

Catastrophic Equipment Failure During an Extended Outage

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Thanks to the LANL teams that investigated and reported on the 1RBM01 Magnet Fire!

The Los Alamos Neutron Science Center

- ***Los Alamos National Laboratory (LANL)*** is located in Northern New Mexico, at the foot of the Jemez Mountains.
- ***The Los Alamos Neutron Science Center (LANSCE)*** is LANL's Signature Science Facility.



LANL Main Technical Area

Town of Los Alamos

LANSCE

Town of White Rock
(out of picture)

 **Los Alamos**
NATIONAL LABORATORY
EST. 1943

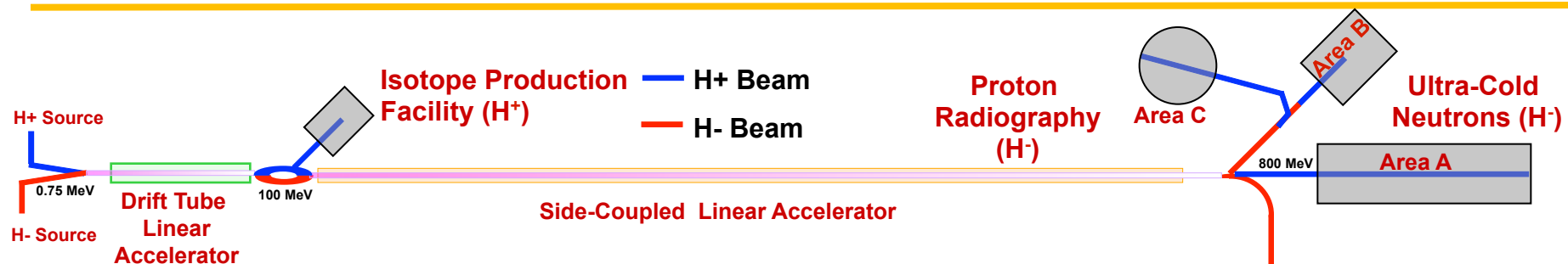
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The Los Alamos Neutron Science Center



Simultaneously delivers H⁺ and H⁻ beams to:

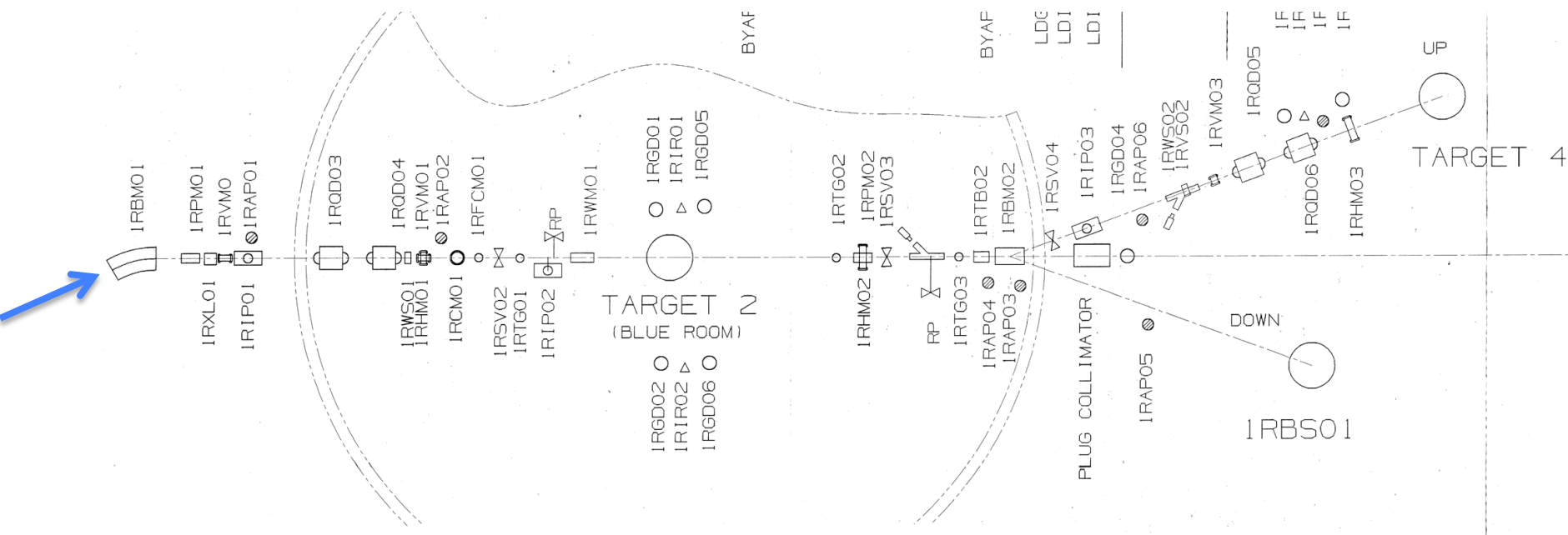
- Isotope Production
- Proton Radiography
- Neutron Production Targets, covering wide range of Neutron Energies.



LANSCCE - WNR

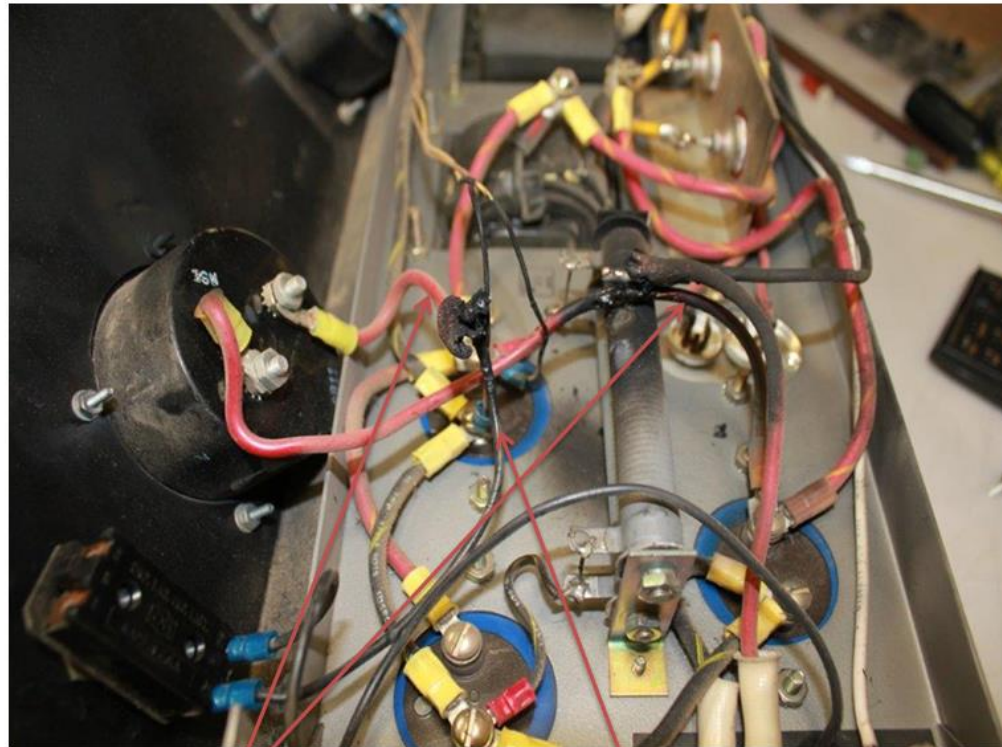
- The LANSCCE WNR facility provides neutron and proton beams for basic, applied, and defense-related research. Examples:
 - *Irradiation of Chips Electronics (ICE and ICE II) to study neutron-induced failures in semiconductor devices (Industry and other labs).*
 - Component testing with proton beam for LHC.
 - Neutron detector development.
 - Big Bang Nucleosynthesis.
 - Cross-section measurements.

LANSCÉ - WNR Beam Line ("1R")



What happened?

- One night, during the 2014 extended maintenance outage: In a “Sola” 24 V power supply, installed around 1970, 120 VAC conductor wires shorted to both positive and negative 24 VDC buses.



Melted Red Wires 24v DC

Melted Black Wire 120v AC

What happened?

- As a result, there were 0 V between the two DC buses, and 120 VAC on both buses w.r.t. rack ground.
- This power supply served one group of racks.
- Another group of racks was served by another, functional Sola supply.
- The negative 24 VDC buses for these two groups of racks were interconnected. This was done some time in the past, for reasons not entirely clear.
- One rack in the second group contained the Control & Monitor chassis and regulation NIM bin for Magnet Power Supply 1RMP01 (PS for magnet 1RBM01).

What happened?

Configuration of Equipment Racks: WER01-WER11



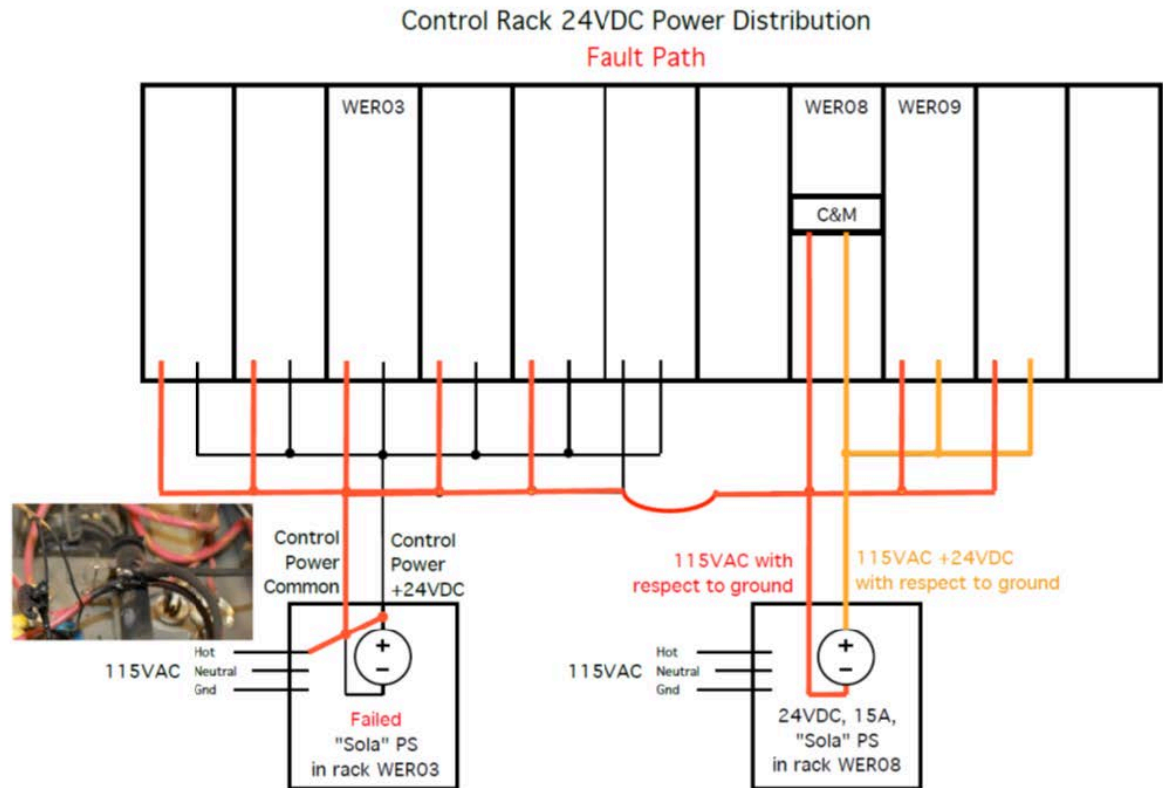
1RMP001 Power Supply
C&M Chassis and
Regulation NIM bin
in Rack WER09

Functional "Sola" 24VDC
Control Power Supply
in Rack WER08

Failed "Sola" 24VDC
Control Power Supply
in Rack WER03

What happened?

- DC buses are insulated, so no current flow to case or ground, but several components were exposed to potential difference greater than what they were designed for.

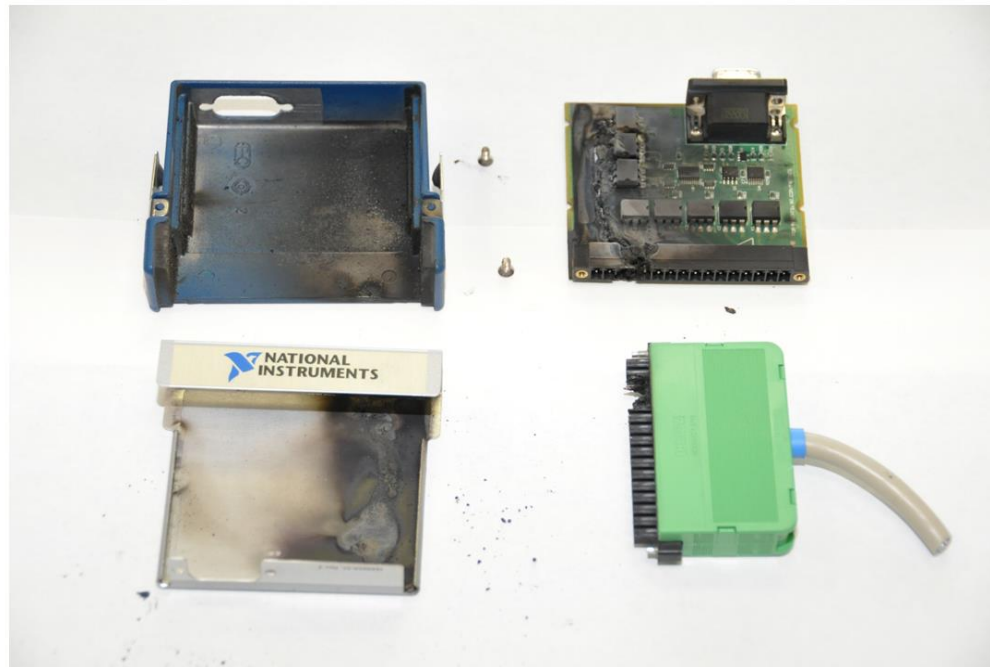


What happened?

- **Insulation in the computer I/O module for 1RMP01 failed, allowing current through a relay, bypassing interlocks and turning power supply on.**

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Photo of Damaged Computer I/O Module



What happened?

- When magnet power supply 1RMP01 came on (**breaker feeding supply was closed**), it ramped the current through 1RBM01 up to the **set point stored in the computer control system** (~1800 Amps).
- The **cooling water system** for this and other magnets in the beam line **had been off**, as is normal during extended outages.
- Coils overheated, melting insulation and Plexiglas enclosure and activated sprinkler head.
- Arcing caused localized temperatures in excess of 1000 °C, as evident from copper beads.

What happened?



What happened?



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What happened next?

- **LANL *Emergency Operations Support Center* (EOSC) received 2 “supervisory” smoke alerts, but did not inform *Los Alamos Fire Department* (LAFD).**
- **LAFD responded to fire suppression system water flow alarms, but concluded these were false alarms and left site before *LANL/LANSCE personnel* arrived. Routine false alarms and inability to locate alarming smoke detectors contributed to this decision.**
- **LANSCE *Duty Officer* (DO) could not be reached for hours. During an extended outage, the DO assumes many of the First-Responder duties from *Central Control Room* (CCR).**

What happened next?

- Rising levels in Radioactive Liquid Waste (RLW) tanks caused LANSCE *Facility* personnel to isolate fire suppression water.
- By then more than 41,000 liters of water had been discharged by sprinkler system, leading to flooding of large area, requiring tremendous subsequent cleanup effort, and initially preventing safe access to the magnet.
- For a while it was thought that a failure of the sprinkler itself had caused the flooding.

What happened next?



What happened next?

- The initial response by LAFD and LANL personnel was impeded by
 - Lack of communication
 - Difficulty to access beam lines
 - Complexity of LANSCE accelerator complex and fire suppression system.

Note: No response by LAFD or LANL would have saved the magnet, 1RBM01!

What happened next?

- For *Accelerator Operations and Technology Division* (AOT) the immediate concern was to repair/replace the 30 degree bending magnet or magnet coils.
- **Spare coils** were documented, but **could not**, despite great effort, **be located**. Most likely they were accidentally disposed off during a major cleanup effort in Area A ... New coils have been ordered, but were not going to be available in time for startup.
- A solution involving two magnets was devised, and, thanks to the enormous efforts of LANSCE personnel and crafts, successfully put in place in time for beam delivery to WNR.

Lessons Learned

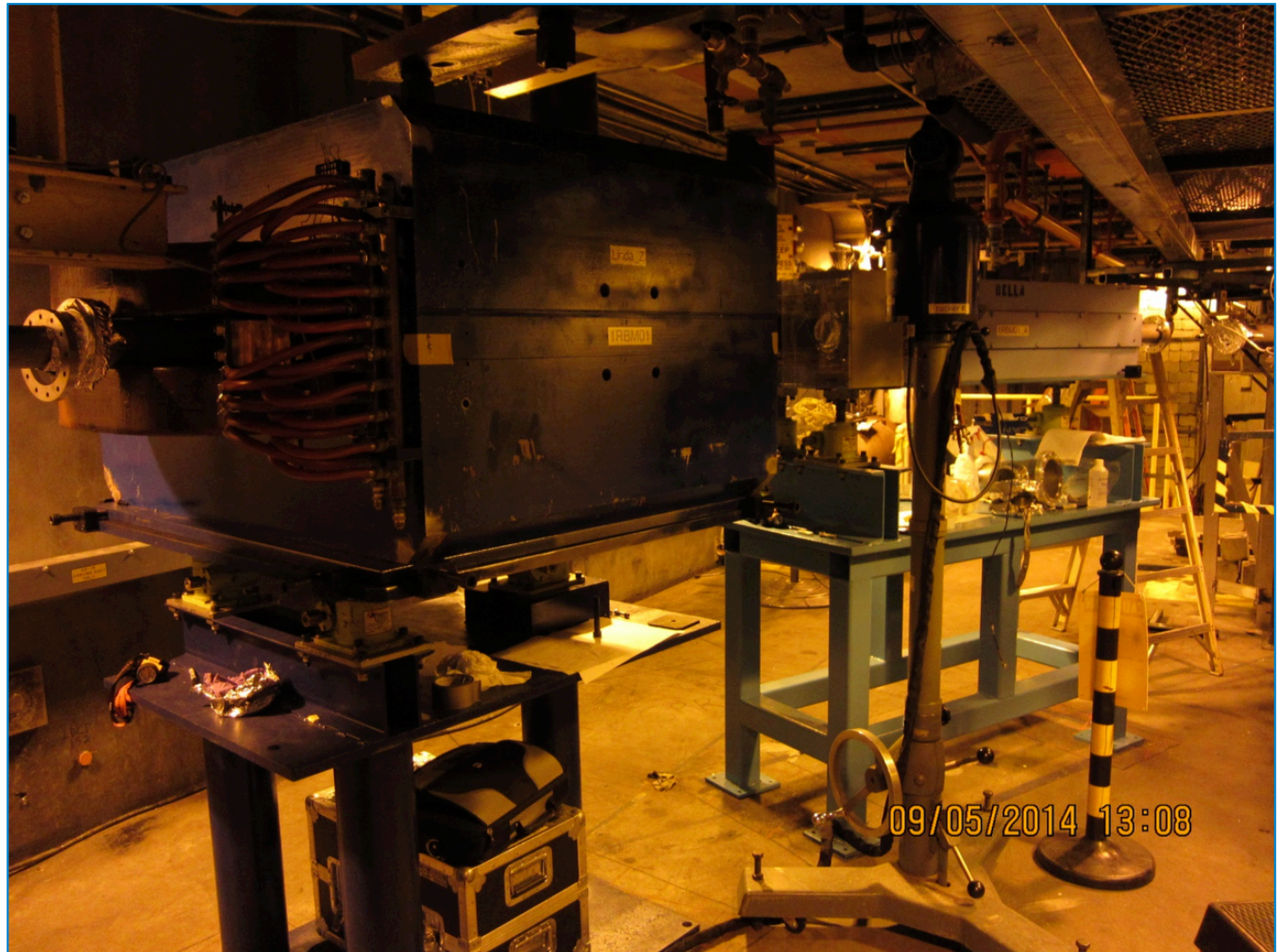
- Two independent reviews came up with numerous *Judgements of Need* (JONs).
- AOT division: In February 2014, as part of normal long-term shut down practices, we
 - ❑ Secured the W02 cooling water system.
 - ❑ Saved operating set points for magnet power supplies in the accelerator control system.
 - ❑ Left the 480 V breaker for the magnet power supply closed.
- Changing ANY ONE of these practices could have saved the magnet!

Lessons Learned

- **As a result, we will**
 - ❑ **Formalize our End-of-Run-Cycle Shut Down Procedures/Processes.**
 - ❑ **Weigh the risk of equipment damage against the potential gain of maintaining configuration (e.g. to make startup easier) and the cost of further equipment isolation.**
- **An *Extent-of-Condition* investigation was performed and numerous power supplies were upgraded.**
- **The fact that the spare coils could not be located made it even harder to repair the WNR beam line in time for startup.**

Lessons Learned

- Burnt magnet had to be replaced with two magnets:



Lessons Learned

- **This was a tremendous effort, requiring**
 - ❑ **Moving heavy magnets in and out of beam line**
 - ❑ **Moving other equipment around (quads, diagnostics, etc.)**
 - ❑ **Un-stacking and restacking shielding**
 - ❑ **Revising cooling water, controls, interlocks, etc.**
 - ❑ **Re-aligning, re-tuning, revising procedures, etc.**
- **Another Lesson Learned: Keep track of your (Legacy-) spare equipment, unless you're really, really sure you won't ever need it again!**

Summary

- Catastrophic equipment failures can and DO occur when you least expect them (e.g. during an outage).
- The direct cause for the failure of bending magnet 1RBM01 was a short in a small piece of equipment.
- The root causes were lack of preventive maintenance and inadequate configuration control.
- This incident brought a lot of other issues to the surface, such as access to beam lines for first responders during outages, etc.
- Lack of control of legacy equipment (i.e. spare coils) made recovery even harder.