State Machine Operation of Complex Systems

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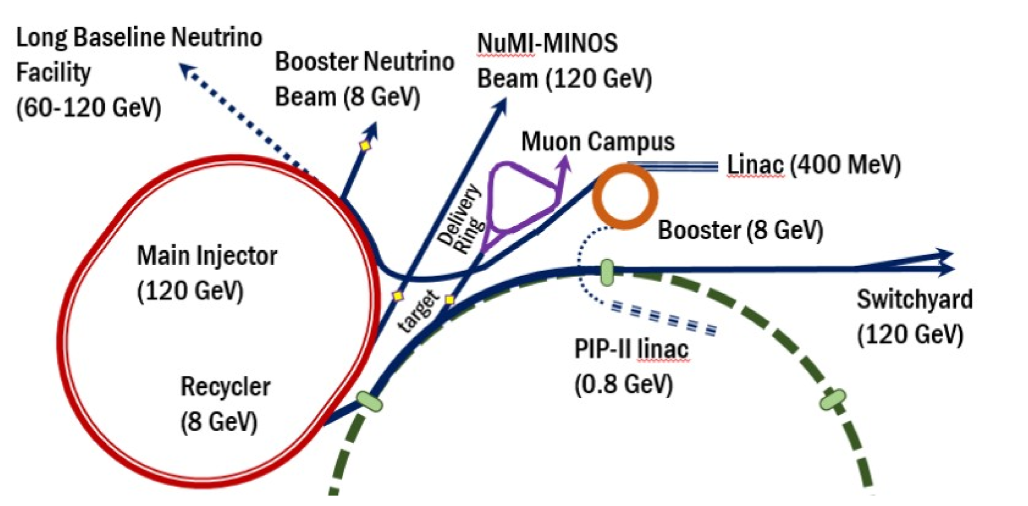
Abstract: Automated procedure for dynamically setting alarms and archiver, thus making them more reliable

Fermilab Accelerator Complex

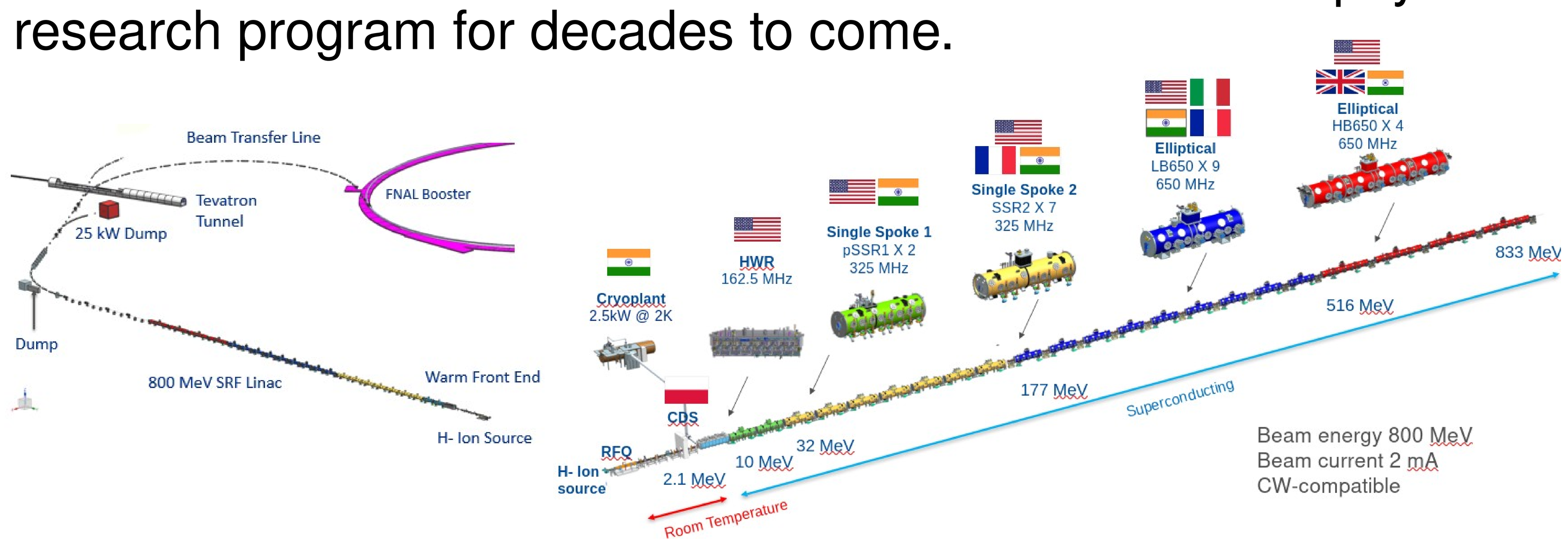
The Fermilab accelerator complex is a series of accelerators which provide proton beams to:

- LBNF/DUNE
- NuMI
- muon campus
- local ν experiments
- test beams



PIP-II

The proton improvement plan phase II is an essential upgrade to the Fermilab accelerator complex to enable the world's most intense beam of neutrinos to LBNF/DUNE and a broad physics research program for decades to come.

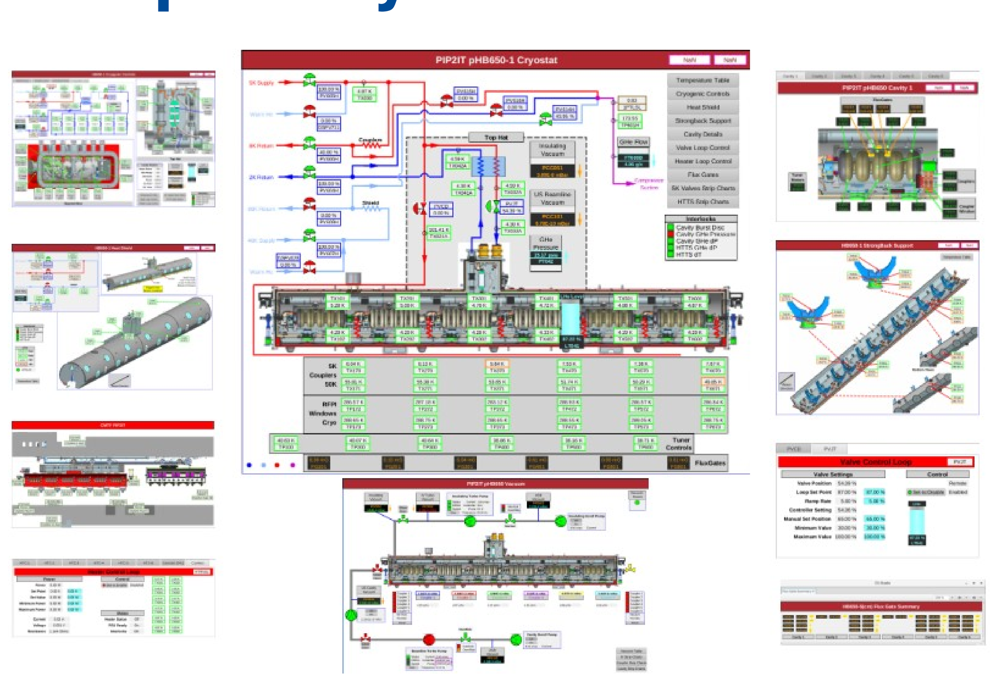


Left: PIP-II project scope. Right: Diagram of PIP-II SCL showing contributions from international partners.

PIP-II is the U.S. first accelerator project to be built with major international contributions; benefits from world-leading expertise, capabilities.

The PIP-II superconducting linac (SCL) will replace the current 400 MeV linac with an 800 MeV, 1.2 MW, 2 mA, CW-compatible linac.

Complex Systems



Example of a complex system: SRF cryomodule. No RF displayed – adds significantly to complexity

- multiple subsystems
- multiple states
- many PVs→for each PV different:
  - alarm limits
  - alarm severities
  - dead bands
  - archiving needs
  - critical PVs

Complex systems: 10-10^5 PVs

States can be:

- Static: PVs expected to be constant
  - alarm limits tight
  - archive in monitor mode with tight deadband
- Dynamic: some/all PVs changing
  - alarm limits match range of expected changes
  - archive in scan mode – deadband not relevant

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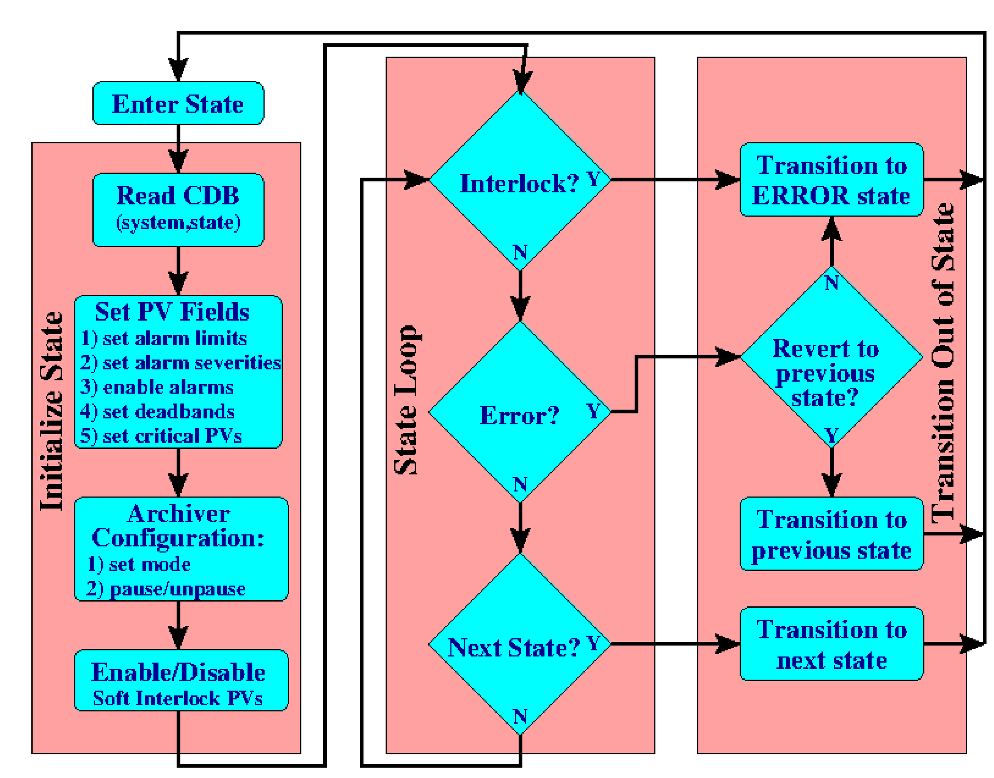
Example of Complex System: SRF Cryomodule

- Offline
- Vacuum Pumping – pumps, valves, gauges, interlocks (dynamic)
- Vacuum Pumped – same PVs (static)
- Cooling HTTS – vacuum + valves, GHe flow, GHe pressure, temperatures, interlocks (dynamic – both vac and cryo)
- Cold HTTS – same PVs (static)
- Cooling Cavities – vacuum + HTTS + additional valves, temperatures, LHe level, interlocks (dynamic: cavities, static: vacuum & HTTS)
- Cold 4K Cavities – same PVs (static)
- Cooling 2K Cavities – same + pump & flow (dynamic)
- additional states not listed here

State Machines

The state machine is *not* intended to control the system nor affect its operation – no user interactions. It *is* a finite state machine, a passive process, which:

1. Identifies the system's state
2. Identifies the PVs of interest
3. Adjusts alarm limits, severities, and deadbands for each PV
4. Sets archiving mode
5. Identifies critical PVs for subsystem owner recognition

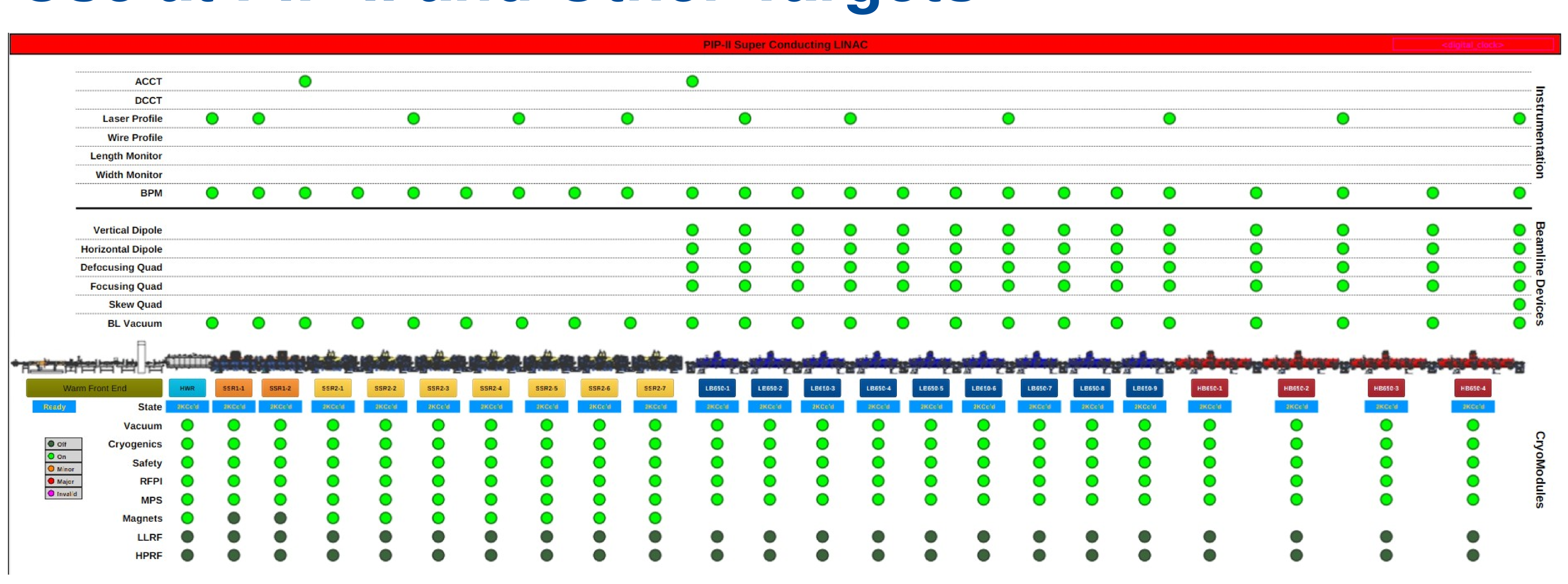


Algorithm used for State Machine: "Initialize State" occurs with each change of state; initialization if performed by Sequencer step below. "State Loop" and "Transition Out of State" are the State identifier step below.

Three Components of State Machine:

- State identifier: IOC automatically identifies state via system PVs
- Configuration database (CDB) – relational db to store PV alarm limits, alarm severities, deadbands, critical PVs, archiving mode
- Sequencer: in EPICS State Notation Language (SNL) – reads state ID, reads CDB, and performs steps to initialize the state

Use at PIP-II and Other Targets



Envisioned PIP-II Main HMI: Status at a glance and central launcher. State Machine system PV is displayed to give operators operational state of each CM

Other targets: PIP-II front end, Cryo plant, ACORN