LCLS RF Stations

Overview of linac RF control

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U.S. DEPARTMENT OF ENERGY
Office of Science

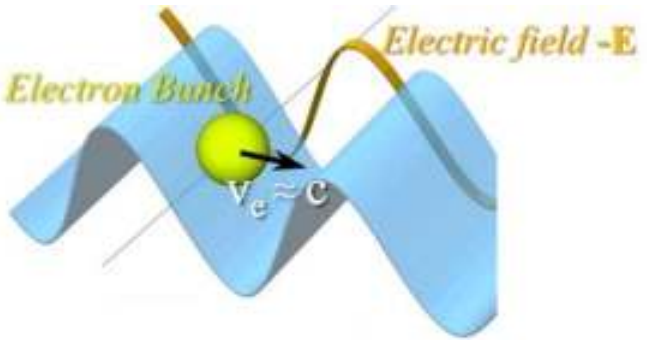
SLAC NATIONAL ACCELERATOR LABORATORY

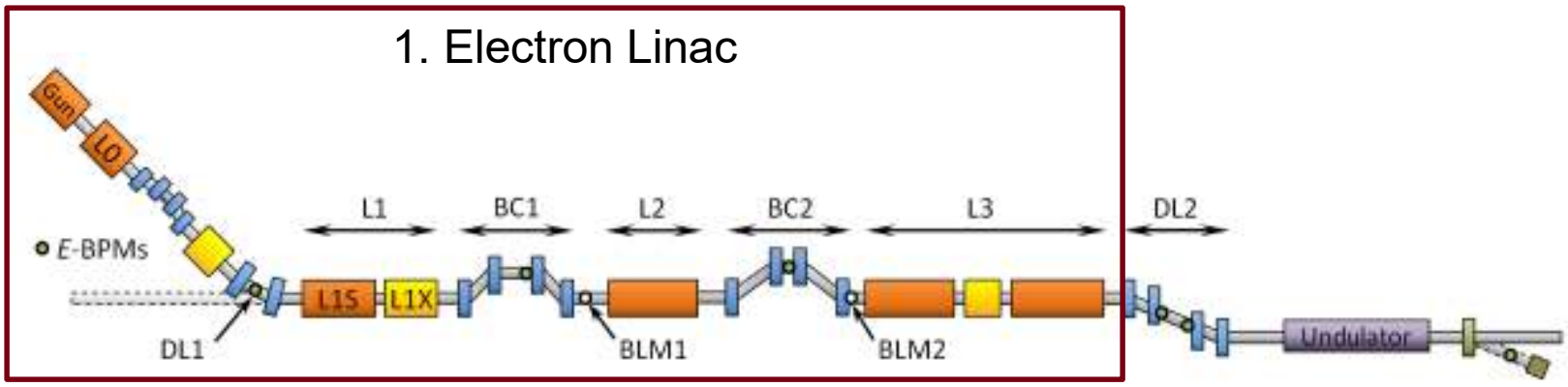
The Linac Coherent Light Source

World's first X-ray Free Electron Laser driven by a 1 km electron linear accelerator (linac)

The Linac Coherent Light Source

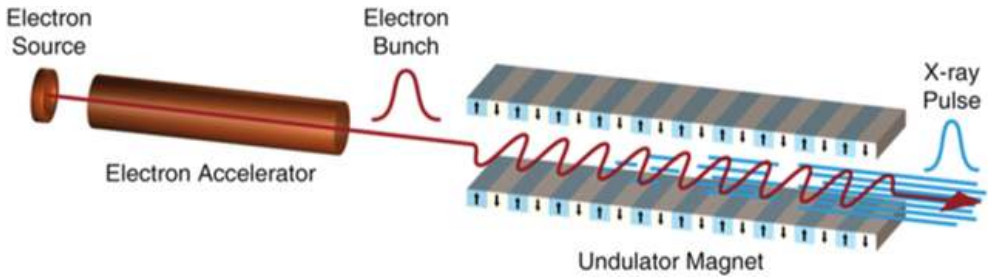
1. The electron linac produces extremely dense, short (10^{-15} seconds) electron bunches accelerated to nearly the speed of light. The very high energy is achieved by the bunches "riding the RF wave," a burst of extremely high-voltage GHz-wave in 1 km of RF cavities powered by RF stations.



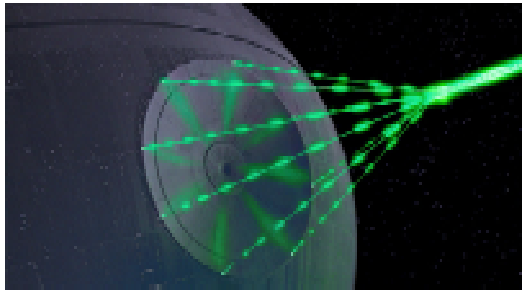


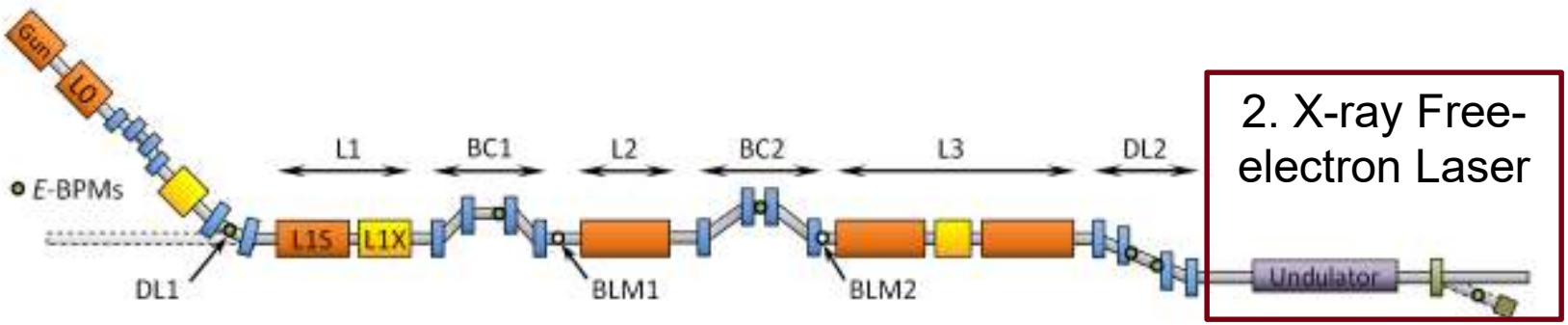
The Linac Coherent Light Source

2. The bunch is then injected in a 130 m long “magnetic undulator.” This shakes off X-rays that eventually re-interact with the bunch and self-amplify. Result: A burst of ultra-fast, extremely intense and coherent X-rays for studying biological, chemical, and material science on molecular time and space scales.



An *X-ray Free-electron Laser*



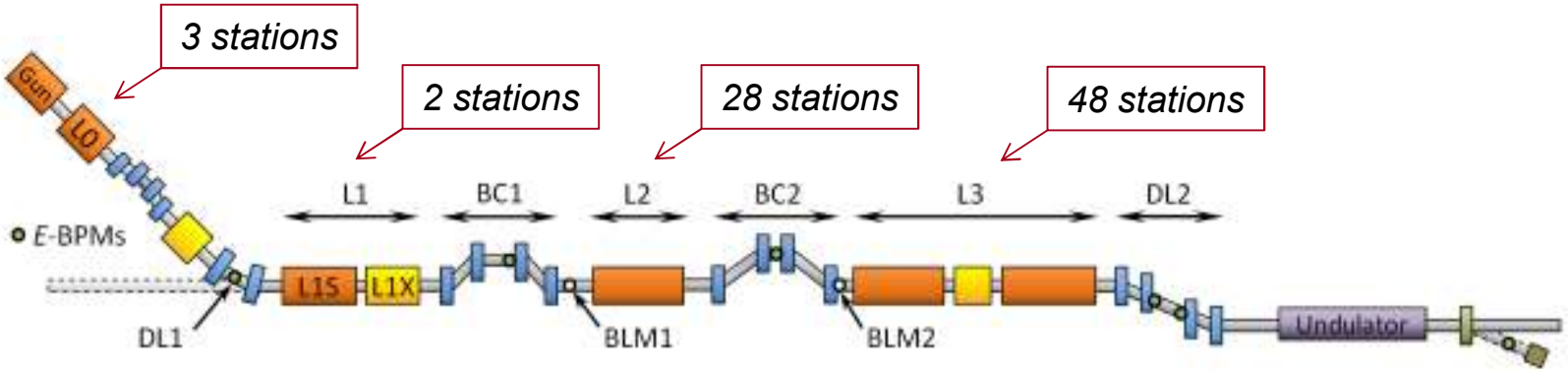


2. X-ray Free-electron Laser

About those RF stations…

There are a lot of them! They're grouped by sub-linacs as well as "sectors." Sub-linacs are:

- L0 = Special – The GUN, L0A and L0B
- L1 = Special – L1S and L1X
- L2 = 28 variously indexed RF stations
- L3 = 48 variously indexed RF stations



About those RF stations…

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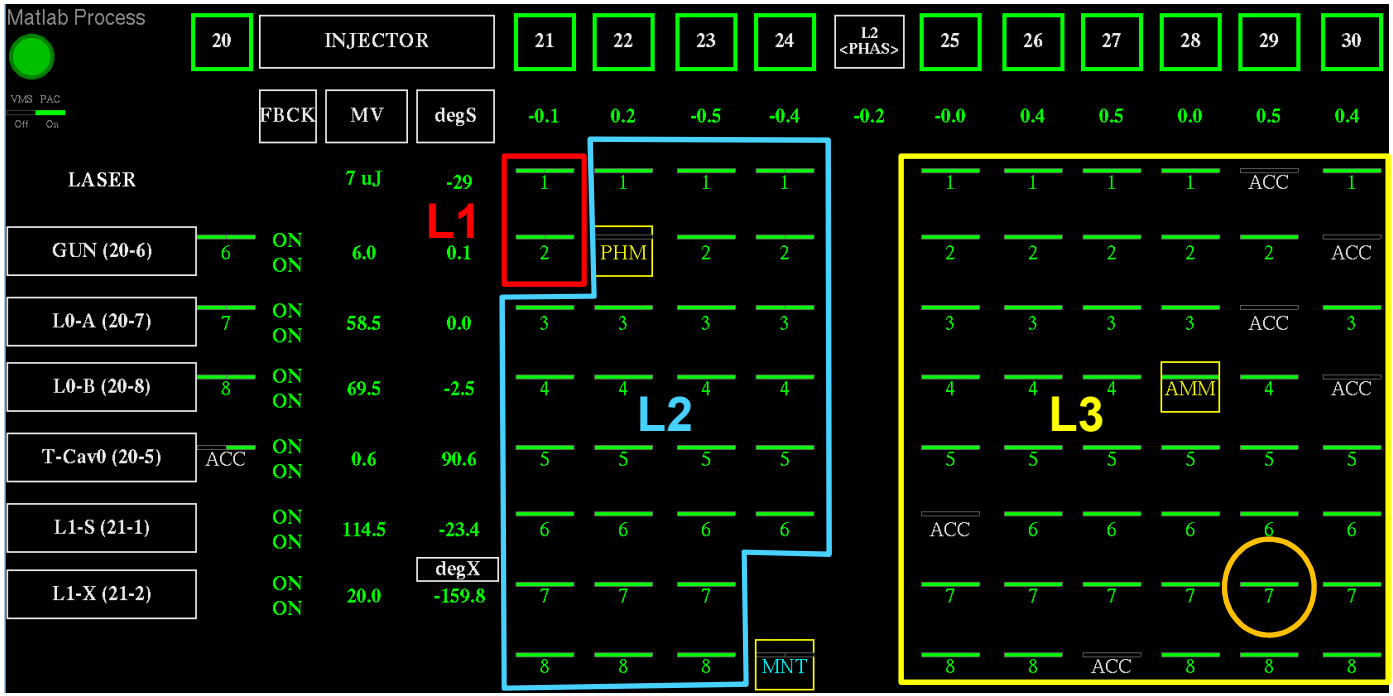
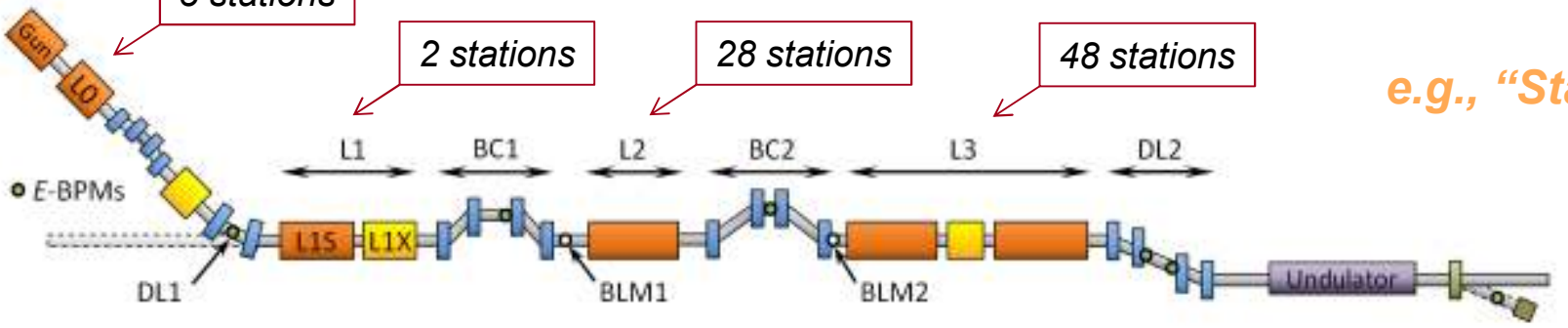
"Sectors" are 21 through 30 with 8 stations per sector



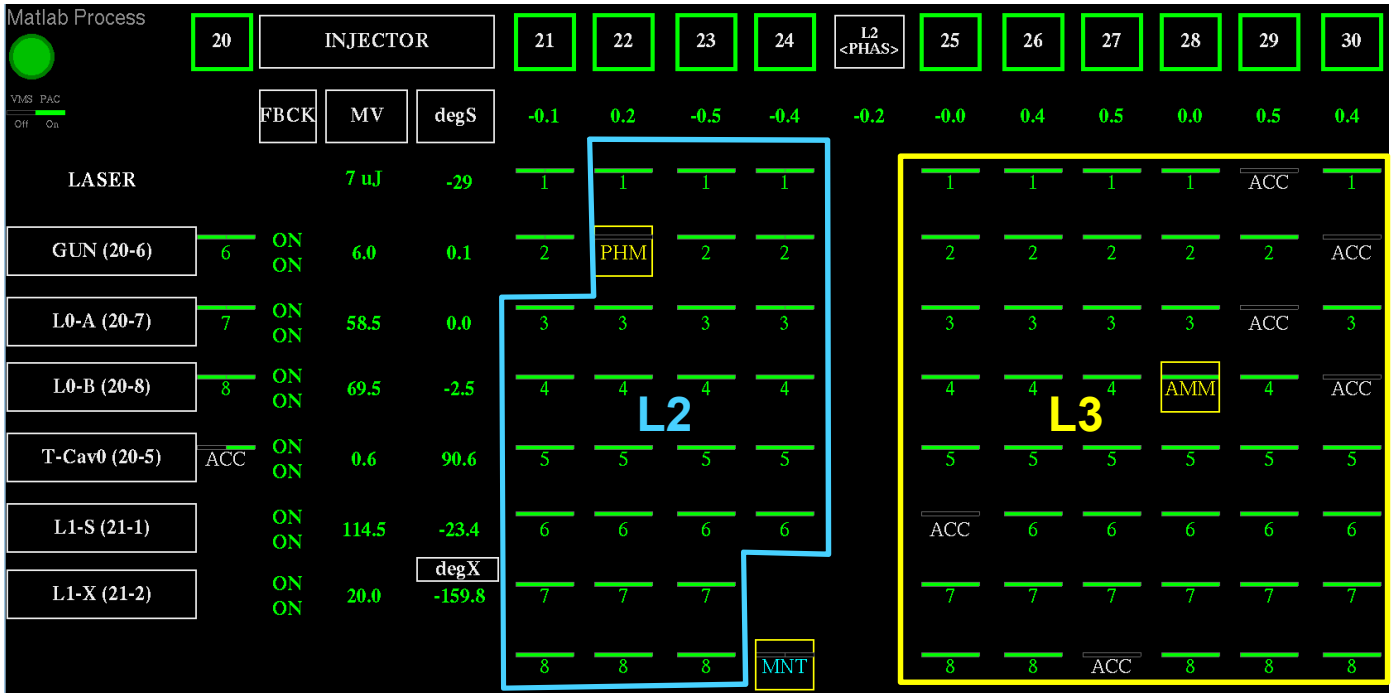


e.g., "Station 29-7"

RF Stations

For our scope, I suggest:

1. Focus only on stations in L2 and L3 (mostly all the same)
   - 21-3 through 24-6, and 25-1 through 30-8 (excluding 28-2)
2. Consider *each station* a separate, trainable case study, but what is learned can apply equally to all the other stations



So what's in an RF station?

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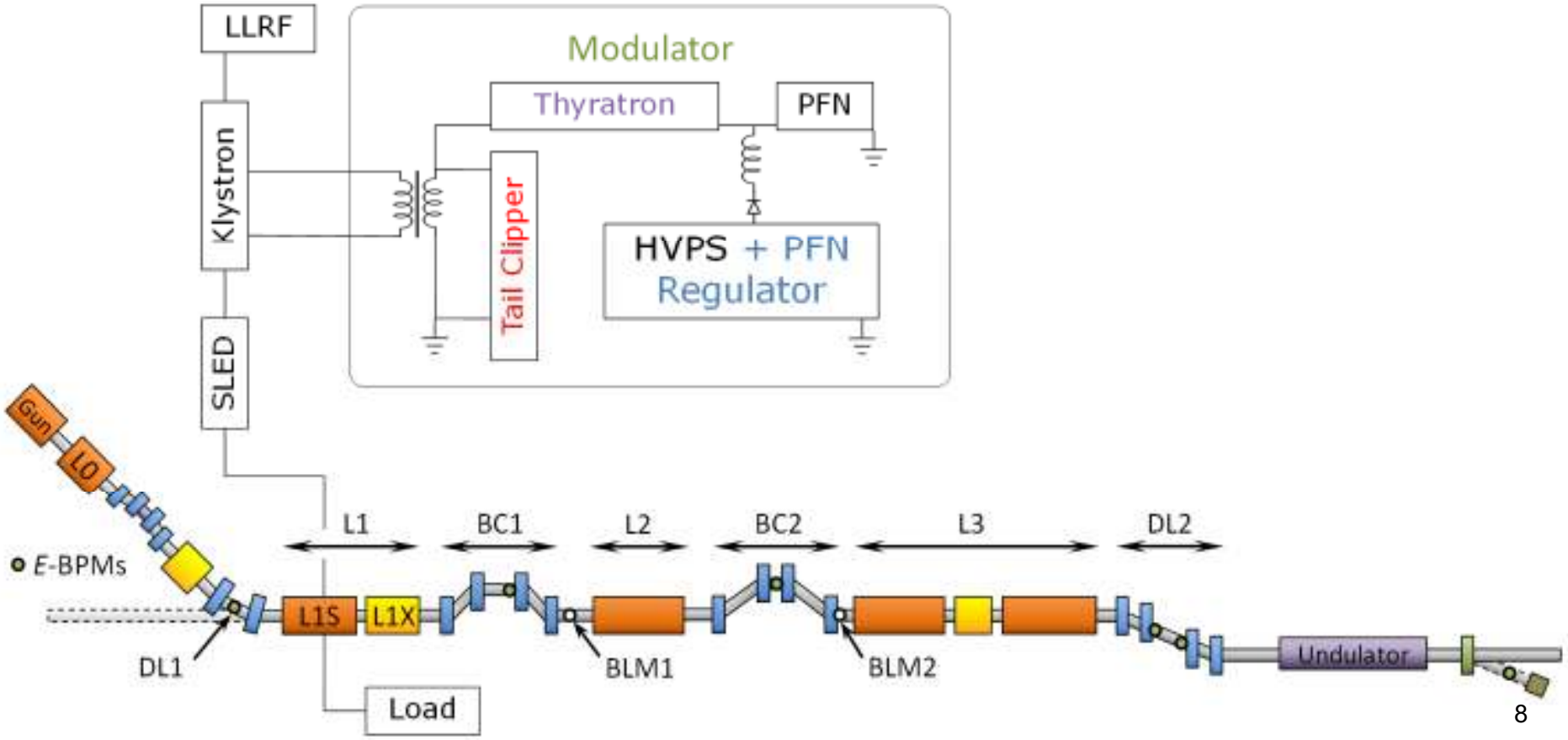
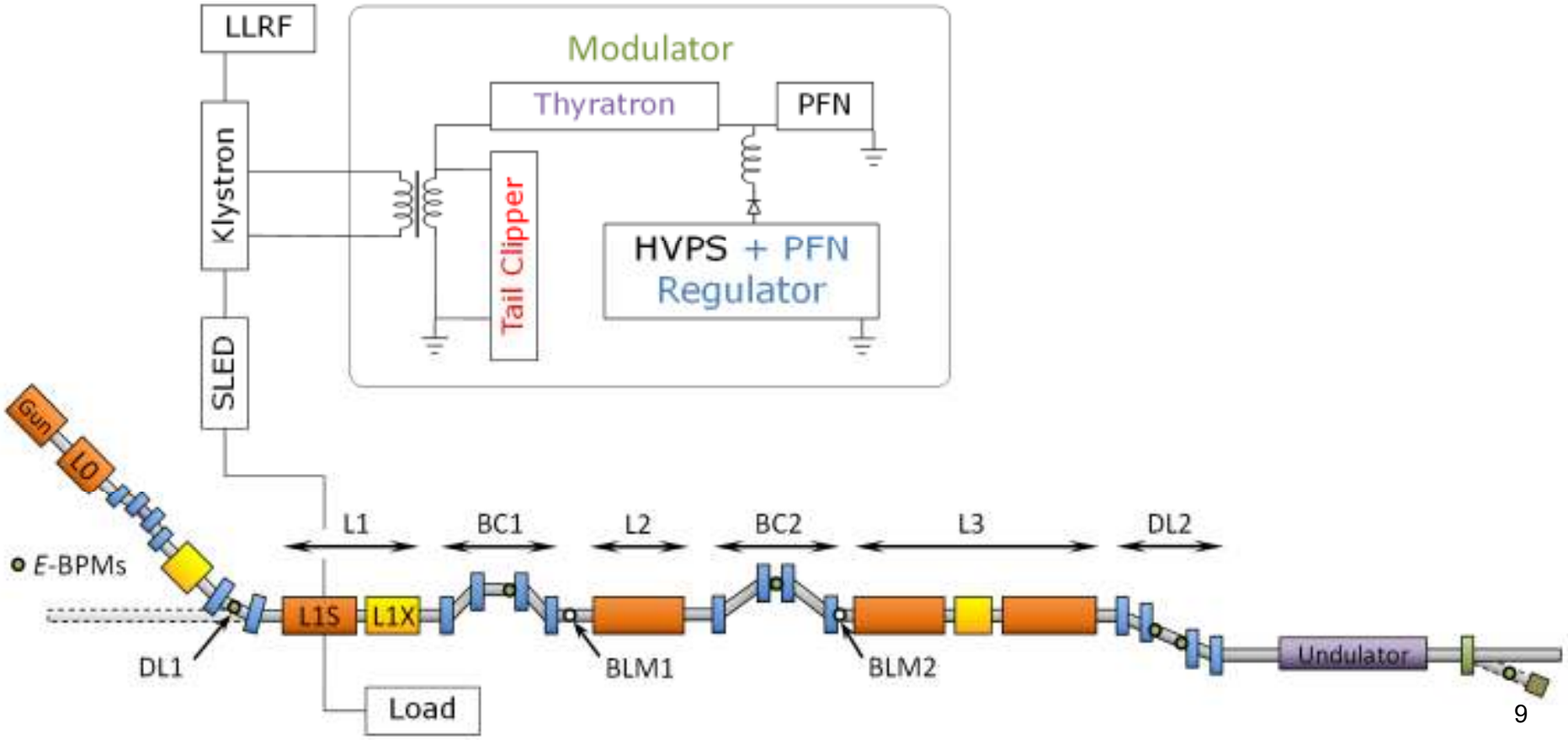
An RF station is comprised of many complex, high-powered, *expensive* components that all require regular maintenance and tuning. Given there are so many, *automated detection and reporting of regularly occurring anamolous signals to predict maintenance needs or impending failures would be of extreme value to the scientific program.*



An RF Station

Overview of working station. 1) Store up high voltage power, 2) dump HV pulse into system, 3) modulate the HV pulse into a burst of RF, 4) send pulse “downstairs” to RF cavity which 5) accelerates an electron bunch before 6) terminating remaining RF power



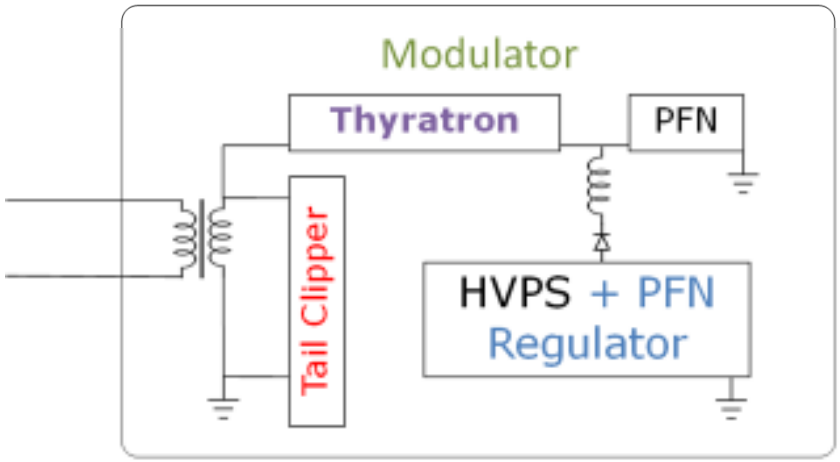
An RF Station

The Modulator has a few major components:

1. High voltage power supply (HVPS)
2. Pulse forming network (PFN) for storing up power
3. **Thyratron** – A tube that acts as a fast, very high-power switch for dumping the power out of the modulator to the next stage

While *PFN tuning* is one opportunity, the *thyratron* health and tuning is extremely important and a common component to fail. Each tube lasts about 1 – 2 years, so a couple need replacing in any given month.

We'll come back to this.



An RF Station

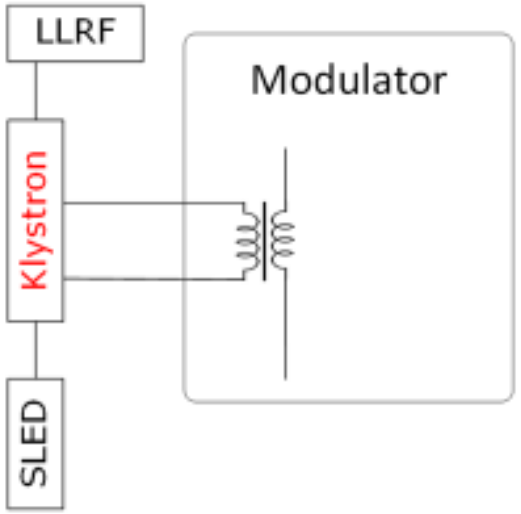
The Klystron's primary function is to convert DC pulse into RF pulse. This is another very high-voltage tube. It generates a low-energy electron plasma beam that is accelerated by the DC pulse and bunched by applying a stable, low-level RF modulation. The resulting modulated beam current drives the high-output RF from the klystron we need.

Common key parameters:

- Klystron "beam voltage" – Roughly the DC voltage applied to the tube, internal beam power
- Solenoid focus power – Magnetic field applied inside klystron for internal beam focusing

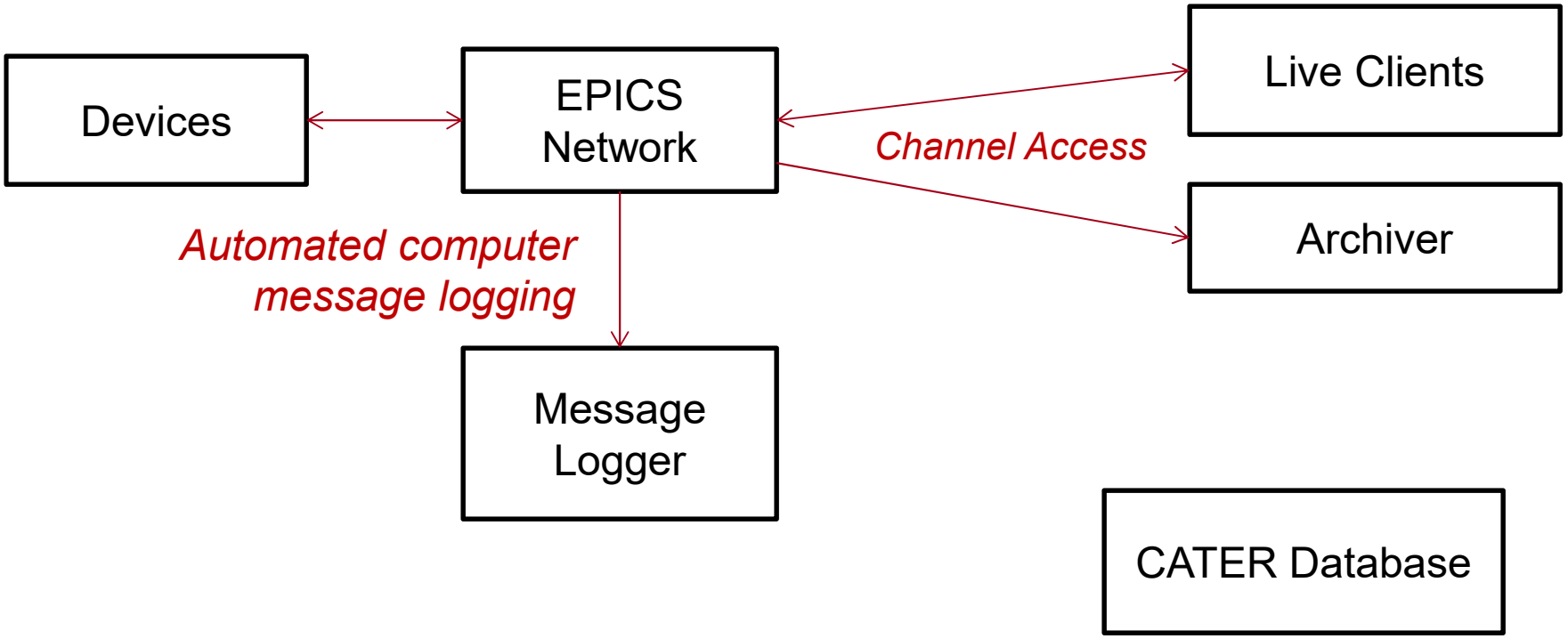
The klystron is another critical component. It's mean time to failure is quite longer than a thyratron, but replacement is costly.

Jargon warning: Frequently "klystron" and "RF station" are used interchangeably.



RF Station Data

How do we talk to these things…? Input of set values and readback of diagnostic values are via the EPICS network



Process Variables

Channel Access “Process Variables” are numbers typically

They are addressed in EPICS with naming standards:

[Device type “Primary”]:[Geographical region or “Micro”]:[Location or “Unit” number]:[ATTRIBUTE]

Example, 29-6 klystron beam voltage

KLYS:LI29:61:BVLT

Human intervention

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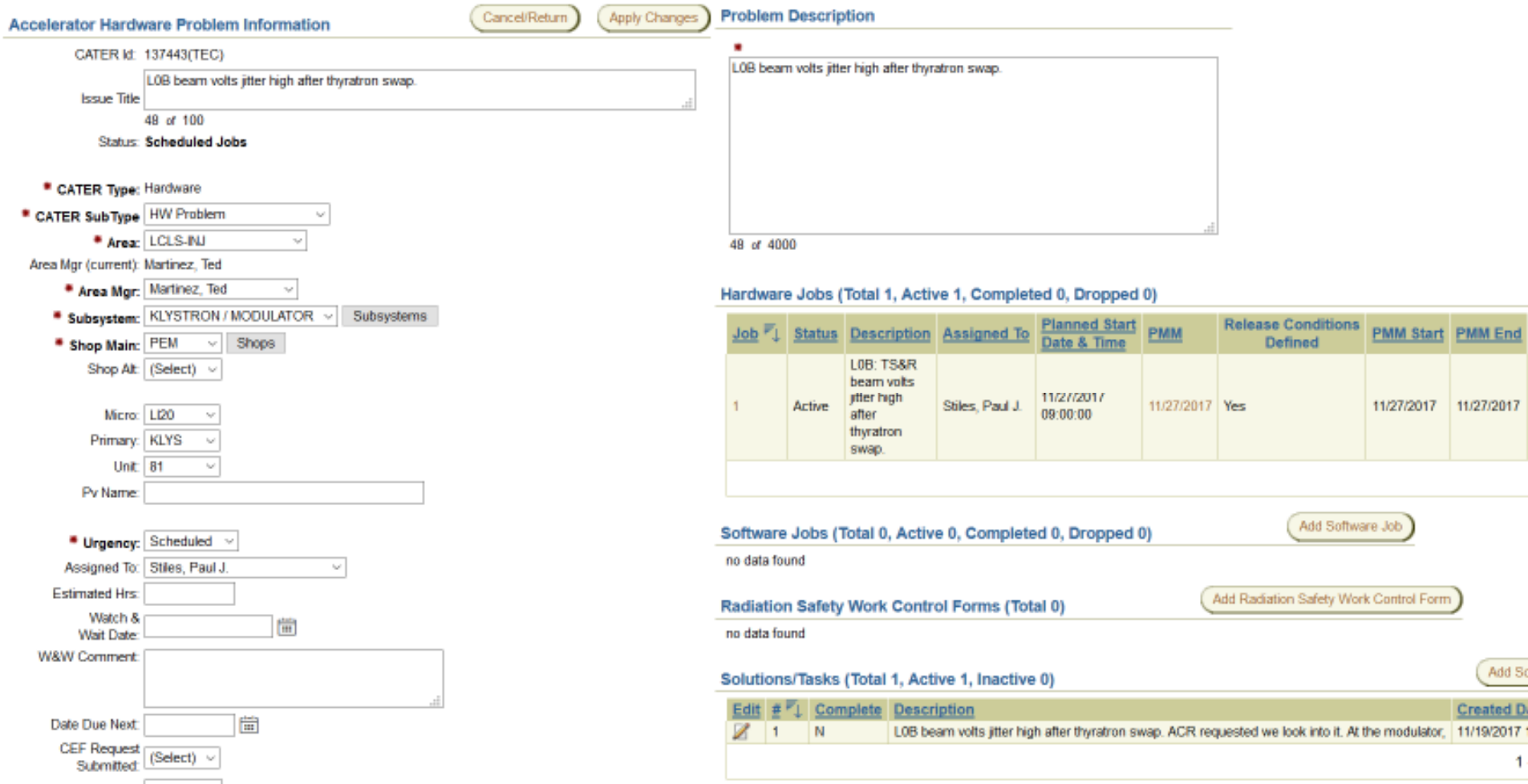
SLAC CATER system for reporting issues and solutions



Accelerator Hardware Problem Information

Cancel/Return | Apply Changes

CATER Id: 137443(TEC)

Issue Title: L0B beam volts jitter high after thyratron swap.

48 of 100

Status: **Scheduled Jobs**

* **CATER Type:** Hardware
* **CATER SubType:** HW Problem
* **Area:** LCLS-INJ

Area Mgr (current): Martinez, Ted

* **Area Mgr:** Martinez, Ted
* **Subsystem:** KLYSTRON / MODULATOR | Subsystems
* **Shop Main:** PEM | Shops

Shop Alt: (Select)

Micro: L20

Primary: KLYS

Unit: 81

Pv Name:

* **Urgency:** Scheduled

Assigned To: Stiles, Paul J.

Estimated Hrs:

Watch & Wait Date:

W&W Comment:

Date Due Next:

CEF Request Submitted: (Select)

Problem Description

L0B beam volts jitter high after thyratron swap.

48 of 4000

Hardware Jobs (Total 1, Active 1, Completed 0, Dropped 0)

Job	Status	Description	Assigned To	Planned Start Date & Time	PMM	Release Conditions Defined	PMM Start	PMM End
1	Active	L0B: TS&R beam volts jtter high after thyratron swap.	Stiles, Paul J.	11/27/2017 09:00:00	11/27/2017	Yes	11/27/2017	11/27/2017

Software Jobs (Total 0, Active 0, Completed 0, Dropped 0) | Add Software Job

no data found

Radiation Safety Work Control Forms (Total 0) | Add Radiation Safety Work Control Form

no data found

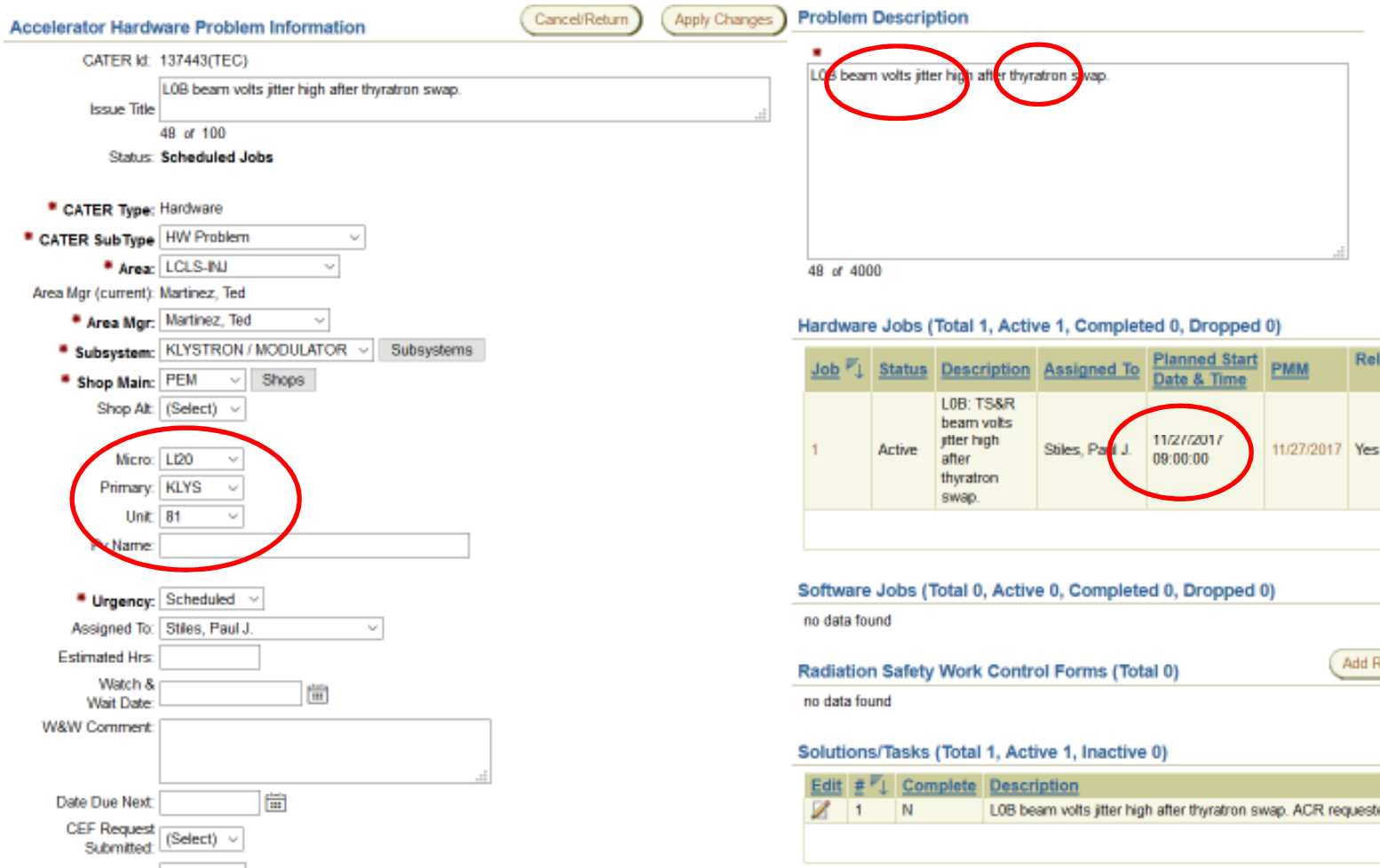
Solutions/Tasks (Total 1, Active 1, Inactive 0) | Add So

Edit	#	Complete	Description	Created D
	1	N	L0B beam volts jitter high after thyratron swap. ACR requested we look into it. At the modulator,	11/19/2017

1

Human intervention

Stations are identified and *keywords* can be found in descriptions (thyratron, klystron, beam voltage…)



Potential attack:

Archiver has numerical data (PVs), can be used for training

CATER database should be used for finding interesting data points with similar cause/solution, or confirm anamoly/failures detected

Live signals, in principle, could also be made available for faster response, but a check of health every several hours is likely sufficient for this scope

Focus on thyratron and klystron health and MTTF