental, calibration and configuration data to PPPL Information Technology Department provided Enterprise Backup System (EBS).			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1088	CIC- 8.3.e	Data Archiving System	11	1.6.2.2	The system shall provide Application Programming Interfaces (API) for developing support for new hardware and software.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1089	CIC- 8.3.e'	Data Archiving System	12	1.6.2.2	This interface shall be both local and remote connectivity.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1090	CIC- 8.4.a	Data Archiving System	13	1.6.2.2	Archived NSTX and NSTX-U Data shall be migrated from obsolete mediums to modern mediums to preserve access to data once its original backup media or access methods becomes obsolete.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1091	CIC- 8.4.b	Data Archiving System	14	1.6.2.2	Archived NSTX and NSTX-U Data shall be migrated from obsolete mediums to modern mediums to preserve access to data once its original backup media or access methods becomes obsolete.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1092	CIC- 8.4.c	Data Archiving System	15	1.6.2.2	Archived NSTX and NSTX-U Data shall be migrated from obsolete mediums to modern mediums to preserve access to data once its original backup media or access methods becomes obsolete.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1093	CIC- 8.5.a	Data Archiving System	16	1.6.2.2	Archived NSTX and NSTX-U Data shall be migrated from obsolete mediums to modern mediums to preserve access to data once its original backup media or access methods becomes obsolete.			X				Subsystem is existing and not being modified as part of recovery scope		
CI&C	Data Arch	1094	CIC- 8.5.b	Data Archiving System	17	1.6.2.2	Archived NSTX and NSTX-U Data shall be migrated from obsolete mediums to modern mediums to preserve access to data once its original backup media or access methods becomes obsolete.			X				Subsystem is existing and not being modified as part of recovery scope		
Test Cell	Test Cell	**Test Cell**														
Test Cell	Test Cell	1095	GRD - 6.8.1.1.a	Test Cell	1	1.8.1.1	NSTX-U shall reside in the former D-Site hot cell, also known as the NSTX-U Text Cell (NTC).				X					
Test Cell	Test Cell	1096	GRD - 6.8.1.1.c	Test Cell	2	1.8.1.1	The so-called "south high bay" shall be considered to be part of the test cell for the purposes of therequirements here.				X					
OSS	Test Cell	1097	GRD - 6.8.1.2.a	ODH Monitor	2	1.8.1.1	The test cell shall be provided with an oxygen deficiency hazard (ODH) monitoring system		X		X	X	Commercial Specifications			
Test Cell	Test Cell	1098	GRD - 6.8.1.2.b	Platforms	3	1.8.1.1.1	Platforms shall be provided for access to the midplane and upper levels of the machine.				X				Subsystem is existing and not being modified as part of recovery scope	
Test Cell	Test Cell	1099	GRD - 6.8.1.2.c	Fire Protection	4	1.8.1.1.6	A fire protection system shall be provided.				X					

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Test Cell	Test Cell	1100	GRD - 6.8.1.2.d	Penetrations	5	1.8.1.1.5	Penetrations in the text cell walls and floor shall have appropriate neutronics shielding or labyrinths.		X							
Test Cell	Test Cell	1101	GRD - 6.8.1.2.e	D-Site Air	6	0.1.1.10	Oil-free, dry compressed air shall be provided for equipment in the test cell.			X						
Test Cell	Test Cell	1102	TC- 2.2.a	Test Cell	1	1.8.1.1	The NSTX-U test cell shall be the former TFTR hot cell; structural design requirements from that design such as floor loading requirements shall continue to apply.		X							
Test Cell	Test Cell	1103	TC- 2.2.b	Test Cell	2	1.8.1.1	Fire retardant materials shall be used for construction where possible to provide 2 hr rated fire stop for walls and 3 hr rated fire stop for floors.		X	X						
Test Cell	Test Cell	1104	TC- 2.2.c	Test Cell	3	1.8.1.1	New structures shall be qualified for seismic events as per Ref. [2].		X				All Analyses Consider Seismic			
Test Cell	Test Cell	1105	TC- 2.2.d	Test Cell	4	1.8.1.1	All relevant life safety and building codes shall apply.				X					
Test Cell	Test Cell	1106	TC- 2.2.e	Test Cell	5	1.8.1.1	Magnetic materials shall satisfy the requirements described in Ref. [3].		X							
Test Cell	Test Cell	1107	TC- 2.2.f	Test Cell	6	1.8.1.1	Conducting loops of area greater than 0.2 m 2 formed by metallic structures within a radius of 3 meters from the centerline of the torus shall be broken by insulating breaks, unless specific exception is granted.		X		X		Considered in designs and analyses			
Test Cell	Test Cell	1108	TC- 2.2.f'	Test Cell	7	1.8.1.1	The insulation shall be rated to withstand a one minute AC hipot test at 2 kV AC rms.					X				Hi-Pot Tests
Test Cell	Test Cell	1109	TC- 2.3.a	Platforms	8	1.8.1.1.1	Platforms shall be provided for access to the midplane and upper levels of the machine, and for the support of equipment and racks.			X						
OSS	ODH	1110	TC- 2.3.b	ODH Monitor	9	1.8.1.1	An oxygen deficiency monitor shall be installed, with locations at least adjacent to the neutral beamlines and under the NSTX-U device.		X		X	X	Commercial Specifications			
Test Cell	Test Cell	1111	TC- 2.3.c	Lighting	10	1.8.1.1.10	Lighting shall be installed both on the ceiling and under platforms where necessary to provide illumination.			X						
Test Cell	Test Cell	1112	TC- 2.3.d	HVAC	11	0.1.1.6	Systems for dew point control and maintenance of negative pressure shall be provided.		X	X			Facilities HVAC			
Test Cell	Test Cell	1113	TC- 2.3.e	D-Site Air	12	0.1.1.10	Oil-free, dry compressed air service (“Instrument Air”) shall be provided for experimental equipment & controls. Additional dry compressed air may be provided for systems not requiring oil-free air.			X						
Test Cell	Test Cell	1114	TC- 2.3.f	Fire Protection	13	1.8.1.1.6	A pre-action fire protection system shall be installed in the NTC.			X	X					
Test Cell	Test Cell	1115	TC- 2.3.g	Fire Protection	14	1.8.1.1.6	Smoke and heat detectors shall be located on the NTC ceiling, and a VESDA system on the ceiling and under all platforms.			X	X					
Test Cell	Test Cell	1116	TC- 2.3.h	Fire Protection	15	1.8.1.1.6	Smoke and heat detectors shall report to the communications center.			X	X					
Test Cell	Test Cell	1117	TC- 2.3.i	Radiation Shielding	16	1.8.1.1.4	Penetrations in the test cell walls and floor shall have appropriate neutronics shielding or labyrinths.		X	X			NSTX-U-CALC-81-02-00			
Test Cell	Test Cell	1118	TC- 2.3.i'	Radiation Shielding	17	1.8.1.1.4	This shielding shall be designed to satisfy the goals in Table 2.3-1:	Table 2.3-1		X						
Test Cell	Test Cell	1119	TC- 2.3.j	Radiation Shielding	18	1.8.1.1.4.5	Penetrations in the test cell walls and floor shall have appropriate fire seals.		X	X			NSTX-U-CALC-81-02-00			

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Test Cell	Test Cell	1120	TC- 2.3.k	Cable Trays	19	1.8.1.1.2	Penetrations shall be sealed to facilitate maintenance of negative pressure in the test cell as per 2.3d.1	as per 2.3d.1	X				NSTX-U-CALC-81-02-00			
Test Cell	Test Cell	1121	TC- 2.3.l	Test Cell	20	1.8.1.1	Cable trays shall be provided to route cables from NSTX-U and associated equipment to racks of the appropriate ground class.			X	X			Sample ground checks	Labelling of cable trays	
Test Cell	Test Cell	1122	TC- 2.3.m	Rack	21	1.8.1.1.7	Racks for 19" rack mountable equipment shall be provided. These racks shall be isolated from the platform floor. Some racks may be electrically referenced to the NSTX-U vessel.			X	X			Field Measuremenets		
Test Cell	Test Cell	1123	TC- 2.3.n	Off-project	22	0.1.1	The test cell shall accommodate the distribution of services such as Instrument Air, House Air, the vacuum exhaust line (which connects to the vent stack), Facility Chilled Water, Potable Water, Deionized Water, and electrical power.			X				Off-Project Interfaces aleready are in exisistence		
Test Cell	Test Cell	1124	TC- 2.4.a	HVAC	23	0.1.1.6	Dewpoint control: The dewpoint setpoint shall be maintained at or below 45 ℉ using the house steam or dehumidifier system.		X	X			Part of a Facilities HVAC Upgrade			
Test Cell	Test Cell	1125	TC- 2.4.b	HVAC	24	0.1.1.6	Negative pressure: The test cell negative pressure shall be maintained between atmospheric and 0.08 in-H2O using the HVAC system.		X	X						
Test Cell	Test Cell	1126	TC- 2.4.c	Platforms	25	1.8.1.1.1	Per general industrial practice, platforms shall be designed for 150 lb/ft 2 .		X							
Test Cell	Test Cell	1127	TC- 2.4.c'	Platforms	26	1.8.1.1.1	The main NSTX-U test cell platforms shall be designed for 250 lb/ft 2 in order to provide additional stiffness and account for possible shielding needs around some of the diagnostics.		X				Facilities conducts calculations,			
Diag	Diagnostic	**Diagnostics**														
Diag	Mach. Inst	1128	GRD - 6.7.3.3.a	Machine Instrumentation	1	1.7.3.4	Machine instrumentation shall be provided to both validate mechanical models of the structure and to trend the long term behaviour of the mechanical system.					X				
Diag	Diagnostic	1129	DIAG- 1.1.b	General	2	1.4.1	All diagnostics installed in, on, or near NSTX-U shall meet the engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].	engineering requirements given in Section 6.4.2		X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Mach. Inst	1130	DIAG- 1.1.c	General	3	1.4.1	The machine instrumentation shall meet the requirements given in Section 6.7.3.3 of the GRD [1] and in the NSTX-U Machine Instrumentation Requirements Document [2].	Section 6.7.3.3 of the GRD [1]	X		X	X	Manufacturer's specification			
Diag	Diagnostic	1131	DIAG- 2.2.a	Magnetics Diagnostics	1	1.4.1.2	The magnetics diagnostics shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	PFC Diag	1132	DIAG- 2.2.b	Magnetics Diagnostics	2	1.4.1.2	The tile-mounted Mirnov sensors shall meet the requirements given in Section 1.1 of the PFC Diagnostics and Fueling Requirements Document [3].				X				The requirements are included in this matrix and are separately addressed RD-03	
Diag	Flux	1133	DIAG- 2.2.c	Magnetics Diagnostics	3	1.4.1.2	The Poloidal Flux Loops that are mounted on the center stack shall meet the requirements given in the Center Stack Air-Side Requirements Document [4].			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1134	DIAG- 2.2.d	Magnetics Diagnostics	4	1.4.1.2	All material used in-vacuum as part of the magnetic diagnostics design shall satisfy GRD vacuum materials requirements [1].			X				Most of the materials used have already been proven to satisfactorily operate in the required environment		Committee will address Halo Rogowski based
Diag	Rogowski	1135	DIAG- 2.3.1.a	Magnetics Diagnostics	5	1.4.1.2	The Plasma Current Rogowski coils shall link the plasma current. They may also link currents in poloidal field coils and the vacuum vessel as well as the plasma current.			X				The Ip Design is not changing and has been demonstrated to operate successfully. In addition, the new Center Stack redesign has been adjusted to allow additional clearance to aid in installation.		
Diag	Rogowski	1136	DIAG- 2.3.1.b	Magnetics Diagnostics	6	1.4.1.2	Plasma Current Rogowski coils shall be located outside the NSTX-U vacuum vessel.			X				The Ip Design is not changing and has been demonstrated to operate successfully		
Diag	Rogowski	1137	DIAG- 2.3.1.c	Magnetics Diagnostics	7	1.4.1.2	The Plasma Current Rogowski coils shall be wound on flexible mandrels (e.g., Teflon) to allow them to be installed on the air-side surface of the center stack casing and the vacuum vessel.			X				The Ip Design is not changing and has been demonstrated to operate successfully		
Diag	Rogowski	1138	DIAG- 2.3.1.d	Magnetics Diagnostics	8	1.4.1.2	The radial build of the Plasma Current Rogowski coils shall be consistent with the space available within the center stack casing plus sufficient clearance to avoid damage to them during installation. This allocation is provided in the Design Point Spreadsheet. [5]			X				The Ip Design is not changing and has been demonstrated to operate successfully. In addition, the new Center Stack redesign has been adjusted to allow additional clearance to aid in installation.		
Diag	Rogowski	1139	DIAG- 2.3.1.e	Magnetics Diagnostics	9	1.4.1.2	The Plasma Current Rogowski coils shall be covered by a copper electrostatic shield			X				The Ip Design is not changing and has been demonstrated to operate successfully		
Diag	Rogowski	1140	DIAG- 2.3.1.f	Magnetics Diagnostics	10	1.4.1.2	The electrostatic shield for the Plasma Current Rogowski coils shall be covered in flexible insulation (e.g., Kapton) with a high voltage standoff rating consistent with the NSTX-U hi-pot requirements.			X				The Ip Design is not changing and has been demonstrated to operate successfully		
Diag	Rogowski	1141	DIAG- 2.3.1.g	Magnetics Diagnostics	11	1.4.1.2	Three Plasma Current Rogowski coils shall be installed. At least two of them shall be instrumented during NSTX-U operations. The third coil shall serve as a spare that can be instrumented in the event of failure of one of the other two coils.			X				The Ip Design is not changing and has been demonstrated to operate successfully		
Diag	Flux	1142	DIAG- 2.3.2.a	Magnetics Diagnostics	12	1.4.1.2	The Poloidal Flux Loops shall be installed at the following locations: 1) on the outer surface of the outer vacuum vessel; 2) on the inner surface of the outer vacuum vessel; 3) behind the primary and secondary passive plates; 4) on the OH coil; 5) on the inner-of coils and potentially their supports, and 6) on the casing, a. [3]			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Flux	1143	DIAG- 2.3.2.b	Magnetics Diagnostics	13	1.4.1.2	The voltage signals from the Poloidal Flux Loops installed on the center stack and inner-of coils shall be integrated as the difference with the voltage measured by a flux loop on the midplane to minimize common mode effects. The signals from all other flux loops shall be directly integrated.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Flux	1144	DIAG- 2.3.2.c	Magnetics Diagnostics	14	1.4.1.2	The voltages on selected Poloidal Flux Loops shall also be directly measured (without integration) to allow the currents flowing in the vacuum vessel to be measured. The number and locations of these sensors shall be determined by the required accuracy of the vacuum vessel current measurement.			X				Subsystem is existing and not being modified as part of recovery scope		

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Category	**Filter**	**SEQ. #**	**Req't ID**	**Subsystem Name**	**Sub-Count**	**SBS**	**Requirement**	**Figure Ref.**	**Anal**	**Demo**	**Insp**	**Test**	**Analysis Artifacts**	**Demonstration Artifacts**	**Inspection Artifacts**	**Test Artifacts**
Diag	PFC Diag	1145	DIAG- 2.3.3.a	Magnetics Diagnostics	15	1.4.1.2	The Mirnov sensors shall be of two types: 1-D sensors capable of measuring the poloidal magnetic field along one axis and 2-D sensors capable of measuring the poloidal field along two orthogonal axes.			X	X			This an optimized implementation of the existing Mirnov design.	Inspect to the appropriate drawings 9D1552	
Diag	PFC Diag	1146	DIAG- 2.3.3.b	Magnetics Diagnostics	16	1.4.1.2	The Mirnov sensors shall be installed at the following locations: 1) between and behind the passive plates; 2) inside tiles mounted on the center stack casing; and 3) inside tiles in the outboard, horizontal, and vertical inner divertor regions.			X	X			Passive plates are not part of the recovery scope. However, ED-1471 provide cable runs for cable to the appropriate ports for completeness. Part of demonstration will likely feed PTP	Drawing 9D1552,9D11556, ED-1471 includes the assembly requirements. Inspection will take place to ensure proper installation	
Diag	PFC Diag	1147	DIAG- 2.3.3.c	Magnetics Diagnostics	17	1.4.1.2	The Mirnov sensors shall be wound of bare copper wire on a ceramic mandrel.				X				At the design review on 28 March 2019, prototype coils were provided and inspection will be verified against 9D1552	
Diag	PFC Diag	1148	DIAG- 2.3.3.d	Magnetics Diagnostics	18	1.4.1.2	The Mirnov sensor windings shall be covered in a high-temperature insulating cement.				X				These components will be inspected for compliance iaw Drawing 9D1552	
Diag	PFC Diag	1149	DIAG- 2.3.3.e	Magnetics Diagnostics	19	1.4.1.2	The Mirnov sensors shall be provided with electrostatic shields.				X				These components will be inspected for compliance iaw Drawing 9D1552	
Diag	PFC Diag	1150	DIAG- 2.3.3.f	Magnetics Diagnostics	20	1.4.1.2	The Mirnov sensor windings shall be connected to the lead wires by TIG welding.				X				These components will be inspected for compliance iaw Drawing 9D1552	
Diag	Diagnostic	1151	DIAG- 2.3.4.a	Magnetics Diagnostics	21	1.4.1.2	The diamagnetic loop system shall utilize a rogowski coil return lead to measure the total toroidal flux.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1152	DIAG- 2.3.4.b	Magnetics Diagnostics	22	1.4.1.2	The diamagnetic loop system shall utilize a rogowski sensor mounted on the TF outer leg.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1153	DIAG- 2.3.4.c	Magnetics Diagnostics	23	1.4.1.2	Electronic differencing of the diamagnetic loop signal and the TF outer leg sensor shall be done before integrations.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1154	DIAG- 2.3.4.d	Magnetics Diagnostics	24	1.4.1.2	A primary and spare loop systems shall be deployed, for redundancy. They may utilize the same rogowski sensor mounted on TF outer leg.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1155	DIAG- 2.3.5.a	Magnetics Diagnostics	25	1.4.1.2	Sensors shall be installed inside the vessel in order to measure slowly growing 3D field perturbations.				X				These components will be inspected for compliance iaw Drawing 9D1552	
Diag	Diagnostic	1156	DIAG- 2.3.5.b	Magnetics Diagnostics	26	1.4.1.2	These sensors shall be located above and below the midplane.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1157	DIAG- 2.3.5.c	Magnetics Diagnostics	27	1.4.1.2	At each of these two locations, there shall be measurements of both the normal and poloidal field perturbations.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Rogowski	1158	DIAG- 2.4.a	Magnetics Diagnostics	28	1.4.1.2	All materials used in the fabrication of the Plasma Current Rogowski coils shall be capable of tolerating a temperature of at least 150 C without damage.		X				Manufacturer's Data Sheets			
Diag	Flux	1159	DIAG- 2.4.b	Magnetics Diagnostics	29	1.4.1.2	All materials used in the fabrication of the Flux Loops and their leads shall be capable of tolerating the maximum bakeout temperature at their installed locations without damage.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	PFC Diag	1160	DIAG- 2.4.c	Magnetics Diagnostics	30	1.4.1.2	All materials used in the fabrication of the Mirnov sensors and their leads shall be capable of tolerating the maximum bakeout temperature at their installed locations without damage.		X				Manufacturer's Data Sheets			

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Diag	Rogowski	1161	DIAG- 2.4.d	Magnetics Diagnostics	31	1.4.1.2	The Plasma Current Rogowski coils shall be instrumented with both high- (10 5 A/V) and low-gain (10 6 A/V) channels to allow up to 4 MA of linked current flowing in the plasma, of coils, and vacuum vessel to be measured (2 MA plasma current and 2 MA currents in vacuum vessel and divertor coils).			X				This is based on the original design. The design has been proven and tested in operation.		
Diag	Rogowski	1162	DIAG- 2.4.e	Magnetics Diagnostics	32	1.4.1.2	The Plasma Current Rogowski coil signals shall be digitized at a minimum rate of 2 kHz.			X		X		This is based on the original design. The design has been proven and tested in operation.		
Diag	Flux	1163	DIAG- 2.4.f	Magnetics Diagnostics	33	1.4.1.2	The number of installed and instrumented Poloidal Flux Loops shall be sufficient to reliably support the magnetic reconstruction and plasma position control functions given in Section 1.1. Spare flux loops shall be installed to provide redundancy.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	PFC Diag	1164	DIAG- 2.4.g	Magnetics Diagnostics	34	1.4.1.2	The number of Mirnov sensors, their locations and the type of Mirnov sensor (1-D or 2-D) at each location shall be determined by requirements for equilibrium reconstruction and plasma position control.				X				These components will be inspected for compliance iaw Drawing 9D1552	
Diag	PFC Diag	1165	DIAG- 2.4.h	Magnetics Diagnostics	35	1.4.1.2	Mirnov sensors shall be designed to measure fields up to the levels indicated on Table 1.4-1 with appropriate setting on integrators.	Table 2.4-1.		X		X		This an optimized implementation of the existing Mirnov design.		
Diag	Flux	1166	DIAG- 2.4.i	Magnetics Diagnostics	36	1.4.1.2	Poloidal flux loops on the shall be configured to measure poloidal flux up to levels indicated in Table 2.4-1.	Table 2.4-1.		X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Flux	1167	DIAG- 2.4.j	Magnetics Diagnostics	37	1.4.1.2	Poloidal flux loops on the CS shall be differenced with respect to the CSC midplane loop, and configured to assess levels up those indicted in Table 2.4-1.	Table 2.4-1.		X				Subsystem is existing and not being modified as part of recovery scope		
Diag	PFC Diag	1168	DIAG- 2.4.k	Magnetics Diagnostics	38	1.4.1.2	The Mirnov, flux loop, and diamagnetic loop sensor signals shall be digitized at a minimum rate of 2 kHz.			X		X		This an optimized implementation of the existing Mirnov design. The existing digitizers continue to be used. Any new digitizers will support the 2 kHz standard		
Diag	Diagnostic	1169	DIAG- 2.4.l	Magnetics Diagnostics	39	1.4.1.2	The RWM sensors shall be designed for the diagnosis of perturbations growing with a 1 millisecond growth rate.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1170	DIAG- 2.4.m	Magnetics Diagnostics	40	1.4.1.2	The RWM sensors shall be designed to measure perturbations with toroidal mode number 1 through 3.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1171	DIAG- 2.4.n	Magnetics Diagnostics	41	1.4.1.2	The sensors shall be capable of resolving perturbations of order 2 G when fully calibrated and processed.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	PFC Diag	1172	DIAG- 3.2.a	PFC Thermocouples	1	1.1.1.1.8	The PFC Thermocouples shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].		X		X		FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, BD12: NSTX-U-CALC-11-22-00, BD3: NSTX-U-CALC-11-14-00, BD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00	As thermocouples don't carry current, any EM loads have previously been demonstrated and only require re-verification	This is identified in RD-014 in subsequent sections.	
Diag	PFC Diag	1173	DIAG- 3.2.b	PFC Thermocouples	2	1.1.1.1.8	The PFC Thermocouples shall meet the requirements given in Section 1.3 of the PFC Diagnostics and Fueling Requirements Document [3].				X				This is identified in RD-014 in subsequent sections.	

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Diag	PFC Diag	1174	DIAG- 3.3.a	PFC Thermocouples	3	1.1.1.1.8	The thermocouples shall be embedded into the PFC tiles with the leads routed through channels in the tiles or mounting hardware and through the vacuum vessel to electrical feedthroughs located at suitable ports.			X				Drawing included to provide paths for routing of all cables. It was also demonstrated as a risk reduction effort that the required gaps in cable ways could accommodate the required quantity of wires identified in Drawings ED1556 & ED1471		
Diag	PFC Diag	1175	DIAG- 3.3.c	PFC Thermocouples	4	1.1.1.1.8	Thermocouples shall be installed in locations that allow spatial non-uniformities in the PFC temperatures to be assessed during bakeout.				X				The locations identified in RD-04 allow this requirement to be met.	
Diag	PFC Diag	1176	DIAG- 3.3.d	PFC Thermocouples	5	1.1.1.1.8	Thermocouples shall be electrically isolated from the tiles.		X			X	PFC Diagnostics FDR Design Includes a Boron Nitride Sleeve;			Tested to verify design.
Diag	PFC Diag	1177	DIAG- 3.4.a	PFC Thermocouples	6	1.1.1.1.8	The thermocouples shall be located in the CSFW PFCs, angled, vertical, inboard, and outboard divertors PFCs, as well as on the primary and secondary passive plate and neutral beam armor PFCs.			X	X			Thermocouples on NB Armor and passive plates are not part of recovery scope	RD-04 defines the locations of diagnostics tiles and will be inspected for compliance with assembly drawings	
Diag	PFC Diag	1178	DIAG- 3.4.b	PFC Thermocouples	7	1.1.1.1.8	Thermocouple implementations in the high heat flux regions shall allow 100 kJ deposited heat to be resolved from noise taking into account interpretation uncertainties. [3]				X				The locations identified in RD-014 allow this requirement to be met.	
Diag	PFC Diag	1179	DIAG- 3.4.c	PFC Thermocouples	8	1.1.1.1.8	The thermocouples located in high heat flux regions of the divertor shall be chosen to remain functional in the event that the PFC surface temperature exceeds the allowable value by 50% [5].		X				Manufacturer's Data Sheets			
Diag	PFC Diag	1180	DIAG- 3.4.d	PFC Thermocouples	9	1.1.1.1.8	The locations of the thermocouples on the PFCs not in the high heat flux regions of the divertor shall be chosen to allow the bulk tile temperature during bakeout to be measured with 10 minute time response to temperature changes. [3]				X				The RD-03 was updated to include locations of all PFC diagnostics.	
Diag	PFC Diag	1181	DIAG- 3.5'	PFC Thermocouples	10	1.1.1.1.8	The PFC thermocouple system shall be designed to allow implementation of additional thermocouples.				X				As part of the systems redesign several additional thermocouples were added per RD-014. The only limitation is the quantity of connection in organ pipes and ports Drawing 9D11556 and 1471	
Diag	PFC Diag	1182	DIAG- 4.2.a	PFC Langmuir Probes	1	1.4.1.17	The PFC Langmuir Probes shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].		X				FW: NSTX-U-CALC-11-10-00, CSAS: NSTX-U-CALC-11-11-00, NSTX-U-11-21-00, BDV: NSTX-U-CALC-11-19-00, IBDH: NSTX-U-CALC-11-18-00, OBD12: NSTX-U-CALC-11-22-00, OBD3: NSTX-U-CALC-11-14-00, OBD4: NSTX-U-CALC-11-16-00, OBD5: NSTX-U-CALC-11-12-00			
Diag	PFC Diag	1183	DIAG- 4.2.b	PFC Langmuir Probes	2	1.4.1.17	The PFC Langmuir Probes shall meet the requirements given in Section 1.2 of the PFC Diagnostics and Fueling Requirements Document [3].				X				Requirements provided in the RD-014	
Diag	PFC Diag	1184	DIAG- 4.3.a	PFC Langmuir Probes	3	1.4.1.17	The PFC Langmuir Probes shall be installed at locations on the Center Stack and inboard and outboard divertor regions where the strikepoint or limiter contact could occur.				X				Inspection will take place to ensure that tiles are installed in accordance with the drawings and RD-014.	
Diag	PFC Diag	1185	DIAG- 4.3.c	PFC Langmuir Probes	4	1.4.1.17	The plasma facing components of the Langmuir Probes shall be made of carbon materials.				X				Alignment to design drawings	

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Diag	PFC Diag	1186	DIAG- 4.4.a	PFC Langmuir Probes	5	1.4.1.17	The PFC Langmuir Probes shall be capable of measuring the electron density (n_e) over the range 10^{17}-10^{21} m^{-3} and the electron temperature (T_e) over the range 1-40 eV. Note that these are not simultaneous parameters, i.e., $n_e = 10^{21}$ m^{-3} and $T_e = 40$ eV are not likely to be achieved simultaneously.			X		X		The Langmuir probes follow the existing design as such will be demonstrated.		
Diag	PFC Diag	1187	DIAG- 4.4.b	PFC Langmuir Probes	6	1.4.1.17	The PFC Langmuir Probe data shall be digitized at a rate of 100 kHz or better; bandwidth requirements for HHFW Langmuir Probes may be substantially higher.			X		X		The Langmuir probes follow the existing design as such will be demonstrated.		
Diag	Diagnostic	1188	DIAG- 5.2.a	Fission Chamber Neutron Detectors	1	1.4.1.1	The fission chamber neutron detector system shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1189	DIAG- 5.3.a	Fission Chamber Neutron Detectors	2	1.4.1.1	The fission chamber neutron detector system shall consist of a set of fission chambers located in the NSTX-U Test Cell and associated signal processing and data acquisition electronics.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1190	DIAG- 5.3.b	Fission Chamber Neutron Detectors	3	1.4.1.1	The number of fission chambers, their locations in the Test Cell, and the amount of fissionable material in each one shall be determined by the requirement to operate at low neutron rates for calibration and at highest expected neutron rates for measurements during plasma operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1191	DIAG- 5.3.c	Fission Chamber Neutron Detectors	4	1.4.1.1	The fission chambers shall be enclosed in neutron energy moderators to reduce the energy of the detected neutrons to enhance sensitivity of the system.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1192	DIAG- 5.3.d	Fission Chamber Neutron Detectors	5	1.4.1.1	The signal processing electronics shall be capable of operating in count mode and in current mode.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1193	DIAG- 5.3.e	Fission Chamber Neutron Detectors	6	1.4.1.1	High voltage bias shall be provided to the fission chambers.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1194	DIAG- 5.3.f	Fission Chamber Neutron Detectors	7	1.4.1.1	At least one of the fission chambers shall have sufficient sensitivity to allow calibration of the system during NSTX-U shutdown using a low-activity Cf-252 source (e.g. 100 mCi) temporarily placed in the NSTX-U vacuum vessel.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1195	DIAG- 5.3.g	Fission Chamber Neutron Detectors	8	1.4.1.1	The system shall be designed to allow transfer of the Cf-252 source calibration of the most sensitive detector to the less sensitive detectors during a low neutron rate NSTX-U discharge.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1196	DIAG- 5.4.a	Fission Chamber Neutron Detectors	9	1.4.1.1	The fission chamber neutron detector system shall be capable of measuring the neutron rate over a range of 0 to 1 x 10^{16} neutrons/s to allow measurements during NSTX-U discharges and during calibration.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1197	DIAG- 5.4.b	Fission Chamber Neutron Detectors	10	1.4.1.1	The system shall be capable of measuring both D-D (3.5 MeV) and D-T fusion (14 MeV) neutrons.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1198	DIAG- 5.4.c	Fission Chamber Neutron Detectors	11	1.4.1.1	The data acquisition electronics shall support data acquisition for a time duration of not less than 8 seconds to support NSTX-U long pulse operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1199	DIAG- 5.4.d	Fission Chamber Neutron Detectors	12	1.4.1.1	The current mode signals from the signal processing electronics shall be digitized at a rate not less than 1 kHz.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1200	DIAG- 5.4.e	Fission Chamber Neutron Detectors	13	1.4.1.1	The data shall be automatically archived by the NSTX-U data acquisition system after each discharge.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1201	DIAG- 5.5.a	Fission Chamber Neutron Detectors	14	1.4.1.1	The fission chamber neutron detector system shall be designed to allow straightford expansion of the system to include additional fission chambers.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1202	DIAG- 6.2.a	Plasma TV System	1	1.4.1.4	The Plasma TV system shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1203	DIAG- 6.3.a	Plasma TV System	2	1.4.1.4	The Plasma TV system shall consist of reentrant viewports and optics to provide two or more wide-angle visible light views of the interior of the NSTX-U vacuum vessel and associated optics, optical fiber bundles, support structures and cameras.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1204	DIAG- 6.3.b	Plasma TV System	3	1.4.1.4	The viewing locations shall be on or near the midplane of the NSTX-U vacuum vessel.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1205	DIAG- 6.3.c	Plasma TV System	4	1.4.1.4	The number of views, locations of the views and field of view of each one shall be chosen to maximize coverage of the interior of the NSTX-U vacuum vessel. A minimum of two wide-angle views located on near-opposite sides of the vacuum vessel are required.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1206	DIAG- 6.3.d	Plasma TV System	5	1.4.1.4	The viewing windows shall be provided with remotely-controlled shutters.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1207	DIAG- 6.3.e	Plasma TV System	6	1.4.1.4	A capability shall be provided to remotely reset the cameras when required due to a fault condition.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1208	DIAG- 6.3.f	Plasma TV System	7	1.4.1.4	The system shall be designed for automated operation and data archival with high reliability during NSTX-U operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1209	DIAG- 6.3.g	Plasma TV System	8	1.4.1.4	Software shall exist to automatically display camera image sequences following the discharge for analysis by operations staff.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1210	DIAG- 6.4.a	Plasma TV System	9	1.4.1.4	The optical angular resolution of the system shall be 30" or better.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1211	DIAG- 6.4.b	Plasma TV System	10	1.4.1.4	The TV cameras shall provide color images in the visible region of the spectrum (400-700 nm).			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1212	DIAG- 6.4.c	Plasma TV System	11	1.4.1.4	The TV cameras shall have sensors with dimensions of 800 X 600 pixels or larger.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1213	DIAG- 6.4.d	Plasma TV System	12	1.4.1.4	The TV cameras shall be capable of operating at a frame rate of 1 kHz or higher for readout of all sensor pixels.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1214	DIAG- 6.4.e	Plasma TV System	13	1.4.1.4	The TV camera data shall be automatically archived by the NSTX-U data acquisition system following each discharge.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1215	DIAG- 6.4.f	Plasma TV System	14	1.4.1.4	The data acquisition electronics shall support data acquisition for a time duration of not less than 10 seconds to support NSTX-U long pulse operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1216	DIAG- 6.4.g	Plasma TV System	15	1.4.1.4	Lenses shall be mounted in the reentrant viewports in a way that allows them to be easily removed for NSTX-U bakeout and then reinstalled in their original position following bakeout or the lenses shall be compatible with the bakeout temperature.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1217	DIAG- 6.5.b	Plasma TV System	16	1.4.1.4	The Plasma TV system shall be designed to allow straightford expansion of the system to include additional cameras.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1218	DIAG- 7.2.a	Filterscope Diagnostic	1	1.4.1.13	The Filterscope diagnostic shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1219	DIAG- 7.3.a	Filterscope Diagnostic	2	1.4.1.13	The Filterscope diagnostic shall consist of optical fibers to relay the light from windows on the vacuum vessel to remotely located detection systems, and detection systems each consisting of an interference filter to isolate the spectral line of interest, a photomultiplier tube (PMT), transimpedance amplifier, and digitizer. Light-collecting optics may be used to couple the plasma light to the fibers but are not required for intense spectral lines.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1220	DIAG- 7.3.b	Filterscope Diagnostic	3	1.4.1.13	The detection system shall be capable of being configured to view the lower and upper divertor regions, the center stack (radial midplane view), the outer wall (tangential midplane view) and other in-vessel regions of NSTX-U for which suitable windows and fibers exist.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1221	DIAG- 7.3.c	Filterscope Diagnostic	4	1.4.1.13	The diagnostic shall be capable of being reconfigured in a simple way during non-operating periods (e.g., via fiber optic connectors) to provide the flexibility to allow a given view to be coupled to a detector unit that is setup to measure a specific line.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1222	DIAG- 7.3.d	Filterscope Diagnostic	5	1.4.1.13	The detector units shall be remotely located in an area outside the Test Cell, e.g., the diagnostic room located off the gallery known as the Data Acquisition Room, or DARM.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1223	DIAG- 7.4.a	Filterscope Diagnostic	6	1.4.1.13	The Filterscope diagnostic shall have sufficient channels to allow the spectral lines and locations listed in Table 7.4-1 to be observed.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1224	DIAG- 7.4.b	Filterscope Diagnostic	7	1.4.1.13	There shall be detector units equipped with filters to measure the Deuterium H-alpha and H-gamma lines and lines of He + , C + , O + , B + , Li, and Li + . The detector units shall allow straightforward exchange of filters to allow other lines to be measured as needed.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1225	DIAG- 7.4.c	Filterscope Diagnostic	8	1.4.1.13	The spectral lines and locations in Table 7.4-1 shall be permanently configured to facilitate trending analysis, while other channels may be adjusted based on research priorities.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1226	DIAG- 7.4.d	Filterscope Diagnostic	9	1.4.1.13	The high voltage bias to the PMTs shall be independently adjustable for each PMT.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1227	DIAG- 7.4.e	Filterscope Diagnostic	10	1.4.1.13	The transimpedance amplifiers shall have adjustable gain and a minimum bandwidth of 2 kHz.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1228	DIAG- 7.4.f	Filterscope Diagnostic	11	1.4.1.13	The data shall be digitized at minimum rate of twice the amplifier bandwidth for 10 seconds starting 0.5 seconds prior to discharge initiation.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1229	DIAG- 7.5.a	Filterscope Diagnostic	12	1.4.1.13	The Filterscope diagnostic shall be designed to allow straightford expansion of the system to include additional channels.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1230	DIAG- 8.2.b	Extreme Ultraviolet Spectrometer System	1	1.4.1.15	The EUV spectrometer system shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1231	DIAG- 8.3.a	Extreme Ultraviolet Spectrometer System	2	1.4.1.15	The EUV spectrometer system shall consist of one or more grazing incidence spectrometers with the spectral coverage of each spectrometer chosen to meet the requirement for overall wavelength coverage and resolution (8.4-b) of the system.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1232	DIAG- 8.3.b	Extreme Ultraviolet Spectrometer System	3	1.4.1.15	If more than one spectrometer is required to simultaneously meet the overall spectral coverage of the system while meeting the spectral resolution requirement, the wavelength coverage of each spectrometer shall overlap the coverage of the spectrometers covering the adjacent wavelength regions to avoid gaps in spectral coverage.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1233	DIAG- 8.3.c	Extreme Ultraviolet Spectrometer System	4	1.4.1.15	The spectrometers shall have the capability to change the width of the entrance slits to allow the spectral resolution and etendue to be varied.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1234	DIAG- 8.3.d	Extreme Ultraviolet Spectrometer System	5	1.4.1.15	The detectors shall be low-noise pixelated detectors (e.g., CCDs) with high sensitivity in the EUV spectral region and variable pixel binning and readout and integration times.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1235	DIAG- 8.3.e	Extreme Ultraviolet Spectrometer System	6	1.4.1.15	The ancillary electronics and controls shall be located outside the Test Cell to the extent possible to protect them from the effects of radiation produced by NSTX-U.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1236	DIAG- 8.3.f	Extreme Ultraviolet Spectrometer System	7	1.4.1.15	Each detector shall have remotely controlled AC power to allow the power to be cycled to clear detector fault modes.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1237	DIAG- 8.3.g	Extreme Ultraviolet Spectrometer System	8	1.4.1.15	The EUV spectrometer system shall be directly coupled to the NSTX-U vacuum vessel with no windows via one or more beamlines which define the spectrometer sightlines.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1238	DIAG- 8.3.h	Extreme Ultraviolet Spectrometer System	9	1.4.1.15	The spectrometer beamlines shall include bellows that allow minor adjustment of the spectrometer sightlines by vertical motion of the spectrometers on mechanical stages.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1239	DIAG- 8.3.i	Extreme Ultraviolet Spectrometer System	10	1.4.1.15	The spectrometer beamlines shall be aimed to provide views of plasma core region near the magnetic axis for typical NSTX-U discharges.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1240	DIAG- 8.3.j	Extreme Ultraviolet Spectrometer System	11	1.4.1.15	The beamlines shall have remotely-operated TIVs that can be used to isolate the spectrometers and beamlines from the NSTX-U vacuum vessel.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1241	DIAG- 8.3.k	Extreme Ultraviolet Spectrometer System	12	1.4.1.15	The EUV spectrometer system shall have a dedicated vacuum pumping system that will allow it to be pumped independently of the NSTX-U vacuum system when the TIVs are closed.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1242	DIAG- 8.3.l	Extreme Ultraviolet Spectrometer System	13	1.4.1.15	The EUV spectrometer system shall have pressure gauges with interlocks that can be set to close the TIVs when the spectrometer pressure exceeds a set value.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1243	DIAG- 8.3.m	Extreme Ultraviolet Spectrometer System	14	1.4.1.15	The beamlines shall incorporate electrical isolation breaks that meet the voltage stand-off requirements for NSTX-U hi-pot [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1244	DIAG- 8.4.a	Extreme Ultraviolet Spectrometer System	15	1.4.1.15	The overall wavelength coverage of the system shall be chosen to allow strong lines of the higher ionization states of all intrinsic or extrinsic impurity species that could be found in NSTX-U to be observed. At a minimum, these impurity species are He, Li, B, C, N, O, Ne, Ar, Ti, Cr, Fe, Ni, Cu, Kr, Mo, Ag, and W. This defines a requirement for overall wavelength coverage of 1-40 nm or greater.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1245	DIAG- 8.4.c	Extreme Ultraviolet Spectrometer System	16	1.4.1.15	The detectors shall be capable of full pixel (unbinned mode) readout in 5 ms or less which determines the maximum time resolution of the system.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1246	DIAG- 8.5.a	Extreme Ultraviolet Spectrometer System	17	1.4.1.15	The EUV spectrometer system shall be designed to allow radiation shielding of the detectors to be added if it is found to be necessary to reduce noise on the data and to minimize radiation damage to the detectors.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1247	DIAG- 9.2.a	Multi-Point Thomson Scattering Diagnostic	1	1.4.1.3	The MPTS diagnostic shall be designed to meet the NSTX-U engineering requirements given in Section 6.4.2 of the NSTX-U General requirements Document (GRD) and in Section 4.2 of the GRD [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1248	DIAG- 9.3.a	Multi-Point Thomson Scattering Diagnostic	2	1.4.1.3	The MPTS diagnostic shall consist of one or more laser beams injected into the NSTX-U vacuum vessel, optics to collect the scattered laser light, optic fiber bundles to relay the light to the remotely-located detection systems, and detection systems (consisting of polychromators and avalanche photodiodes) to measure the spectra of the scattered laser light.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1249	DIAG- 9.3.a	Multi-Point Thomson Scattering Diagnostic	3	1.4.1.3	The lasers and detection systems shall be located in an area that is outside the Test Cell to allow access to these systems during operation (with appropriate interlocks and safety precautions) without requiring access to the Test Cell.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1250	DIAG- 9.3.b	Multi-Point Thomson Scattering Diagnostic	4	1.4.1.3	The lasers and detection systems shall be located in an area that is outside the Test Cell to allow access to these systems during operation (with appropriate interlocks and safety precautions) without requiring access to the Test Cell.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1251	DIAG- 9.3.c	Multi-Point Thomson Scattering Diagnostic	5	1.4.1.3	The MPTS diagnostic laser beams shall have a tangential trajectory in the midplane of the NSTX-U vacuum vessel, with a tangency radius of 39 cm or smaller (consistent with minimizing stray light due to laser scattering from the CS), where tangency is relative to a circle in the horizontal plane centered on the axis of the CS casing).			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1252	DIAG- 9.3.d	Multi-Point Thomson Scattering Diagnostic	6	1.4.1.3	The laser beam delivery optics and light collection optics shall be supported in a way that is mechanically independent of the NSTX-U device to avoid the effects of vibration during NSTX-U operation.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1253	DIAG- 9.3.e	Multi-Point Thomson Scattering Diagnostic	7	1.4.1.3	The laser aiming accuracy shall be 0.5 mm or better at a distance of 20 m and it shall be stable over time.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1254	DIAG- 9.3.f	Multi-Point Thomson Scattering Diagnostic	8	1.4.1.3	The light collection optics shall view the laser beam through a window that is equipped with a remotely-controlled shutter system to prevent the window from being coated during bakeout and plasma operation and to reduce background plasma light when necessary.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1255	DIAG- 9.3.g	Multi-Point Thomson Scattering Diagnostic	9	1.4.1.3	The viewing window shall be demountable to allow it to be easily replaced when the vacuum vessel is at atmospheric pressure.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1256	DIAG- 9.3.h	Multi-Point Thomson Scattering Diagnostic	10	1.4.1.3	The collection optics shall be fitted with a kinematic mount arrangement such that alignment is retained following its removal and re-installation.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1257	DIAG- 9.3.i	Multi-Point Thomson Scattering Diagnostic	11	1.4.1.3	The window through which the laser beam passes into the vacuum vessel shall be at a location where the laser power density incident on the window during a laser pulse is sufficiently low to minimize risk of laser damage to the window.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1258	DIAG- 9.3.j	Multi-Point Thomson Scattering Diagnostic	12	1.4.1.3	A beam dump shall be provided to capture the laser beam after it has passed through the vacuum vessel to prevent stray laser light from contributing to the Thomson Scattering signal.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1259	DIAG- 9.3.k	Multi-Point Thomson Scattering Diagnostic	13	1.4.1.3	The laser beam dump shall have an optical path that is long enough to provide a time delay to prevent residual scattered laser light emanating from the beam dump from contributing to the Thomson Scattering signal during the laser pulse.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1260	DIAG- 9.3.l	Multi-Point Thomson Scattering Diagnostic	14	1.4.1.3	The portions of the laser beam flight tubes that are connected to the NSTX-U vacuum shall have TIVs to allow them to be isolated from the NSTX-U vacuum vessel, and ports to allow them to be independently pumped when the TIVs are closed.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1261	DIAG- 9.3.m	Multi-Point Thomson Scattering Diagnostic	15	1.4.1.3	The entrance and exit laser beam flight tubes shall incorporate electrical isolation breaks capable of voltage stand-off consistent with NSTX-U hi-pot requirements [1].			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1262	DIAG- 9.3.n	Multi-Point Thomson Scattering Diagnostic	16	1.4.1.3	The MPTS diagnostic shall have a system of alignment fibers viewing above and below the axis of the laser beam path. These fibers shall be grouped in a minimum of three sets permitting measurement of the relative alignment between the laser beams and the collection optics in different sections along the laser-beam axis. These sections shall include the inner and outer portions of the field of view.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1263	DIAG- 9.3.o	Multi-Point Thomson Scattering Diagnostic	17	1.4.1.3	Cameras located a each of the laser-beam optics turning mirrors shall be used to measure the position of the beams in real space. The measurements shall be made by viewing the small fraction of transmitted light through a mirror, or by viewing the mirror surface away from the reflected-beam angle.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1264	DIAG- 9.3.p	Multi-Point Thomson Scattering Diagnostic	18	1.4.1.3	The MPTS diagnostic shall incorporate the features necessary to ensure personnel safety for operation of Class IV lasers at PPPL. These shall include a fully-enclosed beam path, interlocks, and appropriate administrative controls.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1265	DIAG- 9.3.q	Multi-Point Thomson Scattering Diagnostic	19	1.4.1.3	The MPTS diagnostic shall have a shutter that blocks the laser path when Test Cell access is permitted. This shutter shall be interfaced to the hard-wired interlock system.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1266	DIAG- 9.3.r	Multi-Point Thomson Scattering Diagnostic	20	1.4.1.3	The MPTS diagnostic shall be designed to allow absolute calibration of the system using Rayleigh and Raman scattering signals from low-pressure gases introduced into the NSTX-U vacuum vessel during shutdown periods.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1267	DIAG- 9.3.s	Multi-Point Thomson Scattering Diagnostic	21	1.4.1.3	A high vacuum compatible light-absorbing coating shall be applied to the portion of the vacuum vessel interior that is within the field of view of the MPTS sightlines to reduce the effect of straylight during calibration.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1268	DIAG- 9.3.t	Multi-Point Thomson Scattering Diagnostic	22	1.4.1.3	The MPTS diagnostic shall incorporate a probe with a stable light source that can be inserted into the vacuum vessel during non-operational periods to measure changes in the transmission of the light collection window.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1269	DIAG- 9.4.a	Multi-Point Thomson Scattering Diagnostic	23	1.4.1.3	The laser system shall have a pulse repetition rate of 60 Hz or higher.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1270	DIAG- 9.4.b	Multi-Point Thomson Scattering Diagnostic	24	1.4.1.3	The light collection optics shall be capable of measuring the scattered laser light over a range of points on the laser beam trajectory that correspond to values of the major radius from 7.5 cm larger than the center stack radius to the radius of the RF limiter with spatial resolution of 4 cm or better in the plasma core and 1 cm or better at the plasma edge.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1271	DIAG- 9.4.c	Multi-Point Thomson Scattering Diagnostic	25	1.4.1.3	The light collection optics, optical fibers, and detection systems shall support measurements at a minimum of 42 spatial locations located across the entire plasma diameter and scrape-off layer.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1272	DIAG- 9.4.d	Multi-Point Thomson Scattering Diagnostic	26	1.4.1.3	The MPTS diagnostic shall be designed to measure T e over a range of 0.003-10 keV.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1273	DIAG- 9.4.e	Multi-Point Thomson Scattering Diagnostic	27	1.4.1.3	The MPTS diagnostic shall be designed to measure n e over a range of 5 X 10^ 12 -5 X 10^14 cm -3 .			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1274	DIAG- 9.5.a	Multi-Point Thomson Scattering Diagnostic	28	1.4.1.3	The light collection optics and optical fibers shall be designed to support expansion to provide measurements at up to 48 spatial locations by implementation of additional detection systems			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1275	DIAG- 10.2.a	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	1	1.4.1.5	The CHERS diagnostic shall be designed to meet the NSTX_U engineering requirements given in Section 6.4.2 of the General requirements Document (GRD) and in Section 4.2 of the GRD			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1276	DIAG- 10.3.a	Charge Exchange Recombination Spectroscopy Diagnostic (CHERS)	2	1.4.1.5	The toroidal-viewing CHERS diagnostic shall consist of one or more spectrometer/detector systems, collection optics, and optical fibers, which will couple spectrometers to the collection optics.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1277	DIAG- 10.3.b	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	3	1.4.1.5	The spectrometers and detectors shall be located outside of the NSTX-U test cell to allow access to these systems during operation. Fiber optics shall be routed through penetrations in the test cell wall from the collection optics to the spectrometers.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1278	DIAG- 10.3.c	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	4	1.4.1.5	The toroidal CHERS collection optics shall be on the midplane and located to optimize the spatial resolution of the CHERS measurements. The original NSTX neutral beam (NB1) shall be viewed so as to cross the NB1 trajectory at or near the tangency radius of the sightlines.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1279	DIAG- 10.3.d	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	5	1.4.1.5	The toroidal-viewing CHERS system shall be designed to allow isolation of the intrinsic background emission of the carbon impurity ions from the active emission that occurs in the NB1 path, such as second set of collection optics that do not view any neutral beam and/or a capability to modulate the NB1 beam source(s) in a manner such that they can be synced to the CHERS detector timing.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1280	DIAG- 10.3.e	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	6	1.4.1.5	The collection optics shall be mounted behind a vacuum window that is protected by a shutter system to prevent coating of the window during bakeout, boronization, lithium evaporation, and plasma operation.			X				Subsystem is existing and not being modified as part of recovery scope		

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Diag	Diagnostic	1281	DIAG- 10.3.f	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	7	1.4.1.5	The number of fiber optics shall allow measurements across the outer half of the plasma from the magnetic axis to the plasma edge in order to provide profile measurements.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1282	DIAG- 10.3.g	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	8	1.4.1.5	The spectral coverage of the CHERS spectrometers shall be adequate to allow wavelength calibration and measurement of the instrumental function using neon glow discharges.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1283	DIAG- 10.4.a	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	9	1.4.1.5	The detector shall be capable of operating at 100 Hz frame rate or higher.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1284	DIAG- 10.4.b	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	10	1.4.1.5	The spatial resolution of the system shall be 4 cm or less in the plasma core and 1 cm or less near the plasma edge.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1285	DIAG- 10.4.c	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	11	1.4.1.5	The CHERS system shall support ion temperature measurements up to 5 keV.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1286	DIAG- 10.4.d	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	12	1.4.1.5	The CHERS system shall support toroidal velocity measurements up to 400 km/s.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1287	DIAG- 10.4.e	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	13	1.4.1.5	The operation of one or more of the NB1 sources is required for CHERS measurements.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1288	DIAG- 10.4.f	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	14	1.4.1.5	Modulation of one or more NB1 sources is required for CHERS measurements when any NB2 sources are operated.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Diagnostic	1289	DIAG- 10.5.a	Charge Exchange Recombination Spectroscopy Diagnostic CHERS	15	1.4.1.5	The light collection optics and fiber optics shall be designed to allow expansion for charge exchange spectroscopy measurements for impurities other than carbon.			X				Subsystem is existing and not being modified as part of recovery scope		
Diag	Mach. Inst	1290	DIAG- 11.3.a	Machine Instrumentation	1	1.7.3.4	Sensors shall provide appropriate galvanic isolation from NSTX-U coil and vessel grounds; fiber-optic based sensors shall be used.				X	X				

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Diag	Mach. Ins	1291	DIAG- 11.3.b	Machine Instrumentation	2	1.7.3.4	The sensors and any related structures shall not impede or modify the underlying mechanical, electrical, or thermal design features of the component to which they are applied				X					
Diag	Mach. Ins	1292	DIAG- 11.3.c	Machine Instrumentation	3	1.7.3.4	The system shall function reliably and accurately with confidence in the magnetic and radiation environment of NSTX-U.			X						
Diag	Mach. Ins	1293	DIAG- 11.3.d	Machine Instrumentation	4	1.7.3.4	The system shall synchronize sampling with the NSTX-U clock system to an accuracy of 0.01 seconds compared to the sample clock.				X	X				
Diag	Mach. Ins	1294	DIAG- 11.3.e	Machine Instrumentation	5	1.7.3.4	The archived shot data sampling rate shall be at least 100 Hz, and should not exceed 1 kHz.			X	X					
Diag	Mach. Ins	1295	DIAG- 11.3.f	Machine Instrumentation	6	1.7.3.4	Raw data, in whatever format is native to the instrumentation system, shall be archived in the MDS+ tree.			X						
Diag	Mach. Ins	1296	DIAG- 11.3.g	Machine Instrumentation	7	1.7.3.4	Calibrated data shall be archived or available in the MDS+ tree.			X						
Diag	Mach. Ins	1297	DIAG- 11.3.h	Machine Instrumentation	8	1.7.3.4	The archived shot data shall be in a format that can be plotted with common tools such as dwscope, jscope, or webtools, and accessed in table form via webtools			X						
Diag	Mach. Ins	1298	DIAG- 11.3.i	Machine Instrumentation	9	1.7.3.4	A clear sensor naming convention shall be established. This convention shall unambiguously identify the sensor location and sensor type. This same convention shall be used in CWDs, fiber labels, and MDS+ tree naming			X						
Diag	Mach. Ins	1299	DIAG- 11.4.a	Machine Instrumentation	10	1.7.3.4	Sensors shall be placed at 9 locations along the length of each of the TF outer legs for the purposes of trending and benchmarking the outer leg deflections.				X					
Diag	Mach. Ins	1300	DIAG- 11.4.a'	Machine Instrumentation	11	1.7.3.4	These sensors shall be used for both benchmarking and protection and will be considered "Necessary"			X						
Diag	Mach. Ins	1301	DIAG- 11.4.b	Machine Instrumentation	12	1.7.3.4	Sensors shall be placed on all TF trusses in order to determine truss loading uniformity. These sensors will be used for benchmarking and will be considered "Necessary"				X					
Diag	Mach. Ins	1302	DIAG- 11.4.c	Machine Instrumentation	13	1.7.3.4	Sensors shall be placed on the upper and lower spoked lids in order to measure the torsional and axial loading of the lid. These sensors will be used for both benchmarking and protection and will be considered "Necessary".				X					
Diag	Mach. Ins	1303	DIAG- 11.4.d	Machine Instrumentation	14	1.7.3.4	Sensors shall be placed on the features that transfer lateral CS loads across the CS bellows. These sensors will be used for both benchmarking and protection and will be considered "for convenience".				X					
Diag	Mach. Ins	1304	DIAG- 11.4.e	Machine Instrumentation	15	1.7.3.4	Sensors shall be placed on the OH pre-load assembly, to monitor expansion and displacement of the OH coil, as well as loss of preload. These sensors will be used for both benchmarking and protection and will be considered "Necessary".				X					

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Diag	Mach. Ins	1305	DIAG- 11.4.f	Machine Instrumentation	16	1.7.3.4	Sensors shall be placed on the TF bundle, immediately behind the Belleville washer stack, in order to assess the twist of the TF bundle. These sensors will be used for both benchmarking and protection and will be considered "Necessary".				X					
Diag	Mach. Ins	1306	DIAG- 11.4.g	Machine Instrumentation	17	1.7.3.4	Sensors shall be placed on the of-4 and of-5 slides to assess the behavior of these slides during operations and bakeout. These sensors will be used for both benchmarking and protection and will be considered "Necessary"				X					
Diag	Mach. Ins	1307	DIAG- 11.4.h	Machine Instrumentation	18	1.7.3.4	Sensors shall be placed on the of-1a and -1b support structures to assess loss of preload. These sensors will be considered "Necessary".				X					
OSS	OSS	**Operations and Safety Systems**														
OSS	OSS	1308	GRD-6.7.3.1.a	PSS-SIS	1	1.7.3.1	Systems shall be provided to prevent access to the NSTX-U test cell and related areas when they are inan unsafe condition					X				PTP to include exception handling Software/logic specific tests to include exception handling NSTXU_1-7-3-1-1_TPLAN
OSS	OSS	1309	GRD-6.7.3.1.b	PSS-SIS	2	1.7.3.1	These systems shall ensure that coils systems, heating systems, and other hazardous experimentalenergy sources are not energized during periods of access to the test cell and related areas.					X				PTP to include exception handling Software/logic specific tests to include exception handling NSTXU_1-7-3-1-1_TPLAN
OSS	OSS	1310	GRD-6.7.3.1.c	PSS-SIS	3	1.7.3.1	These systems shall provide engineered support for search and secure operations, emergency stopfunctionality, and door violation sensing where necessary.					X				PTP to include exception handling NSTXU_1-7-3-1-1_TPLAN
OSS	OSS	1311	GRD-6.7.3.1.b	Ground	1	1.7.3.2	A system shall be provided to annunciate if a loop fault is made on either the vacuum vessel ordiagnostic ground.			X				Updating the ground is not part of Recovery Scope; Demonstration leading up to System Level ISTP		
OSS	OSS	1312	GRD-6.7.3.6.a	Radiation Annunciation	1	1.7.3.7	Annunciated radiation area monitors shall be deployed in the test cell order to ensure compliancewith applicable regulations.		X		X					NSTX-U-PLAN-030-00 D-NSTXU-PTP-MS-001
OSS	OSS	1313	GRD-6.7.3.7.a	CCS	1	1.7.3.8	A system shall be provided to provide a permit to enable/arm select equipment (Neutral Beams, FCPCRectifiers, etc) from the NSTX-U control room.					X				PTP to include exception handling Simulation Will be Supported by Rockwell COTS Studio 5000 Logix Emulate
OSS	OSS	1314	GRD-6.7.3.7.b	CCS	2	1.7.3.8	That system shall in addition be able to provide simple permissives for equipment that cannot acceptthe enable/arm permit.					X				PTP to include exception handling Simulation Will be Supported by Rockwell COTS Studio 5000 Logix Emulate
OSS	OSS	1315	GRD-6.7.3.7.c	CCS	3	1.7.3.8	The system shall be capable of removing the enable/arm/permissive, either individually or collectivelyby the operator, or collectively in the event of a PSS Emergency Stop.					X				PTP to include exception handling Simulation Will be Supported by Rockwell COTS Studio 5000 Logix Emulate
OSS	OSS	1316	OSS-3.1.1.1.a	PSS-SIS	1	1.7.3.1	PSS-SIS Safety Instrumented Functions and their required minimum risk reduction factors shallbe defined by the Layer of Protection Analysis per Ref [9].	Table 3.1.1.1-1	X			X	Commercial Supplier Specifications LOPA NSTXU_1-7-3-1_CALC_100			
OSS	OSS	1317	OSS-3.2.2.a	PSS-SIS	2	1.7.3.1	The Personnel Safety System (PSS-SIS) shall provide interlock and alarm devices, which whencoupled with other safety layers, reduce the risk of an identified hazard risk/severity to "Acceptable" or "Desirable" as per the NSTX-U Project's accepted risk methodology		X			X	Commercial Supplier Specifications LOPA NSTXU_1-7-3-1_CALC_100			
OSS	OSS	1318	OSS-3.2.2.b	PSS-SIS	3	1.7.3.1	The determination of the inclusion or exclusion of devices interlocked through the PSS-SIS shallbe made during the hazard assessment for each facility or modification.		X				Commercial Supplier Specifications LOPA NSTXU_1-7-3-1_CALC_100			

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OSS	OSS	1319	OSS-3.2.2.c	PSS-SIS	4	1.7.3.1	The fail-safe mode for each PSS-SIS signal input and output interface shall be defined.		X			X	Design allows for failsafe			
OSS	OSS	1320	OSS-3.2.2.d	PSS-SIS	5	1.7.3.1	The fail-safe mode of PSS-SIS controls shall be its de-energized state (i.e. zero volts for electricalsignals, and/or loss of communication, that would render the controlled device to its safe state).		X				LOPA NSTXU_1-7-3-1_CALC_100			
OSS	OSS	1321	OSS-3.2.2.e	PSS-SIS	6	1.7.3.1	The features of the PSS-SIS which support Safety Functions shall be tamper resistant.		X				Commercial Supplier Specifications	MAnufacturer's provides unique key		
OSS	OSS	1322	OSS-3.2.2.e'	PSS-SIS	7	1.7.3.1	Fielded components of the PSS-SIS shall have unique labels identifying the equipment as part of the PSS-SIS and allowing identification of components.				X					
OSS	OSS	1323	OSS-3.2.2.f	PSS-SIS	8	1.7.3.1	The features of the PSS-SIS which support Safety Functions shall be testable.				X					
OSS	OSS	1324	OSS-3.2.2.g	PSS-SIS	9	1.7.3.1	The PSS-SIS design, implementation, testing, and training shall be consistent with the use of thesystem as a credited control under the accelerator safety order (ASO)			X						
OSS	OSS	1325	OSS-3.2.2.h	PSS-SIS	10	1.7.3.1	The PSS-SIS shall have the capability to detect inconsistent states of interlocked equipment relative to the desired state. This includes the state of the credited energy isolating devices, andmay also include the state of non-credited isolation devices.					X				
OSS	OSS	1326	OSS-3.2.2.i	PSS-SIS	11	1.7.3.1	The PSS-SIS shall be an islanded system without connection to non PSS-SIS networks.			X		X				
OSS	OSS	1327	OSS-3.2.2.j	PSS-SIS	12	1.7.3.1	The PSS-SIS shall comply with laboratory Cyber Security requirements as applicable Ref [17].			X						
OSS	OSS	1328	OSS-3.2.2.k	PSS-SIS	13	1.7.3.1	The PSS-SIS software shall be documented in accordance with the laboratory Software QualityAssurance Plan as applicable Ref [18].			X						
OSS	OSS	1329	OSS-3.3.a	PSS-SIS	14	1.7.3.1	The PSS-SIS shall not rely on the standard PPPL card reader system (ACAMS) for the implementation of Safety Functions.			X		X				
OSS	OSS	1330	OSS-3.3.b	PSS-SIS	15	1.7.3.1	If digital processing elements are utilized, methods shall be deployed to shutdown interlockeddevices in the event of a significant timing or internal processing errors (e.g. watchdog timers).					X				
OSS	OSS	1331	OSS-3.3.c	PSS-SIS	16	1.7.3.1	The status of any interlocked equipment which is interlocked through the PSS-SIS shall besensed by the PSS-SIS.					X				
OSS	OSS	1332	OSS-3.3.d	PSS-SIS	17	1.7.3.1	The PSS-SIS shall display Safe/Unsafe status and provide centralized control from the NSTX-Ucontrol room including but not exclusive to: a. Alarm/Fault reset b. PSS-SIS status c. Interlocked Equipment status			X						
OSS	OSS	1333	OSS-3.3.e	PSS-SIS	18	1.7.3.1	PSS-SIS equipment shall be rated for a defensible range of environmental parameters for thelocations where they are installed; otherwise environmental parameters shall be monitoredduring PSS-SIS operation.		X				Commercial Specs			
OSS	OSS	1334	OSS-3.3.f	PSS-SIS	19	1.7.3.1	The PSS-SIS shall have means to annunciate status inside and outside of exclusion areas.			X						

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OSS	OSS	1335	OSS-3.3.g	PSS-SIS	20	1.7.3.1	The PSS-SIS shall log critical data in a fashion which allows after-the-fact studies, but does notinterfere with the execution of any safety function.			X						
OSS	OSS	1336	OSS-3.3.h	PSS-SIS	21	1.7.3.1	The PSS-SIS shall provide a means to support test requirements of PSS-SIS interlocked equipment.					X				
OSS	OSS	1337	OSS-3.3.i	PSS-SIS	22	1.7.3.1	The systems in Table 3.3-1 shall be interlocked by the PSS-SIS, reverting to a shutdown state inthe event of a PSS-SIS Emergency Stop.	Table 3.3-1				X				
OSS	OSS	1338	OSS-3.3.j	PSS-SIS	23	1.7.3.1	A latched PSS-SIS Emergency Stop shall be declared upon any one condition in Table 3.3-2occuring.	Table 3.3-2				X				
OSS	OSS	1339	OSS-3.3.k	PSS-SIS	24	1.7.3.1	Upon the occurrence of a PSS-SIS Emergency Stop, the steps in Table 3.3-3 shall be taken.	Table 3.3-3				X				
OSS	OSS	1340	OSS-3.3.a	PSS-SIS	25	1.7.3.1	Areas whose access is monitored by the PSS-SIS shall include those in Table 3.3-4.	Table 3.3-4				X				
OSS	OSS	1341	OSS-3.4.a	PSS-SIS	26	1.7.3.1	PSS-SIS Interlocked Device shall be changed to safe state in a maximum of 4 seconds followingthe activation of a PSS-SIS Emergency Stop.					X				
OSS	OSS	1342	OSS-3.4.b	PSS-SIS	27	1.7.3.1	The time required to transition from NO ACCESS state to when hazards are applied shall be atleast 300 seconds.					X				
OSS	OSS	1343	OSS-3.4.c	PSS-SIS	28	1.7.3.1	The PSS-SIS shall be capable of sending output signals to CCS as further defined in Ref [11]					X				
OSS	OSS	1344	OSS-4.2.2.a	TKS	1	1.7.3.10	The trapped key system shall implement a specific engineered sequence of actions to ensurethat access points are closed and safeguards are in place before protected components are putin an unsafe state.					X				
OSS	OSS	1345	OSS-4.2.2.b	TKS	2	1.7.3.10	The trapped key systems shall be capable of handling multi-layer sequences.					X				
OSS	OSS	1346	OSS-4.2.2.d	TKS	#REF!	1.7.3.10	The trapped key system shall not be able to be bypassed with common tools.			X						
OSS	OSS	1347	OSS-4.2.2.e	TKS	#REF!	1.7.3.10	The keys of the TKS shall be clearly labeled for their interface.				X					
OSS	OSS	1348	OSS-4.2.2.f	TKS	#REF!	1.7.3.10	The keys shall have a feature to deter carrying the keys away from experimental areas (i.e. 'pocketing').			X						
OSS	OSS	1349	OSS-4.3.a	TKS	#REF!	1.7.3.10	The trapped key system shall provide status of key summation blocks to the CCS and/or PSS-SIS.Specific details of this status information are provided in Ref. [12].			X		X				
OSS	OSS	1350	OSS-4.3.b	TKS	#REF!	1.7.3.10	The trapped keys shall be Safety Integrity-level capable as determined necessary by safety analysis.		X				Commercial Keys - Verified by the Vendors			
OSS	OSS	1351	OSS-4.3.c	TKS	#REF!	1.7.3.10	Trapped Keyed doors/gates enclosing occupiable volumes shall have a means to unlock thedoor/gate from inside the enclosed area, or shall have kick-out panels or equivalent to enableegress by any individual trapped in those areas.			X			Demonstrate egress from inside a locked door			
OSS	OSS	1352	OSS-5.2.b	CMS	1	1.7.3.9	Specific safeguarded areas and systems shall be listed in RD-027 Configuration Controlled Safeguard Requirements.				X					
OSS	OSS	1353	OSS-5.3.a	CMS	2	1.7.3.9	The safeguards shall not interfere with the function of the components.				X					

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OSS	OSS	1354	OSS-5.3.b	CMS	3	1.7.3.9	The safeguard design shall provide a means to access equipment when the safeguard is removed.			X						
OSS	OSS	1355	OSS-5.3.c	CMS	4	1.7.3.9	The safeguards shall be placed under configuration management as defined in Table 5.3-1.	Table 5.3-1.			X					
OSS	OSS	1356	OSS-5.3.d	CMS	5	1.7.3.9	Safeguards as defined here shall be clearly labelled as such in their deployed condition.				X					
OSS	OSS	1357	OSS-5.3.e	CMS	6	1.7.3.9	The configured controlled safeguards shall prevent personnel from accessing the correspondinghazard(s) unless they have tools or keys to remove the safeguard.				X					
OSS	OSS	1358	OSS-5.3.f	CMS	7	1.7.3.9	The configuration managed safeguards shall be secured and be tamper resistant.		X	X	X		Commercial Tamper Resistant devices			
OSS	OSS	1359	OSS-5.3.g	CMS	8	1.7.3.9	The configuration managed safeguards shall not create a new hazard.									
OSS	OSS	1360	OSS-6.2.b	CCS	1	1.7.3.8	The features of the CCS which support process control of controlled systems shall be testable.				X					
OSS	OSS	1361	OSS-6.3.1.a	CCS	2	1.7.3.8	The CCS shall provide a permissive signal to local Basic Control Systems (BCS) to transition controlled equipment to and from the energized (hazardous) state.					X				
OSS	OSS	1362	OSS-6.3.1.c	CCS	3	1.7.3.8	The NSTX-U CCS shall control the enabling and arming of the systems defined in Ref [11].					X				
OSS	OSS	1363	OSS-6.3.1.d	CCS	4	1.7.3.8	The NSTX-U CCS shall provide "No-NSTXU-ESTOP" signal to the local BCS for the systems in Ref[11]					X				
OSS	OSS	1364	OSS-6.3.2.a	CCS	5	1.7.3.8	Interfaces between the CCS and the PSS-SIS shall not compromise the PSS-SIS safety functionincluding possible failure modes on the CCS side of the interface.				X	X		Document Review		
OSS	OSS	1365	OSS-6.3.2.b	CCS	6	1.7.3.8	In the event a PSS-SIS Emergency Stop is conveyed from the PSS-SIS, the CCS shall removepermissives, including removing No-NSTXU ESTOP, enable, and arm signals, to the numerous (local) BCS's.					X				
OSS	OSS	1366	OSS-6.3.3.a	CCS	7	1.7.3.8	A central control station for the CCS shall be provided at the CoE Station in the NSTX-U Control Room			X						
OSS	OSS	1367	OSS-6.3.3.b	CCS	8	1.7.3.8	The CCS shall have means to annunciate status of permissives for controlled systems, i.e., armed, enabled.					X				
OSS	OSS	1368	OSS-6.3.3.c	CCS	9	1.7.3.8	The CCS shall have means to control the status of permissives for controlled systems, i.e., armed, enabled.					X				
OSS	OSS	1369	OSS-7.3.1.a	Ground	1	1.7.3.2	A dedicated connection of the vessel to earth ground shall be provided with low-inductance bus-bar.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1370	OSS-7.3.1.b	Ground	2	1.7.3.2	There shall be a mechanism to open this ground for purpose of vessel isolation testing.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1371	OSS-7.3.1.c	Ground	3	1.7.3.2	For specific racks containing equipment that is electrically referenced to the vessel, there shall bededicated low-inductance bus-work referencing those racks to the vessel.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1372	OSS-7.3.1.d	Ground	4	1.7.3.2	For diagnostic racks not requiring a vessel reference, a dedicated single point connection of diagnosticracks to ground shall be provided.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		

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OSS	OSS	1373	OSS-7.3.2.a	Ground	5	1.7.3.2	The GFM shall be capable of identifying loop faults between the vessel ground, diagnostic ground, andbuilding steel ground.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1374	OSS-7.3.2.c	Ground	6	1.7.3.2	The system shall archive data with sufficient fidelity to determine when evolutions in the system loopimpedance occured.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1375	OSS-7.3.2.d	Ground	7	1.7.3.2	This archiving shall be include at least 1 week of data, with ability to download data for off-lineexamination.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1376	OSS-7.3.2.e	Ground	8	1.7.3.2	It shall be possible to “blank” the ground fault detection during machine pulses.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1377	OSS-7.3.2.f	Ground	9	1.7.3.2	The system shall accommodate high-pots and megger tests of the NSTX-U vessel.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1378	OSS-7.3.2.h	Ground	10	1.7.3.2	The system shall provide a visible or audible indication of a detected ground fault.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1379	OSS-7.4.a	Ground	11	1.7.3.2	The GFM shall be capable of detecting loop faults with impedances from 0 Ohms up to at least 500Ohms.			X				Updating the ground is not part of Recovery Scope; Dem nonstration leading up to System Level ISTP		
OSS	OSS	1380	OSS-8.3.a	Radiation Annunciation	1	1.7.3.7	NTC dose rate instruments shall be mounted on each of four walls of the test cell, at approximately the 115’ elevation.				X					
OSS	OSS	1381	OSS-8.3.b	Radiation Annunciation	2	1.7.3.7	NTC dose rate instruments shall reside on a dedicated 120 volt circuit.				X					
OSS	OSS	1382	OSS-8.3.c	Radiation Annunciation	3	1.7.3.7	NTC dose rate instruments shall have hardwired internet connections with dedicated switches.				X					
OSS	OSS	1383	OSS-8.3.d	Radiation Annunciation	4	1.7.3.7	The NTC dose rate instruments shall be capable of operating remote relay contacts throughinternal electronics.					X				
OSS	OSS	1384	OSS-8.3.e	Radiation Annunciation	5	1.7.3.7	Relay for NTC dose rates shall be connected to visual annunciators located at the north and southeast test cell entrances.				X					
OSS	OSS	1385	OSS-8.3.h	Radiation Annunciation	6	1.7.3.7	When the alarm condition clears the lighted annunciators indicating high radiation fields insidethe NTC shall turn off, returning the test cell to its normal posting condition.			X						
OSS	OSS	1386	OSS-8.3.i	Radiation Annunciation	7	1.7.3.7	There shall be stand alone integrating dose Gamma and Neutron monitors located in the northand east boundary trailers.				X					
OSS	OSS	1387	OSS-8.3.k	Radiation Annunciation	8	1.7.3.7	Boundary integrating dose monitors shall be manually monitored. i. Prior to morning startup to collect background readings from the night before.			X						
OSS	OSS	1388	OSS-8.3.k'	Radiation Annunciation	9	1.7.3.7	Boundary integrating dose monitors shall be manually monitored. ii. Following daily operations to collect the daily dose from operations.			X						
OSS	OSS	1389	OSS-8.4.b	Radiation Annunciation	10	1.7.3.7	NTC test cell monitors shall be calibrated annually by the factory. Calibrated instruments shall beavailable for quick replacement.				X					
OSS	OSS	1390	OSS-8.4.c	Radiation Annunciation	11	1.7.3.7	The NTC area monitors shall be capable of measuring from 1 mR/hr to 1.0 R/hr over threedecades.		X							

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OSS	OSS	1391	OSS-8.4.d	Radiation Annunciation	12	1.7.3.7	The boundary trailer monitors shall be capable of measuring integrated dose with a lower limitof detectability of 1 microrem, with a maximum dose of 100 mrem full scale.					X				
OSS	OSS	1392	OSS-8.4.e	Radiation Annunciation	13	1.7.3.7	The boundary trailer monitors shall have a “overflow counter” to handle total counts in excessof 100 mrem (based on counts/mrem calibration).					X				
OSS	OSS	1393	OSS-9.2.a	ODH Monitor	1	1.7.3.11	Design, documentation, drawings, and labeling associated with this system shall be doneconsistent with the use of this system as a credited control under the accelerator safety order(ASO)									
OSS	OSS	1394	OSS-9.2.b	ODH Monitor	2	1.7.3.11	The design shall be guided by ISA–RP92.04.02, Part II–1996 (R2013) Installation, Operation, andMaintenance of Instruments Used to Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres									
OSS	OSS	1395	OSS-9.3.a	ODH Monitor	3	1.7.3.11	Oxygen monitor points shall be located at four locations: ● Underneath the machine in the vicinity of Bays A/L Elevated in the NTC in order to detect He at the elevation of the crane cab ● In the NTC West Shield Door (TFTR movable shield door) pit ● Near the LN2 fill station in the northeast corner of the gallery ● Amongst the HVEs on the north side of the test cell (near the floor)									
OSS	OSS	1396	OSS-9.3.c	ODH Monitor	4	1.7.3.11	Unless otherwise stated, monitor points shall be located at or below five feet from the floor toapproximate average human breathing zones.									
OSS	OSS	1397	OSS-9.3.d	ODH Monitor	5	1.7.3.11	The ODH monitors shall have battery backup capability of at least 1 hour.									
OSS	OSS	1398	OSS-9.3.e	ODH Monitor	6	1.7.3.11	The ODH monitors shall be capable of detecting a low oxygen level regardless of the gas mixture.									
OSS	OSS	1399	OSS-9.3.f	ODH Monitor	7	1.7.3.11	The monitors shall not be affected by magnetic or radiation fields or shall be capable of beingmounted outside the test cell.									
OSS	OSS	1400	OSS-9.3.g	ODH Monitor	8	1.7.3.11	All remote Status/Alarm indicators mounted inside the NTC shall be electrically isolated from theelectronics mounted outside the test cell with isolation as per the GRD [1].									
OSS	OSS	1401	OSS-9.3.h	ODH Monitor	9	1.7.3.11	Connections between air sampling sensors and measurement components shall be routed andlocated in such a manner as to report oxygen deficiencies as efficiently as possible (shortest route).									
OSS	OSS	1402	OSS-9.3.i	ODH Monitor	10	1.7.3.11	The system shall have redundant ODH monitors for each location.									
OSS	OSS	1403	OSS-9.3.k	ODH Monitor	11	1.7.3.11	The system shall have remote status/alarm indicators mounted outside the test cell at the twopersonnel access doors and the two movable shield doors to alert personnel not to enter the testcell.									
OSS	OSS	1404	OSS-9.3.l	ODH Monitor	12	1.7.3.11	The system shall have remote status/alarm indicators mounted inside the test cell.									

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OSS	OSS	1405	OSS-9.4.a	ODH Monitor	13	1.7.3.11	All remote Status/Alarm indicators shall annunciate when either monitor detects the oxygen level is ator below 19.5% oxygen.									
OSS	OSS	1406	OSS-9.4.b	ODH Monitor	14	1.7.3.11	Audible alarms shall be loud enough that personnel at any location within the NTC, including atentrances, will be able to clearly resolve the alarm above the background noise level.	X					90Db per annunciator			
OSS	PSS	Personnel Safety System SIS														
OSS	PSS	1407	PSS-3.1.a	PSS-SIS	1	1.7.3.1	A hazard analysis shall be performed to identify hazardous conditions that require credited controls.		X				Hazard Analysis part of SAD used			
OSS	PSS	1408	PSS-3.1.b	PSS-SIS	2	1.7.3.1	The hazard analysis shall identify the severity and likelihood of unmitigated risks as described in Refs. [3,4] .		X				Hazard Analysis part of SAD used			
OSS	PSS	1409	PSS-3.1.c	PSS-SIS	3	1.7.3.1	Each hazard identified by the analysis shall be mitigated by existing laboratory safety program(s), a PSS-SIS function, some other NSTX-U related safety system, or a combinationthereof.		X				Hazard Analysis part of SAD used			
OSS	PSS	1410	PSS-3.1.d	PSS-SIS	4	1.7.3.1	Safety Instrumented Function(s) requirements shall be developed from a Layer Of Protection Analysis to establish the need for residual risk mitigation by a Safety Instrumented System.		X				LOPA NSTXU_1-7-3-1_CALC_100			
OSS	PSS	1411	PSS-3.1.e	PSS-SIS	5	1.7.3.1	Target Risk Reduction Factors shall be assigned to each Safety Instrumented Function based onthe highest residual risk identified in the analysis that is mitigated by that Safety InstrumentedFunction.		X				LOPA NSTXU_1-7-3-1_CALC_100			
OSS	PSS	1412	PSS-3.2.a	PSS-SIS	6	1.7.3.1	The PSS-SIS Interlocked Systems shall include those identified in Ref. [2], as are the general actionto take in the event of a PSS-SIS Emergency Stop as described in section 3.1 of Ref. [2]...		X			X	Commercial Tools			
OSS	PSS	1413	PSS-3.2.b	PSS-SIS	7	1.7.3.1	In the event of a PSS-SIS Emergency Stop, the neutral beam system interdicted devices shall respond as per Table 3.1-1	Table 3.1-1				X				
OSS	PSS	1414	PSS-3.2.c	PSS-SIS	8	1.7.3.1	In the event of a PSS Emergency Stop, the FCPC rectifiers shall respond as per Table 3.1-2	Table 3.1-2				X				Breaker Replacement FDR -- (ABB Medium Voltage Refurbishment Scope of Work Test Plan) (SV Breaker)
OSS	PSS	1415	PSS-3.2.d	PSS-SIS	9	1.7.3.1	Additionally, the actions in Table 3.1-3 shall be taken.	Tables 3.1-3				X				Breaker Replacement FDR -- (ABB Medium Voltage Refurbishment Scope of Work Test Plan (S1B1 Breaker))
OSS	PSS	1416	PSS-3.2.e	PSS-SIS	10	1.7.3.1	The PSS-SIS shall have the ability to detect inconsistent states of equipment as an additionalaction. The ability to do this shall include the capabilities described in Table 3.1-4.	Table 3.1-4				X				
OSS	PSS	1417	PSS-3.3.1.a	PSS-SIS	11	1.7.3.1	The PSS-SIS shall facilitate establishing and maintaining exclusion areas.					X				
OSS	PSS	1418	PSS-3.3.2.a	PSS-SIS	12	1.7.3.1	The PSS shall monitor the status of all doors, movable shielding, and other accessways that allow access to exclusion areas.			X		X				

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OSS	PSS	1419	PSS-3.3.2.b	PSS-SIS	13	1.7.3.1	Access to a securable area shall be prohibited while the securable area is in NO ACCESS mode.					X				
OSS	PSS	1420	PSS-3.3.2.c	PSS-SIS	14	1.7.3.1	The PSS shall have features to ensure that interlocked devices are not turned on when an exclusion area to which that system delivers energy is in any mode except NO ACCESS.					X				
OSS	PSS	1421	PSS-3.3.2.d	PSS-SIS	15	1.7.3.1	The PSS shall provide clearly visible status indicators of the "Safe" or "Unsafe" status for each of the securable areas.			X						
OSS	PSS	1422	PSS-3.3.2.e	PSS-SIS	16	1.7.3.1	The PSS shall provide an audible and visual warning before transitioning from a "Safe" state to an "Unsafe" state. Note: An administrative announcement over a public address system may substitute for an automated audible warning if it is preceded by a klaxon/horn warning.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1423	PSS-3.3.2.f	PSS-SIS	17	1.7.3.1	The PSS shall provide clearly visible status or warning indicators outside of each entrance to a securable area. The status indicators shall be an indication of the safe or unsafe state within that area.			X						
OSS	PSS	1424	PSS-3.3.2.g	PSS-SIS	18	1.7.3.1	When the unsafe status in any exclusion area is pending, audible warnings must be broadcastwithin the exclusion area.			X						
OSS	PSS	1425	PSS-3.3.2.h	PSS-SIS	19	1.7.3.1	The system shall accommodate the use of the ACAMS card reader for use during ACCESS state toregulate access to designated areas.1			X						
OSS	PSS	1426	PSS-3.3.2.i	PSS-SIS	20	1.7.3.1	The ACAMS door card reader shall not degrade any Safety Instrumented Functions or PSS-SISAdditional Actions.			X						
OSS	PSS	1427	PSS-3.3.2.j	PSS-SIS	21	1.7.3.1	The system shall disable the functionality of the ACAMS door card readers for securable areaswhen in NO ACCESS.			X						
OSS	PSS	1428	PSS-3.3.3.a	PSS-SIS	22	1.7.3.1	The establishment of an exclusion area shall require a visual search and secure (sweep) of the area.				X	X				
OSS	PSS	1429	PSS-3.3.3.b	PSS-SIS	23	1.7.3.1	The search and secure pattern when required in complex spaces shall follow a designated pattern designed to ensure all regions in securable areas are observed.				X					
OSS	PSS	1430	PSS-3.3.3.c	PSS-SIS	24	1.7.3.1	The activation of Search and Secure stations in the improper order shall require the search be restarted.					X				
OSS	PSS	1431	PSS-3.3.3.d	PSS-SIS	25	1.7.3.1	An access violation during the execution of the search and secure process shall require the search be restarted.					X				
OSS	PSS	1432	PSS-3.3.3.e	PSS-SIS	26	1.7.3.1	Dropping the loop in one securable area shall not require that the loops in other unconnectedsecurable areas be dropped.					X				
OSS	PSS	1433	PSS-3.3.3.f	PSS-SIS	27	1.7.3.1	The system can disable the functionality of the ACAMS door card readers for securable areas when conducting a Search and Secure.					X				
OSS	PSS	1434	PSS-3.4.a	PSS-SIS	28	1.7.3.1	PSS-SIS E-STOP buttons shall be provided inside exclusion areas, and one immediately outsideeach entrance to an exclusion area.				X					

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OSS	PSS	1435	PSS-3.4.b	PSS-SIS	29	1.7.3.1	PSS E-STOP buttons within exclusion areas shall be placed such that no accessible area is more than 50 ft from a button				X					
OSS	PSS	1436	PSS-3.4.c	PSS-SIS	30	1.7.3.1	PSS E-STOP buttons shall have a latching feature and require a local physical reset before a system reset can be performed.					X				
OSS	PSS	1437	PSS-3.5.c	PSS-SIS	31	1.7.3.1	The PSS-SIS design shall achieve the required risk reduction as required by associated Safety Instrumented Function(s).		X				LOPA NSTXU_1-7-3-1_CALC_100			
OSS	PSS	1438	PSS-3.5.d	PSS-SIS	32	1.7.3.1	Dual chain independent systems shall be implemented and the independent chains shall extendfrom the sensor to the final device.				X	X				
OSS	PSS	1439	PSS-3.5.e	PSS-SIS	33	1.7.3.1	The signal path between the processing elements of the PSS-SIS and the devices which removehazards in a shutdown situation shall have a minimum number of intermediate components.		X				Part of the design and design review process to optimize the design			
OSS	PSS	1440	PSS-3.5.f	PSS-SIS	34	1.7.3.1	PSS-SIS equipment and wiring shall be located in dedicated PSS-SIS rack				X					
OSS	PSS	1441	PSS-3.5.g	PSS-SIS	35	1.7.3.1	All PSS-SIS functions shall be resilient against single chain undetected failures.					X				
OSS	PSS	1442	PSS-3.5.h	PSS-SIS	36	1.7.3.1	No single chain failure shall result in the ability to energize a hazardous device while personnelmay be exposed to a hazard otherwise mitigated by the PSS-SIS.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1443	PSS-3.5.i	PSS-SIS	37	1.7.3.1	The PSS-SIS shall not be used to provide the normal on/off control of a PSS-SIS interlocked device.				X					
OSS	PSS	1444	PSS-3.5.j	PSS-SIS	38	1.7.3.1	The PSS-SIS shall not automatically reset once a tripped interlock is restored. A manual reset by a qualified operator shall be required.					X				
OSS	PSS	1445	PSS-3.5.k	PSS-SIS	39	1.7.3.1	The PSS-SIS shall have the ability to monitor the mode of interlocked equipment w/o reliance onthe CCS.			X				Demontrate		
OSS	PSS	1446	PSS-3.5.l	PSS-SIS	40	1.7.3.1	The PSS-SIS logic solver shall be immune to unresponsive modes by defaulting to a safe mode.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1447	PSS-3.5.m	PSS-SIS	41	1.7.3.1	The PSS-SIS logic solver shall be immune to error modes by defaulting to a safe mode.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1448	PSS-3.6.a	PSS-SIS	42	1.7.3.1	The PSS-SIS states for a securable area shall be classified as "ACCESS", "NO ACCESS", and "LOCKED".				X					
OSS	PSS	1449	PSS-3.6.b	PSS-SIS	43	1.7.3.1	When in ACCESS, at a minimum a single logical element of each PSS-SIS monitored device shall be ina safe mode.				X					
OSS	PSS	1450	PSS-3.6.c	PSS-SIS	44	1.7.3.1	Inconsistent configurations when in ACCESS shall include those in Table 3.6-1.	Table 3.6-1				X				

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OSS	PSS	1451	PSS-3.6.d	PSS-SIS	45	1.7.3.1	The PSS-SIS shall declare an inconsistent configuration if PCTS links are present while in dummyload testing mode and the NTC is in an ACCESS State.					X				
OSS	PSS	1450	PSS-3.7.1.a	PSS-SIS	44	1.7.3.1	The PSS-SIS shall have capabilities that accommodate specific test modes of PSS-SIS interlockedequipment. Examples of such test modes include those in Table 3.7-1.	Table 3.7.1-1				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1451	PSS-3.7.2.a	PSS-SIS	45	1.7.3.1	Designed features of the PSS-SIS shall facilitate testing of the system to ensure the Safety Functions are properly implemented.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1452	PSS-3.8.1.a	PSS-SIS	46	1.7.3.1	The centralized HMI for the PSS (PSS-CHMI) shall be located at the Station for the Chief Operating Engineer in the NSTX-U Control Room.			X	X					
OSS	PSS	1453	PSS-3.8.1.b	PSS-SIS	47	1.7.3.1	The PSS-CHMI shall provide means for the operator to authenticate (e.g. password, physical device such as token or key).			X						Attempt different access mechanisms
OSS	PSS	1454	PSS-3.8.1.c	PSS-SIS	48	1.7.3.1	The PSS-CHMI shall provide a mechanism i.e., key to ensure that only the authorized individual can access and change permissive status using the PSS-CHMI.			X						
OSS	PSS	1455	PSS-3.8.1.d	PSS-SIS	49	1.7.3.1	The PSS-CHMI shall indicate the access mode of each securable area (ACCESS, NO ACCESS).			X				Demonstrate proper display		
OSS	PSS	1456	PSS-3.8.1.e	PSS-SIS	50	1.7.3.1	The PSS-CHMI shall indicate the interlock status is complete and ready to permit machine operation.			X				Demonstrate proper display		
OSS	PSS	1457	PSS-3.8.1.f	PSS-SIS	51	1.7.3.1	The PSS-CHMI shall indicate that when all exclusion areas are closed. Note: this provides an indicated that all exclusion areas are cleared of personnel			X				Demonstrate proper display		
OSS	PSS	1458	PSS-3.8.1.g	PSS-SIS	52	1.7.3.1	The PSS-CHMI shall indicate whether a ESTOP button has been depressed and its identity/location.			X				Demonstrate proper display		
OSS	PSS	1459	PSS-3.8.1.h	PSS-SIS	53	1.7.3.1	The PSS-CHMI shall indicate for each exclusion area whether a door violation has occurred. It may additionally indicate which door had the violation if there is more than one door to the area.			X				Demonstrate proper display		
OSS	PSS	1460	PSS-3.8.1.i	PSS-SIS	54	1.7.3.1	The PSS-CHMI shall indicate the "safe" status of each PSS interlocked system.			X				Demonstrate proper display		
OSS	PSS	1461	PSS-3.8.1.j	PSS-SIS	55	1.7.3.1	The PSS-CHMI shall have a prominent PSS E-STOP button that functions equivalently to an ESTOP button within a securable area. Note: The interpretation of prominent shall eliminate the use of buttons on flat-screen displays for this function.				X					
OSS	PSS	1462	PSS-3.8.1.k	PSS-SIS	56	1.7.3.1	The PSS-CHMI shall display the fault status of the PSS.			X						
OSS	PSS	1463	PSS-3.8.1.l	PSS-SIS	57	1.7.3.1	The PSS-CHMI shall have a capability to reset an NSTX-U E-STOP			X						
OSS	PSS	1464	PSS-3.8.1.m	PSS-SIS	58	1.7.3.1	Restoration of the PSS system after an E-STOP event shall be achieved through the COE coordinating the resetting the field device as well as the execution of dedicated E-STOP restoration procedures.			X		X				

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OSS	PSS	1465	PSS-3.8.1.n	PSS-SIS	59	1.7.3.1	The local lamp test of the PLC controlled status lamps should be controlled via the PLC HMI.			X						
OSS	PSS	1465	PSS-3.8.2.a	PSS-SIS	59	1.7.3.1	The HMI outside of each door to a securable area shall indicate the PSS state (ACCESS, NO ACCESS.).			X				Demonstrate proper display		
OSS	PSS	1466	PSS-3.8.2.b	PSS-SIS	60	1.7.3.1	The HMI outside each door to a securable area shall indicate the safe or unsafe status of its area.			X				Demonstrate proper display		
OSS	PSS	1467	PSS-3.8.2.c	PSS-SIS	61	1.7.3.1	The HMI outside of each door to a securable area shall indicate if an Emergency Stop condition,due to either an access violation or an E-STOP button, has occurred within that secured area.			X				Demonstrate proper display		
OSS	PSS	1468	PSS-3.8.2.d	PSS-SIS	62	1.7.3.1	The HMI outside of one door to each securable area shall indicate the status of the search and secure status (all doors closed, Search and Secure stated, Search and Secure Complete, Area Loop Set), and provide functionality required to support the Search and Secure.			X				Demonstrate proper display		
OSS	PSS	1469	PSS-3.8.2.e	PSS-SIS	63	1.7.3.1	Audible and visual alerts or other mechanisms inside of exclusion areas shall be used to indicatea pending transition to an unsafe mode.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1470	PSS-3.8.2.f	PSS-SIS	64	1.7.3.1	The fault status of the PSS-SIS shall be displayed at each entrance to an exclusion area.			X				Demonstrate proper display		
OSS	PSS	1471	PSS-3.8.2.g	PSS-SIS	65	1.7.3.1	Junction boxes containing PSS electronics shall have labels indicating that the system is used for PSS and must not be modified unless authorized.				X				Inspect the labeling	
OSS	PSS	1472	PSS-3.9.a	PSS-SIS	66	1.7.3.1	Conduits associated with the PSS-SIS shall be clearly identified.				X				Inspect the conduit identification	
OSS	PSS	1473	PSS-3.9.b	PSS-SIS	67	1.7.3.1	Junction boxes containing PSS-SIS electronics shall have labels indicating that the system is used for PSS and must not be modified unless authorized.				X				Inspect the labeling	
OSS	PSS	1474	PSS-3.9.c	PSS-SIS	68	1.7.3.1	The PSS-SIS shall employ deterrents to prevent and discourage physical tampering or alterationof hardware components.				X					
OSS	PSS	1475	PSS-3.9.d	PSS-SIS	69	1.7.3.1	The PSS shall employ safeguards to prevent and discourage physical tampering or alteration of hardware components.				X					
OSS	PSS	1476	PSS-3.9.e	PSS-SIS	70	1.7.3.1	Features shall prevent the operation of interlocked devices when a tamper-detecting cover to aPSS-SIS logic solver, network rack(s), or it's IO enclosure(s) is disturbed.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1477	PSS-3.9.f	PSS-SIS	71	1.7.3.1	A log/audit trail of tampering shall be maintained.			X						
OSS	PSS	1478	PSS-3.9.g	PSS-SIS	72	1.7.3.1	The PSS-SIS shall monitor and annunciate inputs for inconsistent modes that indicate an unauthorized configuration change.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP

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OSS	PSS	1479	PSS-3.9.h	PSS-SIS	73	1.7.3.1	Any changes made to the PSS during unsafe state shall default the system to safe state					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1480	PSS-3.10.a	PSS-SIS	74	1.7.3.1	The status of critical PSS-SIS I/O shall be logged.			X						
OSS	PSS	1481	PSS-3.10.b	PSS-SIS	75	1.7.3.1	The PSS-SIS access mode of each area shall be logged.			X						
OSS	PSS	1482	PSS-3.10.c	PSS-SIS	76	1.7.3.1	The archival shall be at a rate consistent with the use case of the data.			X						
OSS	PSS	1483	PSS-3.10.d	PSS-SIS	77	1.7.3.1	Storage capacity shall permit at least a full month of data to be stored, with the oldest data being overwritten first.		X	X			Extrapolated values from demonstration			
OSS	PSS	1484	PSS-3.10.e	PSS-SIS	78	1.7.3.1	It shall be possible to archive some portion of the logged data for arbitrary duration. Note: This mode may be used to ensure, for instance, that data being used to understand an event is retained beyond the standard archival window.		X	X			Extrapolated values from demonstration			
OSS	PSS	1485	PSS-3.10.f	PSS-SIS	79	1.7.3.1	The time used for Log-message timestamps for PSS and CCS shall be capable of being correlated if logging is a feature of the CCS.			X						
OSS	PSS	1486	PSS-3.11.a	PSS-SIS	80	1.7.3.1	PSS computing assets shall not communicate on corporate or other control system networks.				X					
OSS	PSS	1487	PSS-3.11.b	PSS-SIS	81	1.7.3.1	A software version control process shall be utilized in the development of this system's software.				X					
OSS	PSS	1488	PSS-3.11.c	PSS-SIS	82	1.7.3.1	Communication between elements of the PSS shall utilize protocols that are inherently secure.				X					
OSS	PSS	1489	PSS-3.11.d	PSS-SIS	83	1.7.3.1	Access to the PSS-SIS (other than the dedicated operator HMIs) shall originate from a computerthat: requires multi-factor user authentication, has up to date security patches, and is PPPLsupplied and managed.			X						
OSS	PSS	1490	PSS-3.11.e	PSS-SIS	84	1.7.3.1	Access to PSS equipment shall be prevented by physical and/or electronic barriers to prevent tampering by unauthorized personnel.		X		X		Commercial specification			
OSS	PSS	1491	PSS-3.11.f	PSS-SIS	85	1.7.3.1	User roles shall be established, assigning privileges to specific roles for which they are required as determined by the system owner.				X					
OSS	PSS	1492	PSS-3.11.g	PSS-SIS	86	1.7.3.1	The PSS documentation shall include policies, procedures and training material necessary for secure operation by qualified individuals.				X					
OSS	PSS	1493	PSS-3.11.h	PSS-SIS	87	1.7.3.1	All unused communication ports and services on PSS equipment shall be disabled. This includes both hardware and software.				X	X				
OSS	PSS	1494	PSS-3.11.i	PSS-SIS	88	1.7.3.1	Vendors selected for Hardware and Software supply shall be confirmed as authorized resellers by manufacturer.				X					

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OSS	PSS	1495	PSS-3.11.j	PSS-SIS	89	1.7.3.1	Comply with PPPL Standard Cyber Security Program Plan (CSPP) with anticipating 800-53r4 controls at the moderate level. Risk management shall be utilized to evaluate deviations with approval of the system owner.				X					
OSS	PSS	1496	PSS-3.11.k	PSS-SIS	90	1.7.3.1	Records to be kept include those in Table 3.11-1.	Table 3.11-1			X					
OSS	PSS	1497	PSS-3.11.l	PSS-SIS	91	1.7.3.1	The development environment, system firmware, system diagnostic data and configuration shall be archived periodically. Each archive shall be verified once stored.				X					
OSS	PSS	1498	PSS-3.11.m	PSS-SIS	92	1.7.3.1	Access to the system for maintenance and monitoring activities shall not create a bridge between PSS network and any other network.				X					
OSS	PSS	1499	PSS-3.12.a	PSS-SIS	93	1.7.3.1	Permanent modifications to installed PSS systems shall be reviewed via the engineering design review process and be accompanied by a USI determination.				X					
OSS	PSS	1500	PSS-3.12.b	PSS-SIS	94	1.7.3.1	Changes to PSS interlocks shall require recertification of the interlock and PSS equipment and functions that are associated with the interlock using approved test procedures per ENG-030.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation(Certification Testing) via the PSS ISTP
OSS	PSS	1501	PSS-3.12.c	PSS-SIS	95	1.7.3.1	Temporary modifications to the PSS shall follow the T-MOD process outlines in ENG-036. As per that procedure, a USID is required for any T-MOD to the PSS.				X					
OSS	PSS	1502	PSS-3.13.a	PSS-SIS	96	1.7.3.1	Provision shall be made for the addition of new Interlocked equipment.				X					
OSS	PSS	1503	PSS-3.13.b	PSS-SIS	97	1.7.3.1	Provision shall be made for the addition of new Exclusion Areas.		X				Spare and room for growth in design discussed at FDR			
OSS	PSS	1504	PSS-3.13.c	PSS-SIS	98	1.7.3.1	Provision shall be made for the addition of ESTOP buttons in and outside of existing or new exclusion areas.		X							
OSS	PSS	1505	PSS-3.13.d	PSS-SIS	99	1.7.3.1	Provision shall be made for additional types of access modes.			X						
OSS	PSS	1506	PSS-3.13.e	PSS-SIS	100	1.7.3.1	Provision to introduce additional external inputs to the PSS in order to trigger response shall be provided. Example: the ability to trigger a transition to the NTC "LOCKED" mode based on a signal from the NSTX-U ODH system.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Test fixtures may be required to introduce errors. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1507	PSS-3.14.a	PSS-SIS	101	1.7.3.1	Reviews for the PSS system shall involve subject matter experts external to PPPL.				X				External Reviewers for CDR, PDR, FDR, and Peer reviews. Hired Industry SMEs	
OSS	PSS	1508	PSS-3.14.b	PSS-SIS	102	1.7.3.1	All PSS equipment shall be properly installed by personnel approved by the NSTX-U Head of Operations				X					

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OSS	PSS	1509	PSS-3.14.c	PSS-SIS	103	1.7.3.1	The PSS pre-operational testing shall follow one or more written procedures. These procedures shall be reviewed and approved by the NSTX-U Head of Operations, in addition to the reviews and approvals mandated in ENG-030 PPPL Technical Procedures .					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1510	PSS-3.14.d	PSS-SIS	104	1.7.3.1	Installation and pre-operational testing activities shall include the activities in Table 3.14-1:	Table 3.14-1				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Pre-operational Tests testing component operations. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1511	PSS-3.14.e	PSS-SIS	105	1.7.3.1	The PSS validation procedure shall follow a written Integrated System Test Procedure. Note: The term “validation” is used for the first functional test of the system. This validation test plan may then go on to be used as a ”certification” procedure or incorporated in to an overall certification procedure					X				Separate OSS ISTP validation
OSS	PSS	1512	PSS-3.14.f	PSS-SIS	106	1.7.3.1	PSS validation shall include static and functional tests of all PSS inputs, outputs, and operational modes					X				
OSS	PSS	1513	PSS-3.14.g	PSS-SIS	107	1.7.3.1	As part of the installation process, all abandoned access control hardware associated with exclusion areas shall be removed.				X					
OSS	PSS	1514	PSS-3.14.h	PSS-SIS	108	1.7.3.1	Any access control equipment that is abandoned in place shall be clearly and permanently labelled as being out of service				X					
OSS	PSS	1515	PSS-3.14.i	PSS-SIS	109	1.7.3.1	Any software developed for the PSS shall implement the PPPL Software QA procedures, as appropriate.				X					
OSS	PSS	1516	PSS-3.15.a	PSS-SIS	110	1.7.3.1	PSS Systems shall undergo periodic certification (proof testing) as required by the system design (e.g. SIL), regulatory requirements, or laboratory policy (whichever is shortest).					X				Periodic tests of systems to include exceptions will be conducted
OSS	PSS	1517	PSS-3.15.b	PSS-SIS	111	1.7.3.1	Problems found during certification shall be repaired and retested before operations are allowed.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1518	PSS-3.15.c	PSS-SIS	112	1.7.3.1	Certification procedures shall include static and functional tests of all PSS inputs, outputs, and operational modes.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1519	PSS-3.15.d	PSS-SIS	113	1.7.3.1	Certifications shall extend from the sensor to the final element.					X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS ISTP
OSS	PSS	1520	PSS-3.15.e	PSS-SIS	114	1.7.3.1	Records of completed certifications shall be maintained by the Operations Center				X					
OSS	PSS	1521	PSS-3.15.f	PSS-SIS	115	1.7.3.1	Each PSS system shall undergo periodic maintenance required to maintain the designed safety integrity level				X					
OSS	PSS	1522	PSS-3.15.g	PSS-SIS	116	1.7.3.1	Only personnel approved by the NSTX-U Operations Head shall be authorized to work on PSS devices or wiring				X					
OSS	PSS	1523	PSS-3.15.h	PSS-SIS	117	1.7.3.1	Operations shall be suspended before any work on a PSS device or component starts			X						

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OSS	PSS	1524	PSS-3.15.i	PSS-SIS	118	1.7.3.1	Operations shall be suspended in any area where a PSS device is suspected of being defective. Operations may not resume until the device is repaired and recertified or it is determined by Operations Group personnel that the device is functioning as designed; the Operations Group Head must concur with this finding.			X						
OSS	PSS	1525	PSSSW-2.4	PSS-SIS SW	1	1.7.3.1	The system will be air-gapped, meaning there shall be no off-network communication(wired, optical, or wireless).			X						
OSS	PSS	1526	PSSSW-2.5.d	PSS-SIS SW	2	1.7.3.1	There shall be no customization of the COTS software (infrastructure).			X						
OSS	PSS	1527	PSSSW-2.5.f	PSS-SIS SW	3	1.7.3.1	If the PLC application includes both safety and non-safety functions, there shall be a logical andvisible distinction between the standard and safety-related portions of the application.			X						
OSS	PSS	1528	PSSSW-2.5.g	PSS-SIS SW	4	1.7.3.1	Software subroutines and modules that contribute to providing Safety Instrumented Functionsshall only use safety-qualified I/O, tags, and operations.				X					
OSS	PSS	1529	PSSSW-2.6.f	PSS-SIS SW	5	1.7.3.1	The non-functional software requirements shall comply with PPPL (engineering) policies and procedures				X					
OSS	PSS	1530	PSSSW-3.4	PSS-SIS SW	6	1.7.3.1	The SIS will be a private, air-gapped system; there shall be nonetworked communication (electrical, optical, or wireless) outside of the SIS.			X						
OSS	PSS	1531	PSSSW-3.4'	PSS-SIS SW	7	1.7.3.1	That being said the communications component of the SIS, which is not part of the logic portion of software shall have these features: ● Support DLR networking, at least three rings. ● Have bandwidth and latency sufficient to support the needs described in the Performance Requirements chapter. ● Provide a configurable RPI for each module or I/O station. ● Provide an RPI period of 100ms or less.			X						
OSS	PSS	1532	PSSSW-3.4''	PSS-SIS SW	8	1.7.3.1	A communication fault with the CHMI shall be capable of automatic recovery (restart of updating display variables).			X		X				
OSS	PSS	1533	PSSSW-3.4''''	PSS-SIS SW	9	1.7.3.1	A communication fault which stops the program execution shall be capable of automatic recovery (restart of logic processing).			X						
OSS	PSS	1534	PSSSW-3.4''''	PSS-SIS SW	10	1.7.3.1	All communication faults shall be capable of being alarmed.			X						
OSS	PSS	1535	PSSSW-4.1.2	PSS-SIS SW	11	1.7.3.1	Once declared, resetting the PSS-SIS EMERGENCY STOP condition shall beachieved through the COE coordinating the resetting the field device(s) as well asthe execution of dedicated E-STOP restoration procedures.			X						
OSS	PSS	1536	PSSSW-4.2	PSS-SIS SW	12	1.7.3.1	Any I/O conditioning shallnot impede the operation of Safety Instrumented Functions or Additional Actions.					X				

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OSS	PSS	1537	PSSSW-4.4	PSS-SIS SW	13	1.7.3.1	There shall be one and onlyone state configured per exclusion area at any given time.					X				
OSS	PSS	1538	PSSSW-4.4.1	PSS-SIS SW	14	1.7.3.1	The access state shall allow personnelaccess to the exclusion area provided the ACAMS card reader authorizesthem.			X						
OSS	PSS	1539	PSSSW-4.4.1'	PSS-SIS SW	15	1.7.3.1	The operator shall have independent disable-control of each card reader.			X						
OSS	PSS	1540	PSSSW-4.4.1''	PSS-SIS SW	16	1.7.3.1	A "reminder chirp" shall sound for 5 seconds every 60 seconds while in LOCKDOWN			X						
OSS	PSS	1541	PSSSW-4.7.1	PSS-SIS SW	17	1.7.3.1	Logic shall be written to ensure sequential order.					X				
OSS	PSS	1542	PSSSW-4.7.1'	PSS-SIS SW	18	1.7.3.1	Logic shall provide a limit for each station-station travel time.					X				
OSS	PSS	1543	PSSSW-4.8	PSS-SIS SW	19	1.7.3.1	This interface shall not impact the SIS's ability to provide its safety functions.					X				
OSS	PSS	1544	PSSSW-4.8'	PSS-SIS SW	20	1.7.3.1	The CCS interface function shall transmit the current state of each signal through the correspondingphysical output and update centralized HMI with the latest status of the signals.					X				
OSS	PSS	1545	PSSSW-4.9.2	PSS-SIS SW	21	1.7.3.1	The system shall provide a mechanism to log in/out the active operator.			X						
OSS	PSS	1546	PSSSW-4.9.3	PSS-SIS SW	22	1.7.3.1	The CHMI screens shall remain visible at all times; the screen saver shall be disabled at all times.			X						
OSS	PSS	1547	PSSSW-4.9.4	PSS-SIS SW	23	1.7.3.1	Login information shall be logged in the System Log.			X						
OSS	PSS	1548	PSSSW-4.10	PSS-SIS SW	24	1.7.3.1	Thealarm module shall not influence the safety-relevant logic of the SIS.				X	X			Code walk through	
OSS	PSS	1549	PSSSW-4.10'	PSS-SIS SW	25	1.7.3.1	The alarm handling function shall transmit the current state of the generated alarm signal to the centralized HMI.			X						
OSS	PSS	1550	PSSSW-5.7.1	PSS-SIS SW	26	1.7.3.1	During operation, alarm information shall be monitored continuously, andany alarm generation is first stored internally within the HMI unit.			X						
OSS	PSS	1551	PSSSW-5.7.1'	PSS-SIS SW	27	1.7.3.1	The configuration shallbe verified that it does not degrade the performance of the HMI unit.			X						
OSS	PSS	1552	PSSSW-5.7.2	PSS-SIS SW	28	1.7.3.1	During operation, data points shall be monitored and stored continuously based on the defined exportingfrequency.					X				
OSS	PSS	1553	PSSSW-5.7.2'	PSS-SIS SW	29	1.7.3.1	Theconfiguration shall be verified that it does not degrade the performance of the HMI unit.			X						
OSS	PSS	1554	PSSSW-5.8	PSS-SIS SW	30	1.7.3.1	A (SIS) time of day fiducial shall be provided to the CCS and is described in FUNC-CCS-09.					X				
OSS	PSS	1555	PSSSW-5.9	PSS-SIS SW	31	1.7.3.1	Software testing shall be performed through one or more Preoperational Test Procedures (PTP).				X	X			Verification that PTP are conducted	
OSS	PSS	1556	PSSSW-5.9.1	PSS-SIS SW	32	1.7.3.1	The system's test plans shall include verification that the non-functional requirements in this document areperforming adequately.				X				Test Plan Review	
General	GRD	**OTHER GRD REQUIREMENTS**														

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General	GRD	1557	GRD- 7	ES&H Requirements	1		The design, manufacture, fabrication, construction, installation, test, operation, maintenance, modification, and eventual decontamination and decommissioning of the NSTX-U including all features associated with the Center Stack Upgrade shall be accomplished in a manner that will protect personnel, visitors, the public, property and the environment from injury				X				Decommisioning inspections to ensure compliance	
General	GRD	1558	GRD- 7'	ES&H Requirements	2		Pursuant to this policy, the NSTX-U project shall: • Comply with all applicable Federal, State, Local, and PPPL ES&H regulations; • Assess and minimize the risks inherent in the NSTX program; • Actively encourage ES&H awareness on the part of NSTX personnel and visitors.		X		X		All FDRs have ES&H in attendance to address any poptential; issues		Design inspections to ensure compliance	
General	GRD	1559	GRD- 7''	ES&H Requirements	3		NSTX shall be designed and operated in accordance with DOE Orders and PPPL Environment, Safety and Health Directives.		X		X		All FDRs have ES&H in attendance to address any poptential; issues		Design inspections to ensure compliance	
General	GRD	1560	GRD - 6.7.1.a	Accelerator Safety Order	4	1.7.1.3	NSTX-U systems and procedures shall comply with the Accelerator Safety Order (DoE Order 420.2c)		X				The ASO is provided at a daily meetings and addressed in reviews regarding systems safety			
General	GRD	1561	GRD - 6.7.2.a	Project Physics	5	1.7.2	NSTX-U project physics shall provide support when called upon. Examples of such support may include, but not be limited to: ● Discharge scenario development ● System requirements definition ● Review participation		X				Physics is generally called upon when there is a design issue and provides clarification on operationg conditions and physics requirements			
General	Disruption	**DISRUPTION ANALYSIS REQUIREMENTS**														
General	Disruption	1562	RD3-1.a	Disruption analysis requirements			Components on NSTX-U shall be designed to withstand forces and loads due to plasma disruption [1].									
General	Disruption	1563	RD3-1.d	Disruption analysis requirements			Eddy current flow in these structures shall be calculated based on the disruption cases described in Section 2. Halo current flow shall be computed based on assumptions presented in Section 3.									
General	Disruption	1564	RD3-1.e	Disruption analysis requirements			Forces shall be calculated based on the induced current flow calculated from the disruption scenario, plus the halo current, crossed with the worst case field at each location which causes the magnitude, of the force to be maximized at that location. See Section 3 for definition of worst case field.									
General	Disruption	1565	RD3-2.a	Disruption analysis requirements			Two disruption modes shall be assessed in the context of eddy currents: Mode 1: induction due to current quench where the plasma position is fixed and no halo currents are included., Mode 2: Induction due to both plasma motion (e.g. Vertical Displacement Event (VDE) or inward translation of the plasma) and the current quench, with halo current included.									

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
General	Disruption	1566	RD3-2.c	Disruption analysis requirements			The eddy current dynamics shall be derived from the data in Table 2.2. In most cases, the plasma starts in an initial position. For a basic calculation, the current at that location is ramped down, while the current at a second position is ramped up; this simulates the effect of plasma motion, and is indicated in Fig. 2.2.	Fig. 2.2								
General	Disruption	1567	RD3-3.a	Disruption analysis requirements			Worst case poloidal fields shall be computed at the location of interest as the sum of the “disruption field” and the “equilibrium field”									
General	Disruption	1568	RD3-3.b	Disruption analysis requirements			The “disruption field” is defined as the worst case field created by either of: ● The worst case of the rapidly translated plasmas in Table 2.1. This shall include the field from the translating plasma and from the eddy currents induced by that translation. ● The field from a stationary plasma located at any of the positions P1-P6.									
General	Disruption	1569	RD3-4.d	Disruption analysis requirements			The halo current time evolution shall be taken as a triangle, with peak amplitude given by 3b) -3c). The base of the triangle shall be 3 msec wide, with the halo current pulse ending when the plasma current goes to zero. See Fig. 2.2 for an example of this evolution.									
General	Disruption	1570	RD3-4.f	Disruption analysis requirements			A ~20 cm poloidal width ( ) of the halo current footprint on the target should w halo be assumed. This requirement shall apply to all wetted surfaces at the entrance of exit points.									
General	Disruption	1571	RD3-4.i	Disruption analysis requirements			As elaborated in Ref. 2, when the halo strike lines bridge the inner-outer vessel boundary, there are up to three possible current paths, corresponding to i) arcing across the tiles (between the IBDH and OBDR1 tiles), ii) flowing through the bellows and other structural elements to close the circuit, iii) and flowing through any elements shunting the bellows (the bakeout bus work, for instance, or the upper “shims”). The I H =f h I P =0.35I P current shall be resistively/inductively distributed amongst these paths, with an assumption of 1 eV deuterium plasma filling the IBDH/OBDR1 tile gap. Further details are provided in Table 4.4	Table 4.4								
General	Disruption	1572	RD3-5.a	Disruption analysis requirements			If fatigue analysis is required, then it should be assumed that all shots disrupt with the distribution as per Table 5-1. The quench rate that gives the maximum load for a particular component shall be assumed.	Table 5-1								
General	Disruption	1573	RD3-5.c	Disruption analysis requirements			Fatigue assumptions for specific components, based Tables 5-1 and 5-2, shall be documented in a design report, calculation, or memo.	Table 5-1								
Diag	PFC Diag	**PFC Diagnostic Fueling Requirements**														
Diag	PFC Diag	1574	2.1.2.b	General Magnetics Requirements	1		If the present copper/omega-bond scheme is utilized for Mirnov coils, then the temperature of the Mirnov coils shall not exceed 500 C at any time during the plasma pulse or subsequent between-shot cooling period.		X				Manufacturer's data sheets			

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Diag	PFC Diag	1575	2.1.2.d	General Magnetics Requirements	2		The tilt of the measurement axis of the Mirnov coin in the toroidal direction shall be < 2 degrees.				X				Included in design and assembly drawings	
Diag	PFC Diag	1576	2.3.2.f	Thermocouples	1		Thermocouple junctions shall be electrically isolated from the tiles in which they are embedded.Target isolation values are 0.5 kV between the electrical features of the thermocouples and the tiles.				X	X			28 March 2018 FDR Thermocouple potted to Boron Nitride Sleeve with Fortafix . Inspection of installation and subsequent test to validate requirement is met. Drawing 9D11556	An electrical isolation Hi-Pot test conducted
Diag	PFC Diag	1577	2.4.1.b	Shunt Tiles	1		Shunt tiles are tiles that are modified so that a low-resistance element resides between the tile bottom and the underlying surface. Steps shall be are taken to ensure that this resistive element is the only electrical path between the PFC surface and the backing structure. This can include insulating washers and insulating coatings on the hardware such as bolts and pins		X		X		NSTXU_1_4_4_1_Calc_012 Halo Current Shunt Analysis		Ensure that drawing is implemented	
Gas	GAS RD-0(	1578	2.5.2.a	Fueling lines			In-vessel gas tubing lines shall be made of 316 stainless steel or similar low-permeability , high temperature material.									
Diag	PFC Diag	1579	2.6.e	Center Column Wire Routing	1		The directions in Table 2.6-1 shall be followed in order to minimize tile variants.	Table 2.6-1			X				Tile variants were reduces as a result of requirements in RD-014 and drawings specify how the component is installed.	
Diag	PFC Diag	1580	2.6.f	Center Column Wire Routing	1		Organ pipes beneath thru-hole tiles in the horizontal target shall not be used for vacuum wire exits.				X				Drawing were updated to ensure that this requirement is met	
Diag	PFC Diag	1581	3.1.c	General requirements	1		Non-ferritic materials should be used for all fasteners. SS316, A286, or Inconel are preferred. Magnetic permeability requirements shall be adhered to as per reference [6].				X				Verify the design and and implemented identified in drawings	
Diag	PFC Diag	1582	3.2.2.a	Inboard Vertical Target Diagnostics, Mirnov Sensors on the Vertical Target	1		2D Mirnov sensors shall be located in approximately the locations indicated in Table 3.2.2-1, which isconsistent with legacy E-ED1324. Design deviations in the location of order 5 cm in height and in toroidaldirection are acceptable, as are small variations in radius. Reductions in sensor count may be acceptablefollowing consultation with the magnetics COG.	Table 3.2.2-1			X				Inspection to ensure that Drawing 9D11556 and and RD-14 is followed	
Diag	PFC Diag	1583	3.2.3.b	Langmuir Probes on the Vertical Target	1		At least 5 probes should be installed in the HHF region, and can be at more than one toroidal location,under the guidance of Table 3.2.3-1.	Table 3.2.3-1			X				Inspection to ensure that Drawing 9D11556 and and RD-14 is followed	
Diag	PFC Diag	1584	3.2.5.a	Halo Current Rogowskis on the Vertical Target	1		Halo current Rogowskis shall be installed as per Table 3.2.5-1. Variations in height on order ~10 cm are acceptable, provided the the two Rogowskis on each target are spaced by the majority of the height of the vertical target.	Table 3.2.5-1			X				Verify upon installation of coils IAW with drawings	
Diag	PFC Diag	1585	3.3.1.b	Diagnostic Requirements for the Horizontal Target, General	1		PFC holes centered around the organ pipes as per E-DC1324 shall be included at the bays indicated in Table 3.3.1-1:	Table 3.3.1-1:			X				Ensure implementation of drawings	

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Diag	PFC Diag	1586	3.3.1.d	Diagnostic Requirements for the Horizontal Target, General	1		The holes at the locations in Table 3.3.2-2 shall be eliminated	Table 3.3.2-2			X				Ensure implementation of drawings	
Diag	PFC Diag	1587	3.3.3.b	Diagnostic Requirements for the Horizontal Target, Langmuir Probes on the Horizontal Target	1		6 probes should be installed in the HHF region, and can be at more than one toroidal location, under the following guidance: ● There shall be at least 4 probes at a fixed toroidal angle, distributed uniformly over the HHF region. This shall be referred to as the "primary" location. ● The probes at the other locations may be placed at the same radial positions				X				Ensure implementation of drawings and RD-14	
Diag	PFC Diag	1588	3.4.2.a	Thermocouples on the Horizontal Target	1		Locations of 2D Mirnov coils shall be approximately as in Table 3.4.2-1. Sensors should be reinstalled at these locations, though small (~3-5 cm) design shifts poloidally and toroidally are acceptable.	Table 3.4.2-1			X				Ensure implementation of drawings and RD-14	
Diag	PFC Diag	1589	3.4.3.2	Outboard Divertor Diagnostic Requirements	1		RF Langmuir probes in Rows 3 & 4 shall be installed in a fashion similar to the design used for the FY16 run campaign. RF Langmuir probes in the former Row 2 shall be of the rail probe design, consistent with power handling requirements in that region.				X				Ensure implementation of drawings and RD-14	
Diag	PFC Diag	1590	3.5.1.a	CSAS Diagnostic Requirements	1		The CS tiles shall have the diagnostics as indicated in drawing E-D1324.				X				Ensure implementation of drawings and RD-14	
Diag	PFC Diag	1591	3.5.1.b	CSAS Diagnostic Requirements	1		Provision shall be made for diagnostic and gas tubing wireways			X				Wireways were demonstrated to ensure that the wireways considered the maximum quantity of cables.	Ensure implementation of drawings and RD-14	
Diag	PFC Diag	1592	3.6.1.a	Center Stack First Wall (C) Tile Diagnostics and Gas Interface	1		Provision shall be made for diagnostic wireways as appropriate.			X				Wireways were demonstrated to ensure that the wireways considered the maximum quantity of cables.	Ensure implementation of drawings and RD-14	
Diag	PFC Diag	1593	3.6.2.a	Mirnov Coils on the CSFW	1		Mirnov coils shall be located at the locations indicated in Tables 3.6.2-1 through 3.6.2-4. Shifts on order of 1-2 cm are acceptable if desired to improve engineering.	Tables 3.6.2-1 through 3.6.2-4			X				Verify compliance to drawings and RD-14	
Diag	PFC Diag	1594	3.6.3..a	Langmuir Probes on the CSFW	1		The CSFW LPs shall be installed as indicated in Table 3.6.3-1.	Table 3.6.3-1.			X				Verify compliance to drawings and RD-14	
Diag	PFC Diag	1595	3.6.4.a	Thermocouples on the CSFW	1		Thermocouples on the CSFW shall be at the locations indicated in Table 3.6.4-1.	Table 3.6.4-1.			X				Verify compliance to drawings and RD-14	
Diag	PFC Diag	1596	3.6.4.b	Thermocouples on the CSFW	1		The TC CSFW midplane toroidal array from the 2015 Upgrade Installation shall be abandoned if favor of increased TC coverage elsewhere. If convenient, the sensors can be abandoned in the tiles, but disconnected and secured at the feedthroughs.				X				Inspection will ensure proper installation of new tile design. Note: Requirement eclipsed by the new PFC design no need to abandon	
Diag	PFC Diag	1597	3.6.4.a'	Shunt Tiles on the CSFW	1		Shunt tiles shall be installed in the floating tiles, at the locations indicated in Table 3.6.4-1.	Table 3.6.4-1.			X				Inspect proper installation in accordance with the drawings and RD-14	

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Diag	PFC Diag	1598	3.7.a	Primary Passive Plate Diag	1		Tiles on four of the upper primary passive plates and four of the lower primary passive plates shall beinstrumented with thermocouples for tile bulk temperature measurements.			X				The Passive Plate Diagnostics are out for scope for the Recovery effort. The LHF TCs can be transitioned from the OBD345 but additional analysis and test is not considered. ED-1471 Wiring diagram included the wiring.		
Diag	PFC Diag	1599	3.7.b	Primary Passive Plate Diag	1		Each plate selected for instrumentation shall have at least two tiles instrumented with TCs. These tilesselected should be approximately centered on the plate surface, consistent with other diagnosticinstallations such as the RWM sensors.			X				The Passive Plate Diagnostics are out for scope for the Recovery effort. The LHF TCs can be transitioned from the OBD345 but additional analysis and test is not considered. ED-1471 Wiring diagram included the wiring.		
Diag	PFC Diag	1600	3.8.a	Primary Passive Plate Diag	1		Tiles on four of the upper secondary passive plates and four of the lower secondary passive platesshall be instrumented with thermocouples for tile bulk temperature measurements.			X				The Passive Plate Diagnostics are out for scope for the Recovery effort. The LHF TCs can be transitioned from the OBD345 but additional analysis and test is not considered. ED-1471 Wiring diagram included the wiring.		
Diag	PFC Diag	1601	3.8.b	Primary Passive Plate Diag	1		Each plate selected for instrumentation shall have at least two tiles instrumented with TCs. These tilesselected should be approximately centered on the plate surface			X				The Passive Plate Diagnostics are out for scope for the Recovery effort. The LHF TCs can be transitioned from the OBD345 but additional analysis and test is not considered. ED-1471 Wiring diagram included the wiring.		
Gas	GAS RD-0(	1602	4.3.a	Private Flux Region Fueling			To assist in mitigating large heat fluxes on the IBDV and IBDH, gas fueling lines shall be installed in the private flux region (PFR) (i.e. the region between the inner and outer strike-points). This is generally within the region defined as R<0.48 and |Z|>1.5.		X				Private Flux FDR			
Gas	GAS RD-0(	1603	4.3.e	Private Flux Region Fueling			Piezo-electric valve with PCS control shall be used to control the fuelling		X				Private Flux FDR			
Gas	GAS RD-0(	1604	4.3.g	Private Flux Region Fueling			As a minimum requirement, a single gas delivery orifice, at a single toroidal location each of top and bottom, shall be implemented. It is desirable, but not required, to generate designs that lead to a more toroidally uniform distribution of gas.		X				Private Flux FDR			
Diag	Diagnostic	**CS Air-Side Diagnostics Requirements**														
Diag	Flux	1605	2.a	General Requirements	1		Each flux loop location shall have a primary and a redundant loop. These two loops shall be located immediately adjacent to each other on the component to which they are mounted.				X				Inspection at installation	
Diag	Flux	1606	2.b	General Requirements	2		For loops on coils, the flux loops can be applied directly to the surface of the ground wrap. The primary and secondary loops shall not be twisted as they traverse the surface of the coil, but rather can be placed one directly adjacent to each other on the coil surface. The two leads of the primary loop shall be twisted starting at the location where they meet, as shall the two leads of the secondary loop. The diameter of a twisted pair can be taken as 0.06" for design purposes				X				Design is included in models	
Diag	Flux	1607	2.c	General Requirements	3		Loops shall be made from 22 AWG insulated magnet wire.				X				Existing design being updated	

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Diag	Flux	1608	2.d	General Requirements	4		The loops shall be protected by a thin wet layup or equivalent. See Table 2-1 of thickness of protection material.	Table 2-1			X				Existing design being updated	
Diag	Flux	1609	2.f	General Requirements	5		Provision shall be made for the local high spots where wire bundles cross over flux loops. Exact size requirement to be a design outcome based on chosen wire routing.		X		X		Part of the MCS Tolerance stack		Metrology	
Diag	Flux	1610	3.1.a	PF-1a Coils	6		Each of-1a coil shall have the following diagnostics mounted outside the ground insulation, but underneath any support slings or structures: ● Four flux loop locations, approximately uniformly spaced along the coil axially, with a primary and spare loop at each location. Suggested locations are shown in Table 3.1-1, with deviations in vertical position of 2-3 cm acceptable. ● Two thermocouples, approximately uniformly spaced along the coil axially; the toroidal angle of the thermocouples can determined by convenience with regard to lead routing. These shall be type E TC wire. ● Two thermocouples, approximately uniformly spaced along the coil axially; the toroidal angle of the thermocouples can determined by convenience with regard to lead routing. These shall be type E TC wire.	Table 3.1-1	X		X		or part of the magnet scope Most sensors in models and on drawings		Metrology and inspection as part of system installation	
Diag	Flux	1611	3.2.a	PF-1b Coils	7		Each of-1b coil shall have the following diagnostics mounted outside the ground insulation, but underneath any support slings or structures: ● Two flux loop locations, approximately uniformly spaced along the coil axially, with a primary and spare loop at each location. Suggested locations are shown in Table 3.2-1, with deviations in vertical position of 2-3 cm acceptable in order to center the loops on the coil ● Two thermocouples, approximately uniformly spaced along the coil axially; the toroidal angle of the thermocouples can determined by convenience with regard to lead routing.	Table 3.2-1	X		X		or part of the magnet scope Most sensors in models and on drawings		Metrology and inspection as part of system installation	
Diag	Thermo	1612	3.3.a	of-1c Coils	8		The legacy of-1c coil had six thermocouples, as enumerated in 9D1095, sheet 37, and 36. Each coils had an array of 2 axially (uniformly spaced) by 3 toroidal. If these are retained, the toroidal angles of the sensors would ideally be 15, 155, and 255 degrees toroidal, though deviations from this are allowed. These shall be type E TCs. These may be retained if convenient, but a minimum of two TCs are required.		X		X		or part of the magnet scope Most sensors in models and on drawings		Metrology and inspection as part of system installation	

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Diag	Flux	1613	3.3.a	PF-1c Coils	9		Each of-1c coil shall have the following diagnostics mounted outside the ground insulation, but underneath any support slings or structures: ● Two flux loop locations, approximately uniformly spaced along the coil axially, with a primary and spare loop at each location. Suggested locations are shown in Table 3.3-1, with deviations in vertical position of 2-3 cm acceptable in order to center the loops on the coil. ● At least two thermocouples, approximately uniformly spaced along the coil 1 axially; the toroidal angle of the thermocouples can determined by convenience with regard to lead routing.	Table 3.3-1	X		X		or part of the magnet scope Most sensors in models and on drawings		Metrology and inspection as part of system installation	
Diag	Flux	1614	4.0.a	OH Coil	10		The OH coil shall have 9 flux loop locations as enumerated in table 4-1	Table 4.1			X			Subsystem is existing and not being modified as part of recovery scope		
Diag	Thermo	1615	4.0.b	OH Coil	11		There shall be 20 thermocouples mounted to the surface of the OH coil, as per the following guidance: ● 2 axial arrays of 9 TCs, with one TC at the OH coil midplane, and 4 each above and below the midplane. The spacing of the TCs in these arrays shall be ~11.8". ● There two axial arrays shall be 180 degrees toroidally displaced. ● At the midplane, there shall be two additional TCs, intermediate in toroidal angle between the axial arrays.			X				Subsystem is existing and not being modified as part of recovery scope. CWD Dawing 1095 provides the interface for these sensors		
Diag	Flux	1616	5.0.b	Casing and Coil Support	12		If practical, flux loops shall be installed on the casing and coils support structures as in the following table	Table 5-2	X		X		Flux loops are included in tolerance stack up		Flux loops are included in the model	
Diag	Thermo	1617	6.0.a	Ceramic Break	13		Thermocouples shall be mounted to the ceramic break in four quadrants			X				Subsystem is existing and not being modified as part of recovery scope. CWD Dawing 1095 provides the interface for these sensors		
Diag	Rogowski	1618	7.0.a	Plasma Current Rogowski Integration	14		There shall be three plasma current rogowski coils integrated to the center-stack assembly.		X		X		Slots provides in flanges and included in tolerance stack up		Metrology and inspection as part of system installation	
Diag	Rogowski	1619	7.0.b	Plasma Current Rogowski Integration	15		The rogowski coils shall be located along the surface of the OH coil along the distance of that coil behind the CSFW.		X		X		Drawing include Ip Rogowski cable runs		Metrology and inspection as part of system installation	
Diag	Rogowski	1620	7.0.c	Plasma Current Rogowski Integration	16		The rogowski coils routing shall not pass them through the bore of the of-1a coils, thereby ensuring that the rogowski does not link their current.		X		X		Drawing include Ip Rogowski cable runs		Inspection as part of system installation	
Diag	Rogowski	1621	7.0.g	Plasma Current Rogowski Integration	17		The rogowski coils shall be located behind microtherm along any part of its trajectory where it would otherwise be exposed to elevated-temperature components within the casing assembly.		X		X		NSTXU_1-1-3-3_CALC-101		Inspection as part of system installation	
Diag	Rogowski	1622	7.0.h	Plasma Current Rogowski Integration	18		After exiting the CS assembly, the Rogowskis shall not directly contact any vessel components that are held at ~150 C by the medium temperature water system.		X		X		NSTXU_1-1-3-3_CALC-101		Inspection as part of system installation	
Diag	Rogowski	1623	7.0.i	Plasma Current Rogowski Integration	19		Any clamps that hold the Rogowski coil along the outer vessel shall have insulating components to aid in voltage isolation. Components shall be designed to provide 2 kV AC RMS isolation between the rogowski and the outer vessel.		X		X	X	NSTXU_1-1-3-3_CALC-101		Inspection as part of system installation	Isolation Testing

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Diag	Rogowski	1624	7.0.k	Plasma Current Rogowski Integration	20		For purposes of design, the cross-section of a Rogowski coil shall be taken as 1.30" by 0.16".		X		X		NSTXU_1-1-3-3_CALC-101		Inspection as part of system installation	
Diag	Mach. Inst						**Machine Instrumentation**									
Diag	Mach. Inst	1624	1	Sensor Requirements	21		A system shall be installed to measure the twist of the TF bundle.				X	X			Two Mechansims Laser	
Diag	Mach. Inst	1625	2.0.a	Sensor Requirements	1		Sensors shall provide appropriate galvanic isolation from NSTX-U coil and vessel grounds; fiber-optic based sensors shall be used.				X					
Diag	Mach. Inst	1626	2.0.b	Sensor Requirements	2		The sensors and any related structures shall not impede or modify the underlying mechanical, electrical, or thermal design features of the component to which they are applied.				X					
Diag	Mach. Inst	1627	2.0.c	Sensor Requirements	3		Sensors and their interconnections shall protected from physical damage.				X				Covers for exposed sensors i.e., lid presented at FDR	
Diag	Mach. Inst	1628	2.0.d	Sensor Requirements	4		Sensors, associated interconnects and mechanical protection devices mounted shall be mechanically rated for temperatures between (and including) 12C and the maximum operating temperature of the coil or system to which they are applied. Maximum operating temperatures on coil can be found in the design point spreadsheet [4].		X				Vendor's specification			
Diag	Mach. Inst	1629	2.0.e	Sensor Requirements	5		The system shall function reliably and accurately with confidence in the magnetic and radiation environment of NSTX-U.			X						
Diag	Mach. Inst	1630	2.0.f	Sensor Requirements	6		The strain sensitivity of shall be 1% of the maximum strain indicated in Section 5.		X				Vendor's specification			
Diag	Mach. Inst	1631	3.0.a	Data acquisition and archiving requirements	7		The system shall synchronize sampling with the NSTX-U clock system to an accuracy of 0.01 seconds compared to the sample clock.					X				
Diag	Mach. Inst	1632	3.0.b	Data acquisition and archiving requirements	8		The archiving window for shot data shall be from from SoP to a user configurable stop time. This stop time will be between 10 and 1200 seconds after SoP.			X						
Diag	Mach. Inst	1633	3.0.c	Data acquisition and archiving requirements	9		The archived shot data sampling rate shall be at least 100 Hz, and should not exceed 1 kHz.			X		X				
Diag	Mach. Inst	1634	3.0.d	Data acquisition and archiving requirements	10		Raw data, in whatever format is native to the instrumentation system, shall be archived in the MDS+ tree.			X						
Diag	Mach. Inst	1635	3.0.e	Data acquisition and archiving requirements	11		Calibrated data, with units of microstrain, shall be archived or available in the MDS+ tree. When temperature data is simultaneously collected, it shall be calibrated to units of deg C for storage.			X						
Diag	Mach. Inst	1636	3.0.f	Data acquisition and archiving requirements	12		The archived shot data shall be in a format that can be plotted with common tools such as dwscope, jscope, or webtools, and accessed in table form via webtools			X						
Diag	Mach. Inst	1637	3.0.g	Data acquisition and archiving requirements	13		The raw and calibrated data shall have MDS+ tag names that clearly identify the sensor location as per the established naming convention.			X						

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Diag	Mach. Ins	1638	3.0.'	Data acquisition and archiving requirements	14		Associated metadata shall also be stored in the MDS+ shot tree. These may include sensor type, sensor location, calibration coefficients associated with the conversion from raw to calibrated data, etc.			X						
Diag	Mach. Ins	1639	3.0''	Data acquisition and archiving requirements	15		Post-processing, multi-sensor plotting, DCPS comparisons, and CoE alarms, based on the archived MDS+ data, shall be specified in a future revision to this document or follow-on requirement document.				X					
Diag	Mach. Ins	1640	4.0.a	Location and channel count specification	16		A clear sensor naming convention shall be established. This convention shall unambiguously identify the sensor location and sensor type. This same convention shall be used in CWDs, fiber labels, and MDS+ tree naming				X					
Diag	Mach. Ins	1641	4.0.b	Location and channel count specification	17		Temperature compensations shall be applied as necessary to achieve the required accuracy.			X		X				
Diag	Mach. Ins	1642	4.0.c	Location and channel count specification	18		All sensors shall be within 0.5" of the location specified in governing drawings; deviations from this require approval of the Integrated Design and Analysis Responsible Engineer at the FDR.				X					
Diag	Mach. Ins	1643	4.0.d	Location and channel count specification	19		For each elevation on the TFOL, there shall be at least 4 sensors on any given side of the coil.				X					
Diag	Mach. Ins	1644	4.1.0	TFOL: Trending and Benchmarking	20		At a minimum, the three mid-span locations [2, 5, and 8] shall be instrumented for strain, as indicated in Fig. 4.1-1 and Table 4.1-1. These sum to 36 measurements. A remaining set of 6 high stress locations per TFOL are also strongly recommended for trending and for eliminating uncertainties in coil fabrication and analysis.	Fig. 4.1-1 and Table 4.1-1		X	X					
Diag	Mach. Ins	1645	4.1.0'.	TFOL: Trending and Benchmarking	21		The FISO-based sensors installed on the TFOLs during the summer 2016 shall be retained as a benchmark for the new system. These were installed under D-NSTX-IP-3831, and their as-installed locations are indicated in the run-copy.				X					
Diag	Mach. Ins	1646	4.2.0	Trusses	22		The radial location shall be specified in the installation drawings. They shall be centered on the trusses and away from the threaded features that may result in local strains.				X					
Diag	Mach. Ins	1647	4.2.0'	Trusses	23		The truss sensors shall accommodate rotation of the trusses.			X				Use analysis data to determine the maximum rotation and ensure sufficient gaps to accomodate rotation		
Diag	Mach. Ins	1648	4.3.0	Spoked Lids	24		It is desired to measure the strain at multiple locations on the spoked lids. At each location, there shall be a measurement on the top and bottom of the lid, at the same radius and toroidal angle; see Fig. 4.3-1.	Fig. 4.3-1.			X					
Diag	Mach. Ins	1649	4.3.0'	Spoked Lids	25		These locations shall accommodate removal of the spoked lids, i.e. have some accommodation to disconnect the sensors. Note that the lower spoked lid is segmented and comes off in individual parts.			X						

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Diag	Mach. Inst	1650	4.5.0	OH Preload	26		There are presently two FISO LVDTs on the Belleville washer spring stack, monitored by the FISO chassis. These shall continue to be instrumented.				X					
Diag	Mach. Inst	1651	4.6.1	TF Torsional Strain	27		The torsional strain of the TF shall be measured at at least 8 toroidal angles.				X					
Diag	Mach. Inst	1652	4.6.1'	TF Torsional Strain	28		They shall be placed at a location beneath the bottom of the conductor faces.				X					
Diag	Mach. Inst	1653	4.6.1''	TF Torsional Strain	29		They shall be designed in such a manner that the belleville washer stack does not interfere with the sensors mounting, and the sensor cables can be extracted from behind the washer stack. The system shall also be consistent with an high voltage insulation put in that region.				X					
Diag	Mach. Inst	1654	4.6.1'''	TF Torsional Strain	30		The exact height shall bedetermined by that which leads to appropriate measurement sensitivity, within the constraints ofpotential interferences (for instance, with the preload mechanism).			X	X					
Diag	Mach. Inst	1655	4.6.1''''	TF Torsional Strain	31		They shall be designed in such a manner that the belleville washer stack does not interfere with thesensors mounting, and the sensor cables can be extracted from behind the washer stack.				X					
Diag	Mach. Inst	1656	4.6.1'''''	TF Torsional Strain	32		The systemshall also be consistent with any high voltage insulation put in that region.				X	X				
Diag	Mach. Inst	1657	4.6.1''''''	TF Torsional Strain	33		Four toroidal angles of the sensor pairs should correspond to the angles of the quadrant joints, i.e, at the angles between the following conductor pairs: ● TFB1 and TFB2 ● TFE1 and TFE2 ● TFH1 and TFH2 ● TFK1 and TFK2 The other four sensors shall be placed at intermediate angles.				X					
Diag	Mach. Inst	1654	4.8.0	Preload on Inner-PF Coils	30		Sensors shall be installed to measure the preload on these four coils.				X					
Diag	Mach. Inst	1655	4.8.0	Preload on Inner-PF Coils	31		Redundant sensors shall be installed to guard against failure of the primary sensor; these redundant sensors need not be instrumented if that can result in some system simplification.				X					
General	Mag Perm	**Magnetic Permeability Requirements**														
General	Mag Perm	1655	RD10-1	Fasteners			Fasteners : Small fasteners on NSTX-U should, in general, be made from 316 (or other low permeability material); here, small is defined as 5/8" thread diameter or below. Other more magnetic alloys of stainless steel (304, 18-8) shall not be used without approval. If quantities of specialized hardened bolts (or others with elevated permeability) are used whose weight exceeds ~1 kg in a localized installation, then approval shall be required. Inconel fasteners should be considered for these installations where possible.									

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
General	Mag Perm	1656	RD10-2	Magnetic Shields and other High μ_R Materials			Magnetic shields are devices designed to exclude the magnetic field from a volume containing some sensitive instrument; they typically have relative permeability levels exceeding 1000, and often exceeding 10,000. All magnetic shields must be reviewed by the magnetic material committee for both i) forces on the shields, and ii) perturbations to the plasma. **Based on past NSTX and present DIII-D practice, the field perturbation at the nearest point on the plasma surface from these shields shall be less than 1 G.**									
General	Mag Perm	1657	RD10-3	Bulk Permeability			For material outside the TF boundary, the relative permeability for base material shall be beneath μ_R =1.2. The permeability of machined components may be up to 1.4.									
General	Mag Perm	1658	RD10-4	Inside TF Boundary			For discrete, large toroidally localized installations on or inside the vessel, every reasonable effort shall be made to keep the final bulk permeability beneath μ_R =1.04. Here, "large" is defined as exceeding ~1.5 kg. Annealing and shot peening are techniques that can be used to reduce the permeability, provided that base material of sufficiently high quality has been procured. Smaller toroidally localized installations can have somewhat higher permeabilities, as indicated by the curves in Fig. 1.	Fig. 1								
General	Mag Perm	1659	RD10-5	Inside TF Boundary			It is anticipated that there shall be some permeability increases in the vicinity of machining or other metal working. These shall not exceed μ_R =1.2. Annealing or other techniques should be considered to eliminate this permeability increase once the machining is finished.									
General	Therm Ana	**Thermal Analysis Requirements**														
General	Therm Ana	1660	RD13-2.0.0	Plasma Scenarios to Model			For these scenarios, three cooling schemes shall be assumed, as in Table 2-5.	Table 2-5								
General	Therm Ana	1661	RD13-2.0.0'	Plasma Scenarios to Model			Consistent with the GRD repetition rate assertions (4.1.4a), the internal components of the system shall operate with a 2400 second repetition rate under the baseline cooling, and a 1200 second repetition rate on one of the Upgraded cooling schemes.									
General	Therm Ana	1662	RD13-2.0.0"	Plasma Scenarios to Model			For analysis, graphite plasma facing component surfaces shall be assumed to have an emissivity of 0.7									
General	Therm Ana	1663	RD13-3.0.0	Bakeout Scenarios to Model			The bakeout simulations shall be done under the following assumptions - Table 3.1	Table 3.1								
General	Therm Ana	1664	RD13-3.0.0'	Bakeout Scenarios to Model			The air side vacuum vessel water system shall add or subtract heat in order to maintain an average vessel temperature of 150 C.									
General	Therm Ana	1665	RD13-3.0.0'	Bakeout Scenarios to Model			The distribution of He flow amongst the various paths shall be based on the relative conductance of the paths.									
GDS	RD 14	**GIS & GDS Parameters Requirements Parameters (Rel 1)**														

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Auxiliary	GDS	1666	1.1.a	Injector Plenum			The plenums shall be able to be filled and evacuated between shots through remote connection.									
Auxiliary	GDS	1667	1.3.e	Piezo-electric Valves			Valves shall have electrical isolation from the vessel as per the GRD [1].									
Auxiliary	GDS	1668	1.4.a	Puff Valves			All puff valve systems shall empty the entire plenum into its associated gas delivery system or directly into the vacuum vessel.									
Auxiliary	GDS	1669	1.4.f	Puff Valves			Valves shall have electrical isolation from the vessel as per the GRD [1].									
Auxiliary	GDS	1670	1.5.b	Supersonic Gas Injectors			SGI valves shall have electrical isolation from the vessel as per the GRD [1].									
Auxiliary	GDS	1671	1.3.b	Massive Gas Injectors			MGI valves shall have electrical isolation from the vessel as per the GRD [1].									
Test Cell	Rad. Shiel	**Radiation Shielding**														
Test Cell	Rad. Shielding	1672	2.0.a	Radiation Shielding	1	1.8.1.1.4	The radiation shielding job shall be divided into multiple phases. Details for only Phase I are provided; assessments following Phase I will allow the Phase II penetrations, if any, to be identified.				X					
Test Cell	Rad. Shielding	1673	2.0.b.i	Radiation Shielding	2	1.8.1.1.4	For the north wall of the test cell, the penetrations and doorways shall be remediated as indicated in Table 2-1 and Figure 2.1.	Table 2-1 and Figure 2.1.	X		X		NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1674	2.0.b.ii	Radiation Shielding	3	1.8.1.1.4	For the northeast wall of the test cell, the penetrations and doorways shall be remediated as indicated in Table 2-2 and Figure 2.2.	Table 2-2 and Figure 2.2.	X		X		NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1675	2.0.b.iii	Radiation Shielding	4	1.8.1.1.4	For the east wall of the test cell, the penetrations and doorways shall be remediated asindicated in Table 2-3 and Figure 2.3	Table 2-3 and Figure 2.23.	X		X		NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1676	2.0.d	Radiation Shielding	5	1.8.1.1.4	The mobile shield block on the northeast wall shall be immobilized.		X		X		NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1677	2.0.e	Radiation Shielding	6	1.8.1.1.4	Following the Phase I Shielding steps, the neutron generator testing of the NSTX-U test cellshielding shall be repeated. During these tests:					X				Neutron Generator Testing
Test Cell	Rad. Shielding	1678	2.0.e.i	Radiation Shielding	7	1.8.1.1.4	The efficacy of Phase I shielding shall be assessed by repeating measurements are previously identified problematic locations.					X	NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1679	2.0.e.ii	Radiation Shielding	8	1.8.1.1.5	Additional penetrations for which are candidates for shielding shall be assessed. Thesemay include, but may not be limited to, those listed in Table 2-6.	Table 2-6	X				NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1680	4.b	Shielding Methods and Design	1	1.8.1.1.4	All radiation shielding shall be designed so as to accommodate any required fire stops, as applicable.				X					
Test Cell	Rad. Shielding	1681	4.c	Shielding Methods and Design	2	1.8.1.1.5	The functionality of piping, cabling, and other services using penetrations shall not be impededby the installation of shielding.				X					
Test Cell	Rad. Shielding	1682	4.d	Shielding Methods and Design	3	1.8.1.1.4	Where concrete or polyethylene beads are used to fill penetrations, steps shall be taken toensure that the penetration volumes are fully filled.				X					
Test Cell	Rad. Shielding	1683	4.e	Shielding Methods and Design	4	1.8.1.1.4	Any polyethylene components in the shielding shall be approved by the fire protection engineer.				X					

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Test Cell	Rad. Shielding	1684	4.f	Shielding Methods and Design	5	1.8.1.1.4	Shielding designs for doors, labyrinths, and windows shall be verified by neutronics analysis.		X				NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1685	4.g	Shielding Methods and Design	6	1.8.1.1.4	Shielding designs shall be consistent with an ALARA philosophy		X				NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1686	4.h	Shielding Methods and Design	7	1.8.1.1.4	All shielding installations shall be documented in a fashion consistent with future configurationmanagement as a credited control under the ASO.				X		NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1687	4.i	Shielding Methods and Design	8	1.8.1.1.4	Any non-permanent element of the neutron shielding (i.e. removable plug, borated polyethylene sheets mounted to walls, etc) shall be clearly labeled as part of the test cell shielding.				X		NSTX-U-CALC-81-02-00			
Test Cell	Rad. Shielding	1688	4.j	Shielding Methods and Design	9	1.8.1.1.4	Labyrinths shall have widths, heights, lighting, and fire protection consistent with applicable lifesafety and architectural codes.				X					
OSS	RADMON	1689	RAD-5.1.a	Radiation Annunciation	1		Radiation annunciation shall use the on relay outputs of the eight existing Ludlum 375 real time dosemonitoring systems , located on the four walls 2 of the test cell.					X				NSTX-U-PLAN-033-00
OSS	RADMON	1690	RAD-5.1.b	Radiation Annunciation	2		The real time dose monitors shall be configured by Health Physics to close relay in any unit when theradiation level exceeds a predetermined level. The determination of this level is the responsibility ofHealth Physics.				X					
OSS	RADMON	1691	RAD-5.1.c	Radiation Annunciation	3		The annunciation system shall be capable of connecting to any of the Ludlum 375 models, which areoften interchanged as part of a calibration program.				X					
OSS	RADMON	1692	RAD-5.2.a	Radiation Annunciation	4		Signs shall be located outside the north and south test cell entrance doors.				X					
OSS	RADMON	1693	RAD-5.2.b	Radiation Annunciation	5		These signs when activated shall read “Danger, High Radiation Area”. Signs to be selected inconsultation with health physics.				X					
OSS	RADMON	1694	RAD-5.2.c	Radiation Annunciation	6		The closure of the output relay on any one of the eight real time dose monitors shall trigger theillumination of the postings.					X				NSTX-U-PLAN-033-00
OSS	RADMON	1695	RAD-5.2.d	Radiation Annunciation	7		When radiation levels drop below the setpoint limits the monitor contacts shall “open” and thelighted sign shall cease illumination.					X				NSTX-U-PLAN-033-00
OSS	RADMON	1696	RAD-5.2.e	Radiation Annunciation	8		The annunciation lights shall be electrically isolated from components within the test cell as perSection 4.2.3 of the GRD [1].					X				NSTX-U-PLAN-033-00
OSS	RADMON	1697	RAD-5.2.f	Radiation Annunciation	9		The system shall be designed so that additional illuminated signs could be added at other D-sitelocations, if necessary.					X				NSTX-U-PLAN-033-00
OSS	RADMON	1698	RAD-5.2.g	Radiation Annunciation	10		The system may use magnetic or solid state relays, but shall not use any programmable devices				X					
OSS	RADMON	1699	RAD-5.2.h	Radiation Annunciation	11		Provision shall be made to bypass any individual monitor if it fails or otherwise becomes inoperativeduring the run. This bypass shall not affect the ability of the other monitors to activate the signs.					X				NSTX-U-PLAN-033-00
General	Dim Contro	**Dimensional Control Requirements**														

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
General	Dim Contro	1700	RD11-3.1.b		1		The heat transfer plates (top and bottom) shall be aligned with respect to the local casing verticaltarget sleeves to within a shift of 0.02", and a tilt of 0.5 mrad.				X					
General	Dim Contro	1701	RD11-3.1.c		2		The heat transfer plates shall have a surface flatness of 0.01".				X					
General	Dim Contro	1702	RD11-3.2.a		3		The PF-4, PF-5 and TF coils shall be aligned to the global coordinate system to within the parameters of Table 3.2-1	Table 3-2.1			X					
General	Dim Contro	1703	RD11-3.2.c		4		The individual pancakes of the PF-4 and PF-5 coils shall be aligned to each other to within thetolerance state in Table 3.2-2.	Table 3-2.2			X				As part of the PF4/5 FDR, Clamp PDR measurements indicate that the requirements are met. Will Inspect following the installation of calmps	
VVIH	VVIH	**Inner-PF Coil Interfaces to Coil Support Designs and Cooling Systems**														
VVIH	VVIH	1704	RD12-2.1.a	Structural Interfaces, EM Vertical Loads			The following EM load cases shall be considered: Static equilibrium of current distributions with 10% headroom, , Static equilibrium of current distributions with 10% headroom and no plasma current., Post-disruption of current distributions following the simple flux conservation model									
VVIH	VVIH	1705	RD12-3.0.b	Thermal Interfaces			Support structures shall allow and facilitate a layer of microtherm or similar insulation. This insulation shall allow sufficient time for emergency response in a coil Loss of Cooling (LoC) situation during bakeout. The required time is provided in the Vacuum Vessel and Internal Hardware SRD [3].									
VVIH	VVIH	1706	RD12-3.0.c	Thermal Interfaces			Structures shall accommodate the range of temperature variation in Table 3-1.1	Table 3-1.1								
VVIH	VVIH	1707	RD12-4.1.a	Spacial Interfaces, Coil Pack Outline			Coil dimensions for the of-1a shall be as per Table 4-1 and Table 4-2.	Table 4-1 and Table 4-2.								
VVIH	VVIH	1708	RD12-4.1.b	Spacial Interfaces, Coil Pack Outline			Coil dimensions for the PF-1b shall be as per Table 4-3 and 4-4.	Table 4-3 and 4-4.								
VVIH	VVIH	1709	RD12-5.0.c	Electrical Power Interfaces			Coils and their support structures shall be designed for the voltage requirements in the Magnets SRD [2].									
VVIH	VVIH	1710	RD12-9.0.c	Fluid Interfaces			The cooling water configuration shall be such that the cold water supply enters the outer layer.									
VVIH	VVIH	1711	RD12-9.0.d	Fluid Interfaces			The supply hose and fittings (high pressure side) shall be provided with purple markings, and the return hose and fittings (low pressure side) shall be provided with black markings.									
VVIH	VVIH	1712	RD12-13.0.a	Diagnostic Interfaces			The inner-PF coils shall have flux loops and thermocouples mounted to them.				X					
VVIH	VVIH	1713	RD12-13.0.b	Diagnostic Interfaces			The support structures and clearances shall allow three plasma current rogawski's to pass through. The rogawski's shall not link the -1a coils, but may link the -1b and -1c coils as appropriate.									
VVIH	VVIH	1714	RD12-13.0.c	Diagnostic Interfaces			Provision shall be made for the wires to exit vicinity of the coils, for connection to multi-conductor field cables.									

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VVIH	VVIH	1715	RD12-Appendix 2.a	Repetition Rate and Cycle Requirements			The coils and associated support structures shall be designed to operate with a 1200 second repetition rate.									
VVIH	VVIH	1716	RD12-Appendix 2.b	Repetition Rate and Cycle Requirements			The baseline case shall be to design the coils for 20,000 full power and current pulses.									
Auxiliary	Bakeout	**Bakeout Upgrades Requirements**								X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1717	2.0.a	Common Requirements			All components in the helium pressure loop shall be designed for the simultaneous maximum temperature (450 C) and MWAP (300 PSIG) of the helium bakeout skid.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1718	2.0.b	Common Requirements			All mechanical design shall be governed by Ref. [3].			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1719	2.0.c	Common Requirements			All pressure systems shall comply with Ref. [4].			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1720	2.0.d	Common Requirements			Permeability PF materials shall be as per Ref. [5].			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1721	3.0.a	Piping Insulation Upgrade			All lengths PF piping shall be covered with insulation, except for potentially small gaps at flanges or other features. Localized gaps in insulation shall be inaccessible to unprotected personnel and shall not impose a flammability hazard.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1722	3.0.b	Piping Insulation Upgrade			Surface temperature on outside PF insulation shall be less than 160 F	1 ASTM C1055		X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1723	3.0.c	Piping Insulation Upgrade			Insulation shall be installed so that the insulation is not compressed.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1724	3.0.d	Piping Insulation Upgrade			Insulation shall be jacketed where possible.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1725	4.1.a	Throttling valves			Throttling valves shall be installed at each He load connection (i.e. vessel feedthroughs, feedthroughs to the horizontal target heating plates, etc.).			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1726	4.1.c	Throttling valves			Provision shall be made to adjust the throttling valves while the systems is in bakeout operation at full rated temperature and pressure.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1727	4.1.d	Throttling valves			Absolute position PF the valve shall be measurable and reproducible with granularity PF at least 1 part in 8 PF the mechanical travel.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1728	4.1.e	Throttling valves			The setup/teardown PF throttling valve remote operator assemblies to transition between plasma and bakeout operational modes shall take a crew PF 2 individuals no more than 1 shift to complete.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1729	4.1.f	Throttling valves			Interface to the CS heating/cooling features (i.e. heat transfer plates) shall be at the vessel side PF the manifold supply valves			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1730	4.2.a	Flow Measurements			Flow measurements shall be made on the piping feeding the two ring manifolds.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1731	4.2.b	Flow Measurements			Flow measurement instrumentation shall be able to be isolated from NSTX-U with electrical isolation consistent with the GRD (2 kV RMS AV hipot requirement) during plasma operations			X				Subsystem is existing and not being modified as part of recovery scope		

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Auxiliary	Bakeout	1732	4.2.c	Flow Measurements			Measurements shall measure flow rates up to 200 CFM, with an accuracy PF 5 CFM.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1733	4.2.d	Flow Measurements			The typical response time PF sensors shall be equal to or less than 10 seconds.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1734	4.2.e	Flow Measurements			All flow measurements shall be available for remote display, for instance via the HMI PF the bakeout PLC or EPICs. Values shall be updated at less than or equal to two second intervals.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1735	4.3.a	Temperature Measurements			Temperature measurements shall be installed on the piping feeding the two ring manifolds.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1736	4.3.b	Temperature Measurements			Temperature measurements shall be installed at the inlet and outlet of each He load connection.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1737	4.3.c	Temperature Measurements			Temperature measurements shall measure from 10 to 500 C, with an accuracy of 5 C.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1738	4.3.d	Temperature Measurements			The typical response time of sensors shall be equal to or less than 10 seconds.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1739	4.3.e	Temperature Measurements			All temperature measurement shall be available for remote display, for instance via the HMI of the bakeout PLC or EPICs. Values shall be updated at less than or equal to two second intervals.			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1740	4.3.f	Temperature Measurements			Temperature sensor and signal processing electronics design shall permit hipot of the NSTX-U vacuum vessel as per the GRD [1] (2 kV RMS AC hipot).			X				Subsystem is existing and not being modified as part PF recovery scope		
Auxiliary	Bakeout	1741	5.0.a	Helium Feedthrough Redesign			The helium feedthroughs at the following 6 vessel flanges shall be replaced with new designs: Bay A/L Upper, Bay D Upper, Bay H Upper, Bay A/L Lower, Bay D Lower, Bay H Lower.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1742	5.0.b	Helium Feedthrough Redesign			The new designs at each of 6 locations shall accommodate both He inlet and outlet feedthroughs on each vessel flange.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1743	5.0.c	Helium Feedthrough Redesign			The feedthroughs shall have compliant features, such as a 6” length of braided flexible tubing, where they connect to in-vessel manifolds, to accommodate various thermal and EM load cases.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1744	5.0.d	Helium Feedthrough Redesign			The feedthroughs shall have compliant features, such as a 6” length of braided flexible tubing, where they connect to in-vessel manifolds, to accommodate various thermal and EM load cases.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1745	5.0.e	Helium Feedthrough Redesign			Each of the 6 feedthrough locations shall have additional feedthroughs ports for up to 32 thermocouples, in order to support expansion of the internal TC deployment.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1746	6.0.a	Medium Temperature Water System Updates			The Medium Temperature Water System (MTWS) shall provide temperature-regulated pressurized water to the ex-VV surface manifolds.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1747	6.0.b	Medium Temperature Water System Updates			The system shall be able to heat the working fluid to a maximum temperature of 155°C.			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	Bakeout	1748	6.0.c	Medium Temperature Water System Updates			The system shall be able to cool the working fluid to a minimum temperature of 20°C.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1749	6.0.d	Medium Temperature Water System Updates			The system pressure shall be maintained at a minimum of 125% the vapor pressure of the water at the peak system temperature in accordance with ASHRAE Systems and Equipment Handbook Section 14.1 (2000).			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1750	6.0.e	Medium Temperature Water System Updates			The system pressure shall have a head pressure provided from a source not part of the subject system (i.e. instrument air) at 125% of the vapor pressure of the water at the peak system temperature in accordance with ASHRAE Systems and Equipment Handbook Section 14.1 (2000).			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1751	6.0.f	Medium Temperature Water System Updates			Heated water volumes shall be kept at a minimum where possible.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1752	6.0.g	Medium Temperature Water System Updates			The circulation pump(s) shall be redundant. If the lead pump fails to provide flow (or trips) the control system shall automatically energize the standby pump and annunciate an alarm. If both pumps fail the bakeout system shall shutdown and an alarm shall be generated.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1753	6.0.h	Medium Temperature Water System Updates			The working-fluid manifolds shall have capability for automated blow-down.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1754	6.0.i	Medium Temperature Water System Updates			The heating system shall be interlocked to the working fluid pressure, temperature, and flow.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1755	6.0.i.i	Medium Temperature Water System Updates			If the working fluid temperature exceeds 155° C the heaters shall de-energize, the bakeout system shall shutdown, and an alarm shall be generated.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1756	6.0.i.ii	Medium Temperature Water System Updates			If the working fluid pressure is less than the minimum 125% of the vapor pressure at temperature , the heaters shall de-energize and an alarm generated.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1757	6.0.i.ii'	Medium Temperature Water System Updates			The vapor pressure at temperature shall be determined by either the pressure at 155°C and/or as calculated by measured temperatures.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1758	6.0.iii	Medium Temperature Water System Updates			If the working fluid pressure is less than 105% of the vapor pressure at temperature, the the heaters shall de-energize, the bakeout system shall shutdown, and an alarm shall be generated.			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	Bakeout	1759	6.0.i.iv	Medium Temperature Water System Updates			If the working fluid temperature continues to exceed 155°C and/or the minimum working fluid pressure cannot be reached after the heaters are de-energized, the working fluid manifold shall be isolated and blown down by the control system, the bakeout system shall shutdown, and an alarm shall be generated. This event response addresses the condition wherein the vacuum vessel is heating the working fluid beyond the design envelope of the system.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1760	6.0.i.v	Medium Temperature Water System Updates			The heating system shall only be permitted to operate when flow is detected in the working fluid manifold.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1761	6.0.j	Medium Temperature Water System Updates			The working fluid loop shall at a minimum be instrumented for pressure (0-200 PSIG) and temperature (10-200°C) at both the supply and return. The flowrate (0-125 GPM) shall be measured at a minimum of one location in the working fluid loop.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1762	6.0.k	Medium Temperature Water System Updates			Instrument values shall be incorporated into the Bakeout System operator interfaces and updated at 2 second intervals so that they may be viewed from remote operator stations.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1763	6.0.l	Medium Temperature Water System Updates			Representative instrument values shall be trended and archived at a minimum of 1 minute intervals.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1764	7.0.a	DC Power to the Top of the Machine			The DC power supplies shall be permanently located in order to feed DC power to connections at the top of NSTX-U.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1765	7.0.b	DC Power to the Top of the Machine			This activity shall include permanent reconfiguration of the control cabling, plug-connected AC power, and water cooling hoses/tubing.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1766	7.0.c	DC Power to the Top of the Machine			DC current shall be supplied to the top of the machine at the three bus connections noted in Ref. [6].			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1767	7.0.d	DC Power to the Top of the Machine			Inner-to-outer vessel bonding jumpers shall be installed at three locations proximal to the lower polar region in order to electrically bond the lower Center Stack IBDH flange to the outer vessel wall. The bonding jumpers shall link the existing CHI inner and outer flags and be rated for the individual feed point ampacities as described in 7.e & 7.f.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1768	7.0.e	DC Power to the Top of the Machine			Bonding jumpers in the lower polar region shall be designed for permanent installation, and qualified for disruption loads [7].			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1769	7.0.f	DC Power to the Top of the Machine			Bonding jumpers in the lower polar region shall be designed with minimal loop areas.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1770	7.0.g	DC Power to the Top of the Machine			At least one bonding jumper shall have a connection to the motorized ground switch, providing switchable vessel ground.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1771	7.0.h	DC Power to the Top of the Machine			Total current delivered to the CS shall be up to 8 kA.			X				Subsystem is existing and not being modified as part of recovery scope		

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Auxiliary	Bakeout	1772	7.0.i	DC Power to the Top of the Machine			DC current ampacity of individual cable or bus connections to individual feed points at the top of the machine shall be 5.3 kA.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1773	7.0.j	DC Power to the Top of the Machine			For non-permanent portions of the installation, the time to completely ready the system with a two person crew shall be <2 shifts.			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Bakeout	1774	7.0.k	DC Power to the Top of the Machine			At minimum, all interlocks, inputs, outputs, and interfaces from the previous implementation of the DC supply systems shall be maintained. These include the interlocks specified in Ref. [2].			X				Subsystem is existing and not being modified as part of recovery scope		
Auxiliary	Auxiliary	**Backing Pump and Pump Cooling System Requirements**														
Auxiliary	VPS	1775	3.1.a	TVPS Backing Pump			This vacuum pump shall be a dry pump to preclude the possibility of backstreaming of oil vapors into the vacuum vessel and contaminating the PFCs.			X						
Auxiliary	VPS	1776	3.1.b	TVPS Backing Pump			The pump exhaust shall connect to the D-Stie vacuum exhaust stack.			X						
Auxiliary	VPS	1777	3.1.c	TVPS Backing Pump			Location of the new backing pump shall be optimized to minimize the required modification for existing pump foreline and exhaust line.			X						
Auxiliary	VPS	1778	3.1.d	TVPS Backing Pump			Vibration from vacuum pump to foreline and exhaust line shall be isolated via formed bellows.			X						
Auxiliary	VPS	1779	3.1.e	TVPS Backing Pump			Conflat flanges with copper gaskets shall be used for foreline connection.			X						
Auxiliary	VPS	1780	3.1.f	TVPS Backing Pump			Conflat or KF/QF flange sealing shall be used for exhaust line connection.			X						
Auxiliary	VPS	1781	3.1.g	TVPS Backing Pump			A dry roughing line shall be created for NSTX-U vessel pump down, so that the vacuum vessel will only see dry vacuum pumps during normal operation. The dry roughing line shall be electrically isolated from vacuum vessel by a ceramic break.			X						
Auxiliary	VPS	1782	3.1.h	TVPS Backing Pump			The vacuum pump shall have remote status and control capability that shall be interfaced to the TVPS PLC.			X						
Auxiliary	CWS	1783	3.2.a	Standalone cooling water system			The standalone cooling water system shall provide water cooling to TVPS vacuum pumps (TP01, TP02 and MP02), NB vacuum pumps (TP10, TP11, MP01, BL01 and MP06), and the TMB vacuum pump (MP08).			X						
Auxiliary	CWS	1784	3.2.b	Standalone cooling water system			The chiller unit shall have an air cooled refrigeration circuit so that vacuum pump operation will be independent of HVAC chilled water system.			X						
Auxiliary	CWS	1785	3.2.c	Standalone cooling water system			The selected chiller unit shall have 30% extra capacity to supply cooling water for vacuum pumps installed in the future in the NTC.			X						
Auxiliary	CWS	1786	3.2.e	Standalone cooling water system			Either NPT or swagelok compression fittings shall be used for water line connections.			X						
Auxiliary	CWS	1787	3.2.g	Standalone cooling water system			The cooling water system shall be connected to the potable water system for filling of the system.			X						

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Auxiliary	CWS	1788	3.2.h	Standalone cooling water system			The cooling water system shall also be configured to use the potable water for backup cooling of the pumps in the event of a failure of the chiller. This configuration and operation shall be manual.			X						
Auxiliary	CWS	1789	3.2.i	Standalone cooling water system			The water system shall have the capability to remotely monitor the the system temperature and total flow rate. These shall be interface to the TVPS PLC.			X						
Auxiliary	CWS	1790	3.2.j	Standalone cooling water system			Insufficient cooling of any individual pump shall be detected and pump operation interlocked via temperature and/or flow switches installed internal or external to the pump.			X						
Auxiliary	CWS	1791	3.2.k	Standalone cooling water system			Water pressure regulators shall be used to adjust supply water pressure to vacuum pump according to the pump cooling intake pressure requirement.			X						
Auxiliary	VPS	1792	4.1.1	Performance Requirements TVPS Backing Pump			The new backing pump shall have sufficient pumping speed and the dry roughing line shall have large enough conductance, so that the roughing down time for a leaktight NSTX-U vacuum vessel from 1 ATM to 30 millitorr shall be less than 2.5 hours.			X						
Auxiliary	VPS	1793	4.1.2	Performance Requirements TVPS Backing Pump			The backing pump shall be able to maintain the outlet pressure of the TVPS turbo pump under the required 2 torr during GDC.			X						
Auxiliary	CWS	1794	4.2.1	Standalone cooling water system; Closed-loop cooling water system			The cooling water system shall be able to supply sufficient cooling water for each pump according to the operation water flow rate listed in Table 1 (Minimum total flow required is 8 GPM).			X						
Auxiliary	CWS	1795	4.2.2	Standalone cooling water system; Closed-loop cooling water system			Supply water pressure shall be regulated to satisfy the maximum cooling water inlet pressure requirement for each pump listed in Table 1.	Table 1		X						
Auxiliary	CWS	1796	4.2.3	Standalone cooling water system; Closed-loop cooling water system			Supply water temperature and flow shall be monitored by the TVPS PLC and interlocked to pump operation.			X						
OSS	CMS	**Configuration Managed Safeguards**														
OSS	CMS	1797	CMS-2.1.a	CMS	1	1.7.3.9.1	The cages in Table 2.1-1 shall be constructed.	Table 2.1-1			X					
OSS	CMS	1798	CMS-2.2.a	CMS	2	1.7.3.9.2	The electrical bus work in Table 2.2-1 shall be covered by the Configuration Managed Safeguards.	Table 2.2-1			X					
OSS	CMS	1799	CMS-2.3	CMS	3	1.7.3.9.3	The exterior surface of any hot-He piping shall be <= 60 C and non-rigid insulating materials shall beprotected by a rigid touch-safe cover.				X	X				Measure Sample pipes through insulation
OSS	TKS	**Trapped Key System**														
OSS	TKS	1800	TKS-3.1.a	TKS	1	1.7.3.10	The trapped key system shall not allow the neutral beam system to transmit high voltage to thetest cell , unless the conditions in Table 3.1-1 are met:	Table 3.1-1				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP

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OSS	TKS	1801	TKS-3.1.b	TKS	2	1.7.3.10	The trapped key system shall not allow the FCPC high voltage to be placed into an unsafe configuration with regard to test cell hazards, unless the conditions in Table 3.1-2 are met:	Table 3.1-2				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP
OSS	TKS	1802	TKS-3.1.c	TKS	3	1.7.3.10	The trapped key system shall not allow the HHFW system to transmit RF power to the test cellunless the conditions in Table 3.1-3 are met.	Table 3.1-3				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP
OSS	TKS	1803	TKS-3.1.d	TKS	4	1.7.3.10	The trapped key system shall not allow the HTHS to heat He unless the conditions in Table 3.1-4are met.	Table 3.1-4				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP
OSS	TKS	1804	TKS-3.2.b	TKS	5	1.7.3.10	For the control of FCPC hazards, the TKS shall prevent pressurization of the Safety Lockout Device when the conditions of Table 3.1-2 are not met, unless the TKS can positively verify thatthe PCTS bus guard is in place (and therefore, no coils are connected to FCPC).	Table 3.1-2				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP
OSS	TKS	1805	TKS-3.2.c	TKS	6	1.7.3.10	For the control of HHFW hazards, the TKS shall prevent the baseball switches in Table 3.2-1 fromdirecting power towards the NTC when the conditions of Table 3.1-3 are not met.	Table 3.2-1				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP
OSS	TKS	1806	TKS-3.2.d	TKS	7	1.7.3.10	For the control of hot He hazards from the HTHS, the TKS shall prevent prevent the heater from beingenergized if the conditions in Table 3.1-4 are met.	Table 3.1-4				X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP
OSS	TKS	1807	TKS-3.3.a	TKS	8	1.7.3.10	The status of each key block shall be made available to the CCS for display in the NSTX-U controlroom.			X		X		Determine that the HMI is displayed		Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS PTP & ISTP
OSS	TKS	1808	TKS-3.3.b	TKS	9	1.7.3.10	The status of each TKS personnel access door shall be made available to the CCS for display in theNSTX-U control room.			X		X		Determine that the HMI is displayed		
OSS	CCS	**Centralized Control System**														
OSS	CCS	1809	CCS-1.a	CCS	1	1.7.3.8	The logical configuration of the system shall be detailed in a system software specification.			X		X				Per PSS PDR: Prototype testing on component levels using a portable test stand. Followed by initial Verification and Validation via the PSS ISTP
OSS	CCS	1810	3.1.a	CCS	2	1.7.3.8	The CCS shall be capable of receiving inputs from the PSS-SIS for all communicated signals.					X				
OSS	CCS	1811	3.1.b	CCS	3	1.7.3.8	The CCS shall have the ability to receive “safe to enable FCPC” and “safe to enable NB” signalsfrom the PSS-SIS.					X				
OSS	CCS	1812	3.1.c	CCS	4	1.7.3.8	The CCS shall have the ability to receive “FCPC configured for dummy load” and “NB configuredfor dummy load” from the PSS-SIS.					X				
OSS	CCS	1813	3.1.d	CCS	5	1.7.3.8	The CCS shall be capable of receiving NSTX-U Emergency Stop status from the PSS-SIS.					X				
OSS	CCS	1814	3.1.e	CCS	6	1.7.3.8	The CCS shall have the ability to receive the following area status information for the NSTX-UTest Cell and MER Mezzanine areas from the PSS-SIS: i. ACCESS ii. Search & Secure (S&S) in progress iii. NO ACCESS iv. LOCKDOWN					X				

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OSS	CCS	1815	3.1.f	CCS	7	1.7.3.8	The CCS shall have the ability to receive the following area status information for the Test Cell Basement Cage Area and the Cable Spread Room from the PSS-SIS: i. ACCESS ii. NO ACCESS iii. LOCKDOWN					X				
OSS	CCS	1816	3.1.g	CCS	8	1.7.3.8	The CCS interface to the PSS-SIS shall not degrade the safety capability of the PSS-SIS.				X	X				
OSS	CCS	1817	3.1.h	CCS	9	1.7.3.8	Communication between the PSS-SIS and the CCS shall be electrically isolated for control signallevels.				X					
OSS	CCS	1818	3.1.i	CCS	10	1.7.3.8	The CCS shall be capable of receiving SIS-alarm signals from the PSS-SIS.					X				
OSS	CCS	1819	3.2.a	CCS	11	1.7.3.8	The CCS shall receive the status of select trapped key blocks including, but not exclusive to thefollowing: i. NB Ready to Enable Key ii. FCPC SLD Ready to Enable Key iii. HHFW Ready to Enable Key					X				
OSS	CCS	1820	3.2.b	CCS	12	1.7.3.8	The CSS shall allow enable and arm permissives when monitored trapped key blocks areproperly configured.					X				
OSS	CCS	1821	3.2.c	CCS	13	1.7.3.8	The CCS shall utilize one key to control the operationally sequenced subsystems, described insection 3.3.					X				
OSS	CCS	1822	3.3.1.a	CCS	14	1.7.3.8	The arming permissive shall not be asserted when the enabling permissive is not asserted orwhen the PSS-SIS is asserting an NSTX-U Emergency Stop.					X				
OSS	CCS	1823	3.3.1.b	CCS	15	1.7.3.8	Provision shall be made for the addition of new equipment as the system evolves.				X					
OSS	CCS	1824	3.3.1.c	CCS	16	1.7.3.8	Electrical isolation shall be provided between the CCS and the systems to which it provides permissives.					X				
OSS	CCS	1825	3.3.1.d	CCS	17	1.7.3.8	The CCS shall be able to initiate a disable and/or disarm of subsystems from the Chief Operating Engineer (COE) stations, for individual systems or en mass.					X				
OSS	CCS	1826	3.3.1.e	CCS	18	1.7.3.8	All signals originating from the CCS shall be latched outputs unless otherwise specified as momentary.			X						
OSS	CCS	1827	3.3.2.a	CCS	19	1.7.3.8	The CCS shall provide enable/arm permissive capability for the equipment as identified in Table3.3.2-1.	Table 3.3.2-1				X				
OSS	CCS	1828	3.3.2.b	CCS	20	1.7.3.8	The CCS enable and arm permissives shall permit the subsystems to operate.					X				
OSS	CCS	1829	3.3.2.c	CCS	21	1.7.3.8	The CCS shall provide a hardwired master disable button that will immediately disable anddisarm all subsystems.			X						
OSS	CCS	1830	3.3.2.d	CCS	22	1.7.3.8	The CCS shall provide a hardwired master disarm button that will immediately disarm all subsystems.			X		X				
OSS	CCS	1831	3.3.2.e	CCS	23	1.7.3.8	The CCS enable and arm permissives shall not directly operate subsystems under independentBCS control.					X				

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OSS	CCS	1832	3.3.3.a	CCS	24	1.7.3.8	The neutral beam system shall be divided into two subsystems (NB #1 and #2, powered by TFTRera NB lineup #5 and #4). From the CCS perspective each beamline will be treated independently.					X				
OSS	CCS	1833	3.3.3.b	CCS	25	1.7.3.8	The CCS shall send the following signals to the Neutral Beams BCS i. Enable permissive ii. Arm permissive					X				
OSS	CCS	1834	3.3.3.c	CCS	26	1.7.3.8	The CCS shall only issue enable/arm permissives to the Neutral Beams when the followingconditions exist: i. The “safe to enable NB” input signal from PSS-SIS is high ii. The “No NSTX-U E-Stop” input signal from PSS-SIS is high					X				
OSS	CCS	1835	3.3.3.d	CCS	27	1.7.3.8	The CCS shall support HV Conditioning, HV Operations, and Dummy Load Testing modes.					X				
OSS	CCS	1836	3.3.3.e	CCS	28	1.7.3.8	The CCS shall receive the following control status signals from the Neutral Beams BCS: i. Enabled ii. Disabled iii. Disarmed iv. Armed					X				
OSS	CCS	1837	3.3.3.f	CCS	29	1.7.3.8	Both enable and arm permissives shall be able to be revoked by the COE.			X		X				
OSS	CCS	1838	3.3.3.g	CCS	30	1.7.3.8	The CCS Neutral Beamlines 1 & 2 interface shall provide a unique key switch to permit enabling.					X				
OSS	CCS	1839	3.3.3.h	CCS	31	1.7.3.8	The CCS Neutral Beamlines 1 & 2 interface shall provide a unique key switch to permit arming.					X				
OSS	CCS	1840	3.3.3.i	CCS	32	1.7.3.8	The CCS Neutral Beamlines 1 & 2 interface shall provide a unique hardwired pushbutton todisable each subsystem.					X				
OSS	CCS	1841	3.3.3.j	CCS	33	1.7.3.8	The CCS Neutral Beamlines 1 & 2 interface shall provide a unique hardwired pushbutton todisarm each subsystem.			X		X				
OSS	CCS	1842	3.3.4.a	CCS	34	1.7.3.8	The CCS shall send the following signals to the FCPC BCS: i. Enable permissive ii. Arm permissive iii. Configure (labeled “switch permit” on legacy HIS documents) iv. Fault reset (shall be a momentary signal)					X				
OSS	CCS	1843	3.3.4.b	CCS	35	1.7.3.8	The CCS shall only issue enable/arm permissives to the FCPC subsystem when the following conditions exist: i. The “safe to enable FCPC” input from PSS-SIS is high ii. The “No NSTX-U E-Stop” input signal from PSS-SIS is high					X				
OSS	CCS	1844	3.3.4.c	CCS	36	1.7.3.8	The CCS shall support FCPC Dummy Load and Open Circuit Testing Mode.					X				

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS	1845	3.3.4.d	CCS	37	1.7.3.8	The CCS shall receive the following control status signals from the FCPC BCS: i. Disable Complete ii. Disarm Complete iii. Level 1 Fault iv. Level 3 Fault v. Level 4 Fault vi. Coils in Configure					X				
OSS	CCS	1846	3.3.4.e	CCS	38	1.7.3.8	Both enable and arm permissives shall be able to be revoked by the COE.			X		X				
OSS	CCS	1847	3.3.4.f	CCS	39	1.7.3.8	The CCS shall only permit switching to the configure mode when the FCPC rectifiers are enabled.					X				
OSS	CCS	1848	3.3.4.g	CCS	40	1.7.3.8	The CCS FCPC interface shall provide a unique key switch to permit enabling of the rectifiers.					X				
OSS	CCS	1849	3.3.4.h	CCS	41	1.7.3.8	The CCS FCPC interface shall provide a hardwired three-way switch with the positions arm,disarm, and configure. The switch shall be configured with disarm in the middle position.					X				
OSS	CCS	1850	3.3.4.i	CCS	42	1.7.3.8	The CCS FCPC interface shall provide a unique hardwired pushbutton to disable the subsystem.					X				
OSS	CCS	1851	3.3.4.j	CCS	43	1.7.3.8	The CCS FCPC interface shall provide a unique hardwired pushbutton to disarm the subsystem.					X				
OSS	CCS	1852	3.3.4.k	CCS	44	1.7.3.8	The Level 1, 3, and 4 rectifier fault reset signal shall be able to be sent by the CCS to the FCPC BCS through the CCS CHMI.					X				
OSS	CCS	1853	3.3.5.a	CCS	45	1.7.3.8	The CCS shall provide two permissives to the Safety Lockout Device that will allow a change of mode. Both signals shall be hardwired momentary signals. i. Permit Restoration of Air ii. Permit Removal of Air					X				
OSS	CCS	1854	3.3.5.b	CCS	46	1.7.3.8	The CCS shall only issue the permit removal of air signal when the: i. FCPC is safe as indicated by its shutdown or disabled signals					X				
OSS	CCS	1855	3.3.5.c	CCS	47	1.7.3.8	The CCS shall only issue a permit restoration of air signal when: i. “Safe to enable FCPC” signal is high ii. “No NSTX-U Estop” signal is high					X				
OSS	CCS	1856	3.3.5.d	CCS	48	1.7.3.8	The CCS shall receive the following status signals from the SLD: i. Air Restored to Control Room ii. Lockout Complete (Safe) to Control Room					X				
OSS	CCS	1857	3.3.5.e	CCS	49	1.7.3.8	The FCPC shall provide a unique hardwired three-way switch with the positions permit to restore air, neutral, and permit to remove air.			X						
OSS	CCS	1858	3.3.5.e'	CCS	50	1.7.3.8	The switch shall be configured with the neutralposition in the middle.			X						
OSS	CCS	1859	3.3.6.a	CCS	51	1.7.3.8	The CCS shall provide one permit to enable signal to both RF systems, HHFW and ECH-PI.			X						
OSS	CCS	1860	3.3.6.b	CCS	52	1.7.3.8	The CCS shall only issue the enable permissive to the RF subsystems when the following conditions exist i. The “No NSTX-U E-Stop” input signal from PSS-SIS is high ii. The “NO ACCESS” input signal from PSS-SIS is high for the NTC area					X				

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS	1861	3.3.6.c	CCS	53	1.7.3.8	The permit to enable signal shall be able to be revoked by the COE.			X		X				
OSS	CCS	1862	3.3.6.d	CCS	54	1.7.3.8	The RF interface shall provide a unique key switch to permit enabling.					X				
OSS	CCS	1863	3.3.6.e	CCS	55	1.7.3.8	The RF interface shall provide a unique hardwired pushbutton to disable the subsystems.			X		X				
OSS	CCS	1864	3.3.6.1.a	CCS	56	1.7.3.8	From the CCS perspective, all six HHFW transmitters shall be treated as one system.			X						
OSS	CCS	1865	3.3.6.1.b	CCS	57	1.7.3.8	The CCS shall send the following commands to the HHFW BCS: i. Enable permissive (RF permit to enable) ii. Arm permissive					X				
OSS	CCS	1866	3.3.6.1.c	CCS	58	1.7.3.8	The CCS shall only issue the arm permissive to the HHFW subsystem when the following conditions exist i. The “No NSTX-U E-Stop” input signal from PSS-SIS is high ii. The “NO ACCESS” input signal from PSS-SIS is high for the NTC area					X				
OSS	CCS	1867	3.3.6.1.d	CCS	59	1.7.3.8	The CCS shall receive the following control status signals from the HHFW BCS: i. Enabled ii. Disabled iii. Disarmed iv. Shutdown					X				
OSS	CCS	1868	3.3.6.1.e	CCS	60	1.7.3.8	The permit to arm signal shall be able to be revoked by the COE.					X				
OSS	CCS	1869	3.3.6.1.f	CCS	61	1.7.3.8	The HHFW shall provide a unique key switch to permit arming.			X		X				
OSS	CCS	1870	3.3.6.1.g	CCS	62	1.7.3.8	The HHFW shall provide a unique hardwired pushbutton to disarm the subsystem.			X						
OSS	CCS	1871	3.3.6.2.a	CCS	63	1.7.3.8	The CCS shall send the following commands to the ECH-PI BCS: i. Enable permissive (RF permit to enable) ii. Arm permissive					X				
OSS	CCS	1872	3.3.6.2.b	CCS	64	1.7.3.8	The CCS shall only issue the arm permissive to the ECH-PI subsystem when the following conditions exist i. The “No NSTX-U E-Stop” input signal from PSS-SIS is high ii. The “NO ACCESS” input signal from PSS-SIS is high for the NTC area					X				
OSS	CCS	1873	3.3.6.2.c	CCS	65	1.7.3.8	The CCS shall receive the following control status signals from the ECH-PI BCS: i. Enabled ii. Disabled iii. Disarmed iv. Shutdown					X				
OSS	CCS	1874	3.3.6.2.d	CCS	66	1.7.3.8	The permit to arm signal shall be able to be revoked by the COE.			X		X				
OSS	CCS	1875	3.3.6.2.e	CCS	67	1.7.3.8	The ECH-PI shall provide a unique key switch to permit arming.			X		X				
OSS	CCS	1876	3.3.6.2.f	CCS	68	1.7.3.8	The ECH-PI shall provide a unique hardwired pushbutton to disarm the subsystem.			X		X				
OSS	CCS	1877	3.4.a	CCS	69	1.7.3.8	The CCS shall provide a fail-safe “No NSTX-U E-Stop” signal for the equipment as identified in Table 3.3.2-1 and Table 3.4-1	Table 3.3.2-1 Table 3.4-1				X				
OSS	CCS	1878	3.4.b	CCS	70	1.7.3.8	“No NSTX-U E-Stop” signal shall go low upon an NSTX-U Emergency Stop being declared.					X				

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS	1879	3.4.c	CCS	71	1.7.3.8	The CSS shall allow the “No NSTX-U E-Stop” signal to be energized when the PSS-SIS is in anACCESS state, under administrative control.					X				
OSS	CCS	1880	3.4.d	CCS	72	1.7.3.8	The CCS shall provide a fail-safe “Loop Set” signal for the equipment identified in Table 3.4-2.	Table 3.4-2				X				
OSS	CCS	1881	3.4.e	CCS	73	1.7.3.8	The “Loop Set” signal shall go low upon the NSTX-U test cell entering the ACCESS or LOCKDOWNstates.					X				
OSS	CCS	1882	3.4.f	CCS	74	1.7.3.8	The “Loop Set” signal shall only be high when the NSTX-U test cell is in the NO ACCESS state.					X				
OSS	CCS	1883	3.4.4.a	CCS	75	1.7.3.8	The CCS shall provide signals to the MPTS Laser Interlock Box that provide functional equivalentsto the legacy “No ESTOP” and “Loop Set” signals.					X				
OSS	CCS	1884	3.4.7.a	CCS	76	1.7.3.8	The CCS shall provide signals to the MGI system that provide functional equivalents to thelegacy “No ESTOP” and “Loop Set” signals.					X				
OSS	CCS	1885	3.4.7.b	CCS	77	1.7.3.8	The CCS shall provide signals to the OH Water Heater system that provide functional equivalents to the legacy “No ESTOP” and “Loop Set” signals.					X				
OSS	CCS	1886	3.5.a	CCS	78	1.7.3.8	The CCS shall provide signals to revoke the ACAMS access to the following man doors: a. NTC North door b. NTC South door			X						
OSS	CCS	1887	3.6.a	CCS	79	1.7.3.8	The CCS HMI (CHMI) shall have a master overview display page indicating a summation of thecondition of the facility.			X						
OSS	CCS	1888	3.6.b	CCS	80	1.7.3.8	The CHMI may have menu-driven sub pages that displays detailed information.			X						
OSS	CCS	1889	3.6.c	CCS	81	1.7.3.8	The CHMI shall have the means for displaying status and providing control capability for the COEfrom the NSTX-U control room.			X						
OSS	CCS	1890	3.6.d	CCS	82	1.7.3.8	The CHMI shall provide means for the operator to authenticate using a password.			X						
OSS	CCS	1891	3.6.e	CCS	83	1.7.3.8	The CHMI shall appear different from the PSS-HMI so that operators and users do not confusethe two systems.			X						
OSS	CCS	1892	3.6.f	CCS	84	1.7.3.8	The CHMI shall have the ability to display any or all status and control information it receivesfrom the PSS-SIS.			X						
OSS	CCS	1893	3.6.g	CCS	85	1.7.3.8	The CHMI shall provide only one operations-relevant operator role; for the NSTX-U Chief Operating Engineer (COE).				X					
OSS	CCS	1894	3.6.h	CCS	86	1.7.3.8	The layout of indications and inputs (buttons, switches) on the CHMI shall be determined in consultation with the NSTX-U COE(s).				X					
OSS	CCS	1895	3.6.i	CCS	87	1.7.3.8	The CHMI will provide the following indications for each sub-system within the capabilities of the interface to include but not limited to: i. subsystem disabled ii. subsystem enabled iii. subsystem disarmed iv. subsystem armed v. subsystem permissive(s) granted			X						

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS	1896	3.6.j	CCS	88	1.7.3.8	The CHMI shall have a push button (or equivalent) to return an individual operationallysequenced subsystem to the disabled condition.			X						
OSS	CCS	1897	3.6.k	CCS	89	1.7.3.8	The CHMI shall allow the operator to individually disarm operationally sequenced subsystem			X						
OSS	CCS	1898	3.6.l	CCS	90	1.7.3.8	The CHMI shall indicate the status of the Safety Lockout Device.			X						
OSS	CCS	1899	3.6.m	CCS	91	1.7.3.8	The CHMI shall have indication that the SLD may be operated to its unsafe position to restorethe air to the Safety Disconnect and Grounding Switches.			X						
OSS	CCS	1900	3.6.n	CCS	92	1.7.3.8	The CHMI shall indicate the summation of the FCPC Safety Disconnect and Ground Switch Positions Loop " Lockout Complete (Safe) to Control Room ".			X						
OSS	CCS	1901	3.6.o	CCS	93	1.7.3.8	The CHMI shall indicate when the FCPC subsystem is in configure mode.			X						
OSS	CCS	1902	3.6.p	CCS	94	1.7.3.8	The CHMI shall provide an indication of when each sub-system may be advanced from the disabled mode to the enabled mode.			X						
OSS	CCS	1903	3.6.q	CCS	95	1.7.3.8	The CHMI shall provide an indication when all operationally sequenced subsystems are enabled.			X						
OSS	CCS	1904	3.6.r	CCS	96	1.7.3.8	The CHMI shall be expandable to include additional equipment.				X					
OSS	CCS	1905	3.6.s	CCS	97	1.7.3.8	The CHMI shall provide a PSS-SIS state indicator status (ACCESS, NO ACCESS, LOCKDOWN).			X						
OSS	CCS	1906	3.6.t	CCS	98	1.7.3.8	The CHMI shall provide alarms to alert the COE, at a minimum, of the following abnormal situations: i. CCS PLC Errors & Failures ii. PSS-SIS input signal mis-match iii. PSS-SIS NSTX-U E-Stop			X						
OSS	CCS	1907	3.6.u	CCS	99	1.7.3.8	The CHMI shall allow the COE to acknowledge or clear an alarm.			X						
OSS	CCS	1908	3.7.a	CCS	100	1.7.3.8	The CCS shall be capable of communicating status signals to the EPICS network for archiving, including but not limited to the following: i. PSS-SIS status (e.g. NSTX-U E-Stop and access modes) ii. Trapped key block status iii. Operationally sequenced subsystem status iv. Local PLC errors & alarms			X						
OSS	CCS	1909	3.7.b	CCS	101	1.7.3.8	The CCS shall be capable of sending signals to the EPICS network at a rate of up to 1 Hz.					X				
OSS	CCS	1910	3.7.c	CCS	102	1.7.3.8	The CCS shall provide a local backup archive for status signals including but not limited to the following: i. PSS-SIS status (e.g. NSTX-U E-Stop and access modes) ii. Trapped key block status			X						
OSS	CCS	1911	3.7.d	CCS	103	1.7.3.8	The CCS shall provide a means for engineering staff to retrieve local archive data without interruption of normal operations.			X						

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS	1912	3.8.a	CCS	104	1.7.3.8	The CCS shall not be required to meet the requirements of an IEC 61508/61511 compliant SafetyInstrumented System.				X					
OSS	CCS	1913	3.8.b	CCS	105	1.7.3.8	The CCS shall use typical process control signal voltages (e.g. 120 Vac, 24 Vac/dc, 5 Vdc)			X						
OSS	CCS SW	1914	CCSSW-2.2	CCS SW	1	1.7.3.8	The CCS shall receivesignals from the PSS-SIS that will be used to determine when subsystems are permitted to operate.					X				
OSS	CCS SW	1915	CCSSW-2.2'	CCS SW	2	1.7.3.8	The CCS shall also receive and display signals from the Trapped Key System (TKS) to allow the COE tomonitor the operating state of NSTX-U.					X				
OSS	CCS SW	1916	CCSSW-2.4	CCS SW	3	1.7.3.8	The CCS shall be programmed using a COTS product portfolio, so no unique engineering solutions are foreseen.				X					
OSS	CCS SW	1917	CCSSW-2.6	CCS SW	4	1.7.3.8	A user manual shall be developed to describe how to operate the system.				X					
OSS	CCS SW	1918	CCSSW-2.6'	CCS SW	5	1.7.3.8	This shall be deliveredwhen the system has been fully installed and commissioned.					X				
OSS	CCS SW	1919	CCSSW-2.7.3	CCS SW	6	1.7.3.8	The external ethernet connections from the CCS to the PPPL network shall be protected by anIT-managed enterprise firewall as appropriate for a controls network VLAN.				X					
OSS	CCS SW	1920	CCSSW-3.1	CCS SW	7	1.7.3.8	The CCS shall utilize two primary user interfaces: a physical front panel display as well as acomputer-based human machine interface (HMI).				X					
OSS	CCS SW	1921	CCSSW-3.1.1	CCS SW	8	1.7.3.8	The CCS shall provide a physical interface located on the front of the CCS control panel that willprovide the means to control the operationally sequenced subsystems.			X						
OSS	CCS SW	1922	CCSSW-3.1.1'	CCS SW	9	1.7.3.8	The front panel shall displaythe status of all the operationally sequenced subsystems in a clear and consistent fashion.			X						
OSS	CCS SW	1923	CCSSW-3.1.1''	CCS SW	10	1.7.3.8	The CCSfront panel shall be distinct from the PSS front panel since these will share space in the same controlrack				X					
OSS	CCS SW	1924	CCSSW-3.1.1'''	CCS SW	11	1.7.3.8	The CCS front panel shall be capable of expansion to incorporate future systems.				X					
OSS	CCS SW	1925	CCSSW-3.1.1''''	CCS SW	12	1.7.3.8	All control elements (e.g. pushbuttons, lights, key switches) shall be 24V DC powered to provide afinger-safe interface.			X	X					
OSS	CCS SW	1926	CCSSW-3.1.1'''''	CCS SW	13	1.7.3.8	All control elements shall be configured to fail safe.					X				
OSS	CCS SW	1927	CCSSW-3.1.2	CCS SW	14	1.7.3.8	The CCS shall provide an HMI for the user to view status and control the system.			X						
OSS	CCS SW	1928	CCSSW-3.1.2.1	CCS SW	15	1.7.3.8	HMI operation screens shall be developed following the principals of high-performance HMI.			X						
OSS	CCS SW	1929	CCSSW-3.1.2.1'	CCS SW	16	1.7.3.8	The CCSshall follow a nominal color convention that may be altered if agreed upon by PPPL subject matterexperts.			X						
OSS	CCS SW	1930	CCSSW-3.1.2.2	CCS SW	17	1.7.3.8	The HMI shall not allow the OVERRIDE mode to be activated, or the OVERRIDESTATUS to be changed, if the user does not have the appropriate authorization.			X						
OSS	CCS SW	1931	CCSSW-3.1.2.2'	CCS SW	18	1.7.3.8	All override events shall be logged by the CCS. (Digital Input)			X						

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS SW	1932	CCSSW-3.1.2.3	CCS SW	19	1.7.3.8	The HMI shall not allow the OVERRIDE mode to be activated, or the OVERRIDE STATUS to be changed, if the user does not have the appropriate authorization.			X						
OSS	CCS SW	1933	CCSSW-3.1.2.3'	CCS SW	20	1.7.3.8	All override events shall be logged by the CCS. (Digital output)			X						
OSS	CCS SW	1934	CCSSW-3.2	CCS SW	21	1.7.3.8	The CCS Hardware Interface shall consist of a Logic Solver, IO modules and Operator Interfaceterminal.				X					
OSS	CCS SW	1935	CCSSW-3.2'	CCS SW	22	1.7.3.8	All components of the CCS shall be commercial off the shelf (COTS) items.				X					
OSS	CCS SW	1936	CCSSW-3.2''	CCS SW	23	1.7.3.8	Cut sheets for allhardware interface components shall be delivered as part of the system installation.				X					
OSS	CCS SW	1937	CCSSW-3.2.3	CCS SW	24	1.7.3.8	The CCS shall utilize 1756 series in-chassis network cards to expand the network communicationcapability of the PLC controller.				X					
OSS	CCS SW	1938	CCSSW-3.2.3'	CCS SW	25	1.7.3.8	Any component of the CCS that is capable of wireless communicationshall have its wireless connection(s) disabled.				X					
OSS	CCS SW	1939	CCSSW-3.4	CCS SW	26	1.7.3.8	The CCS shall be capable of transmitting signals via ethernet to an external OPC DA server.			X						
OSS	CCS SW	1940	CCSSW-3.4'	CCS SW	27	1.7.3.8	The localnetwork infrastructure shall be capable of transmitting signals at a rate of at least 1 Hz.					X				
OSS	CCS SW	1941	CCSSW-3.4''	CCS SW	28	1.7.3.8	This connection shall be protected with an enterprise firewall rule.			X						
OSS	CCS SW	1942	CCSSW-3.4'''	CCS SW	29	1.7.3.8	All local network connections shall be via ethernet using Rockwell Automation COTS software,therefore no unique engineering solutions are envisioned.			X						
OSS	CCS SW	1943	CCSSW-4	CCS SW	30	1.7.3.8	The CCS shall be developed using common software modules for all functions where this is possible.				X					
OSS	CCS SW	1944	CCSSW-4'	CCS SW	31	1.7.3.8	These common software modules shall be tested during development, which will help reduce timeduring commissioning.					X				
OSS	CCS SW	1945	CCSSW-4.1	CCS SW	32	1.7.3.8	Each I/O type (digital input, digital output) shall be be programmed in the CCS as a standardUser-Defined Type (UDT).			X	X					
OSS	CCS SW	1946	CCSSW-4.1.1	CCS SW	33	1.7.3.8	All digital inputs monitored by the CCS shall have a physical address, associating it's rack location, slotlocation, and point number.				X					
OSS	CCS SW	1947	CCSSW-4.1.1'	CCS SW	34	1.7.3.8	These input points shall be mapped to logical tags in the CCS				X					
OSS	CCS SW	1948	CCSSW-4.1.2	CCS SW	35	1.7.3.8	All digital outputs controlled by the CCS shall have a physical address, associating it's rack location, slot location, and point number.				X					
OSS	CCS SW	1949	CCSSW-4.1.2'	CCS SW	36	1.7.3.8	These output points shall be mapped to logical tags in the CCS, which is what will ultimately be used in the programming.				X					

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS SW	1950	CCSSW-4.2.1	CCS SW	37	1.7.3.8	The signal shall transition to the high state when the COE actuates the unique keyswitch on the COE interface panel to the correct position and remain latched in the high state untilthe permissive is revoked.					X				
OSS	CCS SW	1951	CCSSW-4.2.1'	CCS SW	38	1.7.3.8	In the event the signal transitions from the high state to the low state, it shall not return to the high state until the COE again actuates the unique key switch on the COEinterface panel.					X				
OSS	CCS SW	1952	CCSSW-4.2.1''	CCS SW	39	1.7.3.8	All signals that are used as conditions to deactivate the permit toenable signals shall be implemented to be fail-safe (i.e. power off shall revoke the permissive).					X				
OSS	CCS SW	1953	CCSSW-4.2.2	CCS SW	40	1.7.3.8	The (permit to arm) signal shall transition to the high state when the COE actuates the unique key switch on the COE interface panel to the correct position and remain latched in the high state until the permissive is revoked.permit to arm					X				
OSS	CCS SW	1954	CCSSW-4.2.2'	CCS SW	41	1.7.3.8	In the event the signal transitions from the high state to the low state, itshall not return to the high state until the COE again actuates the unique key switch on the COEinterface panel.					X				
OSS	CCS SW	1955	CCSSW-4.2.2'	CCS SW	42	1.7.3.8	All signals that are used to deactivate the permit to arm signals shall beimplemented to be fail-safe (i.e. power off would revoke the permissive).					X				
OSS	CCS SW	1956	CCSSW-4.2.3	CCS SW	43	1.7.3.8	The master disable signal located on theCOE interface panel shall send disable commands to all operationally sequenced subsystems.					X				
OSS	CCS SW	1957	CCSSW-4.2.4	CCS SW	44	1.7.3.8	The master disarm signal located on the COE interface panelshall send disarm commands to all operationally sequenced subsystems.					X				
OSS	CCS SW	1958	CCSSW-4.2.5	CCS SW	45	1.7.3.8	The (permit to remove air)signal shall transition to the high state when the COE actuates the three way switch that controls the SLD to the "vent" position and all FCPC rectifiers report that they are disabled.					X				
OSS	CCS SW	1959	CCSSW-4.2.5'	CCS SW	46	1.7.3.8	The permit to remove airsignal shall be momentary.									
OSS	CCS SW	1960	CCSSW-4.2.6	CCS SW	47	1.7.3.8	The SLD receives a permit to restore air signal (pressurize) from the CCS. The signal shall transition tothe high state when the COE actuates the three way switch that controls the SLD to the "pressurize"position.					X				
OSS	CCS SW	1961	CCSSW-4.2.6'	CCS SW	48	1.7.3.8	The signal shall only transition to the high state when the PSS-SIS Emergency Stop and Safeto Enable FCPC from PSS-SIS signals are configured properly.					X				
OSS	CCS SW	1962	CCSSW-4.2.6''	CCS SW	49	1.7.3.8	The permit to restore air signal shall be momentary.			X						
OSS	CCS SW	1963	CCSSW-4.2.7	CCS SW	50	1.7.3.8	The CCS shall receive feedback signals from the operationally sequenced systems that, at a minimum,defines their current operating status.	Table 4.2.7-1				X				

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS SW	1964	CCSSW-4.2.7'	CCS SW	51	1.7.3.8	These signals shall be used by the COE interface panel and theCCS HMI to indicate the status of the plant to the COE.	Table 4.2.7-1				X				
OSS	CCS SW	1965	CCSSW-4.3.1	CCS SW	52	1.7.3.8	The CCS shall provide the No NSTX-U E-Stop signal as an equivalent to the legacy No E-Stop signal.			X						
OSS	CCS SW	1966	CCSSW-4.3.1'	CCS SW	53	1.7.3.8	The No NSTX-U E-Stop signal shall be high when the PSS-SISEmergency Stop is high, and low otherwise.					X				
OSS	CCS SW	1967	CCSSW-4.3.2	CCS SW	54	1.7.3.8	The CCS shall provide the Loop Set signal as an equivalent to the legacy Loop Set signal.			X						
OSS	CCS SW	1968	CCSSW-4.3.2'	CCS SW	55	1.7.3.8	The Loop Set signal shall be high when the PSS-SIS NTC Area NO ACCESSsignal is high, and low otherwise.			X		X				
OSS	CCS SW	1969	CCSSW-4.5	CCS SW	56	1.7.3.8	The CCS PCshall be capable of audibly annunciating alarms.			X						
OSS	CCS SW	1970	CCSSW-4.5'	CCS SW	57	1.7.3.8	Definitions of PLC alarms and their configuration shall be detailed in an alarm list to be developedduring the implementation phase of the project.				X					
OSS	CCS SW	1971	CCSSW-4.5.3.1	CCS SW	58	1.7.3.8	The CCS PLC shall react to an active alarm according to the program logic. (Activation Response)					X				
OSS	CCS SW	1972	CCSSW-4.5.3.2	CCS SW	59	1.7.3.8	The CCS PLC shall react to an active alarm according to the program logic. (Inactivition Response)					X				
OSS	CCS SW	1973	CCSSW-4.5.3.2'	CCS SW	60	1.7.3.8	Some alarms may becontain logic requiring an operator reset the affected system(s) once the alarm condition hasresolved; requirement of operator initiated reset shall be detailed in the alarm list.			X						
OSS	CCS SW	1974	CCSSW-4.5.3.2''	CCS SW	61	1.7.3.8	The interface program shall log, date and timestamp when the alarm became inactive.			X						
OSS	CCS SW	1975	CCSSW-4.5.3.3	CCS SW	62	1.7.3.8	The interface program shalllog, date and timestamp when the alarm was acknowledged.			X						
OSS	CCS SW	1976	CCSSW-4.6.1	CCS SW	63	1.7.3.8	The CCS shall provide an ethernet connection to the existing plant OPC network to allow EPICS toreach and archive data.				X					
OSS	CCS SW	1977	CCSSW-4.6.1'	CCS SW	64	1.7.3.8	This connection shall be on a separate VLAN from the other CCS networkeddevices.				X					
OSS	CCS SW	1978	CCSSW-4.6.1''	CCS SW	65	1.7.3.8	The switch port that this communication utilizes shall be appropriately protected in a manner decided upon by the PPPL cyber security team.				X					
OSS	CCS SW	1979	CCSSW-4.6.1'''	CCS SW	66	1.7.3.8	The log shall include a timestamp with at least 1 second resolution.			X						
OSS	CCS SW	1980	CCSSW-5.1	CCS SW	67	1.7.3.8	The system shall be capable of simulation using the Rockwell Automation RSLogix Emulate 5000software program.					X				
OSS	CCS SW	1981	CCSSW-5.4.1.1	CCS SW	68	1.7.3.8	The COE front panel interface shall be controlled by one unique key that will be locked and retained until the COE logs in with their password to the HMI and releases the key.			X						

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	CCS SW	1982	CCSSW-5.4.1.1'	CCS SW	69	1.7.3.8	Releasing the key shallactivate a timer in the PLC, and if the key is not utilized on the front panel before the duration of thetimer ends the HMI shall annunciate an alarm.					X				
OSS	CCS SW	1983	CCSSW-5.4.1.1''	CCS SW	70	1.7.3.8	If the COE logs out of the HMI before returning thekey to the appropriate locked position the HMI shall annunciate an alarm.			X						
OSS	CCS SW	1984	CCSSW-5.4.1.2	CCS SW	71	1.7.3.8	The cabinet that houses the CCS equipment shall utilize door switches to monitor any access eventsinto the cabinet.					X				
OSS	CCS SW	1985	CCSSW-5.4.1.2'	CCS SW	72	1.7.3.8	When a door switch detects an entry the HMI shall annunciate an alarm and log thedate and time of the event. The			X						
OSS	CCS SW	1986	CCSSW-5.4.1.2''	CCS SW	73	1.7.3.8	The cabinet shall be locked with uniquely keyed fasteners that cannot beremoved without the use of a specially designed tool.		X				Commercial Spec.			
OSS	CCS SW	1987	CCSSW-5.4.1.2''	CCS SW	74	1.7.3.8	Anyaccessible ports to CCS control equipment (PLC, PC, etc.) shall be covered to prevent access.				X					
OSS	CCS SW	1988	CCSSW-5.4.2	CCS SW	75	1.7.3.8	The CCS shall be assessed by the development team and the PPPL Cyber Security Department				X					
OSS	CCS SW	1989	CCSSW-5.4.2'	CCS SW	76	1.7.3.8	This assessment shall categorize any potential breach of security as either low, medium, or high impact.			X						
OSS	CCS SW	1990	CCSSW-5.4.2''	CCS SW	77	1.7.3.8	The CCS shall be designed and implemented to meet the necessary security mitigation based on this categorization.				X					
OSS	CCS SW	1991	CCSSW-5.4.2'''	CCS SW	78	1.7.3.8	A comprehensive test plan shall be developed and executed afterinstallation of the system to ensure all controls have been implemented and are functioning asexpected.				X	X				
OSS	CCS SW	1992	CCSSW-5.4.2.1	CCS SW	79	1.7.3.8	The CCS local network shall be maintained on a separate VLAN than existing PPPL networks.				X					
OSS	CCS SW	1993	CCSSW-5.4.2.1'	CCS SW	80	1.7.3.8	Theethernet connection to the PPPL network shall be protected using an enterprise firewall maintainedby the PPPL IT department.			X						
OSS	CCS SW	1994	CCSSW-5.4.2.1''	CCS SW	81	1.7.3.8	The interface between the CCS and the PSS-SIS shall be hardwiredelectrical signals that only transmit data from the PSS-SIS to the CCS, creating an air-gapped interfacebetween the PPPL network and the PSS-SIS.					X				
OSS	ODH	**ODH Monitor**														
OSS	ODH	1995	ODH-1	ODH Monitor	1	1.8.1.1.3	This system shall also have remote status indication mountedoutside the test cell at the two personnel access doors to alert personnel not to enter the test cell.			X		X				PTP
OSS	ODH	1996	ODH-2.a	ODH Monitor	2	1.8.1.1.3	Oxygen monitor sensors shall be located at three locations: ● Between beamline #1 and #21 ● Underneath the machine at Bay F2 ● In the south High bay				X	X				PTP
OSS	ODH	1997	ODH-2.b	ODH Monitor	3	1.8.1.1.3	The sensors shall be installed under the machine at or near Bay F, between the two neutral beamboxes, and near the labyrinth in the South High Bay .				X	X				PTP
OSS	ODH	1998	ODH-2.c	ODH Monitor	4	1.8.1.1.3	Sensors shall be located at or below five feet from the floor to approximate average human breathingzones.				X	X				PTP

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
OSS	ODH	1999	ODH-2.d	ODH Monitor	5	1.8.1.1.3	The OD sensors shall have battery backup capability of at least 1 hour.			X		X				PTP
OSS	ODH	2000	ODH-2.e	ODH Monitor	6	1.8.1.1.3	The sensors shall be capable of detecting a low oxygen level regardless of the gas mixture.			X		X				PTP
OSS	ODH	2001	ODH-2.f	ODH Monitor	7	1.8.1.1.3	The sensors shall not be affected by magnetic or radiation fields or shall be capable of being mountedoutside the test cell.			X		X				PTP
OSS	ODH	2002	ODH-2.g	ODH Monitor	8	1.8.1.1.3	Any visual or audible alarms outside the NTC shall be electrically isolated from the test cell withisolation as per the GRD [1].				X					
OSS	ODH	2003	ODH-3.a	ODH Monitor	9	1.8.1.1.3	Audible alarms in the test cell and visual status indicators outside the test cell doors shall annunciatewhen the oxygen level is at or below 19.5% oxygen.			X		X				PTP
OSS	ODH	2004	ODH-3.b	ODH Monitor	10	1.8.1.1.3	Audible alarms shall be loud enough that personnel at any location within the NTC, including atentrances, will be able to clearly resolve the alarm above the background noise level.			X						
OSS	ODH	2005	ODH-3.c	ODH Monitor	11	1.8.1.1.3	Remote status of the system shall be displayed outside the test cell at the North and South personnelaccess doors in easily observed locations.				X					
Test Cell	Fall Prote	**Fall Protection**														
Test Cell	Fall Prote	2006	FP-2.a	Fall Protection	1	1.8.1.1.11	The fall protection system shall be able to support four people to work on top of the machine atthe same time, with at least two individuals at any single location.		X	X			NSTXU_1-8-1-1-11_CALC_100			
Test Cell	Fall Prote	2007	FP-2.a'	Fall Protection	2	1.8.1.1.11	Where necessary for designor analysis, the weight of a person shall be 310 lbs.		X				NSTXU_1-8-1-1-11_CALC_100			
Test Cell	Fall Prote	2008	FP-2.c	Fall Protection	3	1.8.1.1.11	The height and spacing of the fall protection system shall not obstruct safe access to the workarea.			X	X					
Test Cell	Fall Prote	2009	FP-2.g	Fall Protection	4	1.8.1.1.11	The fall protection system shall provide at least 7 feet overhead room for personnel standing onthe cable tray surrounding the top of the vacuum vessel, if a cable based system isimplemented.				X				Cable System Not Implemented	
Test Cell	Fall Prote	2010	FP-2.h	Fall Protection	5	1.8.1.1.11	The fall protection system shall be removable.			X						
Test Cell	Fall Prote	2011	FP-2.i	Fall Protection	6	1.8.1.1.11	The fall protection system shall allow workers to move around the circumference at the top surface of the machine without trapping one-another or without the need to relocate the anchoring points.			X						
Test Cell	Fall Prote	2012	FP-3.a	Fall Protection	7	1.8.1.1.11	Permanently installed components of the fall protection system shall be made using nonmagneticmaterials		X				NSTXU_1-8-1-1-11_CALC_100			
Test Cell	Fall Prote	2013	FP-3.a'	Fall Protection	8	1.8.1.1.11	The magnetic permeability of the parts installed as part of the fall protection system shall not exceed 2.0 mu.1		X				NSTXU_1-8-1-1-11_CALC_100			
Test Cell	Fall Prote	2014	FP-3.b	Fall Protection	9	1.8.1.1.11	The fall protection system shall not contribute a ground to the NSTX-U vessel.				X					
Test Cell	Fall Prote	2015	FP-3.c	Fall Protection	10	1.8.1.1.11	The structures shall be single point grounded.				X					
Test Cell	Fall Prote	2016	FP-3.d	Fall Protection	11	1.8.1.1.11	The permanent parts of the fall protection system shall have insulating breaks to prevent circulating currents in the structural assembly, consistent with the GRD.				X					
Test Cell	Fall Prote	2017	FP-4.a	Fall Protection	12	1.8.1.1.11	The fall protection system shall be designed to be removable.			X						

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
Test Cell	Fall Prote	2018	FP-4.b	Fall Protection	13	1.8.1.1.11	The re-assembly of the fall protection system shall not take more than 30 minutes and shall beable to be completed as routine work practice without the need for specialized tools andexpertise.			X						
Test Cell	Fall Prote	2019	FP-4.c	Fall Protection	14	1.8.1.1.11	The installation of the fall protection system shall not create a falling hazard, i.e. a fall protectionstrategy shall be implemented for installation.				X				JHA and installation procedures ensured requirement met	
Test Cell	Fall Prote	2020	FP-5.a	Fall Protection	15	1.8.1.1.11	The fall protection arrest system shall comply with the safety guidelines of OSHA1926.502 and OSHA 1910.140.						NSTXU_1-8-1-1-11_CALC_100			
Test Cell	Fall Prote	2021	FP-5.b	Fall Protection	16	1.8.1.1.11	Any components connected to the machine-proper shall be designed in accordance with the NSTX Structural Design Criteria.		X				NSTXU_1-8-1-1-11_CALC_100			
RTC&P	STP	**Shorted Turn Protection**														
RTC&P	STP	2022	STP-3.a	Shorted Turn Pro	1	1.7.3.6.9	The Shorted Turn Protection system shall track the NSTX-U timing events and the reception of these in the correct sequence. The timing events are: i. SoP: Start of Pulse ii. EoP: End of Pulse iii. T-60: 60 seconds before SoP iv. T-30: 30 seconds before SoP v. T-n: n seconds before SoP (n is configured for NSTX-U as part of the timing systems) vi. Abort: Event generated if COE aborts a shot									
RTC&P	STP	2023	STP-4.a	Shorted Turn Pro	2	1.7.3.6.9	The System shall be designed to conform to electrical isolation requirements as defined in theGRD [1] Section 4.2.3 parts b and c.									
RTC&P	STP	2024	STP-4.c	Shorted Turn Pro	3	1.7.3.6.9	When equipment must be designed in-house for a specific purpose, it shall conform to industryand PPPL engineering procedures defined for electronics (ENG-023 [3]) .									
RTC&P	STP	2025	STP-4.d	Shorted Turn Pro	4	1.7.3.6.9	The use of material in the construction of this system shall conform to industry standards wherever practical following Reduction of Hazardous Substances (RoHS) directive.									
RTC&P	STP	2026	STP-4.e	Shorted Turn Pro	5	1.7.3.6.9	The computing hardware platform for executing the STP algorithms shall use an operatingsystem (OS) that supports deterministic real-time execution of the algorithm.									
RTC&P	STP	2027	STP-4.f	Shorted Turn Pro	6	1.7.3.6.9	The computing hardware platform for executing the STP algorithm shall include redundancy forcritical components, in particular a) power supplies and b) data storage.									
RTC&P	STP	2028	STP-4.g	Shorted Turn Pro	7	1.7.3.6.9	The software code shall be developed and maintained following the Software Quality AssuranceProcedure [6].									
RTC&P	STP	2029	STP-4.h	Shorted Turn Pro	8	1.7.3.6.9	The software code shall only use library functions that are considered real-time safe.									
RTC&P	STP	2030	STP-4.i	Shorted Turn Pro	9	1.7.3.6.9	Changes to the Shorted Turn Protection software shall only be carried out by I&C grouppersonnel in collaboration with the main stakeholders from NSTX-U operations and Physicsoperations.									
RTC&P	STP	2031	STP-5.1.a	Mechanical	1	1.7.3.6.9	The computing hardware platform for executing the STP algorithm shall be suitable to bemounted in standard computing racks.									

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RTC&P	STP	2032	STP-5.1.b	Mechanical	2	1.7.3.6.9	Associated realtime computing platforms shall be installed in an area with restricted access suchas the FCC or caged area in the Junction Area.									
RTC&P	STP	2033	STP-5.1.c	Mechanical	3	1.7.3.6.9	Where possible, existing data acquisition equipment shall be used (for example FPDP hardwaremodules or analog input devices).									
RTC&P	STP	2034	STP-5.1.c'	Mechanical	4	1.7.3.6.9	Newly developed data acquisition equipment shall conform tothe mechanical and electrical requirements of existing equipment as much as possible.									
RTC&P	STP	2035	STP-5.2.a	Input Data	1	1.7.3.6.9	The system shall have as input data redundant measurements of the following:a. TF coil current and voltageb. OH coil current and voltagec. Currents and voltages of all PF coilsd. Plasma current data, from the plasma current Rogowski coils after compensation forvessel and linked-coil pick-up									
RTC&P	STP	2036	STP-5.2.b	Input Data	2	1.7.3.6.9	Positions of ground switches and line switches for all PF, TF, and OH coils shall be measured									
RTC&P	STP	2037	STP-5.2.c	Input Data	3	1.7.3.6.9	The system shall sample all inputs using the system-wide FPDP clock.									
RTC&P	STP	2038	STP-5.2.d	Input Data	4	1.7.3.6.9	The system shall evaluate the voltage measurement by ensuring the matching measurementsfor a coil voltage are identical to within a configurable measurement difference.									
RTC&P	STP	2039	STP-5.2.d'	Input Data	5	1.7.3.6.9	Measurementsthat are dissimilar by more than the specified difference shall result in triggering a STP Level-1fault.									
RTC&P	STP	2040	STP-5.2.e	Input Data	6	1.7.3.6.9	The system shall evaluate the current measurement by ensuring the matching measurementsfor all coil currents are identical to within a configurable measurement difference.									
RTC&P	STP	2041	STP-5.2.e'	Input Data	7	1.7.3.6.9	Measurements that are dissimilar by more than the specified difference shall result in triggeringa STP Level-1 fault.									
RTC&P	STP	2042	STP-5.2.f	Input Data	8	1.7.3.6.9	The system shall convert the input data stream to the physics and engineering representationrequired by the algorithms.									
RTC&P	STP	2043	STP-5.2.g	Input Data	9	1.7.3.6.9	The system shall adjust the input data measurements for sensor specific compensation, forcharacteristics such as DC offsets and integrator drift.									
RTC&P	STP	2044	STP-5.2.h	Input Data	10	1.7.3.6.9	The sensor specific compensations shall be determined for each shot during the shot cycle at aconfigurable time before the shot									
RTC&P	STP	2045	STP-5.3.a	Configuration & (	1	1.7.3.6.9	The system shall be operated only by trained personnel as departmental training matrices.									
RTC&P	STP	2046	STP-5.3.b	Configuration & (	2	1.7.3.6.9	Logging into the associated realtime computing platform and software execution on thecomputing platform shall be restricted to a group of trained and qualified I&C engineers.									
RTC&P	STP	2047	STP-5.3.c	Configuration & (	3	1.7.3.6.9	Only a maximum of one instance of the system shall be active on a Shorted Turn Protectioncomputing platform at any time.									

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RTC&P	STP	2048	STP-5.3.d	Configuration & (	4	1.7.3.6.9	Each STP system shall provide a user interface (UI) on a computer screen / terminal in the PPPLcontrol room.									
RTC&P	STP	2049	STP-5.3.e	Configuration & (	5	1.7.3.6.9	The system shall be started by executing a command line command.									
RTC&P	STP	2050	STP-5.3.f	Configuration & (	6	1.7.3.6.9	The UI shall at a minimum provide functionality to: i. Configure the system to adapt its functionality for the setup of the NSTX-U machine. ii. Load and save configurations from/to a dedicated and secure data archiving system such as an MDS+1 tree. iii. Change the operating state the system is in. iv. Provide status of all important status items, including Shorted Turn Level-1 fault status. v. Provide operating state, and status of key operating parameters. vi. Provide a summary view of the operation during the last shot. vii. Clear a detected STP Level-1 fault									
RTC&P	STP	2051	STP-5.3.g	Configuration & (	7	1.7.3.6.9	Configuration and/or selection of operating modes shall be done by accessing suitable parameters from a dedicated and secure NSTX-U MDS+ tree.									
RTC&P	STP	2052	STP-5.3.h	Configuration & (	8	1.7.3.6.9	The system shall be designed to accommodate changes in position of the SDS cabinet bus links									
RTC&P	STP	2053	STP-5.4.a	Status Indication	1	1.7.3.6.9	For the operator, status indication and events during operation shall be done using the providedUI.									
RTC&P	STP	2054	STP-5.4.b	Status Indication	2	1.7.3.6.9	A detected harmful condition shall be indicated by raising a STP Level-1 fault through adedicated signal sent to the Hardware User Interface in the Junction Area.									
RTC&P	STP	2055	STP-5.4.c	Status Indication	3	1.7.3.6.9	A dedicated signal changing its state at a suitable frequency shall be emitted.									
RTC&P	STP	2056	STP-5.4.c'	Status Indication	4	1.7.3.6.9	The signal shall bemonitored and passed on to the Hardware User Interface in the Junction Area to indicate thecontinuous operation of the system.									
RTC&P	STP	2057	STP-5.4.c''	Status Indication	5	1.7.3.6.9	Non-reception of this signal by the Hardware UserInterface shall trigger a STP Level-1 fault.									
RTC&P	STP	2058	STP-6.1.a	Operating States	1	1.7.3.6.9	The Shorted Turn Protection algorithm shall be executed as part of a deterministic finite statemachine (FSM).									
RTC&P	STP	2059	STP-6.1.b	Operating States	2	1.7.3.6.9	The FSM shall track NSTX-U timing events (T-30, T-n, SoP, EoP, Abort) to: i. Determine the protection phase (from SoP to EoP) in which the protection algorithm is active ii. Issue an STP Level-1 fault if any of the tracked timing events are received out of sequence									

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Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	STP	2060	STP-6.1.c	Operating States	3	1.7.3.6.9	The FSM shall have dedicated states to distinguish between operation phases to prevent parameter changes during the protection phase in the following manner: i. A setup phase in which the operator is allowed to change system parameters. During this phase UI activity is allowed. ii. A ready phase in which the system is waiting for the timing event indicating that the next shot is imminent (T-60). In this phase the only allowed operator activity is to change the system phase back to the setup phase. During this phase UI activity is allowed. iii. A parameter access and calibration phase (between T-60 and SoP) in which modified parameters are stored, required parameters system parameters are read, and measurements to account for sensor specific calibrations. During this phase UI activity is NOT allowed. iv. An active protection phase (between SoP and EoP) in which the STP algorithm is being executed. During this phase UI activity is NOT allowed. v. A data storage phase (after EoP) in which all logged pulse data is being stored. During this phase UI activity is NOT allowed.									
RTC&P	STP	2061	STP-6.1.d	Operating States	4	1.7.3.6.9	The FSM shall have dedicated states for all failure states. Leaving any of the failure states, shalli. be triggered by operator UI interaction, andii. shall only be possible after all available data has been written to MDS+ data storage.									
RTC&P	STP	2062	STP-6.2.a	Timing	1	1.7.3.6.9	The system shall operate with a cycle time of 200us, based on the 5kHz data sampling frequencyfor the control and protection systems.									
RTC&P	STP	2063	STP-6.2.b	Timing	2	1.7.3.6.9	The system shall receive and process a new set of measured data every 200us.									
RTC&P	STP	2064	STP-6.2.c	Timing	3	1.7.3.6.9	The system shall update the STP Level-1 fault output signal once every 200us.									
RTC&P	STP	2065	STP-6.2.d	Timing	4	1.7.3.6.9	The execution of the algorithm shall be no more than 1000us.									
RTC&P	STP	2066	STP-6.2.e	Timing	5	1.7.3.6.9	If the algorithm execution time is longer than 200us, the algorithm shall be structured in a wayensuring that no input data sample is lost.									
RTC&P	STP	2067	STP-6.2.g	Timing	6	1.7.3.6.9	The system shall toggle the output signal to indicate that the system is alive once every 200us,generating an active pulse of 25% - 50% duty cycle.									
RTC&P	STP	2068	STP-6.3.a	Input Data	1	1.7.3.6.9	The system shall receive its input data as an FPDP data stream in the same format used for theother control and protection systems.									
RTC&P	STP	2069	STP-6.3.b	Input Data	2	1.7.3.6.9	The system shall verify the timely reception of FPDP data packets.									
RTC&P	STP	2070	STP-6.3.c	Input Data	3	1.7.3.6.9	The system shall verify the integrity of the received FPDP data packets, checking the order of thereceived data words and - if available - using other in-stream data integrity features like CRC-32.									
RTC&P	STP	2071	STP-6.3.d	Input Data	4	1.7.3.6.9	The system shall verify the consistency of pairs of data values expected to be identical within FPDP data packets.									
RTC&P	STP	2072	STP-6.3.e	Input Data	5	1.7.3.6.9	The system shall verify and maintain read access to the MDS+ system for reading parameters.									
RTC&P	STP	2073	STP-6.4.a	Algorithm	1	1.7.3.6.9	The STP shall accommodate stepping a replaceable, modular short detection algorithm that isactive between the start of the pulse (SoP) to the end of the pulse (EoP).									

Category	Filter	SEQ. #	Req't ID	Subsystem Name	Sub-Count	SBS	Requirement	Figure Ref.	Anal	Demo	Insp	Test	Analysis Artifacts	Demonstration Artifacts	Inspection Artifacts	Test Artifacts
RTC&P	STP	2074	STP-6.4.b	Algorithm	2	1.7.3.6.9	Commonly used languages and coding methods for real-time system development, e. g., C/C++code generated from a Simulink model shall be accommodated.									
RTC&P	STP	2075	STP-6.4.c	Algorithm	3	1.7.3.6.9	The detection algorithm shall use an approximate model of the NSTX-U conducting structures,measured voltages applied to coils, and estimates of the interaction of the conductors with themeasured plasma current to predict the conductor currents at each step.									
RTC&P	STP	2076	STP-6.4.d	Algorithm	4	1.7.3.6.9	The algorithm shall compare the predictions to measured currents and compare the errors topredefined thresholds.									
RTC&P	STP	2077	STP-6.4.e	Algorithm	5	1.7.3.6.9	The algorithm shall declare a fault for a coil if the error threshold for that coil is exceeded. A fault on any coil shall cause a latching STP Level 1 fault to be declared.									
RTC&P	STP	2078	STP-6.4.f	Algorithm	6	1.7.3.6.9	Algorithm parameters (e.g., thresholds, model parameters, and parameters needed for the calculation of estimation uncertainty) shall be configuration controlled and the parameters usedshall be archived with each shot.									
RTC&P	STP	2079	STP-6.4.g	Algorithm	7	1.7.3.6.9	Measurements, as well as calculated currents, uncertainties, and faults for each coil shall be archived to enable post-shot analysis.									
RTC&P	STP	2080	STP-6.5.a	Output Data	1	1.7.3.6.9	The system shall verify and maintain write access to the MDS+ system for writing system resultsand state changes in a suitable format.									
RTC&P	STP	2081	STP-6.5.b	Output Data	2	1.7.3.6.9	The system shall store all relevant output data in memory during the active operation period and write the output data to the MDS+ system after the end-of-pulse event.									
RTC&P	STP	2082	STP-6.5.c	Output Data	3	1.7.3.6.9	The system shall log (and later commit to the MDS+ system) all relevant events detected by andoccurred in the system, including suitable event details and time stamp.Relevant events shall include:i. detected faults,ii. detected loss of input data stream,iii. changes of the internal system state.									
RTC&P	STP	2083	STP-6.5.d	Output Data	4	1.7.3.6.9	If logged data cannot be committed to the MDS+ system for storage, the system shall remain inthe current state that is attempting to write the data.									
RTC&P	STP	2084	STP-6.5.d'	Output Data	5	1.7.3.6.9	Abandoning the data storage process shall require operator action using the UI.6.6 Output									
RTC&P	STP	2085	STP-6.6.a	Output Fault Sigr	1	1.7.3.6.9	The signal to indicate that the system is alive shall be fail-safe: a broken signal path must be detected as a system no longer in operation.									
RTC&P	STP	2086	STP-6.6.b	Output Fault Sigr	2	1.7.3.6.9	The STP Level-1 fault signal shall be fail-safe: a broken signal path must be detected as a STP Level-1 fault.									
RTC&P	STP	2087	STP-6.6.c	Output Fault Sigr	3	1.7.3.6.9	The emitted STP Level-1 fault signal shall be implemented so that it can be combined with otherexisting faults signals inside the Hardware User Interface.									

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RTC&P	STP	2088	STP-6.7.a	Output Fault Sigr	4	1.7.3.6.9	The system shall have the ability to test in the final configuration, either in concert or individually, the following aspects: i. Input interconnections (e.g. currents, voltages, timing signals, etc.) ii. Software, including both IO, framework, and algorithms iii. Output interconnections (e.g. to DCPS HUI and the HCS)									
RTC&P	STP	2089	STP-6.8.a	Output Fault Sigr	5	1.7.3.6.9	The components of the shorted-turn protection system which are not monitored by the WDTshall have a fail dangerous rate of <10 2 -4 /pulse									
RTC&P	STP	2090	STP-6.8.b	Output Fault Sigr	6	1.7.3.6.9	The software components of the Shorted Turn Protection system, which are monitored by theWDT, shall be designed to have a fail-dangerous rate of less than 0.5% per pulse3 [									
RTC&P	STP	2091	STP-6.8.c	Output Fault Sigr	7	1.7.3.6.9	The WDT circuitry which monitors the operating state of the STP shall have a fail-dangerous rate of <0.5% per pulse.									
RTC&P	STP	2092	STP-6.8.d	Output Fault Sigr	8	1.7.3.6.9	The voltage and current sensors shall have less than 2 critical failures per 10,000 pulse or 0.0002/pulse.									