Exceptional service in the national interest

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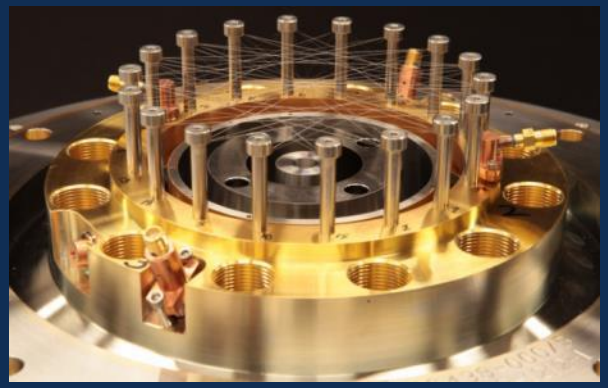
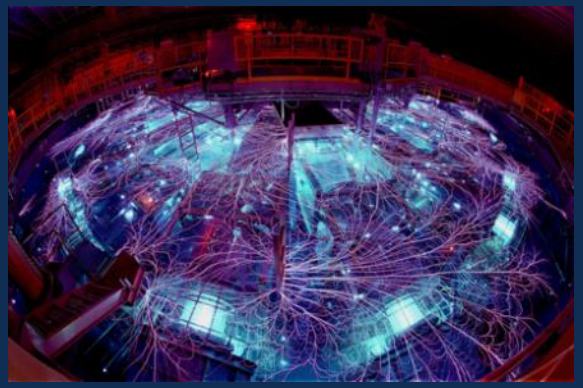
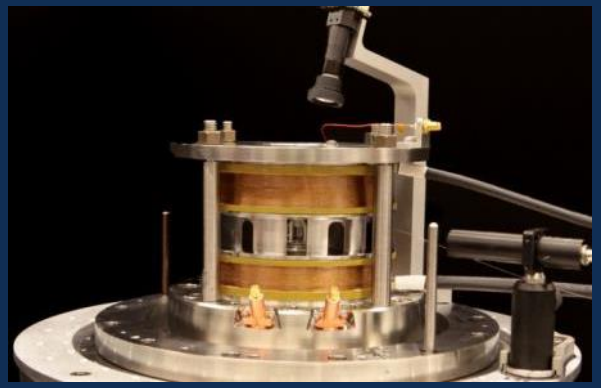






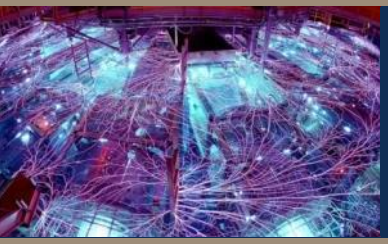
Z Machine Overview

Joel Lash, Ph. D.

Senior Manager, Z Facility R&D

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



Summary

Pulsed Power / Facility

- 22 MJ stored energy
- 3 MJ delivered to the load
- 26 MA peak current
- 1 - 100 Megabar
- 100 - 1000 ns pulse length
- ~1 shot per day / ~150 shots per year

Subsystems

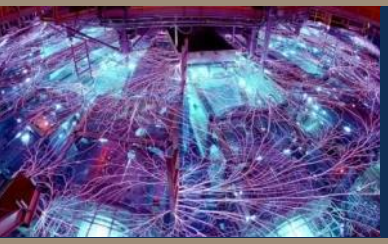
- Laser X-ray Backlighter
- Cryogenics
- External Magnetic Fields
- Gas Fills
- Explosive Containment for High Z Materials

Experimental Loads

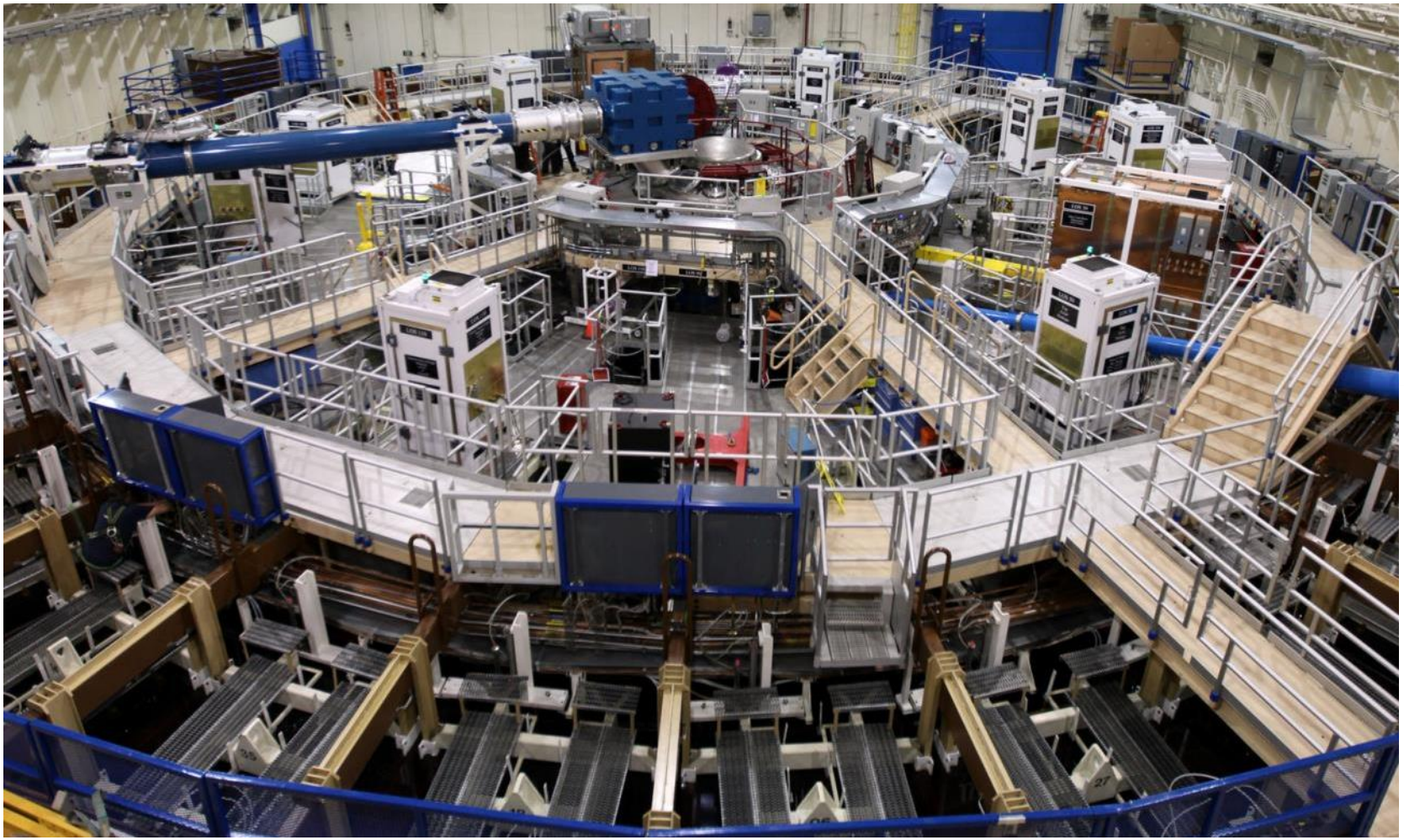
- Wire Arrays – Radiation Sciences
- Liners – Inertial Confinement Fusion, Material Sciences
- Gas Puff – Radiation Sciences
- Flyer Plates – Material Sciences

Diagnostics

- X-Ray
- Neutron
- Optical
- ZBL Backlighter



Z is a unique world class pulsed power facility at Sandia National Laboratories



36 Marx generators
2160 capacitors

~ 1M gallons of transformer oil
~ 0.5M gallons of deionized water

66,000 liter vacuum vessel

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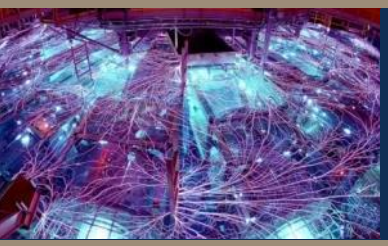
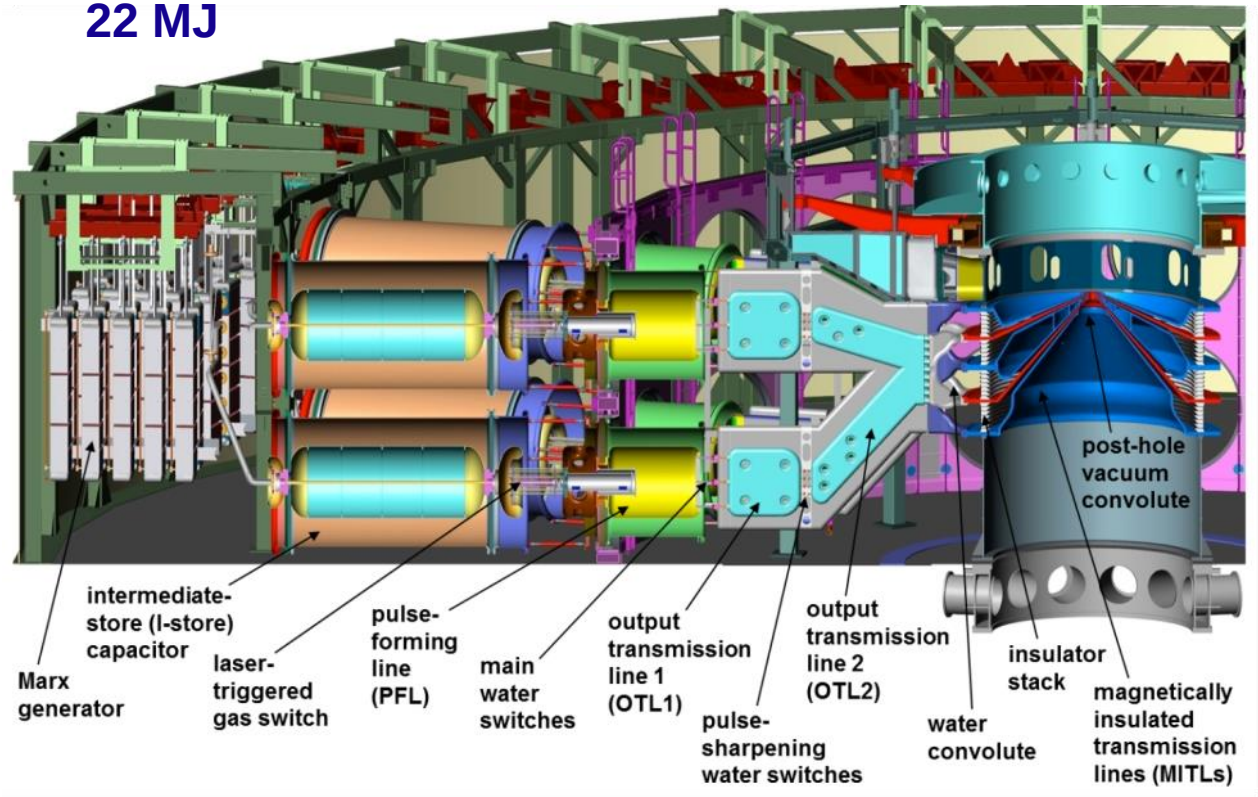


Z compresses electrical energy in both space and time . . .

20 TW
22 MJ

80 TW
8 MJ

Charge for 3 minutes to reach 85 kV



330 TWs & 2.5 MJ of x-ray output in a few ns

. . . and literally shakes the earth almost every day!

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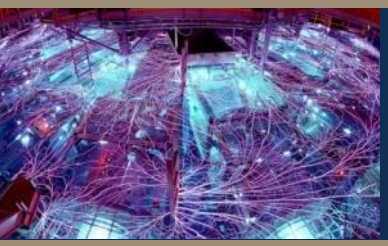
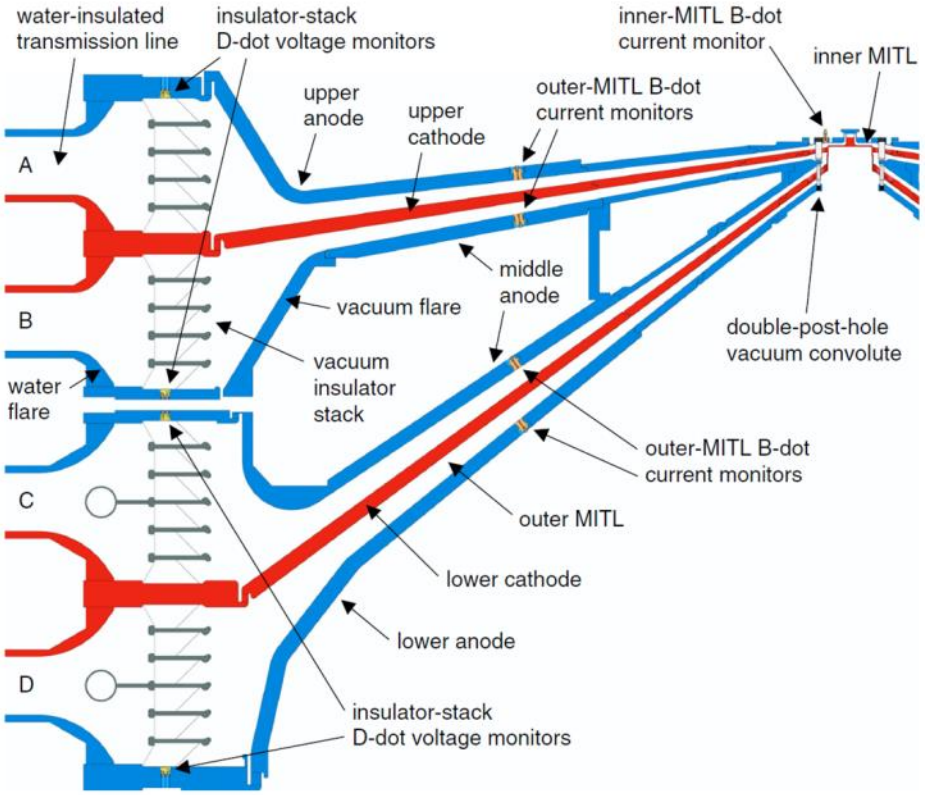
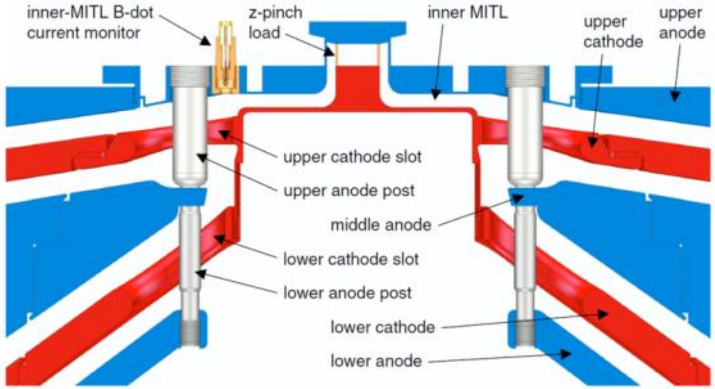


A complex series of conductors combine currents for the load

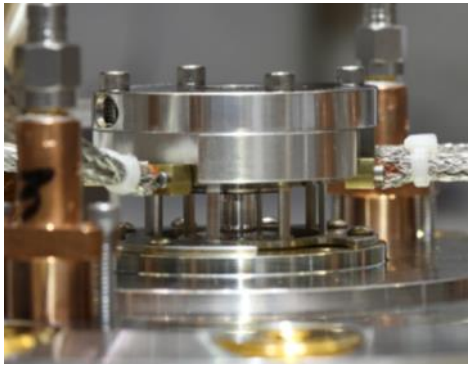
Z vacuum insulator stack and MITLs



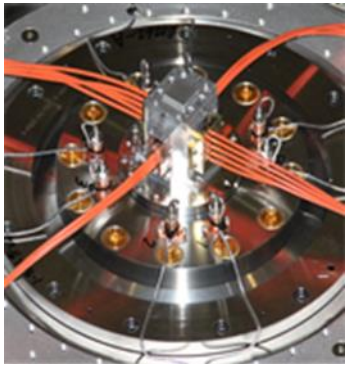
Post hole convolute system and load



ICF liner load



DMP load



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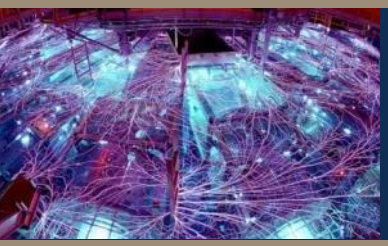
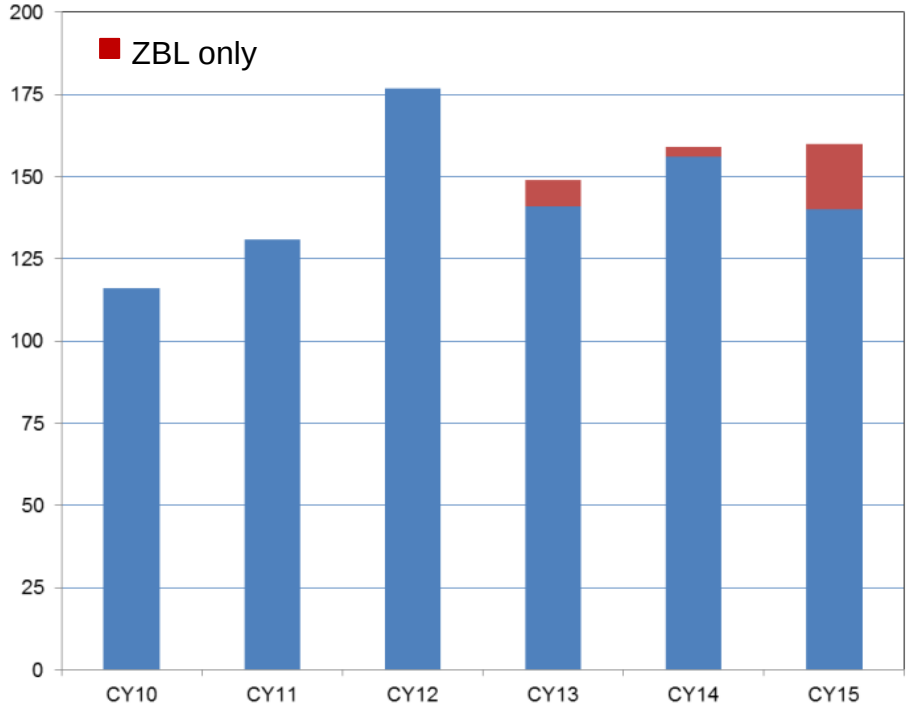


Z Shot Rate and Shot Planning

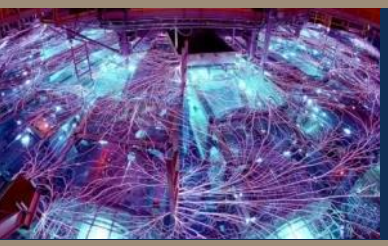
Z Shots by Calendar Year



~767 Shot Days were requested by LANL, LLNL, and SNL in CY16 – 3X more shot requests than available!

Z Shot Planning

- Typically plan for 140 – 160 shots a year based on budget
- Single shift operation:
  - 6 am work day start
  - 5 pm shot window closes
- Nominally 1 shot per shot day
  - 3 – 6 days for containment shots
- Most maintenance performed in parallel with daily shot preparations
- External PIs work with internal PIs for planning and execution



Z Core Capabilities: Z-Beamlet

Z-Beamlet Basics

Z facility

- ZBL is routinely used to deliver ~ 2.4 kJ of 2ω light in 2 pulses for backlighting experiments on Z
- In 2014 we added bandwidth to the laser; can now deliver ~4.5 kJ of 2ω in a 4 ns pulse.
- It should be possible to reach 6-10 kJ of laser energy (e.g., as on the NIF)
- ZBL Parameters:
  - Up to 6 kJ @ 1053nm
  - Up to 4.5 kJ @ 527nm
  - Up to 4 shots per day
  - Typically 0.3 – 4 ns pulse length in a 31x31 cm^2 beam
  - 1 - 9 keV radiography

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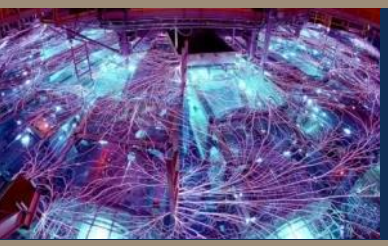
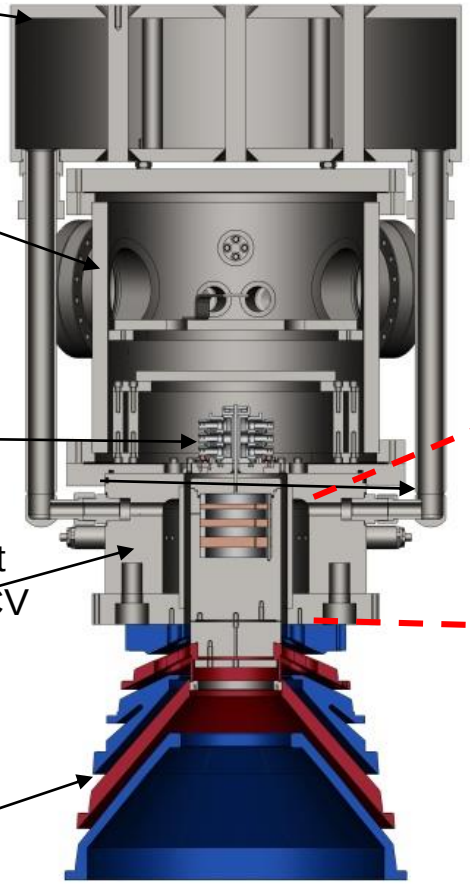


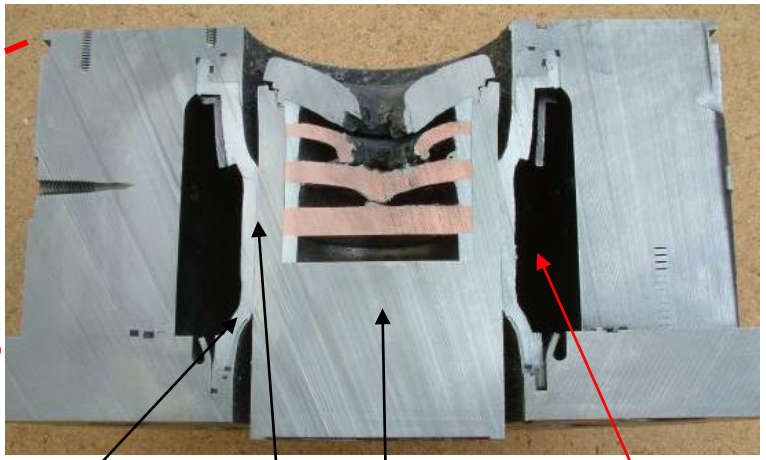
Z Core Capabilities: High Z

Primary containment system

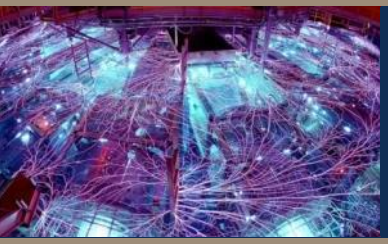


Post-shot cross section of UCV showing metal to metal seal between anode closure tube and cathode

- Valve closes in ~ 40 μs
- Leak spec is < 1e-5 atm-cc/sec
- Typical leak rates are 1e-8 atm-cc/sec



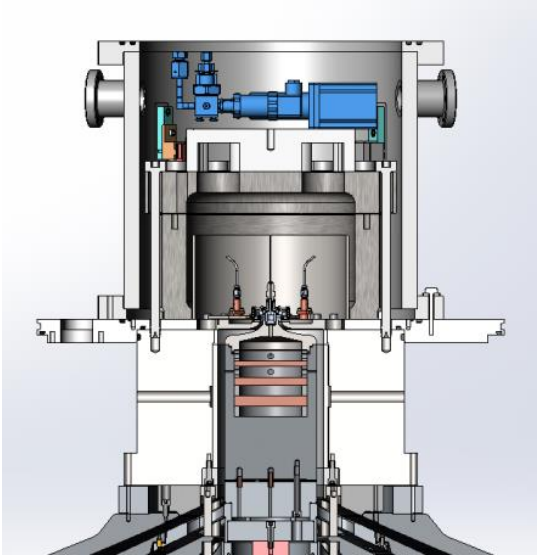
We have a proven containment system for Pu experiments used many times

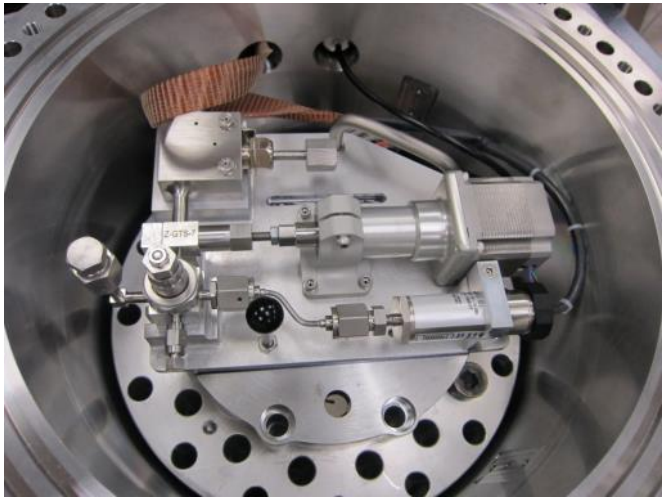


Upcoming Capabilities: Tritium

A Sandia Grand Challenge LDRD project is assessing the feasibility of using an explosive containment system

- Conducted three tritium containment development experiments using light gas surrogates
- Validated use of the existing hazardous material containment system as a viable test platform for tritium





- Developed and demonstrated the Z Gas Transfer System (ZGTS)
- Planning to conduct two trace tritium (0.1% - 1.0%) experiments in CY16 using the ZGTS in a containment system

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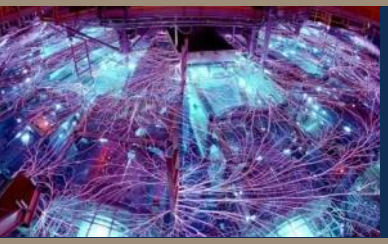
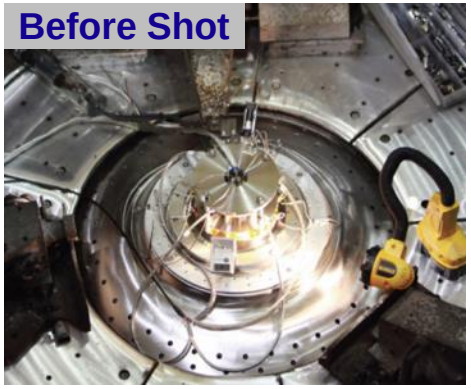
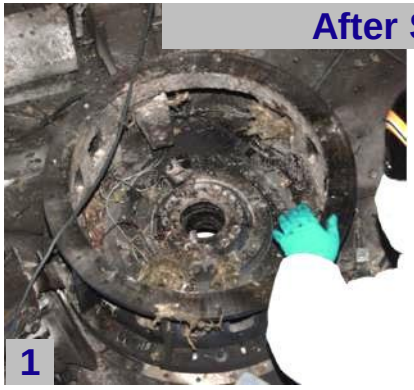


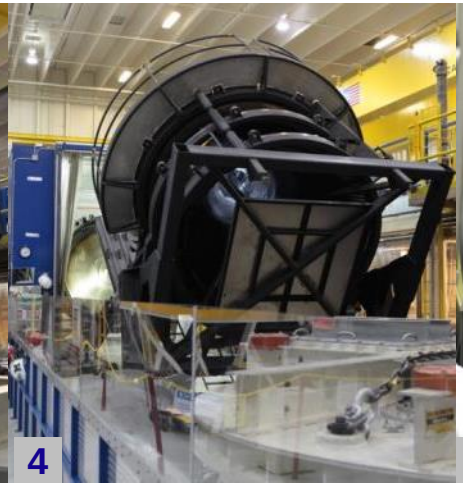
Daily Z Activities: Unload and Refurb of Z's Center Section





During a Z experiment several kilograms of material is destroyed and vaporized. Significant refurbishment activities are required between each shot which consist of:

1. Removal of in-chamber diagnostics and blast shield
2. Removal of Post Hole Convolutes
3. Removal of Magnetically Insulated Transmission Lines (MITL)
4. MITLs are flipped and placed into a HEPA filtered 'garage'
5. Cleaning / Grinding of MITLs and plastic insulator stack. All work requires Tyvek and Respirators due to Beryllium exposure



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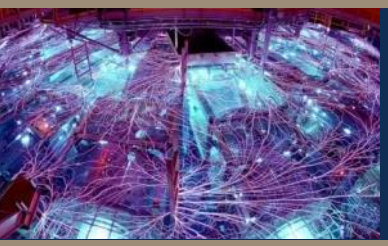
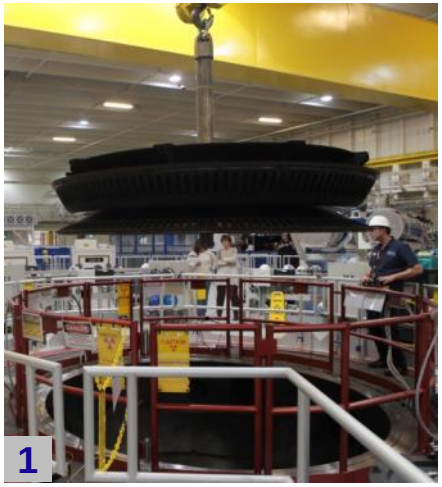
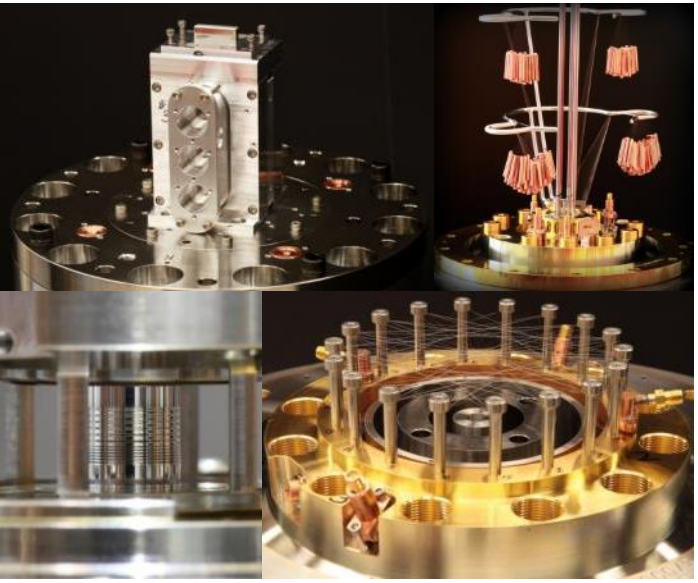
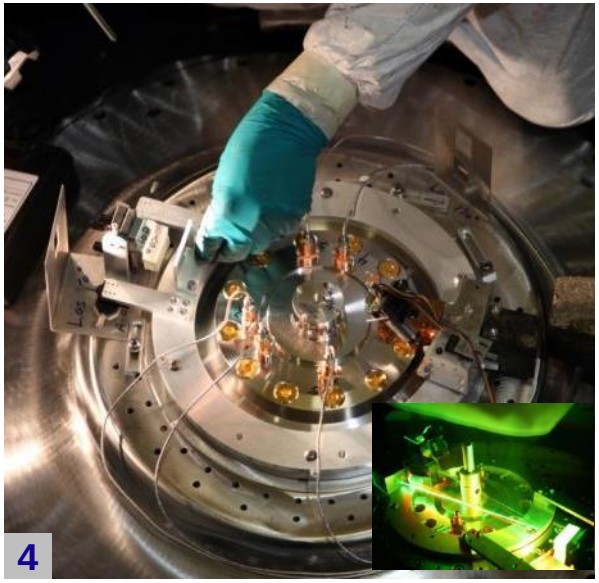


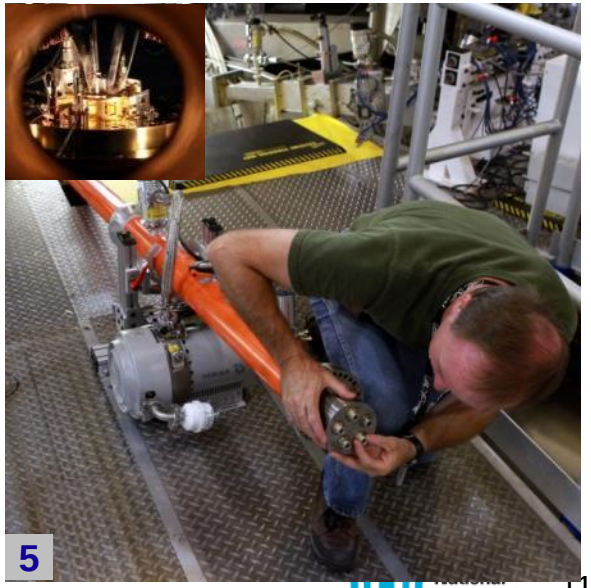
Daily Z Activities: Loading and Diagnostic Activities

1. Install Magnetically Insulated Transmission Lines
2. Install post hole convolutes
3. Install the target
4. Install in-chamber diagnostics
5. Align diagnostics







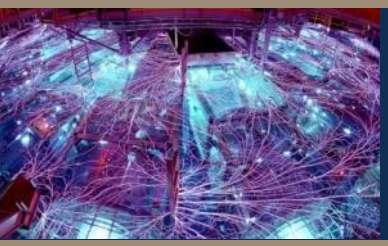


Daily Z Activities: Oil & Water Processing

Oil System Control Panel (circa 1985)

- Drain/Fill ~400,000 gallons of water
  - 30 minutes to drain or fill
- Drain/Fill ~600,000 gallons of oil
  - 80 minutes to fill and 65 minutes to drain

- Water is stored in twelve 50,000 gallon underground tanks
- Oil is stored in four 250,000 gallon tanks outside of the building



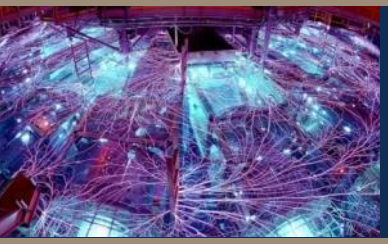
Daily Z Activities: Pulsed Power Inspections, Repairs & Configuration

- Drain oil and water tanks
- Teams will first ‘ground’ the machine
- Inspection of over 4000 components consisting of capacitors, resistors, gas switches, laser alignment, plastic rods
- Perform repairs and preventative maintenance as needed

Shorting of Marx Banks

Removal of a Pulse Forming Line (PFL)

Inspection of a Marx Trigger Generator (MTG)



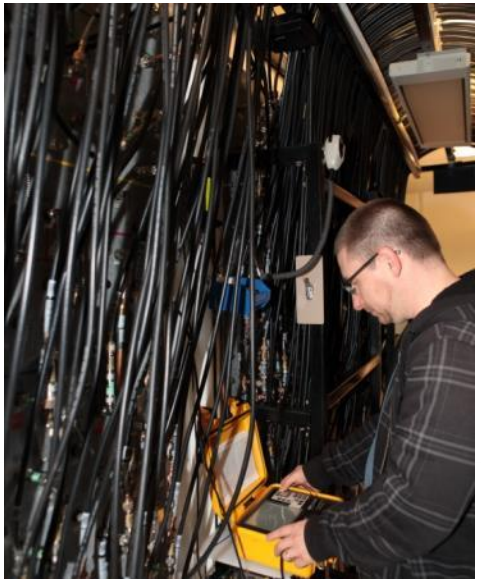
Daily Z Activities: Shot Preparations

Vacuum System

- 20 Vacuum Pumps (Cryo, Turbo & Roughing) on a 66,000 liter vessel
- Able to achieve shot pressure in 90 minutes ($3x10^{-5}$Torr)
- Control system is circa 1985

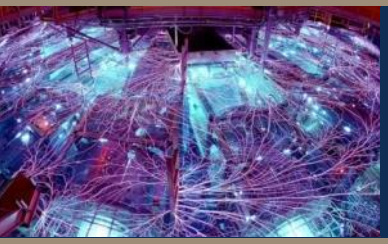
Sulfur Hexafluoride (SF6) System

- System contains ~3000 lbs. of SF6
- SF6 is used as an insulating gas for laser trigger gas switches, Marx spark gaps, and Marx trigger generators.
- Infrastructure is circa 1985



Control Monitor & Data Acquisition System

- We record ~800 fast signals on each shot.
- A 2-man team operates the machine for downline activities



Safety and Facility Upgrades

Vacuum Chamber Air Exchange

Replacing the Be Refurbishment Tent

Replacing Aging/Legacy Equipment

- Over the past few years, many legacy control and monitoring systems have been replaced and/or upgraded.
- We are developing new systems to improve the capability, safety and reliability of control and data acquisition systems for Z.

Z's control system computer. In place since 1993. Replaced May 2015

Z's vacuum control system In place since 1985.

Z's water drain/fill control system In place since 1985.

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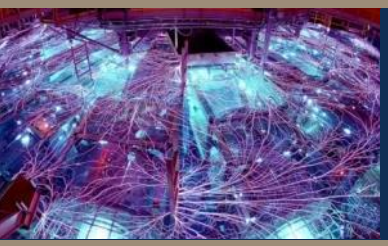
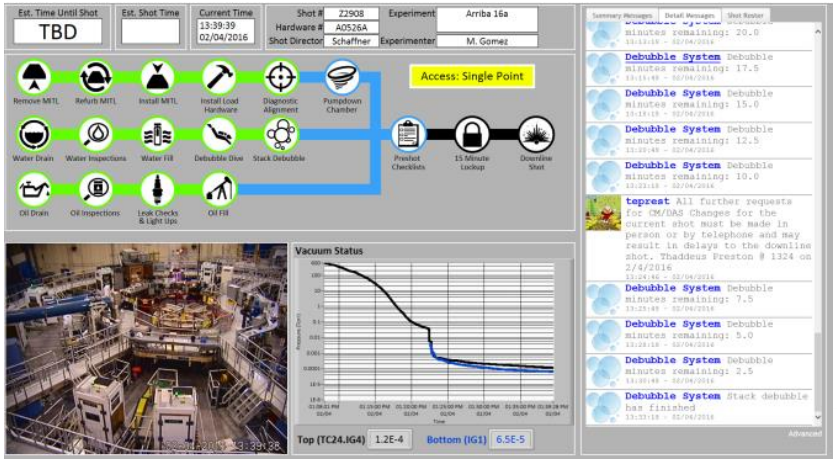


Improved Information Management and Communications

Z Shot Schedule

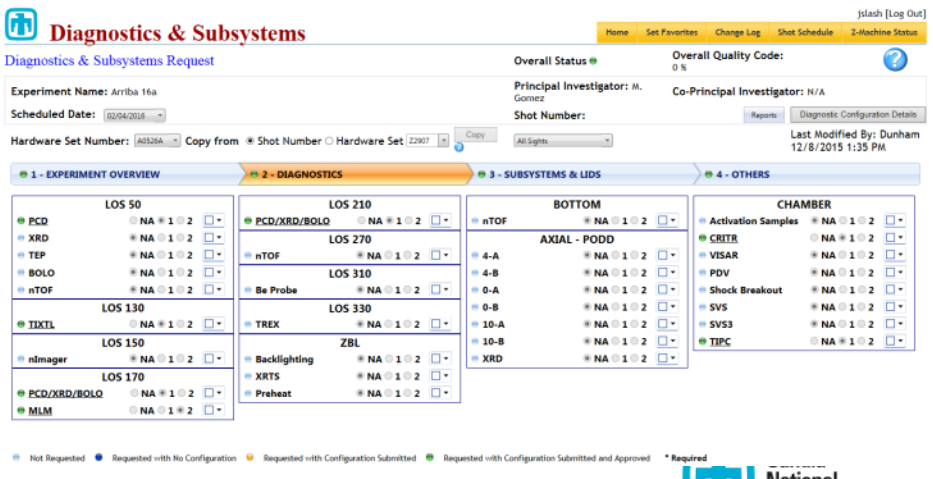
Lab-Wide Z Status Page

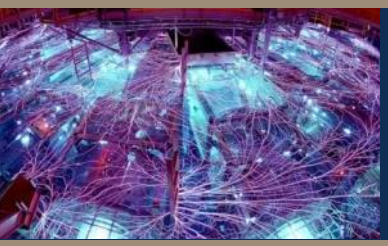


Z Shot Roster

	Mon 04/20/2015	Tues 04/21/2015	Wed 04/22/2015	Thurs 04/23/2015	Fri 04/24/2015
Experiment Name	**D2 Puff**	**D2 Puff**	**Hydroliquid**	**Union 2**	**Pulseshaping 3**
Shot Director	De Luna	De Luna	De Luna	De Luna	De Luna
Principal Investigator	Knapp	Knapp	Knudson	Lemke	JP Davis
Engineering POC	Reneker	TBD	Williams	Twyeffort	Williams
CM Operator	Baker	Baker	Radovich	Preston	Bock
CM Coordinator	Ploor	Ploor	Preston	Ploor	Preston
DAS Operator (CM POC)	Baker	Ploor	Preston	Ploor	Preston
Vacuum Shot Support	Bock	Bock	Bock	Bock	Bock
ESS Shot Support	Roznowski / Rakes	Divett / Jojola	Cortez / Speas	McCarthy / Avila	Cortez / Avila
LTS Shot Support	Potter	Potter	Potter	Potter	Potter
Access Evacuator (Top)	Roznowski / Potter	Jojola / De Luna	Speas / Potter	Avila / De Luna	Cortez / Potter
Access Evacuator (Bottom)	De Luna / Ploor	Divett / Baker	Cortez / De Luna	McCarthy / Potter	Avila / Bock
MITL Refurb & Wipe	York / Citrin / White	York / Citrin / White	York / Citrin / White	York / Citrin / White	York / Citrin / White
Stack Refurb & Wipe	Justus / Roebuck / White	Justus / Roebuck / Macrunnels	Justus / Roebuck / Macrunnels	Justus / Roebuck / Macrunnels	Justus / Roebuck / Macrunnels
Lab 101	York / Olivas	York / Olivas	York / Olivas	York / Olivas	York / Olivas
Top Side Load	York / Citrin	Macrunnels / Citrin	Macrunnels / Citrin	Macrunnels / Citrin	Macrunnels / Citrin
Bottom Side Load	White / Roebuck	Roebuck / White	Roebuck / Olivas	Roebuck / Justus	Roebuck / White

Z Diagnostic Request System





WP&C at Z leverages Sandia's corporate processes and structure

Work Planning and Control Criteria for Safe Design and Operations (MN471021)

Division 1000 Implementation of MN471021 Work Planning and Control Criteria for Safe Design and Operations

Center 1600 Engineered Safety and Work Planning and Controls (DRAFT)

Requirements for New or Changed Systems at the Z Facility (ADM_REQMTSYS_ADPRO)

Acceptance of Work Scope

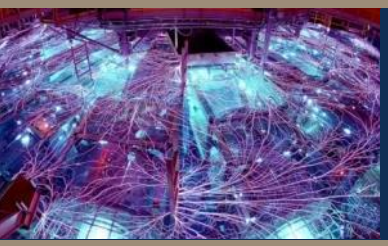
Acceptance of Safety Case

Safety Case is documented in WP&C Repository

Work Authorization

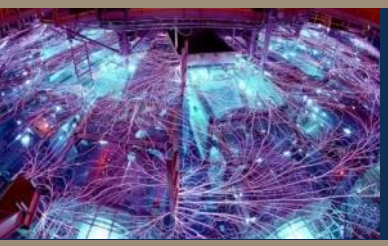
Procedures (Technical Work Documents) to Perform Work

Procedures (or SWP) and JSA approved and available for use



Z facility activities involve many similar and some unique and complex hazards

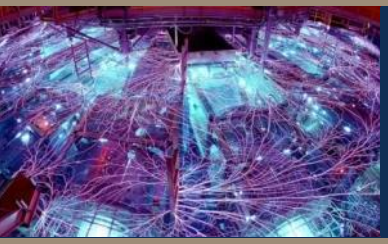
- High voltage – 10's of Kilovolts to Megavolts
- High currents – up to 26 Million amps in Z
- X-rays – 2 Megajoules (~ stick of dynamite equivalent)
- Neutrons
- Radioactive materials
- Beryllium operations
- Underwater diving
- Heavy lifting – the Z voltage insulator stack is ~39,000 lbs
- Large fluid movement – e.g. ~600,000 gallons of oil
- Laser light – 6,000 Joules at ZBL
- Adhesives, solvents, rad and Be waste
- Complex mechanical structures with human interaction hazards



Commonality and consequence drives our WP&C/Safety Case approach

- Many hazards are common to our AWL that span and cross-cut multiple organizations
- High consequence puts the focus on those hazards which create the greatest personnel risk
- With Z having 10s of people from many organizations working together in parallel and in proximity, our initial approach was to think about ‘safety areas’ as a synonym for ‘safety case’
- This forces more of the discussion to be at the system level looking at interfaces and communications and motivates critical questions from a different vantage point – this will provide us the greatest value

- **Focus on the discussions and critical thinking which become embodied in the Manager Safety Case narrative.**



We created a Safety Case universe to envelope Z activity-level work

Safety Area
Gas House Systems
Oil Systems
Water Systems
Craining / Rigging / Hoisting
General Lab: B-Dot Calibration Lab
Gas Puffs on Z
Diving at Z
Beryllium Safety
General Lab: Cable and Component Assembly (MO2
Diagnostic Operations at 983
Z Shot Execution (CM/DAS)
Dark Room (960/2097A)
MCP Lab (970/211) NSTec Ops
General Labs: Imaging & Spectroscopy Light Labs
1600 Storage Facilities
ZBL Ops on Z
Z Pulsed Power
Center Section Ops
Vacuum at Z
Laser Trigger Section at Z
Load Assembly (Lab101)
Z Shot Planning
General Lab: Neutron Diagnostics for Z
Applied B-Field on Z
Cryo / Gas Fill Operations
Pu/U Handling and Experiments

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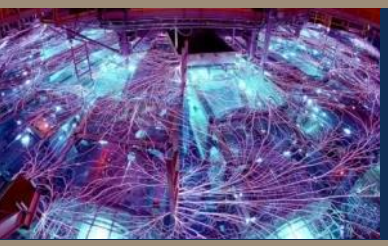
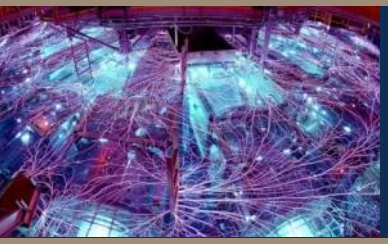


Management led Safety Case development has shown benefits

- Identified a potential improvement by adding an audible high-bay alarm if diver air quality does not meet specified standards
- Examining technical basis for 2 kV Marx bank discharge threshold being the safe-entry level for post-shot operations
- Investigating Control Monitor system reliability in measuring ‘zero energy’ in the Pulsed Power system
- Added second air monitoring system to mitigate asphyxiation hazard in Z gas house
- Gas feed line caps were installed for the Z Gas Puff system to prevent the potential spread of Be contamination between shots
- Purchased and installed Smoke Absorbers at soldering stations
- Implemented periodic inspection of wall mounted cable rack in trailer lab
- Designing engineered system to replace manual system currently in place to move fluids in and out of Z (primarily a facility safety concern)
- Identified mitigations for head injuries while working in Z diagnostic boats



Questions?