National Spherical Torus eXperiment Upgrade

National Spherical Tokamak Experiment-Upgrade

NSTX-Upgrade

SYSTEM REQUIREMENTS DOCUMENT

CENTRAL INSTRUMENTATION AND CONTROL

NSTX-U-RQMT-SRD-009-00

Revision 0

April 3, 2018

GREGORY J TCHILINGUIRIAN

Digitally signed by GREGORY J TCHILINGUIRIAN
Date: 2018.04.03 17:10:25 -04'00'

Prepared By: Greg Tchilinguirian, Central Instrumentation and Control RE

Stefan Gerhardt

Digitally signed by Stefan Gerhardt
DN: cn=Stefan Gerhardt, o=Physics, ou=PPPL, email=sgerhard@pppl.gov, c=US
Date: 2018.04.03 17:16:08 -04'00'

Reviewed By: Stefan Gerhardt, Systems Engineering and Integration

Charles L. Neumeyer

Digitally signed by Charles L. Neumeyer
DN: cn=Charles L. Neumeyer, o=PPPL, ou, email=neumeyer@pppl.gov, c=US
Date: 2018.04.03 17:18:42 -04'00'

Reviewed By: Charles Neumeyer, NSTX-U Project Engineer

Russell Feder

Digitally signed by Russell Feder
Date: 2018.04.04 04:56:00 -04'00'

Reviewed By: Russ Feder, NSTX-U Project Manager

PAUL SICHTA

Digitally signed by PAUL SICHTA
Date: 2018.04.04 09:52:22 -04'00'

Reviewed By: Paul Sichta, Control and Data Technical Authority

Valeria Riccardo

Digitally signed by Valeria Riccardo
Date: 2018.04.04 10:01:56 -04'00'

Approved By: Valeria Riccardo, PPPL Chief Engineer

4/4/2018

Jonathan E. Menard Jonathan Menard

Accepted By: Jon Menard, NSTX-U Project Director

Change Record

Revision	Date	Description of Change
0	4/3/18	Initial Release

References 5

1: Scope and Format 6

2. Plant Control Input/Output System (WBS 1.6.1.1) 8
2.1: Functions 8
2.2. Material and Design Requirements 8
2.3: Configuration Requirements & Essential Features 8
2.4 Baseline Performance & Operational Requirements 9
2.5. Upgrade Performance & Operational Requirements 10
2.6. Interfaces 10

3. Plant Control and Monitoring System (WBS 1.6.1.2) 13
3.1: Functions 13
3.2: Material and Design Requirements 13
3.3: Configuration Requirements & Essential Features 13
3.4. Baseline Performance & Operational Requirements 14
3.5. Upgrade Performance & Operational Requirements 14
3.6. Interfaces 15

4. Timing and Synchronization System (WBS 1.6.1.3) 17
4.1: Functions 17
4.2: Material and Design Requirements 17
4.3: Configuration Requirements & Essential Features 17
4.4. Baseline Performance & Operational Requirements 18
4.5. Upgrade Performance & Operational Requirements 18
4.6. Interfaces 18

5. NSTX-U Control Room And Fusion Control Center (WBS 1.6.1.4) 22
5.1: Functions 22
5.2: Material and Design Requirements 22
5.3: Configuration Requirements & Essential Features 22
5.4. Baseline Performance & Operational Requirements 23
5.5. Upgrade Performance & Operational Requirements 23
5.6. Interfaces 23

6. NSTX-U Test Cell Surveillance System (WBS 1.6.1.5) 25
6.1: Functions 25
6.2: Material and Design Requirements 25

6.3: Configuration Requirements & Essential Features 25
6.4. Baseline Performance & Operational Requirements 26
6.5 Upgrade Performance & Operational Requirements 26
6.6. Interfaces 26
7. Data Input/Output System (WBS 1.6.2.1) 28
7.1: Functions 28
7.2: Material and Design Requirements 28
7.3: Configuration Requirements & Essential Features 28
7.4. Baseline Performance & Operational Requirements 29
7.5. Upgrade Performance & Operational Requirements 29
7.6. Interfaces 29
8. Data Archiving System (WBS 1.6.2.2) 32
8.1: Functions 32
8.2: Material and Design Requirements 32
8.3: Configuration Requirements & Essential Features 32
8.4. Baseline Performance & Operational Requirements 33
8.5. Upgrade Performance & Operational Requirements 33
8.6. Interfaces 33

References

[1] NSTX-U-RQMT-GRD-001, NSTX-U General Requirements Document
[2] ENG-010 "Control of Drawings, Software, and Firmware" Rev. 6
[3] ENG-023 "Electrical Equipment Approval " Rev. 1
[4] Environmental Safety & Health Directives Manual (ESHD 50008)
[5] TFTR-10A2-H57 Standard Timing Pulse
[6] Policy P-106 “Information Technology (IT) Backup Policy”
[7] GEN-023 “Records Management”

1: Scope and Format

a) This document gives the requirements for the basic functions of the NSTX-U Central Instrumentation and Control Systems and further refines the requirements outlined in the General Requirements Document Section 6.6. For each of these functions Central Instrumentation and Control shall provide support, maintenance and upgrades:

- A physical interface to subsystems in other NSTX-U WBS areas as required, centralizing Plant Control Input/Output Interface including hardware (WBS 1.6.1.1)
- An integrated, distributed control and monitoring system of NSTX-U's engineering subsystems (WBS 1.6.1.2)
- Components of the timing and synchronization system which provides synchronized control of processes throughout the NSTX-U environment (WBS 1.6.1.3)
- A facility for research and operations staff with additional space for computing resources supporting machine operations. (WBS 1.6.1.4)
- Test cell audio/video equipment for visual monitoring of NSTX-U vessel components. (WBS 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 (WBS 1.6.2.1)
- A secure yet accessible experimental data repository for both engineering data and physics data (WBS 1.6.2.2)

b) NSTX-U Central I&C will the provide the functions outlined in Section 1a and will manage the design, installation, configuration and support for items such as the Plant Control I/O System, Plant Control and Monitoring System, Timing and Synchronization System, NSTX-U Test Cell Surveillance System, the NSTX-U Control Room and computing facility, Software Archiving and Recovery System, Data I/O System, and Data Archiving System.

c) 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:

   a. Be in conformance with the CI&C SRD
   b. Conform with GRD [1] requirements
   c. When upgrading, being integrated with, or replacing existing WBS elements they shall comply with the Central Instrumentation and Control SRD.

d) The format of this document, including interfaces specifications, is provided in the NSTX-U General Requirements Document [1].

2. Plant Control Input/Output System (WBS 1.6.1.1)

2.1: Functions

The purpose of the NSTX-U Plant Control I/O system is to integrate a wide variety of computing hardware and communication protocols that are typical for the process control industry and the experimental research realm.

2.2. Material and Design Requirements

a) 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.

b) 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 ENG-010 [2].

c) 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.

2.3: Configuration Requirements & Essential Features

a) Plant Control shall not provide system, machine or personnel protection and should not be considered a protection system.

b) The system shall provide analog input, digital input, analog output and digital output functionality as required by application.

c) The system shall provide and interface with the Timing and Synchronization system and provide timing signal inputs and outputs

d) 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.

e) Some features of the system shall be capable of continuous operation as required.

f) The system shall be capable of interfacing directly with I/O points, or through industry standard networks.

g) Plant Control I/O data shall be archived either by a dedicated process control archiver system or to WBS element 1.6.2.1 when the data is specific to an NSTX or NSTX-U shot. Non-shot specific data shall be retained for a period of at least six months.

h) The system shall be physically distributed throughout the facility to simplify connectivity to monitored and controlled systems.

2.4 Baseline Performance & Operational Requirements

a) 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.

b) 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.

c) 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.

d) The NSTX-U The Plant Control I/O System shall support existing CAMAC Data Acquisition component performance. 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.

e) Additional Plant Control I/O System components that do not utilize existing CAMAC infrastructure shall support performance equal to or better than defined previously.

2.5. Upgrade Performance & Operational Requirements

a) 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.

b) The system shall be capable of incremental or modular upgrades to improve performance and satisfy future requirements.

2.6. Interfaces

***Table 2.6.1**: Interfaces for Plant Control Input Output System (WBS 1.6.1.1)*

Interfacing WBS	Interfacing System	Type of Interface	Interface Boundary	Interface Description	Required Interface Documentation
1.8.1.1.2	NTC Cable Trays	Structural	At tray	Fibers or cables reside in cable trays	N/A
1.4.1.2	Magnetics	Electrical Signal	Electrical Connection	Control I/O systems used to archive magnetics data	CWD
1.7.3.6.5	DCPS Hardware Interface, Expansion Chassis & WDTs	Electrical Signal	Electrical Connection	Control I/O system used to provide DCPS I/O functionality from Plant Control and Monitoring (EPICS) via the Hardware Interface	CWD
1.6.1.3	Timing and Synchronization System	Electrical Signal	Electrical Connection	Digital Communication Protocols, Process Controllers, Equipment I/O	CWD
1.6.1.2	Plant Control and Monitoring	Electrical Signal	Ethernet Port	Digital Communication Protocols, Process Controllers	CWD
0.1.1.3	PPPL Network Infrastructure	Ethernet	Ethernet Port	PPPL Network	CWD
1.1.2.2	Vacuum Vessel Thermocouples	Electrical Signal	At the electronics input	Voltages from the TCs are digitized and calibrated to provide temperature data, archived.	CWD
1.1.3.4	Bus Bar Systems and Bus Tower	Electrical Signal	At digitizer input	Signals from the coil current transducers on RWM coil cables are digitized	CWD
1.3.1.2	Vacuum Gauges and Residual Gas Analyzers	Electrical Signal	Front panel of digitizer	Vacuum pressure measurements provided to the Data Acquisition systems	CWD
1.3.4.5	Valve Driver and Interface Systems	Electrical Signal	Vacuum system PLC	OPC networking is used to communicate with the	CWD

1.2.4.7	Neutral Beam Control Systems	Electrical Signal	At digitizer panel	Various signals (voltage, current) archived with the shot.	CWD
1.2.1	High Harmonic Fast Wave (HHFW)	Electrical Signal	At Digitizer	Various signals are digitized as part of the primary NSTX-U data I/O system	CWD
1.2.3	Electron Cyclotron Pre-Ionization (ECH)	Electrical Signal	At Digitizer	Various signals are digitized as part of the primary NSTX-U data I/O system	CWD
1.5.2.1	TF Power Systems Converters	Electrical Signal	At digitizer front panel or breakout panel	TF rectifier internal signals, ground currents, and line-to-ground voltages are digitized via the control I/O system.	CWD
1.5.2.2	OH Power Systems Converters	Electrical Signal	At digitizer connectors	OH rectifier internal signals, ground currents, and line-to-ground voltages are digitized via the control I/O system.	CWD or Schematic
1.5.2.3	PF Power Systems Converters	Electrical Signal	At digitizer connectors	PF rectifier internal signals, ground currents, and line-to-ground voltages are digitized via the control I/O system.	CWD
1.5.2.4.1	SPA DC Link	Electrical Signal	At digitizer connectors	Various signals are digitized (voltage, current, control, etc.)	CWD or Schematic
1.1.1.1.8	PFC Thermocouples	Structural	Connectors on digitizers	Signals from digitizers interfaced to NSTX-U data acquisition system	CWD
1.6.1.2	Plant Control and Monitoring	Electrical Signal	Ethernet Port	Digital Communication Protocols	CWD
1.6.1.4	Control room	Spatial	Computers and related equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.7.3.6.5	DCPS Hardware Interface, Expansion Chassis & WDTs	Electrical Signal	Digitizer (SAD) in JA	Pulse Timing	CWD
1.7.3.6.9	Shorted Turn Protection System	Electrical signal	Network Interface	The data from the system are archived in MDS+ following the discharge	CWD
1.7.3.6.8	Ip Calculator System	Electrical Signal	At input to Ip Calculator chassis	Data from Ip Calculator is digitized for archival in MDS+	CWD
1.5.1.1	Fixed and Variable Frequency 13.8 kV Experimental Power	Electrical Signal	Digital I/O from CAMAC System	Information on the Motor Generator passed to the Plant Control and Monitoring Systems (EPICS)	CWD
1.5.4.3	DCCT Signal	Electrical	At digitizer input	Outputs of the HSCs are digitized	CWD

	Conditioner	Signal		for archival in MDS+	
1.3.2.4	Water System PLC	Electrical Signal	Cooling Water System PLC.	PLC networking/communication is used to communicate with the Cooling Water System PLC.	CWD
1.5.1.2	D-Site Auxiliary Power	Electrical Power	various	Power for control I/O systems at D-site	Electrical Schematic for Directly Wired Components
1.5.2.4.2	SPAs Inverters	Electrical Signal	At digitizer input	Data from SPA inverters digitized	CWD
1.5.3.1	TF Convertor DC Systems	Electrical Signal	At digitizer inputs	Some signals from DC systems are directly digitized (ground fault currents, coil voltages)	CWD
1.5.3.2	OH Convertor DC Systems	Electrical Signal	At digitizer inputs	Some signals from DC systems are directly digitized (ground fault currents, coil voltages)	CWD
1.5.3.3	PF Convertor DC Systems	Electrical Signal	At digitizer inputs	Some signals from DC systems are directly digitized (ground fault currents, coil voltages)	CWD
1.5.3.4	Switching Power Amplifier DC Systems	Electrical Signal	At digitizer inputs	Some signals from DC systems are directly digitized (coil voltages, coil currents)	CWD
0.1.1.11	C-Site Power	Electrical Power	various	Electrical power for Control I/O Systems at C-Site	Electrical Schematic for Directly Wired Components
1.3.2.3	Deionized Make-Up System	Electrical Signal	At output of CAMAC system modules	Control cooling tower pumps and valves	CWD

3. Plant Control and Monitoring System (WBS 1.6.1.2)

3.1: Functions

The purpose of the Plant Control and Monitoring System (PCMS) is to provide supervisory control and monitoring of the NSTX-U facility by interfacing with the software and hardware used by many of the engineering and data WBS elements.

3.2: Material and Design Requirements

a) The system shall use Enterprise or Industrial grade, commercially available computing equipment in its construction.

b) The PCMS shall interface with the PPPL network infrastructure.

3.3: Configuration Requirements & Essential Features

a) The PCMS shall not provide system, machine or personnel protection for system to which it interfaces and should not be considered a protection system.

b) The PCMS must be compatible with a wide array of hardware and software types using diverse languages, operating systems and communication protocols.

c) The PCMS must be designed with scalability in mind and should work well in a distributed configuration.

d) The design of the PCMS shall facilitate monitoring and control of the Control I/O System (WBS 1.6.1.1) by parties inside and outside of the NSTX-U control room (WBS 1.6.1.4).

e) The PCMS shall provide process synchronization from the Timing and Synchronization System (WBS 1.6.1.3) events or process-specific conditions to NSTX-U subsystems.

f) The PCMS shall function as the Control I/O data acquisition system and archive system configuration, sampling, acquisition, and display.

g) The PCMS shall provide Historical Trending (continuous slow sampling, storage, and display).

h) The PCMS shall provide alarm annunciation (hierarchical alarm display, notification, and logging).

i) The PCMS shall provide access and system security, limiting access of “control points” to authorized users.

j) The PCMS shall provide a uniform Human Machine Interface to access Process Data throughout the experimental complex.

3.4. Baseline Performance & Operational Requirements

a) 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.

b) 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).

c) The NSTX-U PCMS shall support archiving existing CAMAC Data Acquisition channels. 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.

d) Human Machine Interfaces (HMI) shall be provided to engineering operators to interface with NSTX-U subsystems. Each HMI shall utilize a common interaction tools such as trackballs, mice, touch-screens and keyboards. Displays shall use color monitors or televisions, sized appropriately for viewing in their location.

e) 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.

f) The Baseline performance for IO, processing and controller capabilities shall be met or exceeded as outlined in table 2.4.1

Table 2.4-1 Baseline Performance for Plant Control I/O System

Parameter	**NSTX-U Baseline Requirement**
IO Controller Host Throughput	1.5K points/sec
IO Controller record processing	7.5K records/second
IO Hardware periodic Scan Rate	2100 pts@2 second scan rate
PLC periodic scan rate	677 pts@2 second scan rate

3.5. Upgrade Performance & Operational Requirements

a) The PCMS shall be upgradable to operate on replacement computing hardware as technologies evolve.

b) The PCMS shall upgradable to support newer Control I/O hardware as legacy equipment is phased out and replaced with newer equipment.

c) The PCMS shall be scalable to include additional I/O points and controllers

d) The number of supported PCMS Human Machine Interfaces shall be scalable to include additional Operator Interface HMI's.

3.6. Interfaces

***Table 3.6-1**: Interfaces for Plant Control and Monitoring System (WBS 1.6.1.2)*

Interfacing WBS	Interfacing System	Type of Interface	Interface Boundary	Interface Description	Required Interface Documentation
1.3.5.3	Li Evaporator (LITER)	Electrical Signal	Ethernet Network	Data written to epics using Channel Access	CWD
1.8.1.1.2	NTC Cable Trays	Structural	At tray	Fibers and cables reside in cable trays	N/A
1.6.1.3	Timing and Synchronization System	Electrical Signal	Ethernet Port	Digital Communication Protocols	CWD
1.6.1.1	Control I/O systems	Electrical Signal	Ethernet Port	Digital Communication Protocols	CWD
1.6.2.1	Data I/O systems	Electrical Signal	Ethernet Port	Digital Communication Protocols	CWD
0.1.1.3	PPPL Network Infrastructure	Ethernet	Ethernet Port	PPPL Network	CWD
1.2.4.7	Neutral Beam Control Systems	Electrical Signal	Connection to NB PXI equipment	An Industrial PC Connects to Neutral Beam PCI eXtensions I/O	CWD
1.5.4.1	Hardwired Control System & PLC	Electrical Signal	Connects to FCPC HCS PLC	PLC communications/networking is used to interface with the FCPC HCS PLC	CWD
1.3.1.4	Vacuum System PLC	Electrical Signal	PLC ethernet port, CAMAC Crate	i) Information on vacuum pressures and system status are provided to the Plant Control and Monitoring (EPICS) system for control and HMI. ii) Shot cycle synchronization information is provided to the shutter and TIV control system	CWD
1.3.2.4	Water System PLC	Software	Network Connection	Digital communications between dedicated water systems PLC and Plant Control and Monitoring (EPICS)	CWD
1.2.1	High Harmonic Fast Wave (HHFW)	Electrical Signal	PPPL ethernet	Plant Control and Monitoring (EPICS) system	CWD

				used for various HHFW controls	
1.2.3	Electron Cyclotron Pre-Ionization (ECH)	Electrical Signal	PPPL Ethernet and CAMAC Serial Highway	Plant Control and Monitoring (EPICS) system used for various EC-PI controls	CWD
1.6.1.1	Control I/O systems	Electrical Signal	Ethernet Port	Digital Communication Protocols, Process Controllers	CWD
1.6.1.4	Control room	Spatial	Computer equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.6.2.1	Data I/O systems	Electrical Signal	Ethernet Port	Digital Communication Protocols	SDD?
1.6.2.2	Data Archiving Systems	Electrical Signal	Ethernet	Digital Communication Protocols	CWD
1.3.1.5	Probe drive controls	Electrical Signal	At RS232 connector	Plant Control and Monitoring (EPICS) system provides commands to the probe drive controller.	CWD
1.5.1.2	D-Site Auxiliary Power	Electrical Power	wall plug	Power for Plant Control and Monitoring (EPICS) system hardware at D-Site	N/A
0.1.1.11	C-Site Power	Electrical Power	Wall Plug	Electrical power for Timing and Synchronization Systems at C-Site	N/A

4. Timing and Synchronization System (WBS 1.6.1.3)

4.1: Functions

The purpose of the Timing and Synchronization System is to provide a common timing and synchronization system to all other WBS elements.

4.2: Material and Design Requirements

a) The System shall be designed to conform to electrical isolation requirements as defined in the GRD Section 4.2.3 Part c.

b) A combination of industry standard and in-house designs shall be used to design and implement the NSTX-U Timing and Synchronization System.

c) Where practical, equipment and software will be utilized that is commercially available and supported by vendors or open source software communities.

d) 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).

a) 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.

4.3: Configuration Requirements & Essential Features

a) The Synchronization System shall generate and distribute synchronous events (preprogrammed) to the NSTX-U subsystems. 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.

b) The Synchronization System must generate and distribute a shot number that will be incremented sequentially to uniquely identify each experiment.

c) The Synchronization System must generate and distribute synchronized clock pulses to subsystems and the Central I&C System devices to initiate and execute time dependent processes by counting periodically generated clock pulses.

d) The NSTX-U Timing and Synchronization System shall be programmable via Human Machine Interface enabling the configuration of clock settings.

e) The clock link shall supports at least 16 encoded “events” which can be used to signal actions to occur at desired times.

f) The NSTX-U Timing and Synchronization System configuration and shot timing shall be archived to the Data archiving system (WBS 1.6.2.1).

g) The system shall provide digital input and digital output functionality as required by application.

4.4. Baseline Performance & Operational Requirements

a) The NSTX-U Timing and Synchronization System shall provide repeatable timing and distributed encoded events to support “pulsed” plasma operations.

b) 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.

c) 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.

d) The Facility clock link shall be distributed throughout the experimental complex at C-Site and D-Site. The distribution network shall use a “star” topology, with the clock signal originating in the NSTX-U Control Room.

e) The clock link must use a 1 MHz Manchester (bi-phase) encoded clock signal to provide a common timebase for all NSTX-U timing functions unless a separate timebase is desired or cannot be utilized for technical reasons.

f) 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.

4.5. Upgrade Performance & Operational Requirements

a) The Timing and Synchronization System shall be upgradable to support faster facility clock rates.

b) The Timing and Synchronization System shall allow for the addition of network based timing and synchronization.

c) The Timing and Synchronization System shall allow the modification or redefinition of encoded clock events.

4.6. Interfaces

***Table 4.6-1**: Interfaces for Timing and Synchronization System (WBS 1.6.1.3)*

Interfacing WBS	Interfacing System	Type of Interface	Interface Boundary	Interface Description	Required Interface Documentation
1.8.1.1.2	NTC Cable Trays	Structural	At tray	Fibers and cables reside in cable trays	N/A
1.7.3	Integrated Machine Operations	Electrical Signal	Electrical Connection	Timing & Sync Signals	CWD
1.6.1	CI&C Control Systems	Electrical Signal	Electrical Connection	Timing & Sync Signals to Control I/O equipment	CWD
0.1.1.3	PPPL Network Infrastructure	Ethernet	Ethernet Port	PPPL Network	CWD
1.4.1.2	Magnetics	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to various magnetics diagnostics	CWD
1.4.1.3	Multi-pulse Thompson Scattering (MPTS)	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to instruments in the MPTS diagnostic	CWD
1.4.1.4	Plasma TV	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to plasma TC diagnostics	CWD
1.4.1.5.1	Toroidal CHERS	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to Toroidal CHERS diagnostic suite	CWD
1.4.1.5.2	Poloidal CHERS	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to Poloidal CHERS diagnostic suite	CWD
1.4.1.6	FIDA	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to FIDA diagnostic suite	CWD
1.4.1.7	BES	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to BES diagnostic	CWD
1.4.1.8	MSE	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to MSE diagnostics	CWD
1.4.1.9.1	SSNPAs	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to SSNPA	CWD
1.4.1.10	FIReTIP	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to FIReTIP diagnostic	CWD

1.4.1.11	High-K Scattering	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to High-k Scattering diagnostic	CWD
1.4.1.12	Microwave Diagnostics	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to Microwave diagnostic	CWD
1.4.1.13	Visible Spectroscopy	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to spectroscopy diagnostics	CWD
1.4.1.14	Physics Imaging Systems	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to various imaging system diagnostics	CWD
1.4.1.15	Vacuum Spectroscopy	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to vacuum spectroscopy diagnostics	CWD
1.4.1.16	SXR Spectroscopy	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to SXR spectroscopy diagnostics	CWD
1.4.1.20	Bolometers & Vacuum Radiation Sensors	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to bolometer diagnostics	CWD
1.4.1.21	IR Cameras for Thermography	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to IR camera diagnostics	CWD
1.2.1	High Harmonic Fast Wave (HHFW)	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to HHFW control systems	CWD
1.2.4.7	Neutral Beam Control Systems	Electrical or Fiber Optic Signal	At diagnostic or electronics input	Shot synchronization and timing information provided to neutral beam control systems	CWD
1.3.2.4	Water System PLC	Electrical Signal	At connector block on PLC	The central clock provides timing and synchronization functions for the water system PLC	CWD
1.4.1.13.1	Filterscopes	Electrical Signal	Connectors on digitizers	Facility clock signals to trigger detectors	CWD
1.6.1.1	Control I/O systems	Electrical Signal	Electrical Connection	Digital Communication Protocols, Process Controllers, Equipment I/O	CWD
1.6.1.2	Plant Control and Monitoring	Electrical Signal	Ethernet Port	Digital Communication Protocols	CWD
1.6.1.4	Control room	Spatial	RTU mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure	Rack Diagrams

				standards	
1.6.1.5	Test cell audio/video	Electrical Signal	Electrical Connection	Digital Communication Protocols, Process Controllers, Equipment I/O	CWD
1.6.2.1	Data I/O systems	Electrical Signal	Electrical Connection	Digital Communication Protocols, Process Controllers, Equipment I/O	CWD
1.7.3.6.5	DCPS Hardware Interface, Expansion Chassis & WDTs	Electrical Signal	At digital input to DCPS	Sampling clock for digitizers	CWD
1.7.3.6.8	Ip Calculator System	Electrical Signal	At connector on Ip Calculator Chassis	Pulse events (Start, T0, End)	CWD
1.7.3.5.1	PDP Timer	Electrical Signal	Input of PDP	PDP Timer receives trigger pulse	CWD
1.5.1.2	D-Site Auxiliary Power	Electrical Power	wall plug	Power for clock system distribution at D-Site	N/A
1.4.1.1	Neutron measurements	Electrical Signal	At trigger input to digitizers and other hardware	Facility clock signals to trigger detectors	N/A
0.1.1.11	C-Site Power	Electrical Power	Wall Plug	Electrical power for the timing and synchronization system	N/A
1.7.3.4.1	Fiber Optic Strain, Temp., Disp. Meas.	Electrical Signal	At inputs to electronics	Timing markers and triggers delivered to instrumentation systems	CWD

5. NSTX-U Control Room And Fusion Control Center (WBS 1.6.1.4)

5.1: Functions

The purpose of the NSTX-U Control Room is to provide a centralized location for researchers to direct and monitor the experimental operation of the NSTX device. Additional space is allocated to house Central I&C equipment.

The purpose of the NSTX-U Fusion Control Center is to provide a secure space to house computers, control and application processors, fiber optics, and electronic equipment used to operate the experiment and provide data to users of the facility.

5.2: Material and Design Requirements

a) Furniture used in the NSTX-U control room shall meet PPPL ergonomic directives as defined in ESHD 50008, Section 9, Chapter 9 [4].

b) AC power supplied will meet requirements for computer terminals and office equipment used.

c) 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.

d) The fire detection and suppression systems shall be built in accordance with PPPL facility requirements.

e) The AC Power systems shall be built in accordance with PPPL facility requirements.

5.3: Configuration Requirements & Essential Features

The NSTX-U Control Room shall:

a) Be installed in the location previously occupied by the TFTR Control Room.

b) Facilitate interaction among experimental physicists and operations personnel to promote an interactive work environment.

c) Provide racks to house NSTX-U operations computer systems and related development equipment

d) Provide a cable tray system to economically and easily route power cables, signal cables and fiber optic cables.

e) Provide furniture to support the engineering and experimental physics activities.

f) Provide AC power distribution throughout the room from the electrical distribution panel provided.

g) Be secured and prevent access by unauthorized individuals.

The NSTX-U Fusion Control Center shall:

h) Provide racks to house NSTX-U computer systems and related equipment

i) Be secured and prevent access to unauthorized individuals.

j) Provide a cable tray system to route power cables, network cables, signal cables and fiber optic cables.

k) Provide sufficient cooling for equipment operating within.

l) Provide fire detection and suppression protection for equipment contained within.

m) Provide AC power sufficient for equipment operating within.

5.4. Baseline Performance & Operational Requirements

a) A large display of at least 9 square meters shall be provided in the control room to facilitate viewing experimental results and information. It shall be visible from the physics and engineering operations stations, and to the majority of other workstations.

b) Workstations without a view of the large display may be provided with auxiliary views of the same information.

c) An area for critical operations staff shall be provided and separated by visual boundaries.

5.5. Upgrade Performance & Operational Requirements

a) The NSTX-U Control Room shall be capable of being reconfigured to accommodate changes in furniture and power requirements.

b) The NSTX-U Fusion Control Center shall be capable of being reconfigured to accommodate changes in rack space and support system requirements.

5.6. Interfaces

Table 5.6-1*: Interfaces for NSTX-U Control Room and Fusion Control Center (WBS 1.6.1.4)*

Interfacing WBS	Interfacing System	Type of Interface	Interface Boundary	Interface Description	Required Interface Documentation
1.6.2.2	Data Archiving Systems	Spatial	Computer equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.6.1.2	Plant Control and Monitoring	Spatial	Computer equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.7.3	Integrated Machine Operations	Spatial	Computers and related equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.6.1.3	Timing and Synchronization System	Spatial	RTU mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.6.1.1	Control I/O systems	Spatial	Computers and related equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.6.2.1	Data I/O systems	Spatial	Rack space	Equipment used for these systems shall be mounted in racks contained in the facility	Mechanical Drawing
1.6.2.2	Data Archiving Systems	Spatial	Computer equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
0.1.1.11	C-Site Power	Electrical Power	Wall Plug	Electrical power for the control room itself	N/A
1.6.1.5	Test cell audio/video	Location	In control room racks	Receiver chassis are located in racks in the control room	N/A

6. NSTX-U Test Cell Surveillance System (WBS 1.6.1.5)

6.1: Functions

The purpose of this system is display and record conditions in the NSTX-U Test Cell to provide operators with the opportunity to observe conditions that are unavailable before and after a pulse.

This system also provides for the relay of a small number of analog signals from the D-site Junction Area to the control room.

6.2: Material and Design Requirements

a) Camera, microphones, display and recording equipment shall be Commercial, Off the Shelf (COTS) in origin.

b) Display and view manipulation equipment should meet Ergonomic and Human Machine Interface (HMI) standards for mounting, placement and design.

c) 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.

d) Cameras shall be of an aim-able type in locations where a single view is insufficient to capture areas of interest.

e) Display equipment shall support viewing all relevant cameras simultaneously.

6.3: Configuration Requirements & Essential Features

a) 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.

b) The TCSS shall record video, and optionally audio, from an adjustable, pre-selected time and cease recording at a preselected time.

c) The TCSS shall utilize existing network and other infrastructure wherever practical.

d) Data generated by the TCSS shall include metadata that describes when they were generated.

e) 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.

f) The recorded content shall be archived in a format that can be viewed by common media playback software.

g) The archived data shall be retained until deemed unnecessary or obsolete.

h) The primary display and HMI equipment shall be placed in the NSTX-U Control Room.

i) Analog signal links between the junction area and the control room shall be electrically isolated.

j) The analog shall have the transmitting function in the junction area and receiving function in the control room.

k) The analog signal links shall have an input range appropriate for accepting signals from the DCCT Conditioning Circuits.

6.4. Baseline Performance & Operational Requirements

a) 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.

b) There shall be 16 channels in the analog links between the junction area and the control room.

6.5 Upgrade Performance & Operational Requirements

a) The system shall be designed such that it shall be possible to add additional cameras and recorders.

6.6. Interfaces

Table 6.6-1*: Interfaces for NSTX-U Test Cell Surveillance System (WBS 1.6.1.5)*

Interfacing WBS	Interfacing System	Type of Interface	Interface Boundary	Interface Description	Required Interface Documentation
1.8.1.1.2	NTC Cable Trays	Structural	At tray	Trays support cables for cameras	N/A
1.8.1	Project D-Site Locations	Spatial	Cameras Mounted multiple, varying locations	Camera Assemblies mounted to racks, wall and other fixtures.	Mechanical Diagrams
1.6.1.3	Timing and	Electrical	Electrical Connection	Digital Communication	CWD

	Synchronizatio n System	Signal		Protocols, Process Controllers, Equipment I/O	
0.1.1.3	PPPL Network Infrastructure	Ethernet	Ethernet Port	PPPL Network	CWD
1.8.1.1.1	NTC Platforms	Structural	At platform or platform support	Cameras mounted to platforms	N/A
1.8.1.1.4	NTC Walls	Structural	At NTC wall	Cameras mounted to NTC walls	N/A
1.5.4.3	DCCT Signal Conditioner	Electrical Signal	At output of the signal conditioners	Output signals from the DCCT signal conditioners are passed to the analog transmission links	N/A
1.6.1.4	Control room	Location	In control room racks	Receiver chassis are located in racks in the control room	N/A
0.1.1.6	Other D-Site Physical Infrastructure	Location	In junction area racks	Transmitter chassis are located in the D-site junction area	N/A
0.1.1.11	C-Site Power	Electrical Power	Wall plug	AC power for fiber optic receivers	N/A
1.5.1.2	D-Site Auxiliary Power	Electrical Power	wall plug	Power for NTC audio/video system	N/A

7. Data Input/Output System (WBS 1.6.2.1)

7.1: Functions

The NSTX-U Data I/O system is used for the acquisition of both critical and non-critical diagnostic data as well as control and monitoring of diagnostic systems.

7.2: Material and Design Requirements

a) 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),

b) The Data I/O System shall utilize existing CAMAC resources from the TFTR I&C system in order to reduce costs where possible.

c) The Data I/O System shall interface with critical and non-critical Diagnostic systems to provide data acquisition, synchronization control and monitoring.

d) 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).

e) The Data I/O System shall interface with the Timing And Synchronization System (WBS 1.6.1.3) to provide hardware based triggering.

f) The Data I/O system shall be physically distributed throughout the facility to simplify connectivity to monitored and controlled systems

g) 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.

7.3: Configuration Requirements & Essential Features

a) The Data I/O System shall not provide system, machine or personnel protection and should not be considered a protection system.

b) The Data I/O System shall provide analog input, digital input, analog output and digital output functionality as required by application.

c) The Data I/O System shall provide and interface with the Timing and Synchronization system and provide timing signal inputs and outputs.

d) The Data I/O System shall be capable of receiving signals to initiate operation of I/O equipment for a specified period of time.

e) The Data I/O System shall be capable of interfacing directly with I/O points, or through industry standard networks.

f) The Data I/O System shall be physically distributed throughout the facility to simplify connectivity to diagnostic systems.

7.4. Baseline Performance & Operational Requirements

a) 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.

b) Data acquired shall be available for offloading to the shot database with 60 seconds after recording completes.

c) The Data I/O System shall support a 1200 second repetition rate, with all data archived within 900 seconds of the pulse ending.

Table 7.4-1: *Data I/I System Acquisition rates and baseline channel count*

Sample Rate	**Available Channels**
Up to 3Ms/s	24 Differential
Up to 1Ms/s	288 Differential
Up to 40Ks/s	1500 Differential

7.5. Upgrade Performance & Operational Requirements

a) The Data I/O System shall be scalable to meet increased demands for performance and user load.

7.6. Interfaces

Table 7.6-1*: Interfaces for Data Input Output System (WBS 1.6.2.1)*

Interfacing WBS	**Interfacing System**	**Type of Interface**	**Interface Boundary**	**Interface Description**	**Required Interface Documentation**
1.6.1.2	Plant Control and Monitoring	Electrical Signal	Ethernet Port	Digital Communication Protocols	CWD
0.1.1.3	PPPL Network	Ethernet	Ethernet Port	PPPL Network	CWD

	Infrastructure				
1.6.1.4	Control room	Spatial	Rack space	Equipment used for these systems shall be mounted in racks contained in the facility	Mechanical Drawing
1.6.1.3	Timing and Synchronization System	Electrical Signal	Electrical Connection	Digital Communication Protocols, Process Controllers, Equipment I/O	CWD
1.8.1	Project D-Site Locations	Spatial	Rack Space	Equipment used for these systems shall be mounted in racks contained in the facility	Mechanical Drawing
1.4.1.2.5	Digitizers and Integrators	Electrical Signal	Connectors on CAMAC digitizers	Signals from digitizers interfaced to NSTX-U data acquisition system	CWD
1.4.1.17	Langmuir Probes	Electrical Signal	Connectors on digitizers	Signals from digitizers interfaced to NSTX-U data acquisition system	CWD
1.4.1.1	Neutron measurements	Electrical Signal	Connector on CAMAC digitizers	Signals from digitizers interfaced to NSTX-U data acquisition system	CWD
1.4.1.13.1	Filterscopes	Electrical Signal	Digitizers located in DARM	Acquisition of data from digitizers	CWD
1.4.1.3	Multi-pulse Thompson Scattering (MPTS)	Electrical Signal	Connectors on digitizers	Digitized data from detectors and lasers	CWD
1.7.3.4.1	Fiber Optic Strain, Temp., Disp. Meas.	Electrical Signal	At digitizer input	Some signals from the instrumentation system will have their signals digitized	CWD
1.4.1.6	FIDA	Electrical Signal	At connectors of digitizer	Signals are digitized	CWD
1.4.1.8	MSE	Electrical Signal	At connectors of digitizer	Signals are digitized	CWD
1.4.1.9.1	SSNPAs	Electrical Signal	At connectors of digitizer	Signals are digitized	CWD
1.4.1.10	FIReTIP	Electrical Signal	At connectors of digitizer	Signals are digitized	CWD
1.4.1.11	High-K Scattering	Electrical Signal	At connectors of digitizer	Signals are digitized	CWD
1.4.1.12	Microwave Diagnostics	Electrical Signal	At connectors of digitizer	Signals are digitized	CWD
1.4.1.16	SXR Spectroscopy	Electrical Signal	At connectors of digitizer	Signals are digitized	CWD
1.4.1.20	Bolometers & Vacuum Radiation Sensors	Electrical Signal	At connectors of digitizer	Signals are digitized	N/A

1.6.1.2	Plant Control and Monitoring	Electrical Signal	Ethernet Port	Digital Communication Protocols	CWD
1.6.2.2	Data Archiving Systems	Electrical Signal	SCSI	Digital Communication Protocols	CWD
1.5.1.2	D-Site Auxiliary Power	Electrical Power	various	Power for Data I/O systems	Electrical Schematic for Directly Wired Components
1.4.1.2.6	High Frequency MHD Sensors	Software	At digitizer input	Data from sensors digitized for archival	N/A
1.4.1.7	BES	---	At digitizer inputs	BES data digitized	N/A
0.1.1.11	C-Site Power	Electrical Power	Wall Plug	Electrical power of the data I/O systems	N/A

8. Data Archiving System (WBS 1.6.2.2)

8.1: Functions

The purpose of the Data Archiving System is to archive and retrieve experimental, calibration and configuration data from a centralized location.

8.2: Material and Design Requirements

a) 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).

b) The Data Archiving System shall use Enterprise grade, commercially available computing equipment in its construction.

c) The Data Archiving System shall interface with the PPPL's Ethernet network infrastructure.

d) The Data Archiving System shall interface with a heterogenous mixture of hardware and software and their interface requirements.

e) The Data Archiving System shall adhere to the Lab-wide Information Technology Policy for short term backups of experimental data [6]. These backups shall be sent off-site for storage.

f) Archiving of NSTX-U experiment data shall adhere to Lab policies for long term archival and records management [7]. In accordance with Level 2 Research. Data shall be retained for a period of 25 years after the experiment has ceased operation.

8.3: Configuration Requirements & Essential Features

a) The Data Archiving System will use a storage hardware configuration that supports redundancy for experimental and system data.

b) All experimental, calibration and configuration data acquired during machine operations from NSTX through NSTX-U shall be available for retrieval.

c) 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).

d) Changes to existing calculated data will be detected and backed up to the EBS

e) The system shall provide Application Programming Interfaces (API) for developing support for new hardware and software. This interface shall be both local and remote connectivity.

8.4. Baseline Performance & Operational Requirements

a) A minimum of 50 clients shall be able to concurrently connect to the shot database in sufficient number for the system to support critical activities.

b) Shot Data shall be made immediately available upon being written to disk by the Data and Control I/O systems.

c) The system shall backup newly acquired data to the EBS within one day of archiving.

d) Modifications to the calculated data will be backed up to the EBS as detected, periodically.

8.5. Upgrade Performance & Operational Requirements

a) The Data Archiving System shall be scalable to meet increased demands for performance and user load.

b) 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.

8.6. Interfaces

***Table 8.6.-**: Interfaces for Data Archiving System (WBS 1.6.2.2)*

Interfacing WBS	Interfacing System	Type of Interface	Interface Boundary	Interface Description	Required Interface Documentation
1.3.5.4	Granule Injector	Software	At ethernet port	Granule injector writes data to MDS+	MDS+ API[1]
1.6.2.1	Data I/O systems	Electrical Signal	SCSI	Digital Communication Protocols	CWD
1.6.1.2	Plant Control and Monitoring	Electrical Signal	Ethernet	Digital Communication Protocols	CWD
0.1.1.3	PPPL Network Infrastructure	Ethernet	Ethernet Port	PPPL Network	CWD
1.6.1.4	Control room	Spatial	Computer equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams

1.4.1.4	Plasma TV	Software	At ethernet port	Archival of plasma TV files	MDS+ API[1]
1.7.3.4.1	Fiber Optic Strain, Temp., Disp. Meas.	Software	Software within data processing unit	Some element of the instrumentation system will directly input data to MDS+	MDS+ API[1]
1.6.1.4	Control room	Spatial	Computer equipment mounted in FCC Racks	Installed in racks with correct spacing using Unit Measure standards	Rack Diagrams
1.7.3.6.3	Real Time Control Software (PCS, FPDP)	Software	At ethernet port	Archived data, including data that is used for shot restores, is archived in the MDS+ database	MDS+ API[1]
1.7.3.6.6	DCPS Software	Software	At ethernet port	Outputs: Archived data, including data that is used for shot restores, is archived in the MDS+ database	MDS+ API[1]
1.7.3.6.9	Shorted Turn Protection System	Software	At ethernet port	Data is archived to MDS+ by the shorted turn system	MDS+ API[1]
1.7.3.6.4	DCPS Autotesters	Software	At ethernet port	Data from the Autotester is directly archived in MDS+	MDS+ API[1]
1.3.4.3.2	Massive gas injectors	Software	At ethernet port	MGI system receives timing information from MDS+, archives data to MDS+	MDS+ API[1]
1.4.1.5.1	Toroidal CHERS	Software	At ethernet port	Computers archive data in MDS+	MDS+ API[1]
1.4.1.5.2	Poloidal CHERS	Software	At ethernet port	Computers archive data in MDS+	MDS+ API[1]
0.1.1.11	C-Site Power	Electrical Power	Wall Plug	Electrical power for the data archiving systems	N/A
1.4.1.15	Vacuum Spectroscopy	Software	At ethernet port	Software associated with the cameras writes data to the data archival system	MDS+ API[1]

[1] Model Data System plus (MDS+) is the implemented database software for the NSTX-U Data Archiving System