OAK RIDGE National Laboratory

Control Systems Design for STS Accelerator

U.S. DEPARTMENT OF ENERGY

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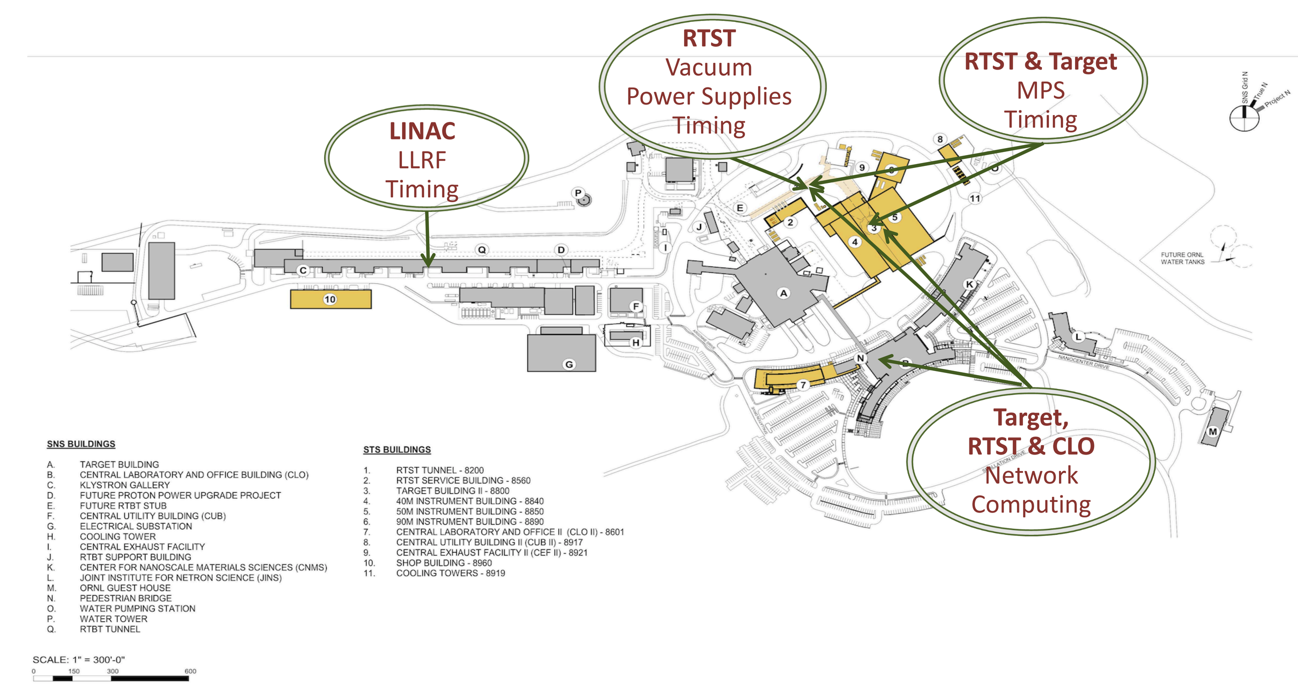
Abstract

STS accelerator systems will build a Ring-to-Second-Target (RTST) transport beamline from the present Ring to Target Beam Transport (RTBT) to the second target. The Integrated Control Systems (ICS) will provide remote control, monitoring, OPI, alarms, and archivers for the accelerator systems, such as magnet power supplies, vacuum devices, and beam instrumentation. The ICS will upgrade the existing Linac LLRF controls to allow independent operation of the FTS and STS and support different power levels of the FTS and STS proton beam. The ICS accelerator controls are in the phase of preliminary design for the control systems of magnet power supplies, vacuum, LLRF, Timing, Machine protection system (MPS), and computing and machine network. The accelerator control systems build upon the existing SNS Machine Control systems, use the SNS standard hardware and software, and take full advantage of the performance gains delivered by the Proton Power Upgrade (PPU) Project at SNS.

Control Systems Requirements and Scope

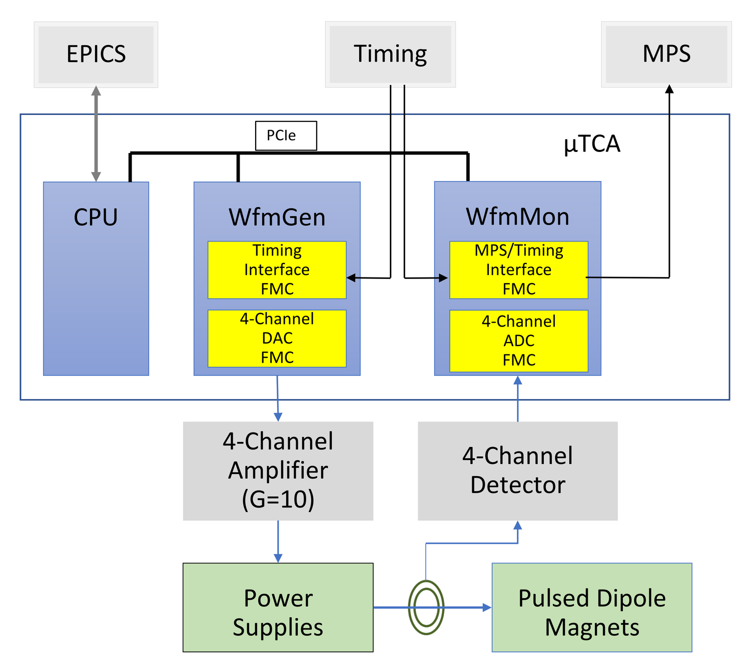
- The RTST accelerator control system shall provide remote control, monitoring, graphical user interface, alarms, and archivers for accelerator systems, along with the necessary computing and network equipment and software environment sufficient for commissioning and initial operation.
- The control system shall provide magnet power supply control and vacuum system control for the RTST.
- The Machine Protection System (MPS) shall provide interlocks to shut off the proton beam to protect the accelerator and target equipment, and to be integrated with the existing SNS Machine Protection System.
- The Timing System shall enable independent and interleaved operation of FTS and STS and provide timing events and proton beam-related data to the accelerator, target, and instrument systems of the Second Target Station (STS).
- The Low-Level Radio Frequency (LLRF) controls shall enable independent operation of the FTS and STS and support different power levels of the FTS and STS proton beam.
- The accelerator control system shall provide the necessary computing and network resources to support the operation of the STS accelerator, beam instrumentation, conventional facilities, and target systems.
- The Accelerator Control System shall maintain compatibility with existing SNS control systems



Magnet Power Supply Controls

STS Accelerator Systems will install 4 pulsed dipole, 60 quadrupole, 15 dipole, and 24 corrector magnets to extract the proton bream from the RTBT and direct it to the RTST, and then transport it to the second target. Both DC magnet power supplies and pulsed dipole power supplies are utilized to provide current for these magnets.

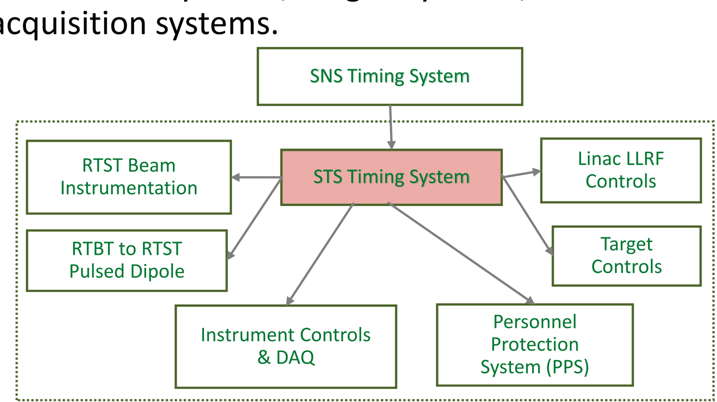
- The control interface for the DC magnet power supplies is established through Ethernet or serial communication.
- A MicroTCA-based Waveform Generator and Waveform Monitor system will be developed to provide a comprehensive control solution for the pulsed dipole magnet power supplies. The primary function of the Waveform Generator is to generate excitation ramp-up signals for the power suppliers. The Waveform Monitor samples the readback current signals for the power supplies and validates the current waveform.



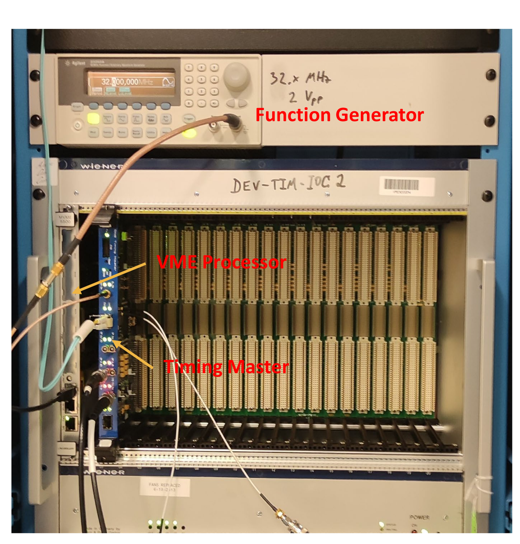
STS Extraction Pulsed Dipole Waveform Generator/Monitor

Timing System

STS timing system is an extension of the existing SNS timing system, which serves to synchronize the operation of the LINAC, accumulator ring, and neutron instruments, while also distributing timing events, and machine data to accelerator systems, target systems, and instrument data acquisition systems.

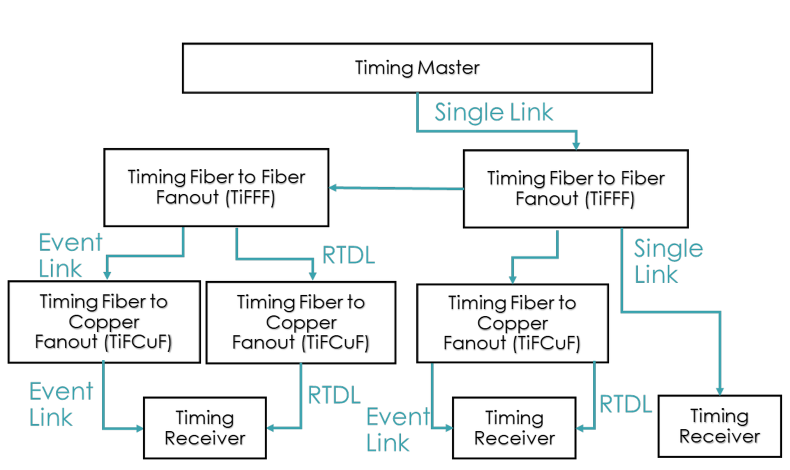


STS Timing System Interface



STS Timing Master Test Stand

The VME Timing Master test stand was constructed to validate the Timing events and the Real-Time Data Link (RTDL) frames that support FTS and STS operations. The test stand consists of a VME processor, a Timing Master card, and a function generator simulating the Ring Clock.



Basic Timing System Layout

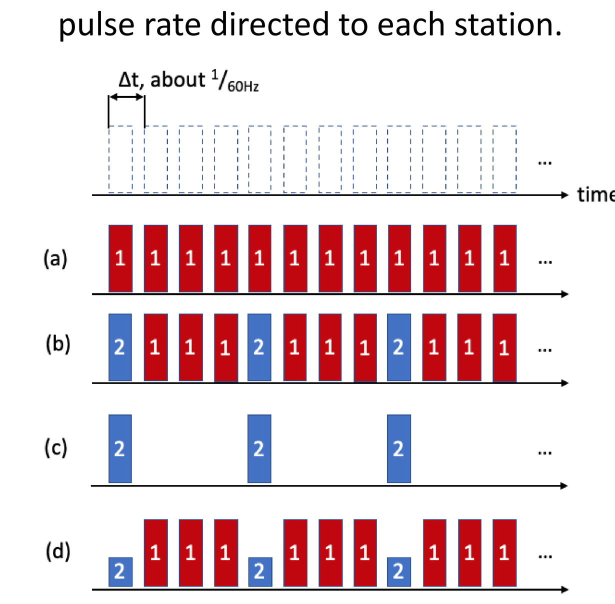
Operating in a unidirectional manner, the SNS Timing System originates from the Timing Master and broadcasts to various timing clients across the SNS site. It's composed of two serial transmission links: the Event Link (EL) and the Real-Time Data Link (RTDL). The Event Link conveys 8-bit timing events defining SNS Machine Cycle segments. The RTDL transmits 24-bit data frames that specify machine operating parameters preceding a machine cycle. The Single Link (SL) combines EL and RTDL, transmitting timing events and RTDL frames in a single fiber to timing receivers.

Vacuum Controls

The RTST vacuum control system utilizes the Allan-Bradley (AB) PLCs and EPICS soft IOC to control the vacuum devices (pumps, gauges, valves), and provide interlocking to the Machine Protection system (MPS) as well. Communication between the PLC and EPICS IOCs will be facilitated via EtherNet/IP, while Linux workstations will serve as the operation interface.

Run Permit System

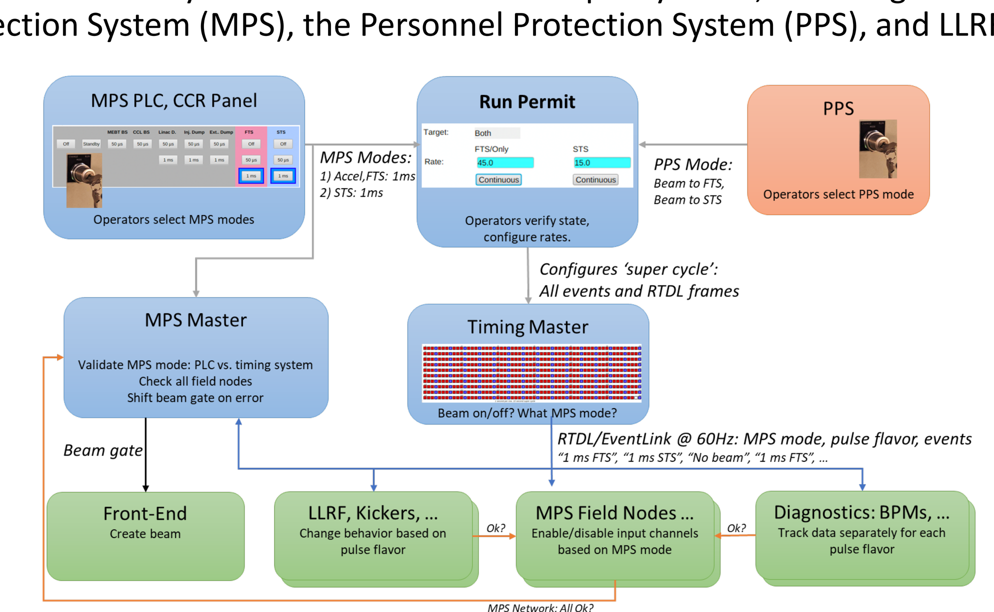
The Run Permit System is a high-level software tool that helps operators coordinate the independent beam delivery to the FTS and STS. It grants operators the ability to enable and disable the beam for either or both target stations while maintaining precise control over the pulse rate directed to each station.



Accelerator Operating Modes for FTS (1) and STS (2)

(a) FTS beam only at a nominal rate of 60 Hz
(b) FTS beam with 45 pulses per second and STS beam at 15 Hz
(c) STS beam only at its maximum rate of 15 Hz
(d) Both FTS and STS operating at their full rate, with reduced charge and thus power for STS pulses

The Run Permit System interfaces with multiple systems, including the Timing system, the Machine Protection System (MPS), the Personnel Protection System (PPS), and LLRF, etc.

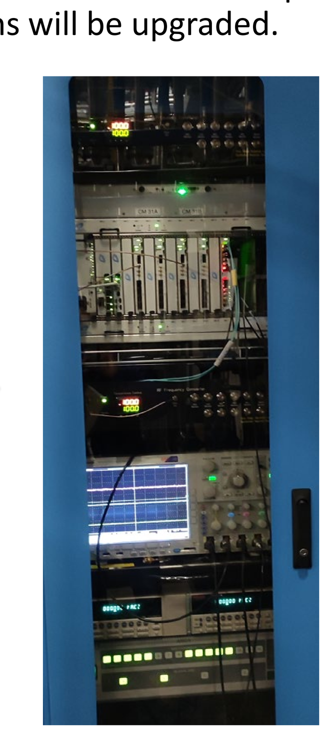


Linac LLRF Controls

The STS project will replace 96 original Linac LLRF systems using the hardware design of the PPU LLRF systems based on the µTCA platform. The existing racks will be retained, but the original VXI crates and down-converters will be supplanted by µTCA crates and Frequency Conversion Chassis (FrCC) chassis. A total of 55 new µTCA crates for 96 LLRF systems will be upgraded.

- No support for two-beam flavors
- No pulse-to-pulse AFF correction
- Low bandwidth 40 MB/s limited to 20 Hz
- Hardware obsolescence

VXI Platform



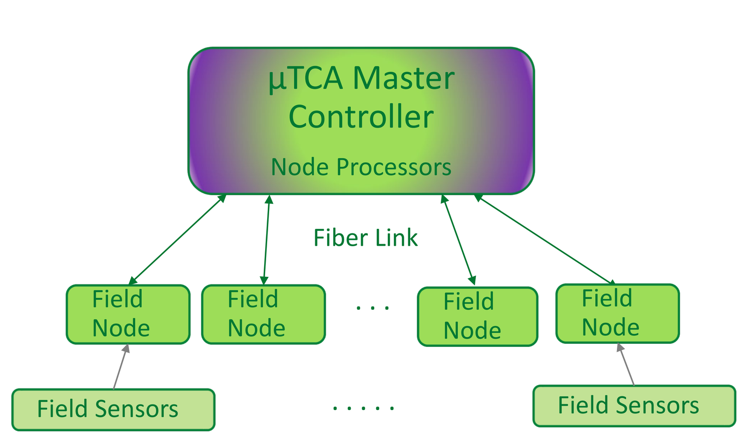
MicroTCA Platform

µTCA Crate

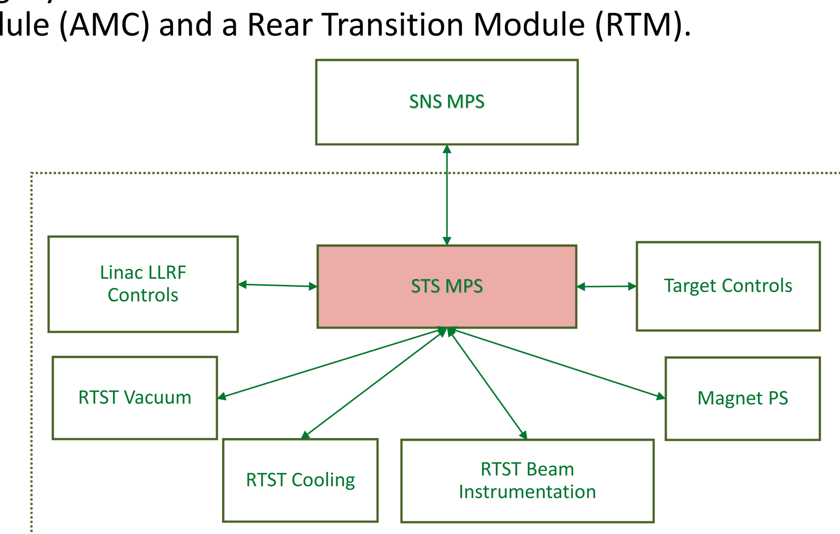
- Processor Card (IOC)
- Field Control Module (FCM)
- High Power Protection Module (HPM)
- Timing Receiver
- Frequency Conversion Chassis (FrCC)

Machine Protection System (MPS)

The STS MPS extends the existing SNS MPS by providing additional field nodes to STS sub-systems. The upgraded SNS MPS is a distributed architecture, comprising a µTCA master controller, fiber link infrastructure, and field nodes. The Master Controller Configuration includes a µTCA chassis housing a processor (IOC), crossbar switch, node processors, and trigger control mechanisms. Its primary role is to swiftly disable beam generation in response to any qualified fault reported from a downstream node, thereby ensuring the safety and integrity of the accelerator. Each field node is housed in a compact 1U µTCA chassis and is equipped with an AdvancedMC module (AMC) and a Rear Transition Module (RTM).



MPS Architecture



STS MPS Interface with other systems

Conclusion

The STS Project has received DOE approval for Critical Decision 1 which defines the project cost range and allow preliminary design work. The cost and schedule for ICS Accelerator Control systems have been well defined, and the preliminary design for the subsystems is under development. Some systems, such as the Timing system, Run Permit system, Linac LLRF Controls, Core software, and Machine network, have finished the preliminary design review, and are ready for the final design. Based on the operation of existing SNS control systems and taking full advantage of the success of the PPU Project, the STS ICS Accelerator Control systems design is right on track for the next milestone of the STS Project.