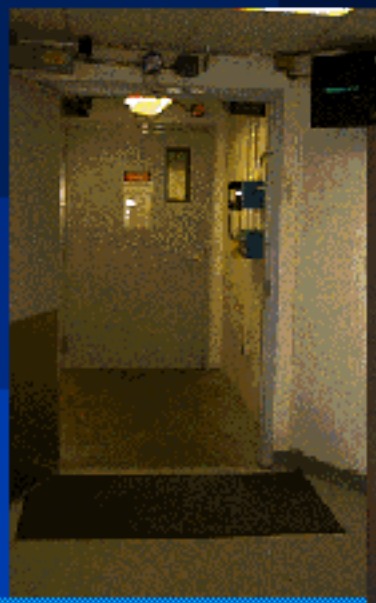
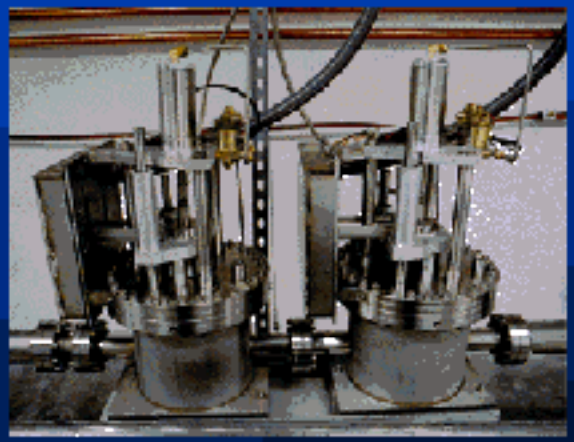
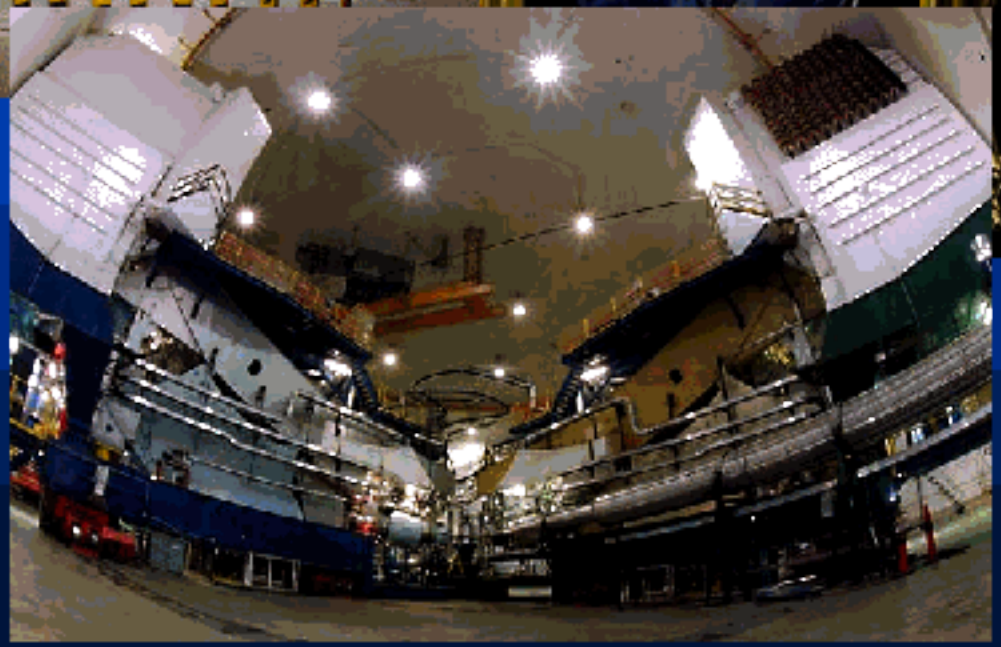



OPERATIONEL
SAFE
PUSH TO SAFE





The Safety Systems Zone

Safety Systems - How Not to Become a JLab Legend

…or…

How we Prevent Natural Selection in Your Daily Life

Outline

- What the heck is a Safety System
- What the hazard
- Personnel Safety Systems
- Laser Safety Systems
- Machine Protection Systems
- Safety Systems Group
- Lunch

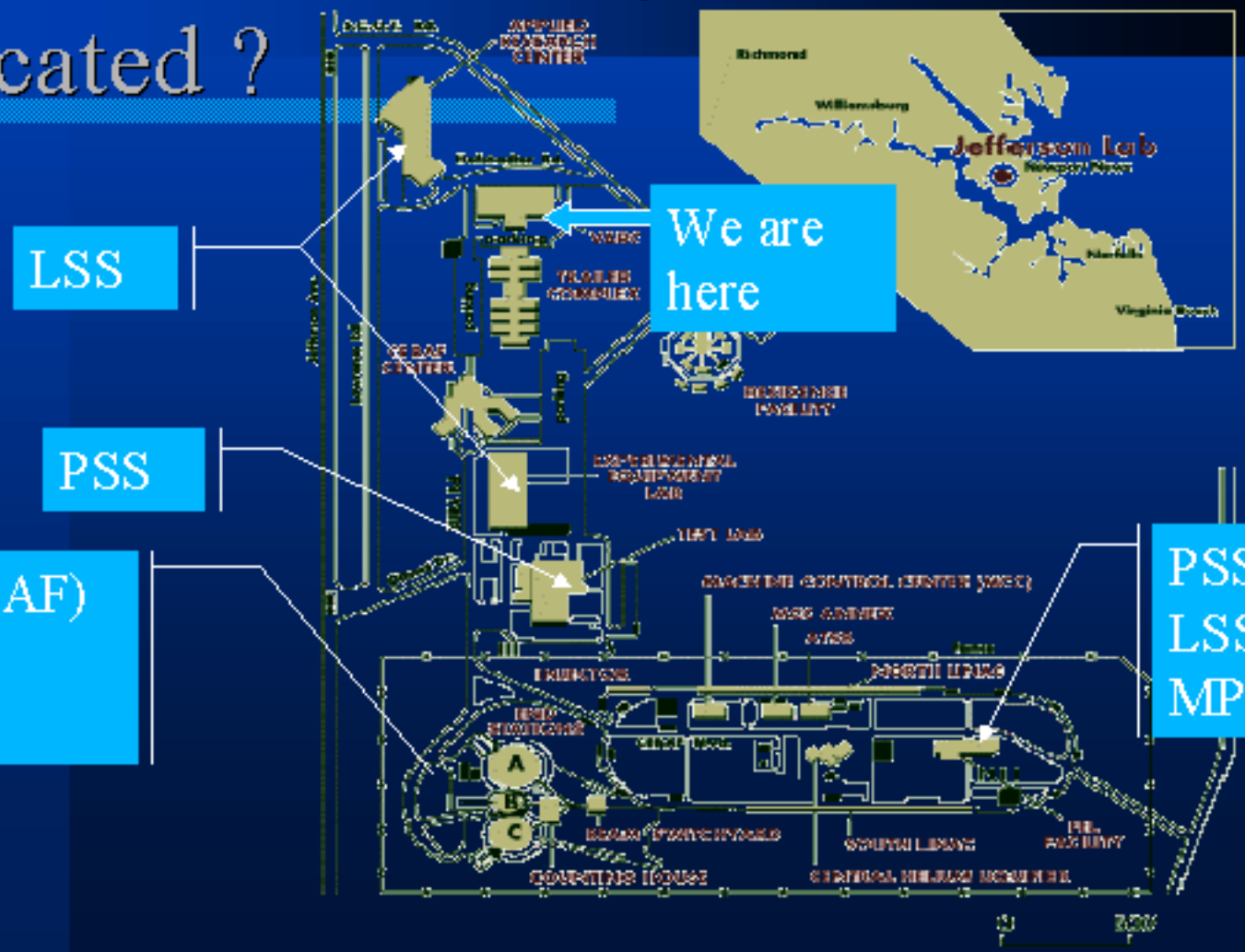
So, What is a Safety System?

- A Safety System is an electrical or electronic system which prevents hazards from hurting people or equipment
- It uses “Interlocks” that shut down equipment if people or stuff are in danger of being harmed

What Kind of Systems are at JLab?

- A Personnel Safety System (PSS) protects people from radiation and high voltage hazards
- A Laser Safety System (LSS) Protects people from high power laser hazards
- A Machine Protection System (MPS) protects equipment from beam related damage.

Where Are these Systems Located ?

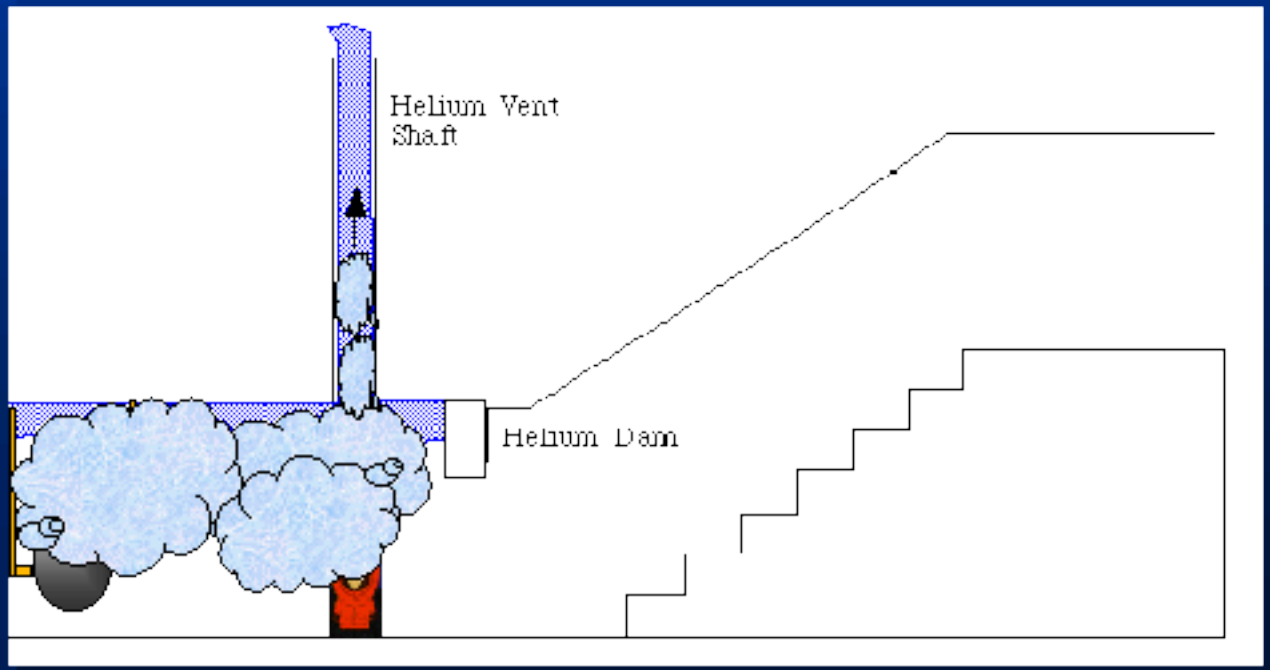


Why are they Required

- To keep people away from special hazards while the accelerator is running
- To keep the electron beam away from people at all times.
- To protect expensive equipment from radiation damage.

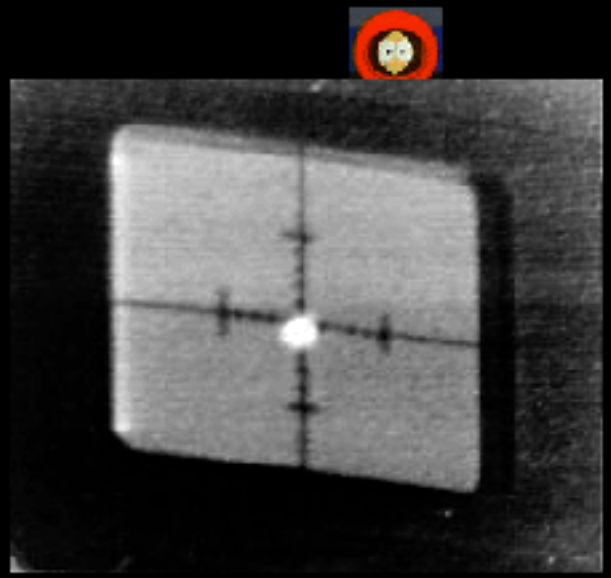
What kind of Personnel Hazards are in the tunnel when the accelerator is running ?

There is a chance of oxygen deficiency caused by a leak of of an inerting gas, such as helium.



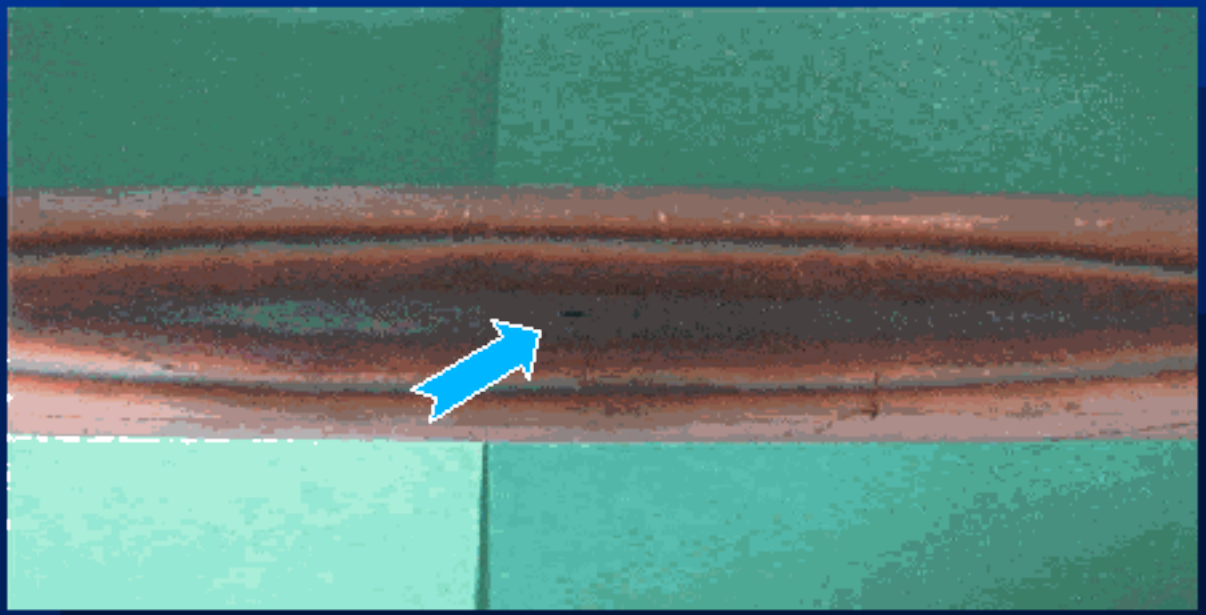
Prompt radiaiton from operation of the electron beam

Being around the beam could be "bad"...



What Kind of Equipment Hazards are there?

- **Beam can burn a hole in a beam line component in a few tens of microseconds**

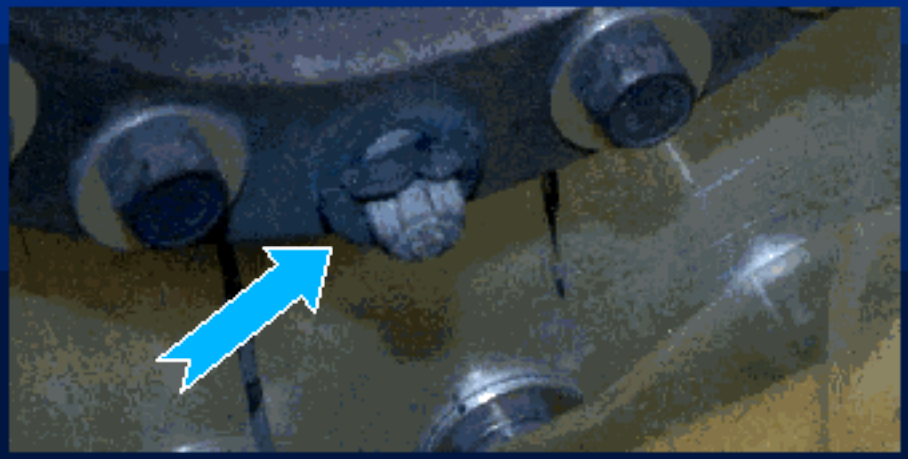



Prompt radiation and high power microwaves from operation of the accelerator cavities

Electrocution from exposed conductors on the big arc dipole magnets

Equipment Damage -Cont'd

- **Low level beam loss causes equipment damage**



Equipment Damage -Cont'd

Other Contributions

- JLab PSS design is the “standard” other labs use in implementing new safety systems
- Leader in reliability based design

SSG Professional Contributions

- Sit on ISA/ANSI committee for programmable safety systems
- Consult with several other labs on PSS design
- Members of System Safety Society
- Group a DOE Subject Matter Expert (SME)

SSG duties

- Safety System design
- System Analysis
- Configuration Control
- Operator Training
- System Maintenance (and failure tracking)
- Availability Improvement

Safety Systems Group

- 2 Engineers
- 3 Technicians
- Responsible for all PSS systems
- All MPS systems

Safety Systems Who-What?

- Personnel Safety Systems
  - All - Safety Systems Group
- Machine Protection Systems
  - FSD/BLM - Safety Systems Group
  - BCA - RF Development/AES
  - Gun Interface - Injector/AES
- Laser Safety Systems
  - FEL I&C

In the Works

- Beam Envelope Limiting System
  - Measures Beam Power to each endstation
  - Manages load so that total stays under 1 MW total
  - Uses voting techniques to maintain availability
  - Due 3Q '99

Beam Current Accounting (BCA)

- Compares beam current in injector to that delivered to each endstation

  trips on > 1 μA difference

- Sets max current allowed to each experiment

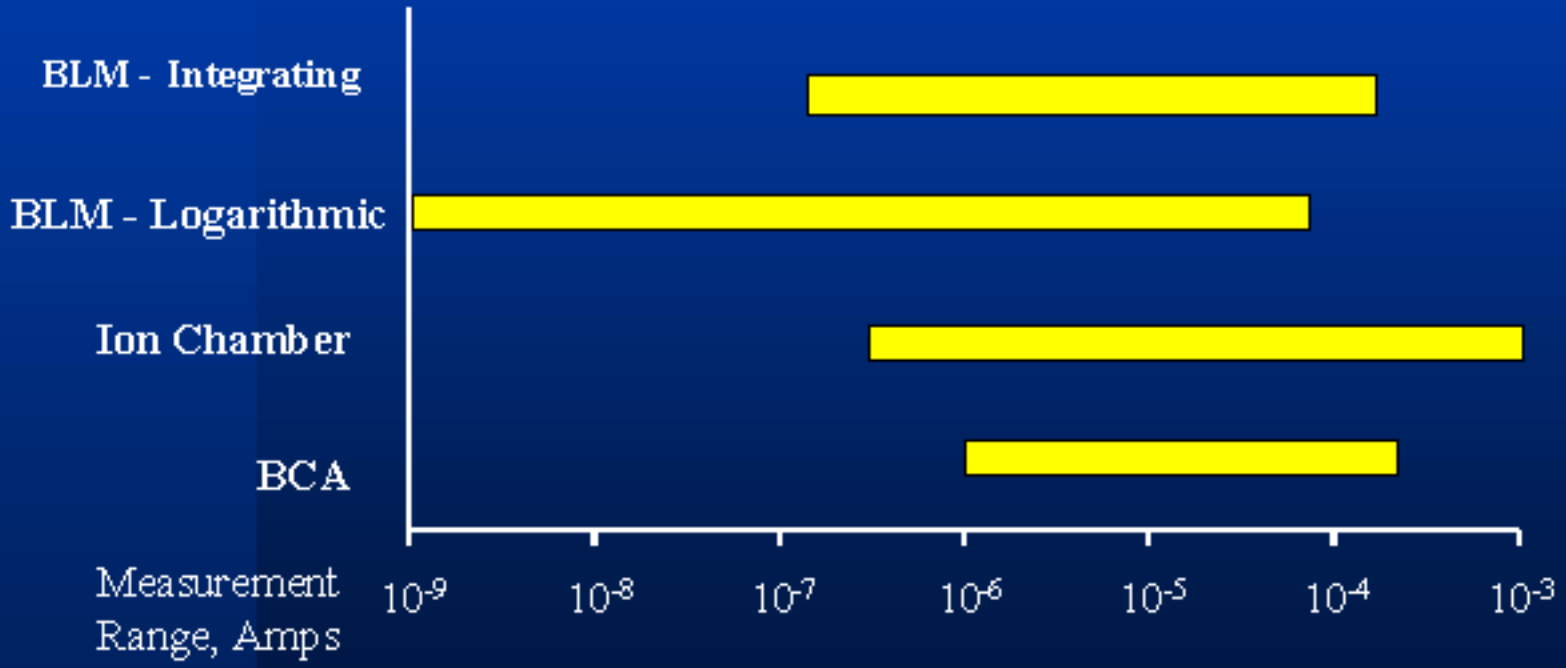
Beam Loss Ion Chambers (BLIC)

- Measures Radiation Dose Rate
- Calibrated to NIST standard
- Measures very high energy/current beam loss
- Very reliable - originally designed as a PSS instrument

Beam Loss Monitoring System (BLM)

- Photomultiplier based
- Detects particle shower from beam loss
- Used where very high sensitivity required
- Also used where single point protection needed

Sensitivity

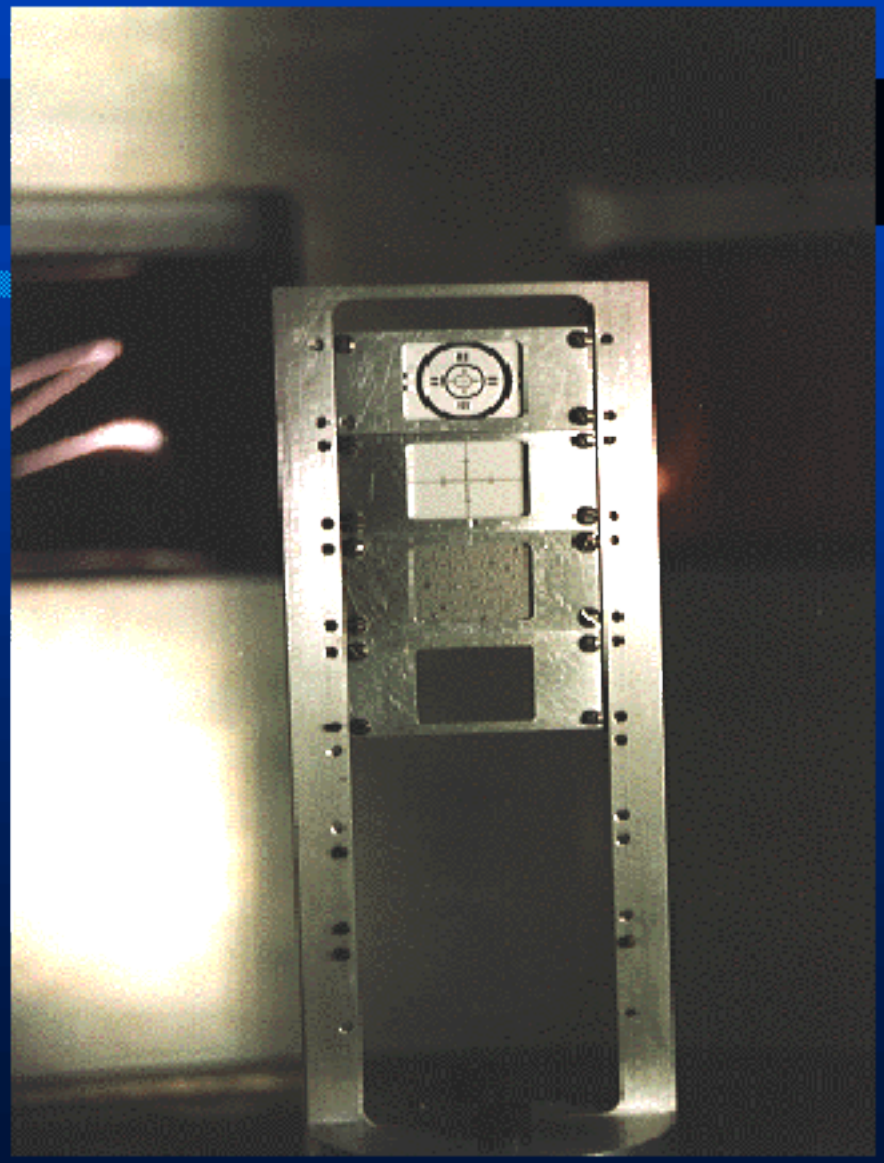


Beam Loss Detectors

- Beam Loss Monitor System
- Beam Loss Ion Chambers
- Beam Current Accounting

Example - Target Protection

FSD Senses when target ladder moves. Motion trips off beam so that target fixture is not harmed



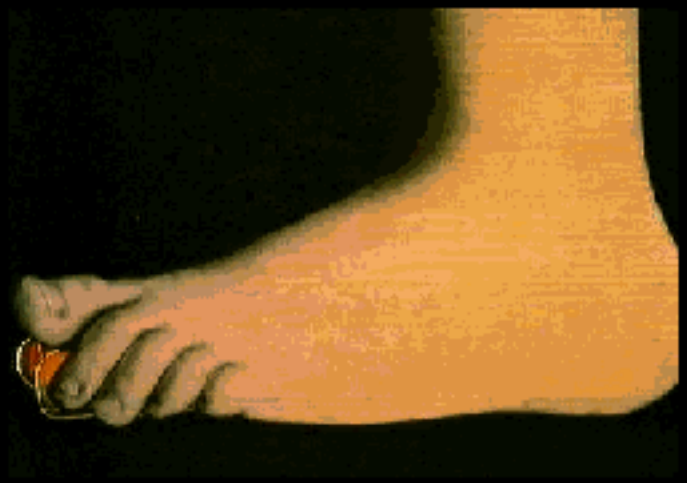
Fast Shutdown System (FSD)

- Can shut the beam down in < 20 us
- Arranged in a hierarchical structure
- Uses a 5 MHz heartbeat between nodes
- Over 50 nodes in CEBAF machine
- 9 Nodes in the FEL

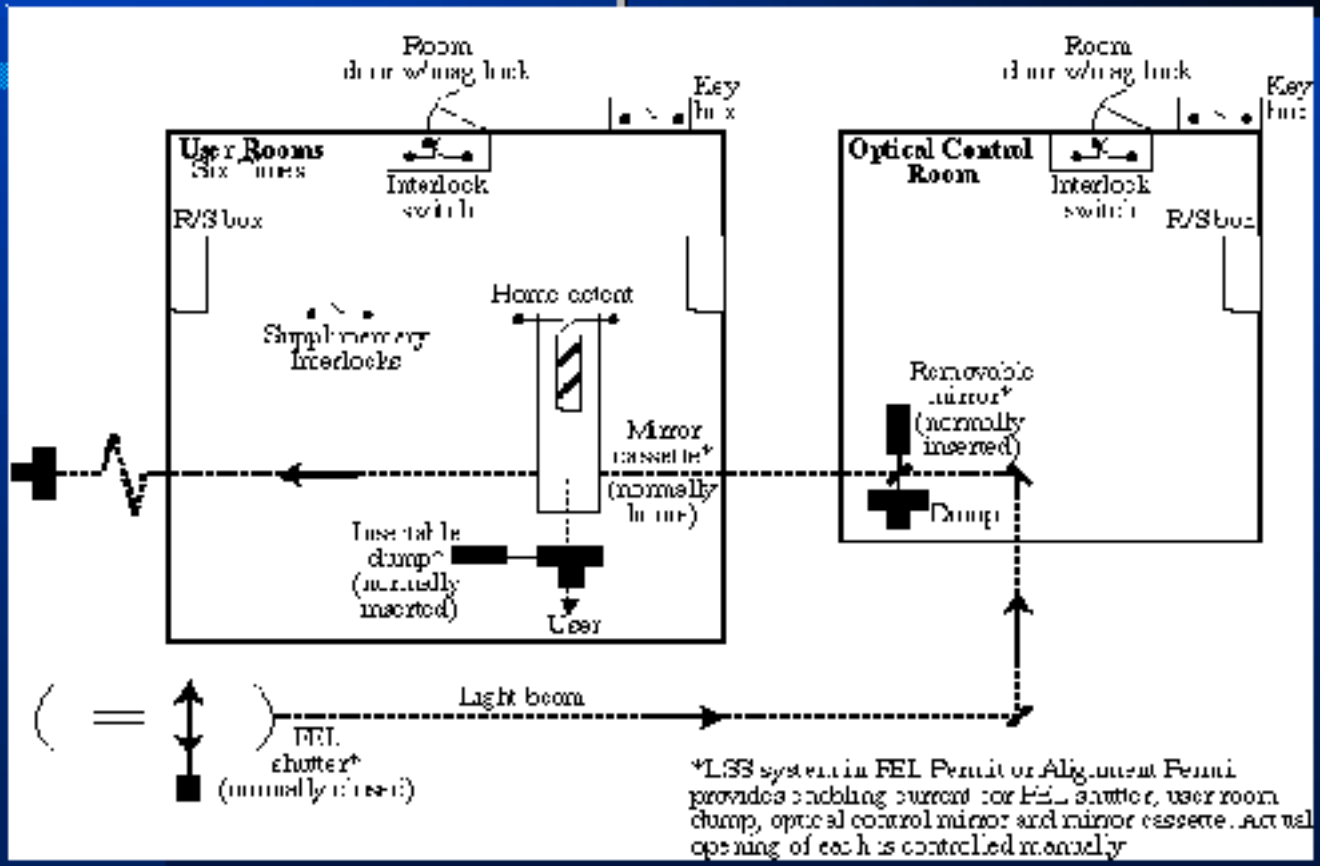
Machine Protection System

- Installed in the CEBAF and FEL
- Composed of
  - **Fast Shutdown (FSD) system**
  - **Beam Loss Monitoring (BLM) system**
  - **Beam Current Accounting (BCA) system**
- Protects stuff, not people

And now for something completely different



FEL LSS Components



Example of 100W Laser Power

FEL LSS

- Uses an electron beam to make laser light
- 1 kW Infrared 3-6 μm

Laser Safety Systems

- Used wherever a 1/2 Watt or higher power laser is exposed in a room
- Now installed in the FEL, ARC, EEL, and Hall A

Other Safety System equipment - Beam Current Monitors

- Limits max current in accelerator to < 190 μA
- Limits current at the location of a beam stopper to < 1μA
- Uses beam kickers to deflect the beam out of the pipe in < 200 μs

Safety System Layering

When there may be a hazard in the tunnel...

- Magenta Lights on outside doors flash
- Run/Safe Boxes indicate “Unsafe”
- Tunnel lights turn off (Linacs)
- A 120 Decibel siren alarms (endstations)
- If any door is opened, the system drops out

Beam Permit

- No one in allowed in the tunnel
- Beam May be operated in this area

Power Permit

No One is allowed in the tunnel.

Everything except the beam may be operated in this area.

Includes:

- **Large Magnets**
- **RF Accelerator Systems**

Controlled Access

- The tunnel has been swept. People may go in if they are logged in by the control room and take a special key, which prevents equipment from turning on.

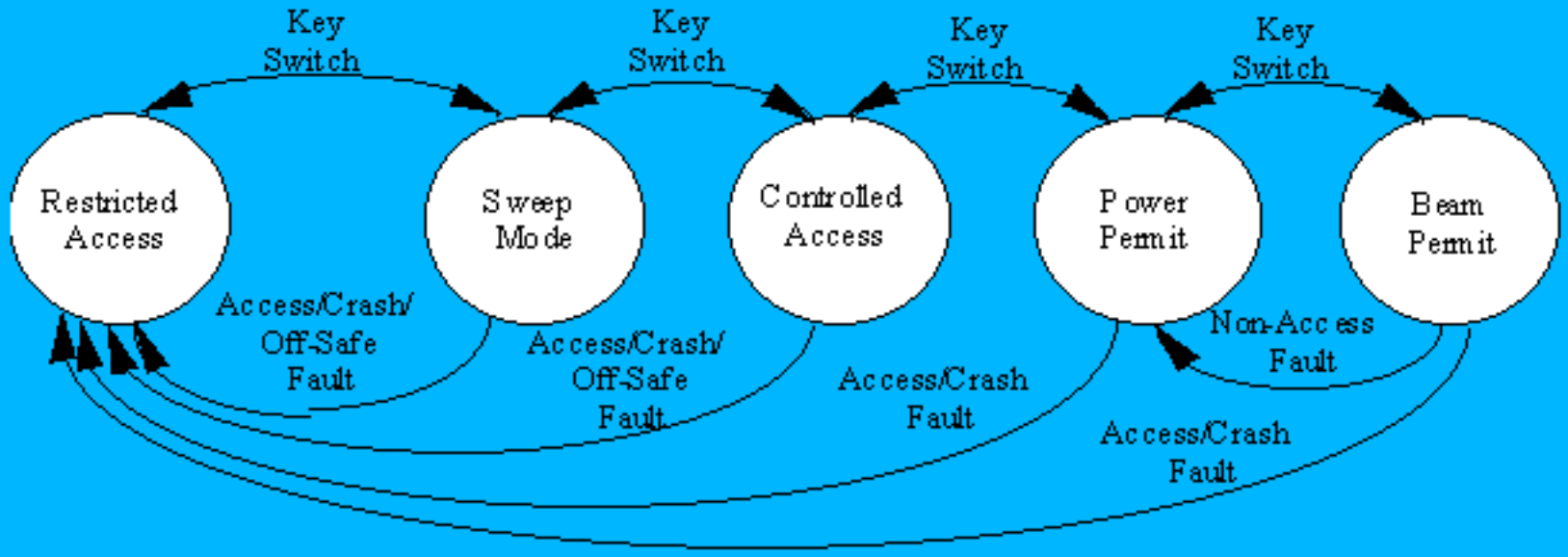
Sweep In Progress

- People are searching the tunnel to make sure no one is inside before starting beam operations
- During this operation 2-3 “sweepers” walk a predefined pattern, arming boxes as they go.

Restricted Access

- Tunnel is open for anyone with proper training.
  - **Minimum of ODH and radiation worker 1.**

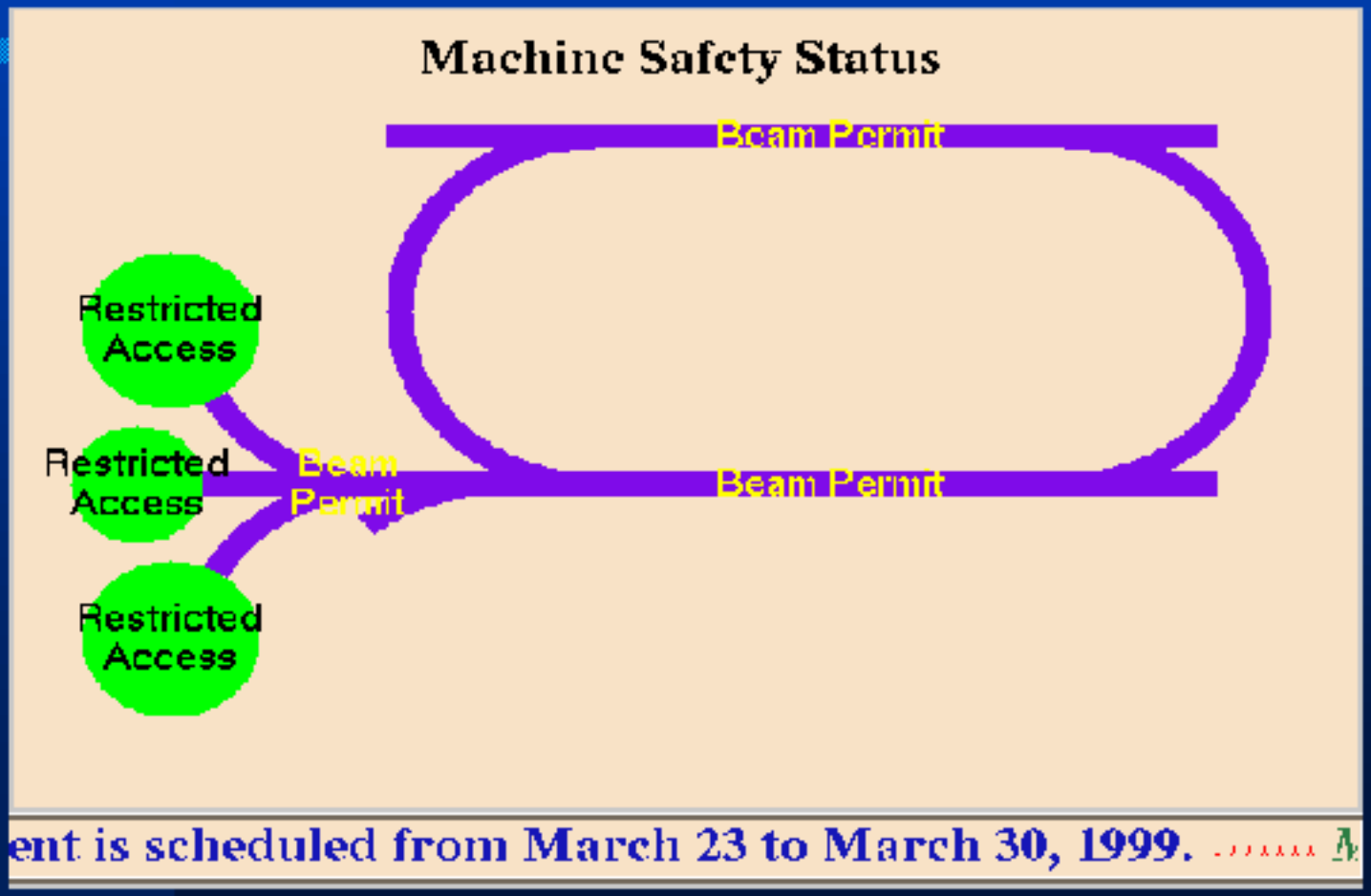
5 PSS Access States



The PSS operates in one of 5 states.

- Only the control room operator can switch to a higher state.
- Any fault, such as a door being opened, will cause the PSS to drop
- When that happens all hazardous devices are turned off.

Machine States



Example of a Safety Interlock

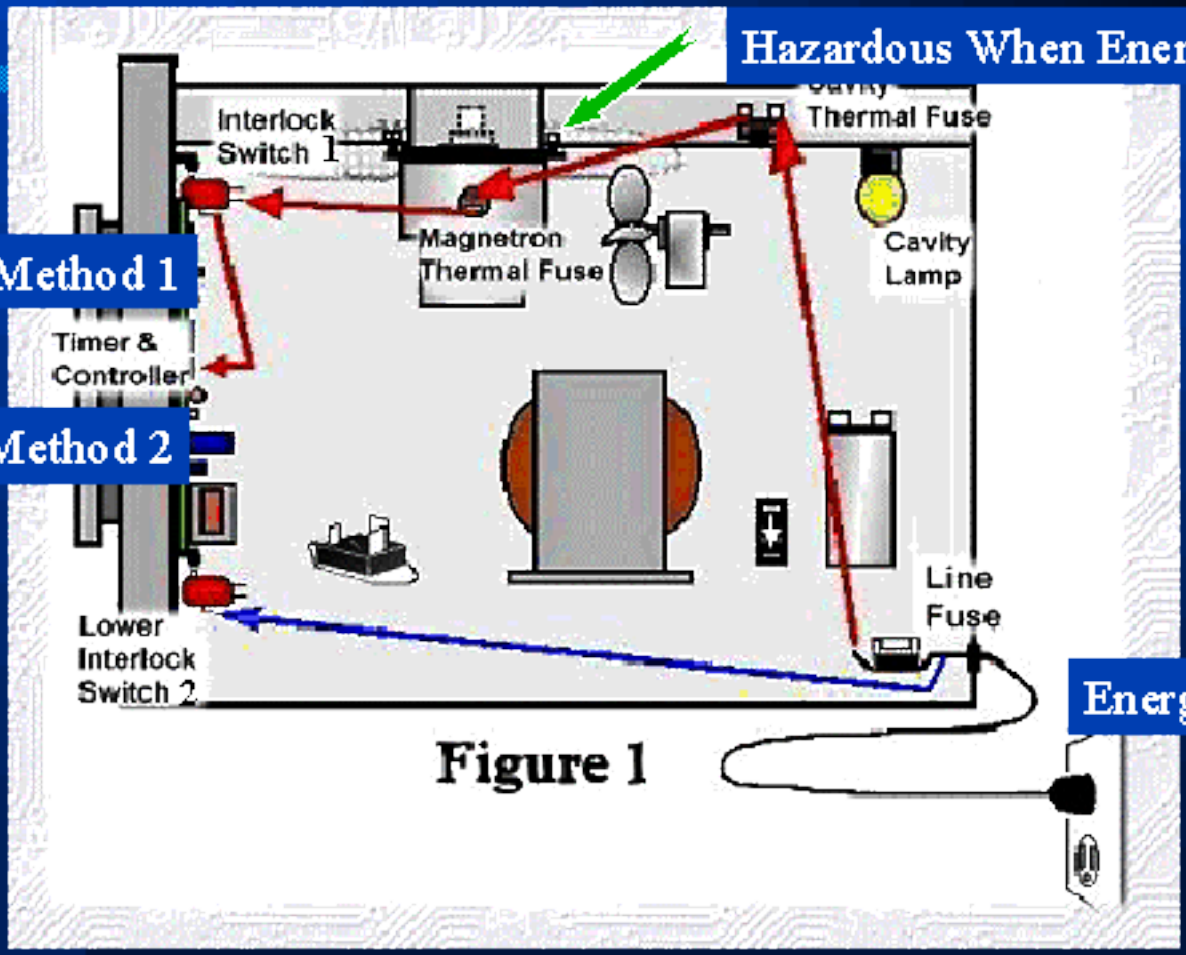
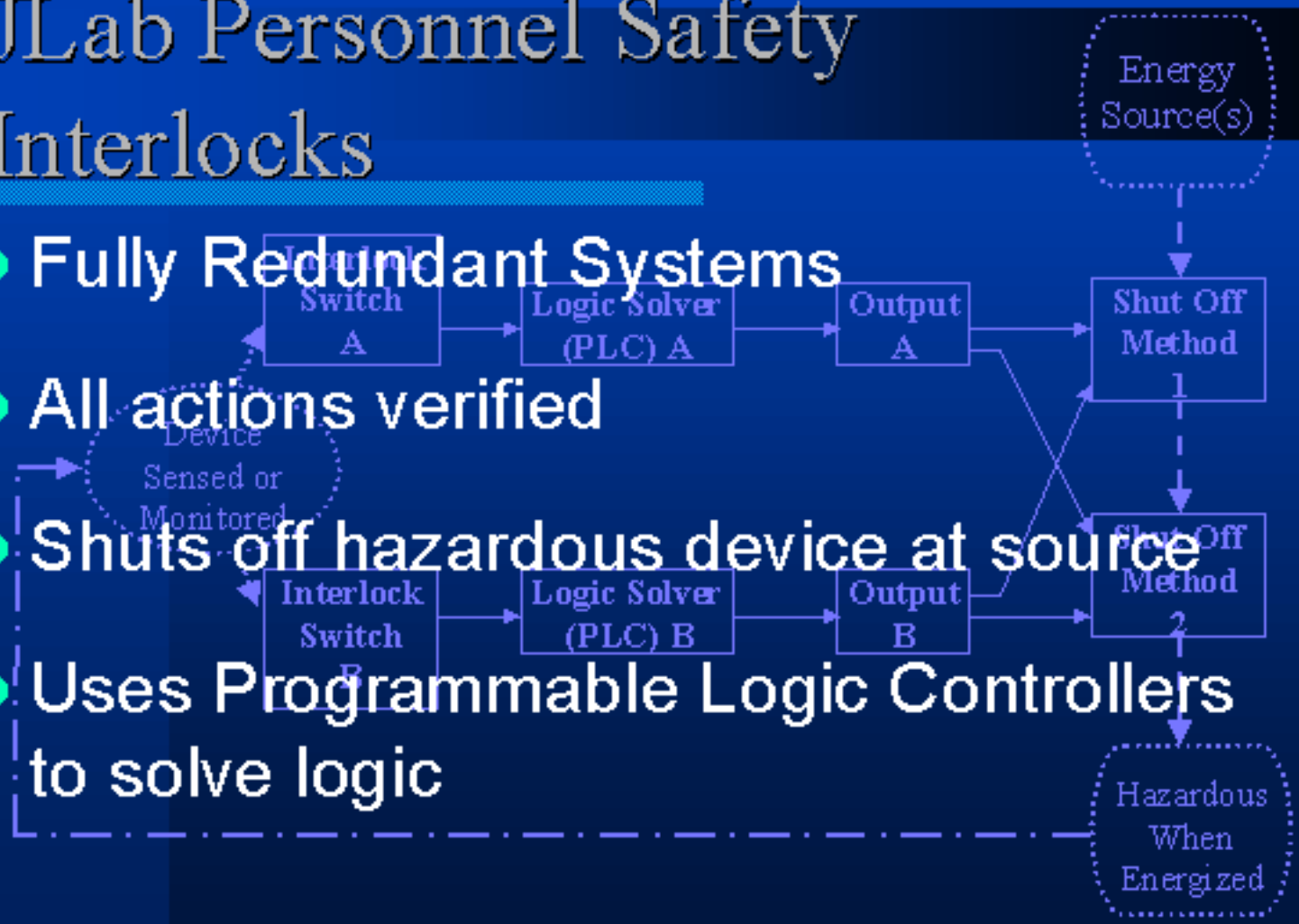


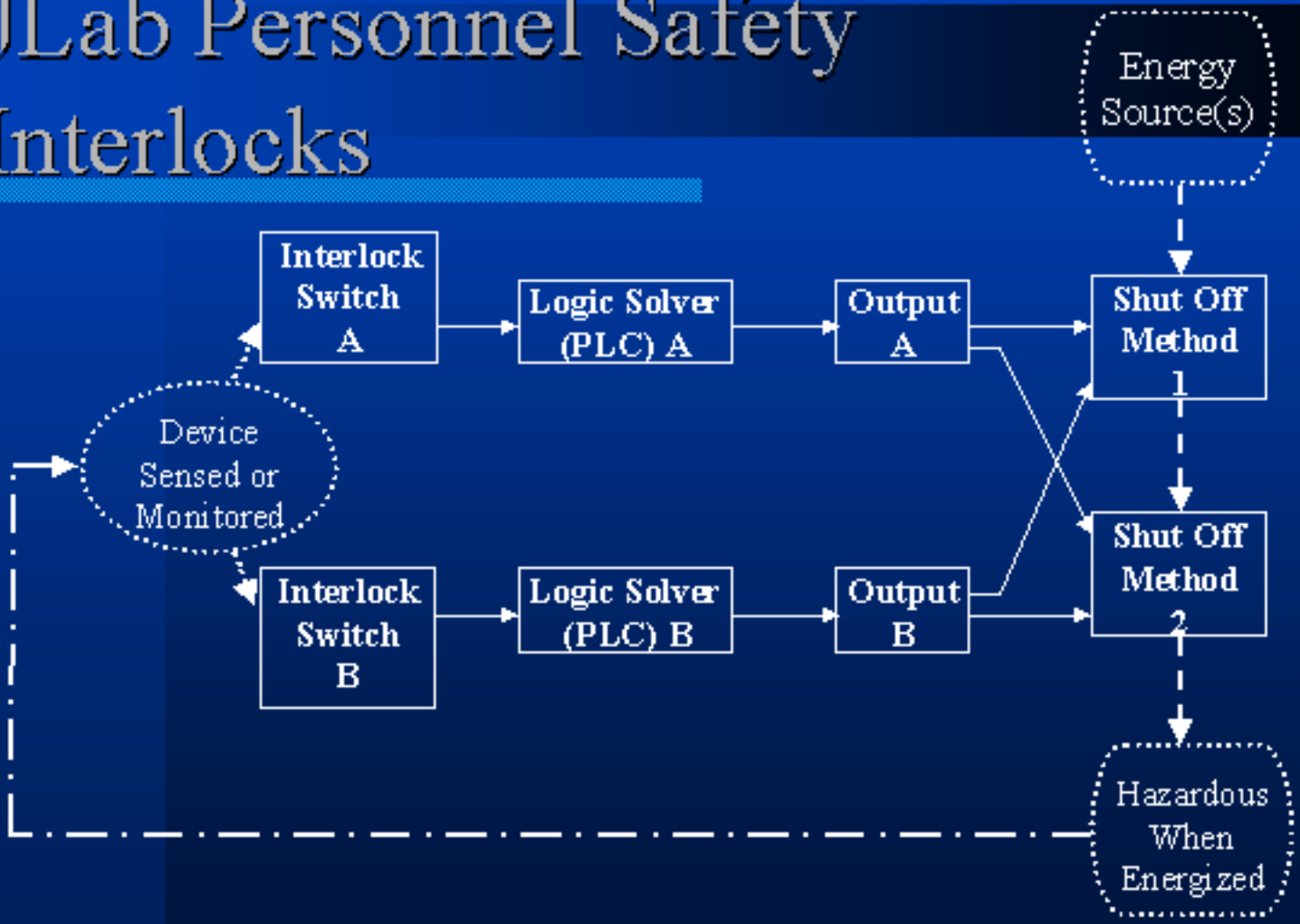
Figure 1

JLab Personnel Safety Interlocks

- Fully Redundant Systems
- All actions verified
- Shuts off hazardous device at source
- Uses Programmable Logic Controllers to solve logic

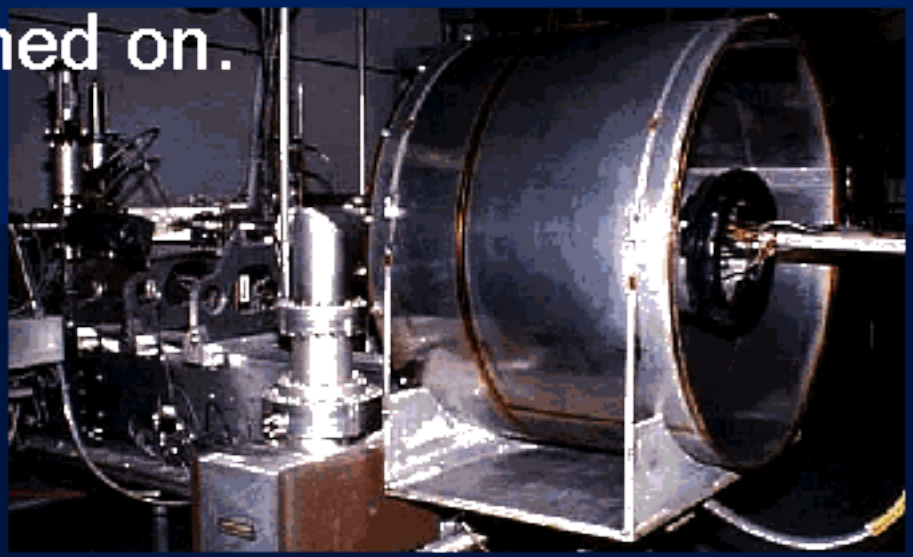


JLab Personnel Safety Interlocks



Each of these segments has it's own fully redundant Personnel Safety System

All report status back to the injector. The injector has the final say as to when or if beam is turned on.

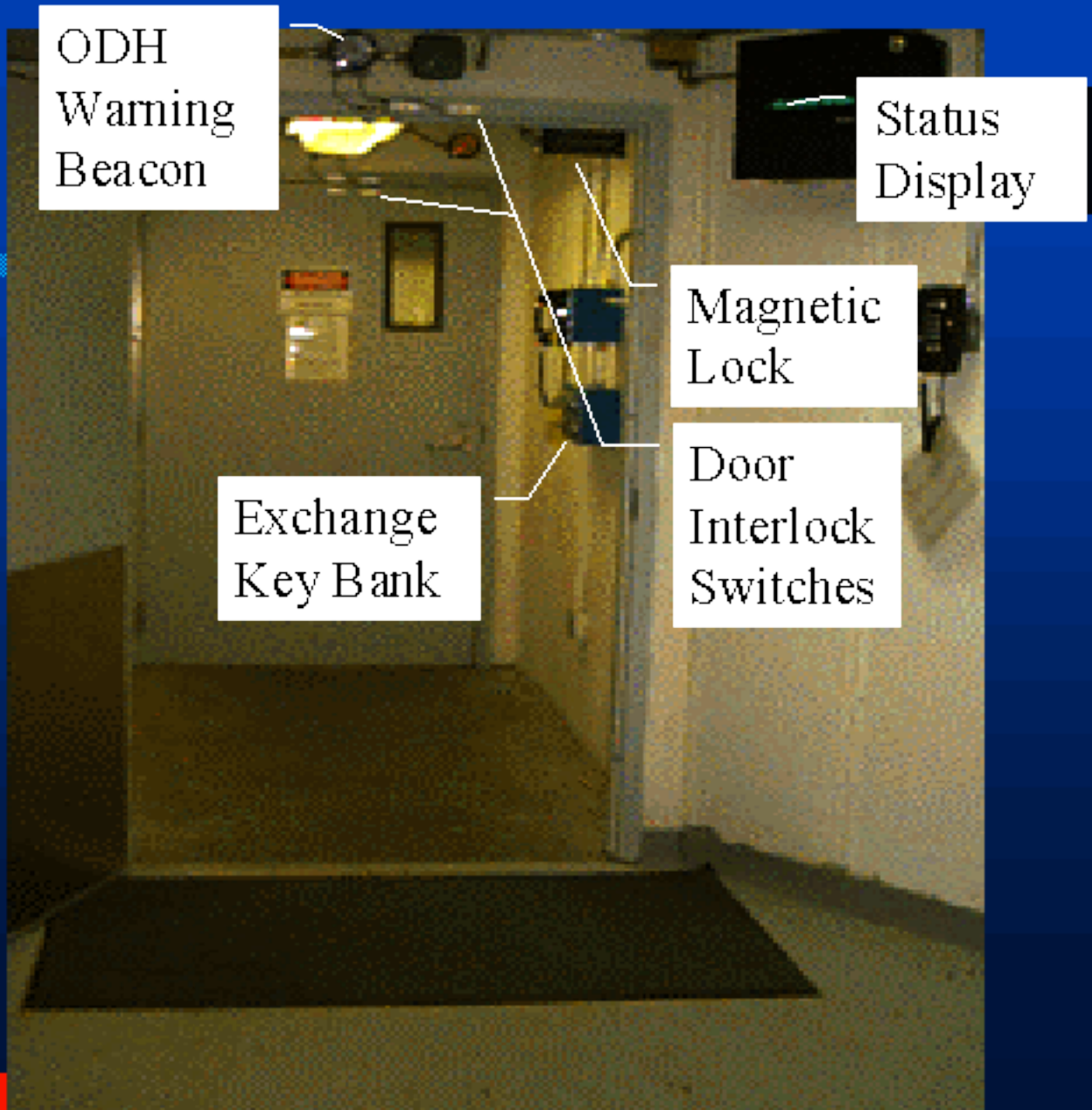


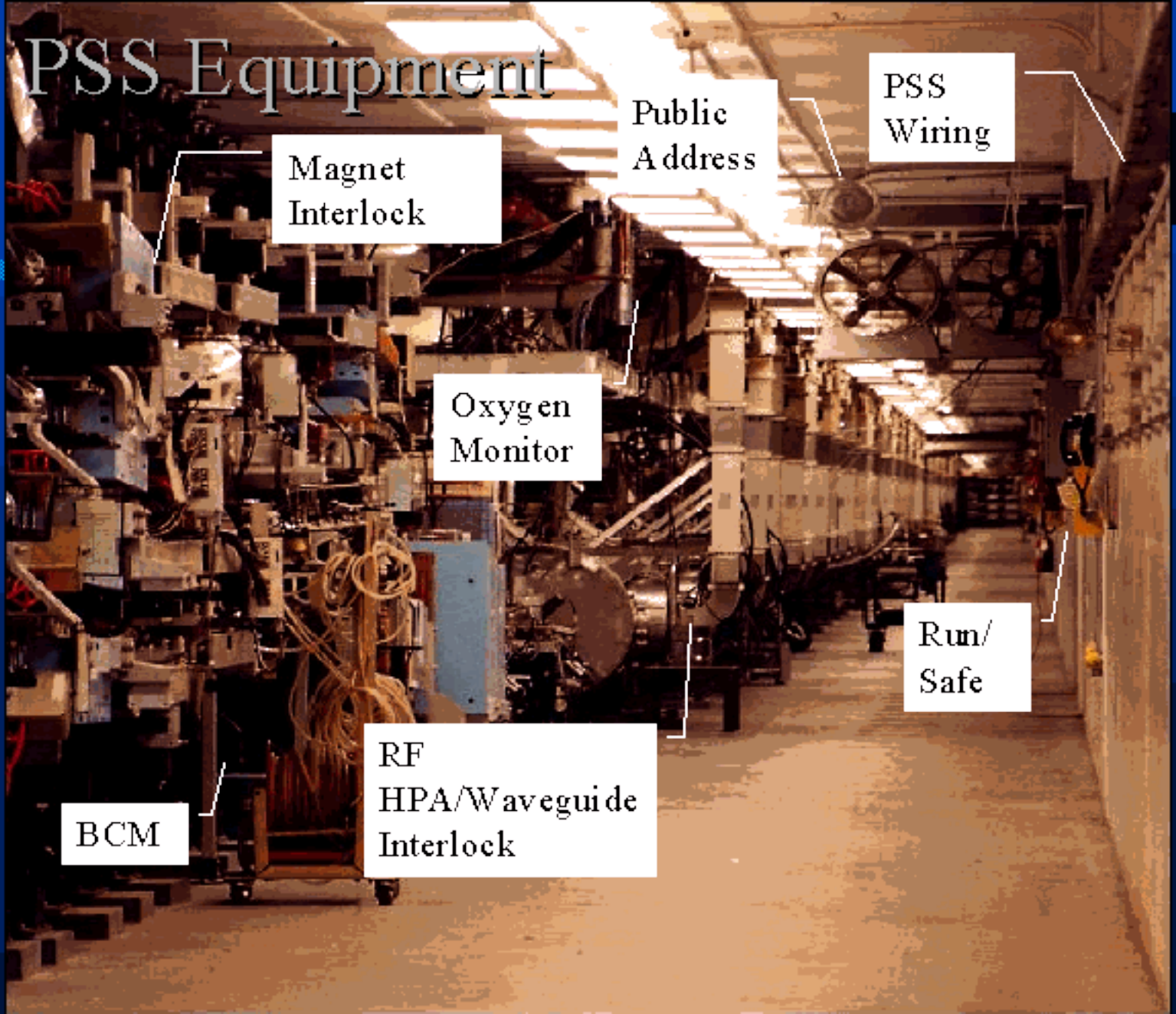
Segmentation

The PSS for the main machine divides the accelerator into 6 segments.

- North Linac
- South Linac
- Beam Switchyard (BSY)
- Hall A
- Hall B
- Hall C

More PSS Equipment




PSS Equipment
Public Address
PSS Wiring
Magnet Interlock
Oxygen Monitor
Run/ Safe
RF HPA/Waveguide Interlock
BCM

Devices interlocked through the PSS

- Electron Guns
- Accelerator/BSY Arc Magnet Power Supplies
- RF Accelerator High Power Amplifiers

PSS Measures

- Monitor the status of the tunnel entrance/exit points
- Monitor crash switches
- Monitor control inputs
- Monitor the status of hazardous devices
- Allow/Disallow hazardous device to operate based on the above

First Line (non-PSS) Measures

- Adequate passive shielding design.
- Locked gates or doors to keep personnel away from hazardous areas.
- Administrative procedures for the proper operation of hazardous devices.
- Employee awareness training on the hazards present during beam operations.
- Passive helium venting of tunnel areas.

Personnel Safety System - Cont'd

- Prevents large arc magnets from turning on if people are in the tunnel
- Sets Off alarms if oxygen level is low in high risk areas

Personnel Safety System - Cont'd

- Prevents Exposure to Prompt Radiation
- Keeps Beam Away from People and People Away from Beam
- Prevents RF from operating into an open waveguide
- Prevents Gun from turning on if people are downstream

Personnel Safety System

- Composed of the Safety Interlock Systems
- Beam Current Monitor (BCM)
- Oxygen Deficiency Monitor (ODH) system
- Over 2,500 inputs/outputs

Any idiot would know that you're not supposed to go through a door with radiation on the other side. Why are all these extra interlocks required?

At Jefferson Lab we don't have just any idiots.

We borrow techniques from each of these industries to incorporate into our systems

PLCs
Safety
Standards

Software
Evaluation
Techniques

System
Segmentation
PLC Logic

Voting
Techniques
Software
Structure

How do the JLab safety systems compare to those in other occupations ?

- The radiaiton aspect is similar to that in medical accelerators
- The redundant programmable controller arrangement is similar to that used in chemical factories
- The tunnel segmentation is similar to that used by railroad segment safety switching systems

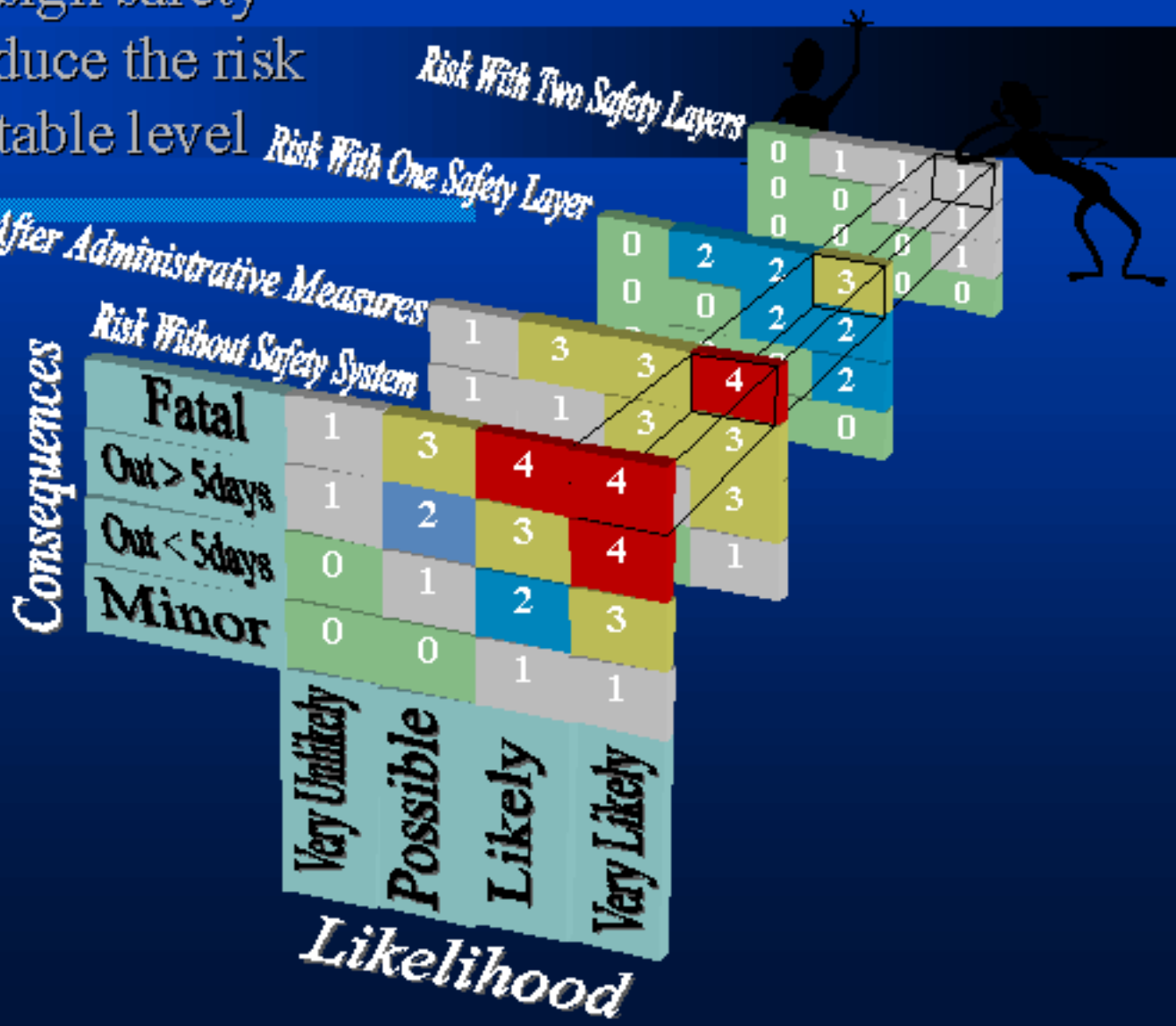
How do JLab's safety systems compare to those of other labs ?

- We are pretty much the same as other new labs in most respects
- The "Continuous" aspect of our beam makes fast protection more critical than most places
- Because we use electrons, we don't have as much of a problem with lingering radiation (activation) as labs that use heavy particles

How do the Safety Systems Compare in Reliability ?

- **PSS - No failure in 4,380,000 hours (500 years)**
- **LSS - No failure in 876,000hours (100 years)**
- **MPS - No failure in 8760 hours (1 year)**

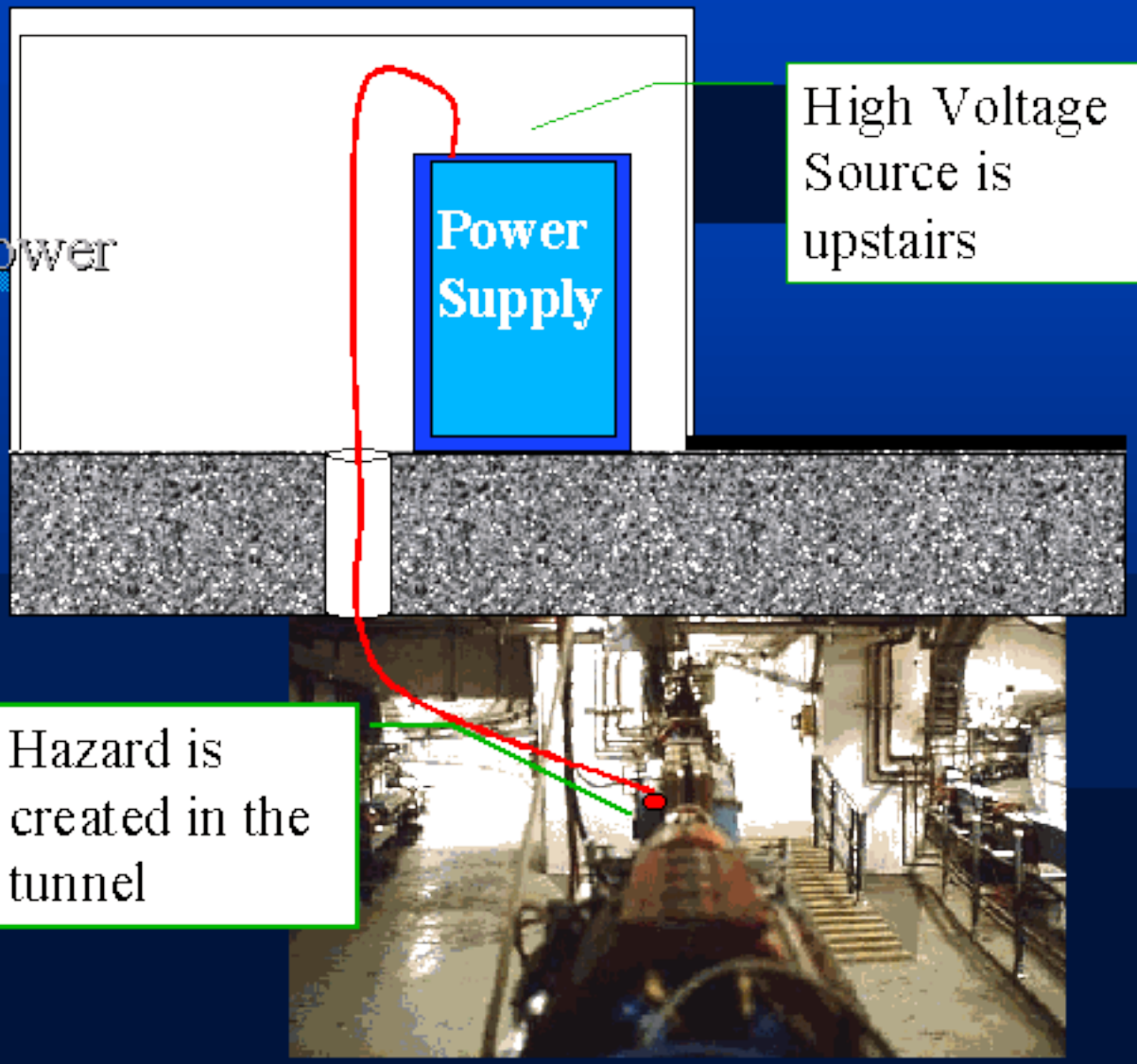
We then design safety layers to reduce the risk to an acceptable level



First we assess how much of a risk the hazard presents by determining the outcome if there were an accident and then how often it could possibly happen.
Each of these is assigned a value between 1 and 4.

How much safety system is enough?

Example, Magnet Power Supply



Why do these hazards require separate "safety" systems?

The hazards generally have two unique characteristics:

- They are located remotely from the equipment which generates them, i.e. they are not self-contained
- You can mitigate the hazard by shutting off power to this remote device

Conclusions

- Safety Systems Protect People and Equipment
- These systems are only a back-up to catch mistakes
- The safety systems group works hard to to keep you and your equipment in one piece