

# Human Performance Improvement (HPI) Practices in Accelerator Operations

DOE Accelerator Safety Workshop

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October 9, 2024

**SLAC** NATIONAL  
ACCELERATOR  
LABORATORY

Stanford University | U.S. DEPARTMENT OF  
**ENERGY**

# Agenda

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## Human Performance Improvement (HPI) Practices in Accelerator Operations

- Intro
- Background
- SLAC HPI:
  - Building on the Familiar
  - Making HPI part of culture
- Continuous improvement
- Wrap-up

# Intro (who am I)

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Lydia J. Young, Ph.D

## SLAC

- 2023-present: Deputy ALD for Engineering, Accelerator Directorate (AD)
  - 4 Divisions: Mechanical, Electronics, Safety Systems Engineering, Cryogenics
- (2014-23) Division Director, AD Mechanical Engineering & Technical Services Division (METSD)
  - ★ • 5 departments (MechEng, Design, Technical Planning, Metrology, Manufacturing -175 FTEs at peak)
  - LCLSII design/fab/install; LSST fab; SuperCDMS fab; LCLS linac operations

## Other

- LBNL Contractor Assurance, Requirements Management Program Manager
- Over 20 years in semiconductor capital equipment industry in roles VP Technology, CTO, General Manager, Technical Product Program Manager, Director of Engineering as well as individual contributor. Products: electron beam lithography, plasma chemical vapor deposition, wafer/LCD panel inspection and repair

## Education:

- BA Physics, Mount Holyoke College
- MS Applied Physics; Ph.D. Nuclear Science and Engineering; both Cornell University
- US Patent Agent

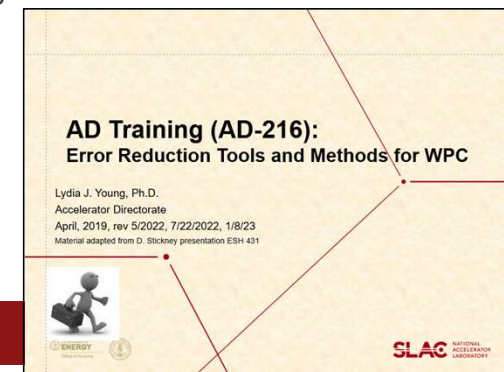
# Start of the Journey

## Human Performance Improvement (HPI) at SLAC

- Recognized as a needed best practice by D. Stickney (former SLAC Electrical Safety Officer) approximately 2018.
- Late 2018 recognition of need for “near perfection” in interconnection of LCLSII superconducting cryomodules (particle-free!)
- LCLSII long downtime started late 2018: installation of 2+ miles of beamline and equipment.

→ **PERFECT opportunity to introduce HPI and Enhanced Rigor WPC.**

- Course 431: electrical focused, very detailed, a bit long for the 60+ METSD staff installing LCLSII
- Created and implemented by early spring 2019:
  - A shorter AD216 class; renamed Error Reduction Tools and Methods
  - Enhanced Rigor WPC protocols
  - Both targeted for Field Teams



We've learned a lot along the way.....

# SLAC – view from above

LCLS-superconducting linac: Field work from 2016 through 2022.

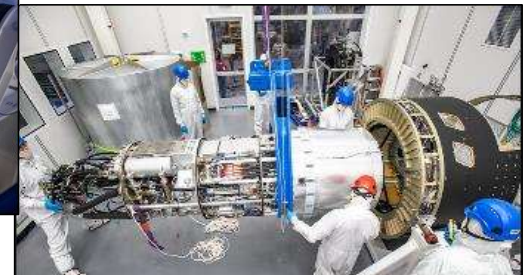
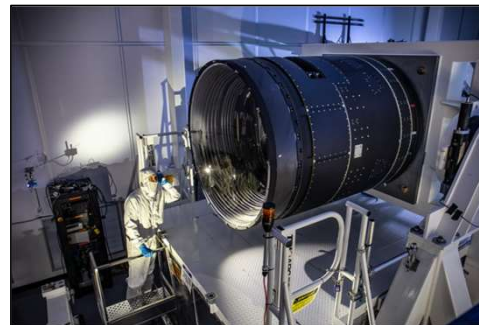


3.6km new/replaced beamline including srf cryomodules and two new undulator lines.  
AD-METS Division: > 400,000 hrs (2017-2021) incl 11 DART (=0.08% lost time)

# Opportunities for Application

## Opportunities if managed → Habit in time

- LCLSII:
  - 2.5 miles of scientific equipment.
  - The needed perfection for superconducting beamline
  - Lots of people (several hundred)
  - Install time approx. late 2018, peak just before COVID, continuous vacuum achieved Dec 2021; commissioning still underway
- LSST camera:
  - The zillion dollar one-of-a-kind
  - Needed perfection in assembly, handling, shipping
  - Smallish team
  - 2019 to 2024 – SHIPPED to Chile!
- SLAC fabrication shops: Supporting multiple projects




We've learned a lot in practice along the way.....



# Approach: HPI Building on the Familiar

WPC Basics with emphasis on what can go wrong unless....

**SLAC WPC – Pre-Job Briefing**  
Tool: The back of your ISEM Card



**Work Safety!**

**The 6 Key Questions at a Pre-Job Briefing**  
Ask yourself, your peers, and your supervisor:

1. Describe Work Activity, Scope, and Goals to Team
2. What are the Hazards, Controls, Critical Steps and Risk/Potential?
3. What must go right?
4. What could go wrong?
5. What Error Likely Occurrences and Mitigations?
6. How to respond to something unexpected or unexpected?


**EVERYONE has these - No Excuse!**

The old card  
has 6 boxes -  
get a new card!

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**SLAC WPC – 3 Steps**

- 1) Job Planning
- 2) Pre-job Briefings
- 3) Execution of Work



**How to incorporate Error Reduction methods into WPC?**

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**SLAC WPC – Job Planning: Critical Steps**

**Identify Critical Steps**  
(...those steps that may pose unacceptable consequences if performed out of sequence, if omitted, or if an undesired outcome occurs...)

**Consideration of "critical" should include:**

- Irreversible actions
- Increased chance of error
- Outcome can be severe or intolerable

**Goal is to focus attention on potential consequences so appropriate defenses can be put in place**

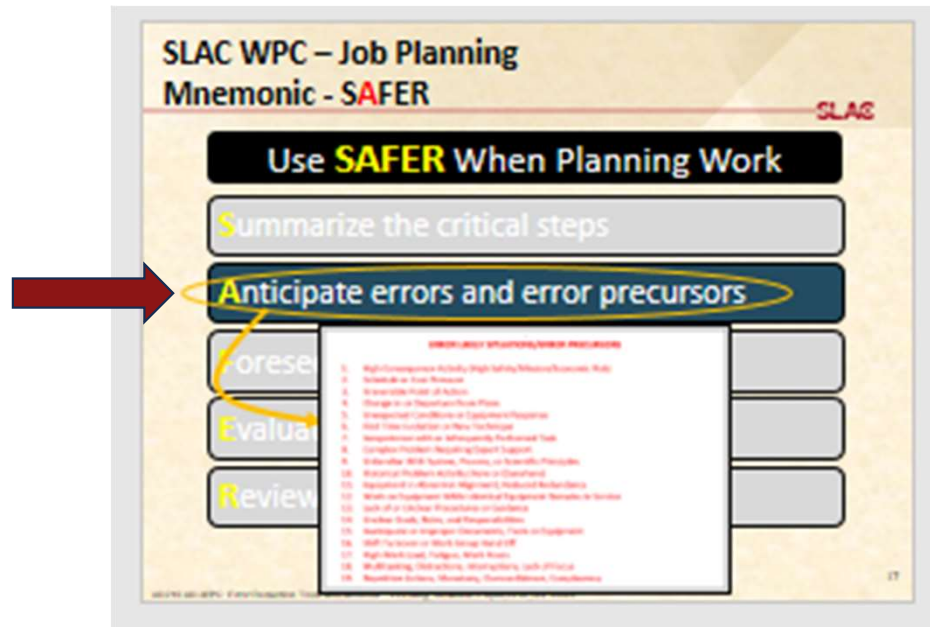
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SLAC ESH Manual, Chapter 02

Course AD216 - approximately 300 trained since May 2019. Does not include the many repeats of messaging through All-Hands, Safety Forums, immediate feedback after events

# Approach: HPI Building on the Familiar –

Introduce some tools, visuals – heighten awareness!



- ERROR LIKELY SITUATIONS/ERROR PRECURSORS**
- High Consequence Activity (High Safety/Mission/Economic Risk)
  - Schedule or Cost Pressure
  - Irreversible Point of Action
  - Change in or Departure From Plans
  - Unexpected Conditions or Equipment Response
  - First Time Evolution or New Technique
  - Inexperience with or Infrequently Performed Task
  - Complex Problem Requiring Expert Support
  - Unfamiliar With System, Process, or Scientific Principles
  - Historical Problem Activity (Here or Elsewhere)
  - Equipment in Abnormal Alignment; Reduced Redundancy
  - Work on Equipment While Identical Equipment Remains in Service
  - Lack of or Unclear Procedures or Guidance
  - Unclear Goals, Roles, and Responsibilities
  - Inadequate or Improper Documents, Tools or Equipment
  - Shift Turnover or Work Group Hand Off
  - High Work Load, Fatigue, Work Hours
  - Multitasking, Distractions, Interruptions, Lack of Focus
  - Repetitive Actions, Monotony, Overconfidence, Complacency

**Badge card!**

- ERROR PREVENTION/MITIGATION TOOLS**
- WORK PLANNING AND TAILGATE TOOLS**
- Plan (or Pause, Evaluate, Replan): Determine/Confirm Critical Steps, What-ifs, Error Barriers
  - Review Plan: Confirm Critical Steps, What-ifs and Adequacy of Error Barriers
  - Evaluate Short Term Benefit vs. Long Term Detriment (Future Risk or Cost)
  - Improve Focus: Control Urgency; Eliminate Short Cuts, Distractions and Multitasking
  - Verify (or Re-verify) Adequacy of Work Plans and Procedures
  - Review Historical Problem Solutions; Incorporate into Work Plan
  - Challenge Assumptions; Appoint Devil's Advocate; Avoid Group Think
  - Ensure Adequate Skills, Knowledge, Tools, PPE and Equipment
  - Reinforce Work Plans, Procedures, Communication Protocols, Roles & Responsibilities
- WORKER TOOLS [USE DURING EXECUTION OF WORK]**
- DISTRACTED? Increase Attention
    - Self Check: STAR (Stop, Think, Act, Review)
    - Peer Check
  - UNCOMFORTABLE? Increase Verification
    - Ask Questions, Validate, Verify; Peer Check; Review Work Plan and Procedures
  - CONFUSED? Increase Knowledge
    - Speak Up; Get Help or Expert Advice

Emphasis on remaining attentive and aware always – especially for ROUTINE work



# Approach: HPI Building on the Familiar –

Introduce some tools, visuals – heighten awareness!

## SLAC WPC – Pre-Job Briefing

SLAC

Chapter 2: *Work Planning and Control*  
Non-construction Tailgate/Pre-job Release Form

Product ID: 517 | Revision ID: 1276 | Date Published: 25 January 2011 | Date Effective: 25 January 2011

ENVIRONMENT, SAFETY & HEALTH DIVISION

Company name / work group: \_\_\_\_\_ Date: \_\_\_\_\_  
Company designated representative: \_\_\_\_\_ Phone: \_\_\_\_\_

**What are the critical steps of today's work?**

**What can go wrong?**

**What can we do to prevent this?**

Job Planning captures in JSA, Procedures, travellers, scripts, etc.

General Discussion

What are the critical steps or phases of today's work?

What can go wrong?

What can we do to prevent this?

Chemical Hazards Materials known/expected to be present

Weather Conditions Review plans for changing or extreme weather

Emergency Procedures Call 911 in an emergency, first aid treatment to SLAC clinic (Building 040), review evacuation procedure and location

Sample form: see url at top of form

- ### ERROR LIKELY SITUATIONS/ERROR PRECURSORS
1. High Consequence Activity (High Safety/Mission/Economic Risk)
  2. Schedule or Cost Pressure
  3. Irreversible Point of Action
  4. Change in or Departure From Plans
  5. Unexpected Conditions or Equipment Response
  6. First Time Evolution or New Technique
  7. Inexperience with or Infrequently Performed Task
  8. Complex Problem Requiring Expert Support
  9. Unfamiliar With System, Process, or Scientific Principles
  10. Historical Problem Activity (Here or Elsewhere)
  11. Equipment in Abnormal Alignment; Reduced Redundancy
  12. Work on Equipment While Identical Equipment Remains in Service
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  15. Inadequate or Improper Documents, Tools or Equipment
  16. Shift Turnover or Work Group Hand Off
  17. High Work Load, Fatigue, Work Hours
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**Badge card!**

- ### ERROR PREVENTION/MITIGATION TOOLS
- #### WORK PLANNING AND TAILGATE TOOLS
1. Plan (or Pause, Evaluate, Replan): Determine/Confirm Critical Steps, What-ifs, Error Barriers
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  12. CONFUSED? Increase Knowledge
    - a. Speak Up; Get Help or Expert Advice

Emphasis on remaining attentive and aware always – especially for ROUTINE work

# Approach: HPI Building on the Familiar

And expanding the practices...

- Culture adjustments:
  - Team = Everyone has a say
  - Even if it means Re-plan
  - “Are we ready?”
  - “Am I ready?”

## Tools for Workers: Pause When Unsure

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### Pause When Unsure

Unexpected results or equipment response; confusion, uncertainty...

### Usage

Pause the activity

Place equipment and job site in a safe condition

Inform supervision; evaluate; re-plan; new safety tailgate



**EVERYONE** has the responsibility to speak up.  
**EVERYONE** has the responsibility to listen.  
If Re-plan is needed, **DO IT.**

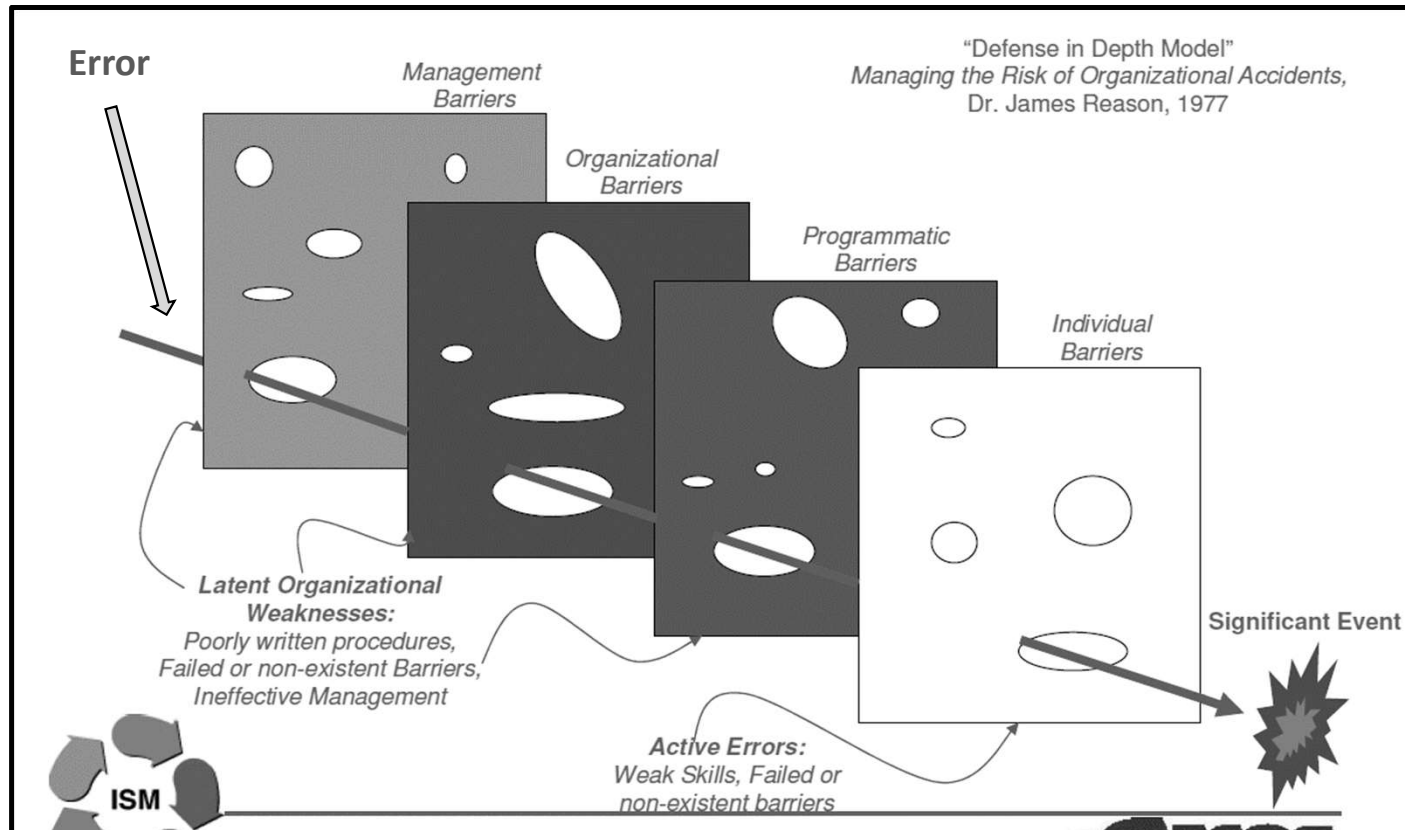
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DOE Accelerator Safety Workshop - LJYoung

AD216 AD-WPC: Error Reduction Tools and Methods LJYoung, RRalston – April, 2019, rev 1/8/23

# Approach: Building on the Familiar –

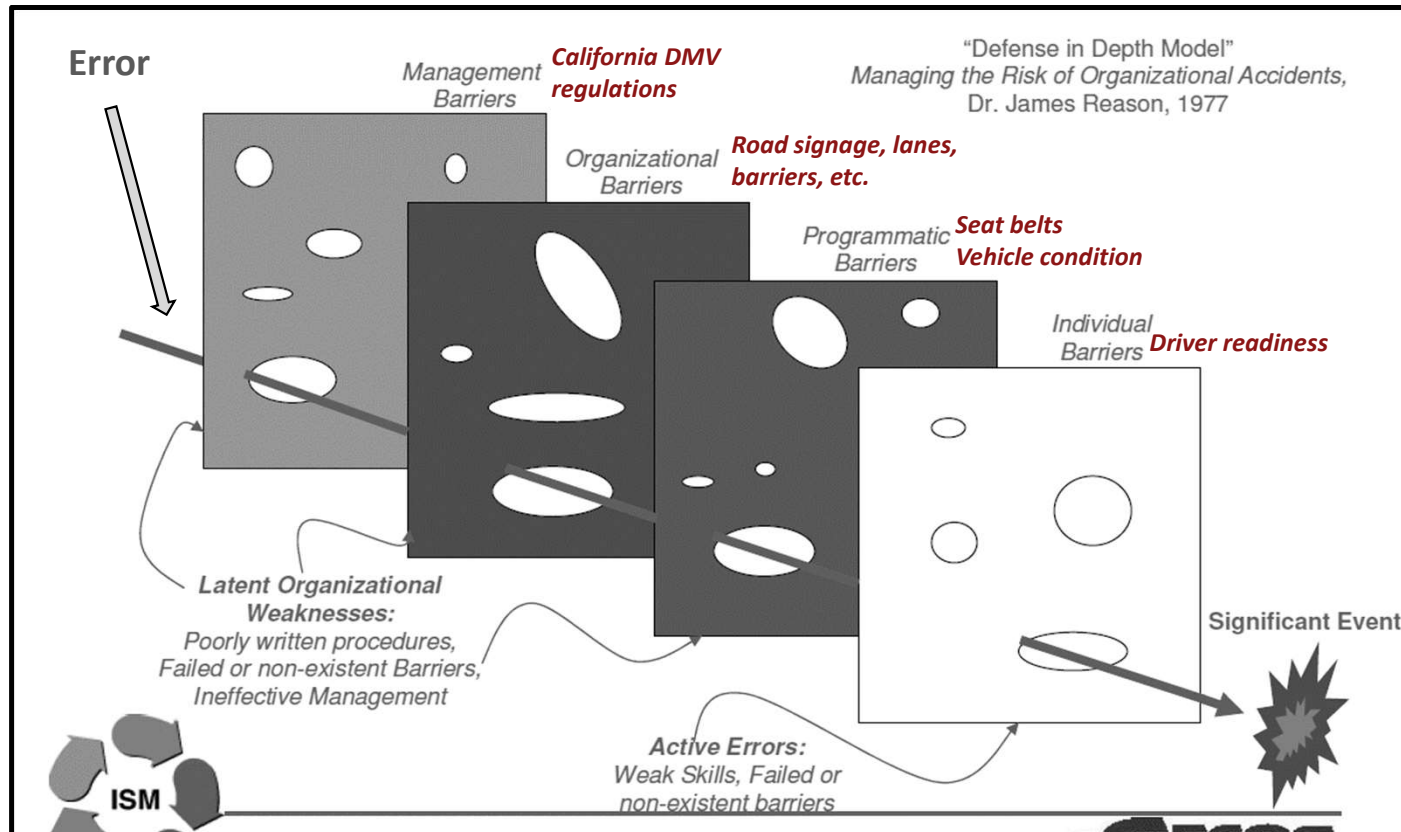
## Defense in Depth: Error Mitigation



Training improvements 2022-2023: Making this slide meaningful.....

# Approach: Building on the Familiar –

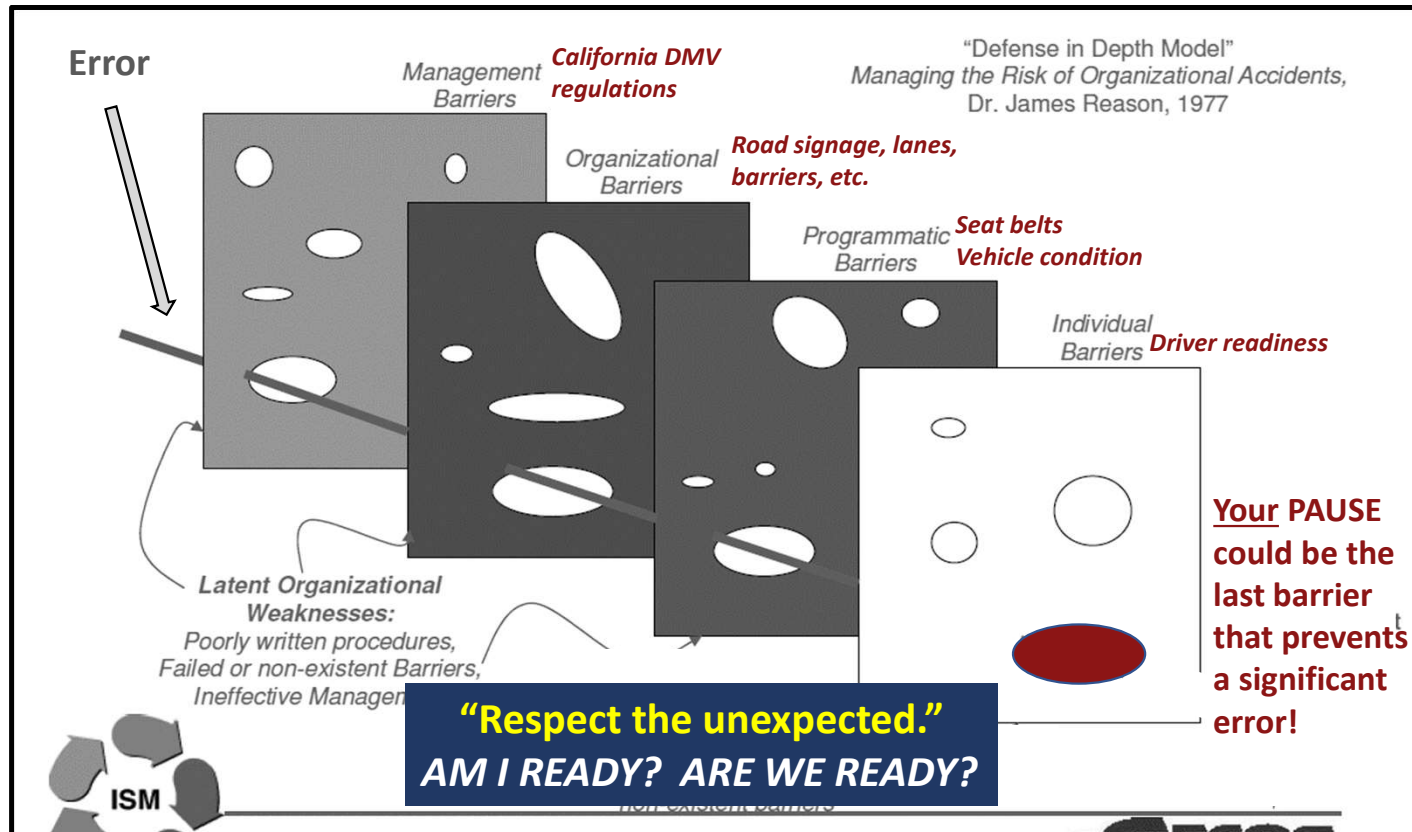
## Defense in Depth: Error Mitigation – Driving a Vehicle



Training improvements 2022-2023: Making this slide meaningful.....a real life example explains the definitions...

# Approach: Building on the Familiar –

## Defense in Depth: Error Mitigation – Driving a Vehicle



Training improvements 2022-2023: Making this slide meaningful.....a real life example...with the essential messages

# Approach: Building on the Familiar –

- Choice of this example of driving really “hits home.”
- “Approach each task every day as if it were new.”

**Let's go back to:**  
**An Analogous Experience that (almost) everyone can relate to**

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- **Driving a vehicle safely**
  - Initially learning yourself
  - Continuing to apply the rules you learned, the actions you were trained to do, the years of practice you have.
  - Teaching your family members

**ERROR LIKELY SITUATIONS/ERROR PRECURSORS**

1. High Consequence Activity (High Safety/Mission/Economic Risk)
2. Schedule or Cost Pressure
3. Irreversible Point of Action
4. Change in or Departure From Plans
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Driving a vehicle example WHICH APPLY????  
What do YOU do to mitigate?

Use **STAR** for Self-Checking

**Stop** - Pause to focus attention on the immediate task.

**Think** - Understand what will happen when correct (or incorrect) action is performed.

**Act** - Perform the action.

**Review** - Confirm anticipated result has occurred or apply contingency if required.

Use the 2-Minute Rule at the job site  
Ask: Are we ready to go?

When you operate a vehicle, do you think “this is routine, I know what I’m doing”  
When you had a near-miss, how did you react, how did you feel?  
If you experienced a worse result, how did the incident change you?

AD216 AD-WPC: Error Reduction Tools and Methods LJYoung, rev 1/8/23

# Approach: Expanding the Familiar –

## Enhanced Rigor WPC

- Team members selected and trained. Plenty of practice.
- For Cryomodule installs, it “worked”!!
- First turn on of Cryomodules (2023): NO evidence of added field emission compared to before ship/immediately after receipt.

## SLAC WPC – Job Planning Enhanced Rigor WPC

- Introduced in early 2019 when trying to figure out a “fool-proof” process for LCLSII Cryomodule installations.
- Basic process:
  - Define what work will be executed with ER-WPC
  - Define the WPC QC Elements to be applied
  - Provide the training and tools

**SLAC**

ACLSII Cryo Plug Exchange Procedure

Document Number: SLAC-130-02-011

Document Approval:

Engineer: Rob Cox, Mechanical Engineer

Reviewer: Stephanie Liu, LCLSII Section Area Engineer

Reviewer: Peng Zhou, LCLSII Section Area Engineer

Supervisor: Lydia Young, AD METS Division Director

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4 - Definitions

Terms	Definitions
LLC1a	Gate valve between LockBlock and Gun
LLC1b	Gate valve between LockBlock central chamber and lock chambers
LLC1c	Multi-use gate valves
LLC1d	Gate valve between Gun and LLE
LLC1e	Procedure Users must record information at steps flagged with this score
LLC1f	Procedure Users must hold and perform the indicated action at steps flagged with this score
LLC1g	Warning - Procedure Users must check for irregular conditions at steps flagged with this score
LLC1h	Procedure Users can exercise a microbreak (ergonomic break) at steps flagged with this score

**SLAC** AD-METS Division Non-Routine Job Safety Analysis Form

1. When do I need to do a Non-Routine JSA?

2. You should consider performing a non-routine work activity if...

3. The Three Questions of Job Safety Analysis and Mitigation:

- What needs to be done?
- What are the risks/hazards?
- How can we be safest?

Category 1 and Category 2 Activities	01 Live/Hot/High Voltage/High Radiation		02 High Voltage/High Radiation		03 High Voltage/High Radiation		04 High Voltage/High Radiation		05 High Voltage/High Radiation		06 High Voltage/High Radiation		07 High Voltage/High Radiation		08 High Voltage/High Radiation		09 High Voltage/High Radiation		10 High Voltage/High Radiation	
	WPC QC Element	Cat 1	Cat 2	Cat 1	Cat 2	Cat 1	Cat 2	Cat 1	Cat 2	Cat 1	Cat 2	Cat 1	Cat 2	Cat 1	Cat 2	Cat 1	Cat 2	Cat 1	Cat 2	
Technical Lead	Rob Cox	Rob Cox	Lydia Young	Dian Yermolan	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox	Rob Cox
Design/Process SME																				
Access Hierarchy of Controls																				
Version controlled procedures (in COMS)																				
Roles and Responsibilities Documented																				
Personal Identifying and Object																				
Area Preparation Checklist																				
Tool/Resource/Material Checklist																				
Practice Run with test plan																				
Job Specific Training (e.g. per Serial No.)																				

SRF Commissioning – Gradient Performance

**Gradient Performance**

- Cryomodule commissioning has been very successful
- 97% of installed cavities fully operational (planned 94%)
- **No observable change in cavity performance from installation at SLAC**
- Total commissioned voltage exceeds design by >20%

Excellent performance is a direct result of clean assembly and installation in the tunnel



AD will continue practices from LCLSII.  
QA will have/has a class on Enhanced Rigor WPC.

Feedback took 3 years to arrive to prove the value of Enhanced Rigor WPC with HPI...and now we have (some) believers

# Application of the Messages for Emphasis

Review and repeat the Messages especially after Incidents towards making these HABIT.

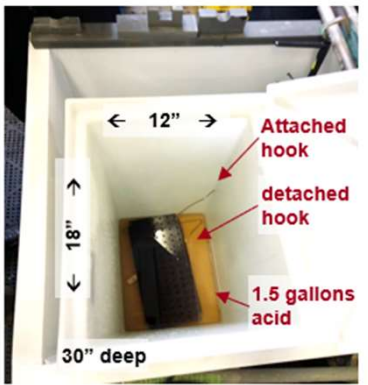


**Event 1:** Lift of 2x 115lb plates – Not properly bolted together before lifting.

Causes: Change of plan without team replan

Followup #1 – within 2 days: Work team discussion

Followup #2 – within 2 weeks: Multi-dept mini-workshop – planning, replanning, pause if unsure!



**Event 2:** While lowering 5lb plate, plate slipped cause chemical splashing.

Causes: Mis-sizing of part/tank; worker assumptions; plan not reviewed.

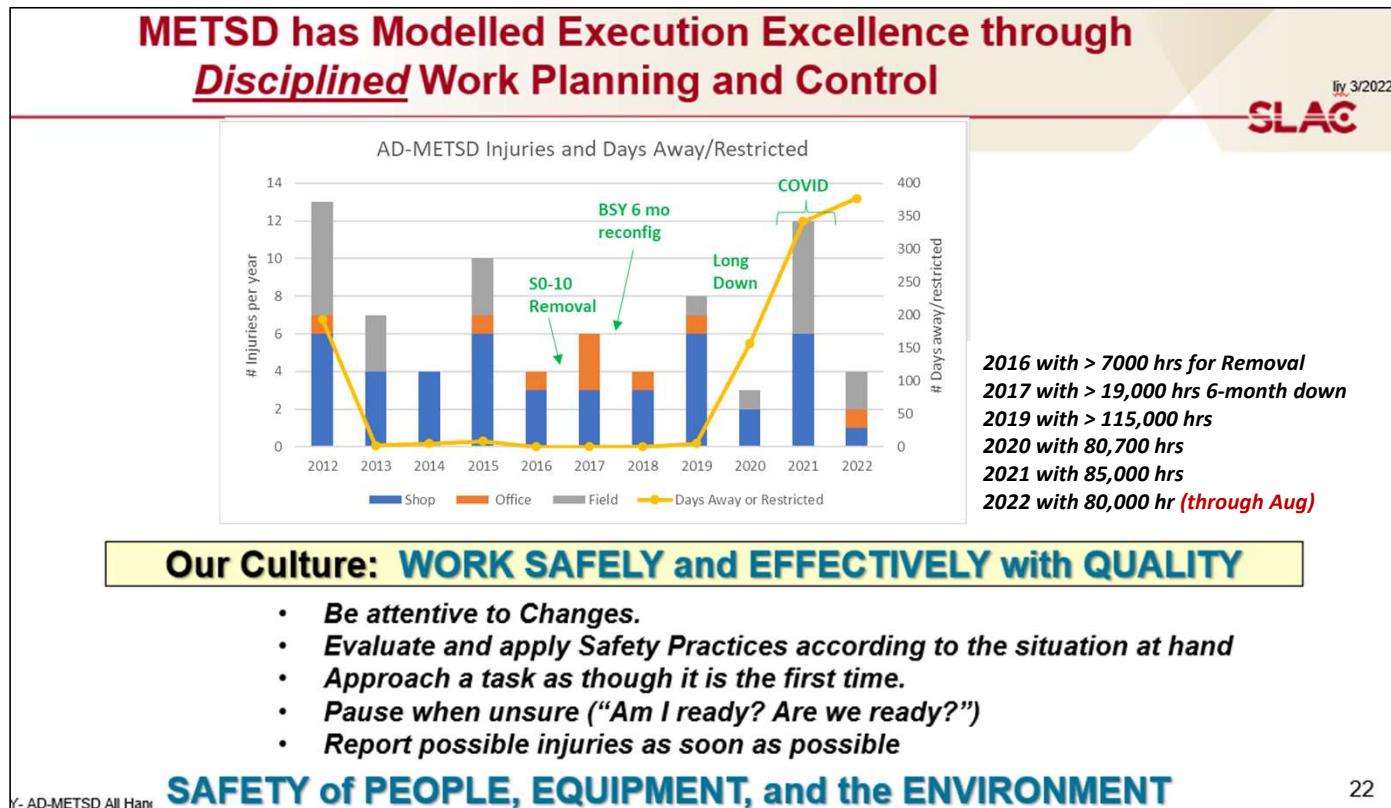
Followup – same day: Work team discussion

Immediate Feedback to Teams is an effective Best Practice to adjust culture.



# Signs of Success?

We watched Field Work very carefully.....

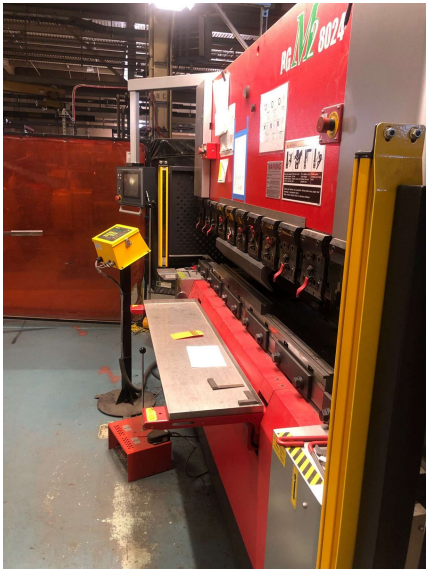


...and thought we were doing well.....UNTIL.....

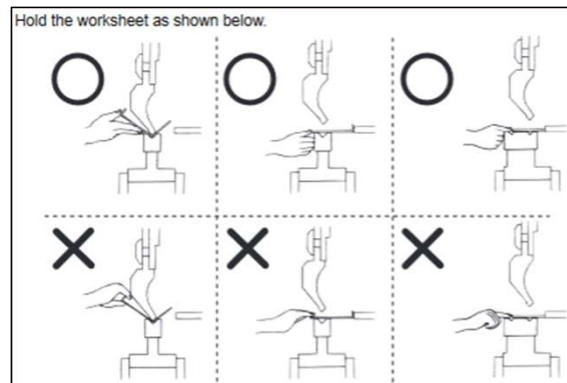


# ....The Shops

A 2022 Event made all in the Division stop and think again.



**Event 3: Brake Press (bend metal) - Mispositioned thumbs.**  
Cause: Skill of craft judgment, situational awareness.



- Followup meeting with Division Leads. Key realization:
  - METSD Shop Activities vs Field Activities: *Differences require different emphases in WPC*
    - Shop work: Individuals
    - Skill of craft judgment
    - No habit of asking for others to check “Readiness”

The Lesson: A field job has more constant eyes and more levels of experience – more people to call for Pause  
*What error mitigation practices can we develop and apply to the shop environment?*

# Amended thinking to address the Shops, too

## Work still in progress – Ideas include:

- Culture: One that is open to questions and to be questioned. This is a culture where we teach each other and learn from each other. We seek to be collaborative.
- Review and update and apply(!) the training modules of 8-10 years ago;
- Create a Skill Set matrix/database: Use to evaluate current staff, to develop training.
- Determine how to assess someone is “ready” (judgment!)
- Cross-train across shops
- Devise and apply deliberate methods to capture/share/teach Tribal Knowledge

### Key Change for METSD Shop Activities: Walk-ins

New process that requires JSA evaluation as part of acceptance of a Walk-in job

- “Prompts” within the JSA itself
- Specific mandatory “holds” within the Step list – embeds 2 key HPI best practices

**SLAC AD-METS Division Non-Routine Job Safety Analysis Form**  
Date Published: 22 July 2022 | Date Effective: 22 July 2022

This form is used to document the job safety analysis (JSA) required for the authorization and release of non-resident yellow and red work. Note red work requires final release through a targeted briefing. Approved forms are to be kept in the work package; work packages are to be kept for 30 days after completion of the work, yellow or red by the authorizing supervisor or field manager (See Work Planning and Control, Work Planning and Control Procedures (SLAC-A-125-041C-002) and Work Planning and Control, Construction Work Planning and Control Procedures (SLAC-A-125-041C-005)).

**1. When do I need to do a Non-Routine JSA?**  
a. When the work is not covered under your ATA.

**2. You should consider performing a non-routine work activity if...**  
a. Work, system, equipment, technical factors, or people are unfamiliar to you.  
b. You arrive at the work site and believe it would be useful to review the job steps prior to start.  
c. The job doesn't feel or look right; you experience that inner voice that says “hang on a moment”...**STOP WORK!**

**3. The Three Questions of Job Safety Analysis and Mitigation:**  
a. What needs to get done?  
b. What are the risks/hazards?  
c. How do we do it safely?

**Hazard Identification Examples**  
**Contact with:** Electricity, Chemicals, Heat/Cold, Ionizing/Non-ionizing Radiation, Gases/Fumes, Oxygen Deficiency, Pressurized Sources  
**Struck by:** Moving or Flying Objects, Falling Material  
**Strikes against:** Stationary or Moving Objects, Protruding Objects, Sharp or Jagged Edges  
**Fall:** To Same Level, To Lower Level

**Additional Hazards When you press Go/Start:** Electrical, Pressure (gas/water), Heat/Cold, Motion, Oxygen Deficiency  
**Oversaw/over:** Lifting, Pulling, Pushing  
Note: Oversaw/over is the biggest cause of injury at SLAC.  
**Adverse environmental impact:** Chemicals, Fire, Spills, Releases  
**Security:** Unknown/Unauthorized people in area, Missing/Damaged Materials, Equipment at Work Site

Step Number <sup>a</sup>	Step <sup>a</sup>	Hazard <sup>a</sup>
1 <sup>a</sup>	COVID Safety Protocols <sup>a</sup>	COVID Exposure <sup>a</sup>
2 <sup>a</sup>	2-minute Pause: Check for readiness by others to verify conditions and/or setup <sup>a</sup>	(as noted below) <sup>a</sup>
3 <sup>a</sup>	a	a
4 <sup>a</sup>	a	a
5 <sup>a</sup>	a	a
6 <sup>a</sup>	Pre-Execution Hold Point <sup>a</sup>	a
7 <sup>a</sup>	a	a
a	-	-

SLAC-A-001-1303-000-0000 Working Draft | 1 of 1

Process that embeds “prompts” to help focus individual and supervisor

**“Experience comes from good judgment. Good judgment comes from bad experience.”**

**Realization → ...but!!!!...we managers cannot “permit” bad experiences...so, how to train to develop good judgment?**

# HPI, WPC: the Journey continues

Learnings continue to drive messaging, training, and methods to adjust culture

- For Staff:

- Apply 2 Minute Rule prior to start of work.
- **Ask: Am I ready? Are we ready?**
- **Pause if unsure.** Do not hesitate to ask for help
- Practice asking “what if’s”.
- During planning, participate and encourage others to join in.
- Assess Lessons Learned from a task/job; feed forward to next work
  - At daily tailgates, reflect on what went well, what didn’t.

- For Managers/Supervisors:

- **Making HPI/WPC habit takes effort and will always be a continuing challenge.**
- *Experience comes from good judgment. Good judgment comes from bad experience. BUT...we SLAC managers cannot “permit” bad experiences.* How can we improve our training program to help people develop good judgment?

**AD216 Course: Defense in Depth: Error Mitigation**

• Are we focusing when Pausing?  
• Are we reviewing with a super-critical eye? Eyes?  
• Are we speaking up?  
• Are we listening to others?

• **What can we do better?**

20230105 METSD All Hands - WPC - by  
AS216 AD-WPC Training Error Reduction Tools and Methods | L'Young, R.R. et al. - April 2019, revised July 2022

***Error is pervasive. The unexpected is pervasive... What is not pervasive are well-developed skills to detect and contain these errors at their early stages.*** - Dr. Karl Edward Weick @ University of Michigan

# Thank you! Questions?

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