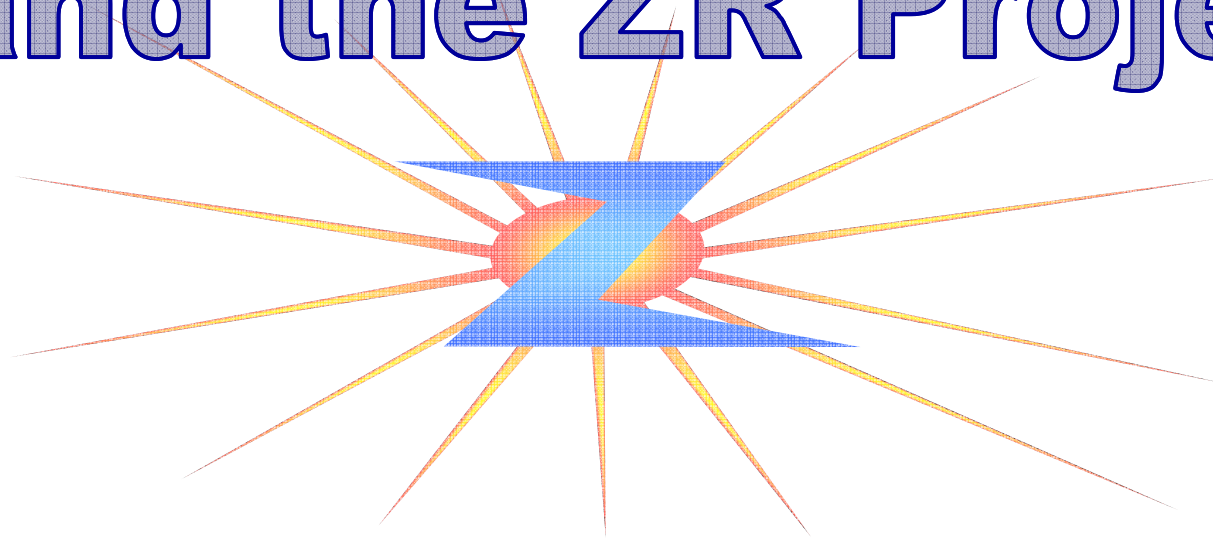


Powered up: Z and the ZR Project



Sandia Technology Symposium Presentation
March 3, 2008

Ed Weinbrecht representing the Pulsed Power Sciences Center




Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.





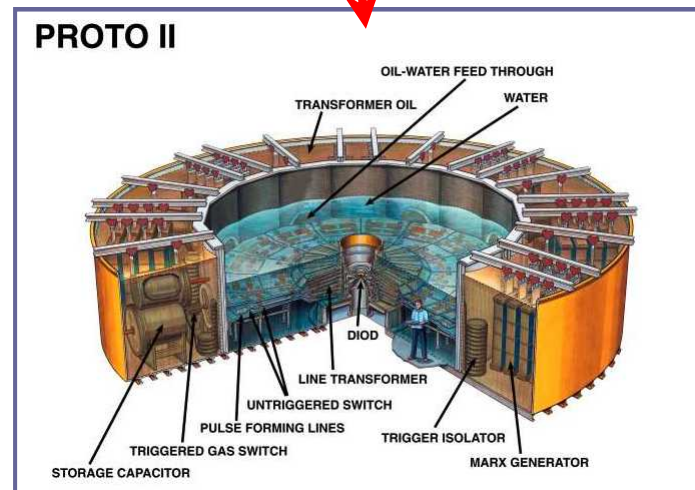
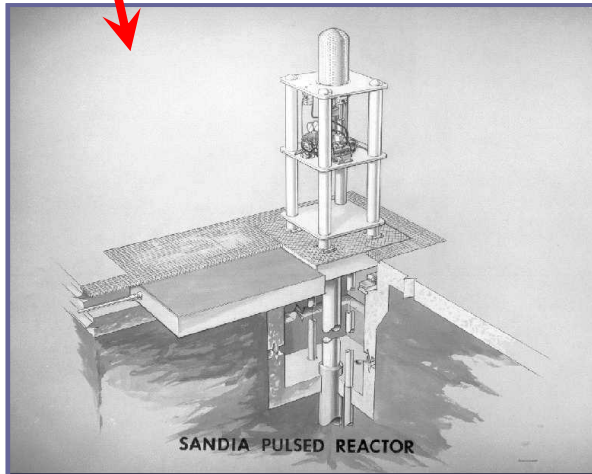
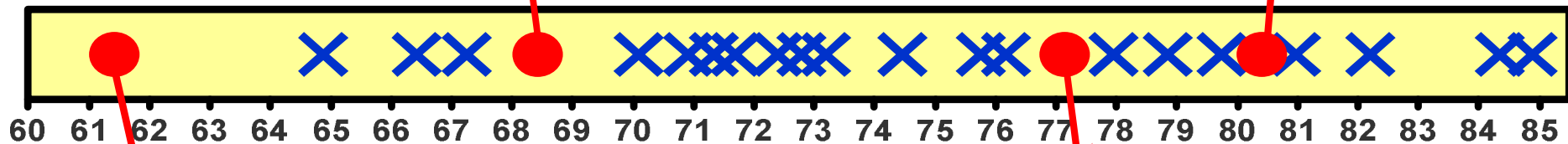
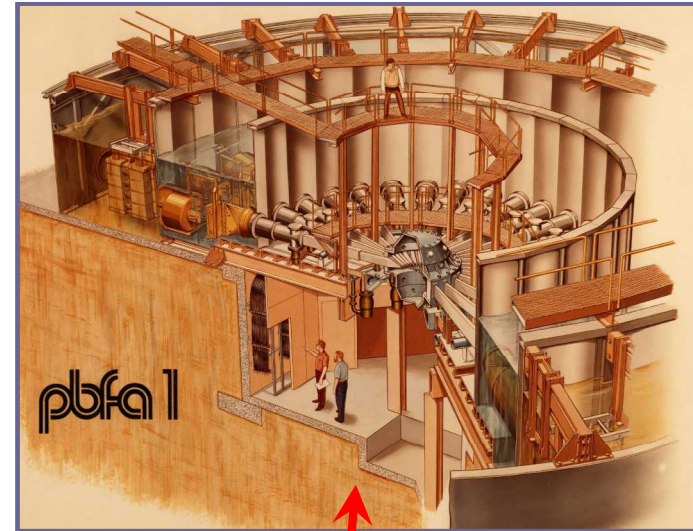
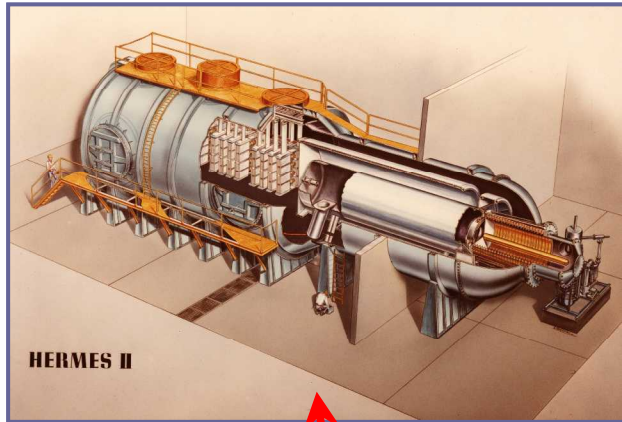
“Readers Digest” Overview of Z

- **Short history of Z**
- **How Z works and what we do with it**
- **Refurbishing Z -- challenges and successes**
- **A fusion future**

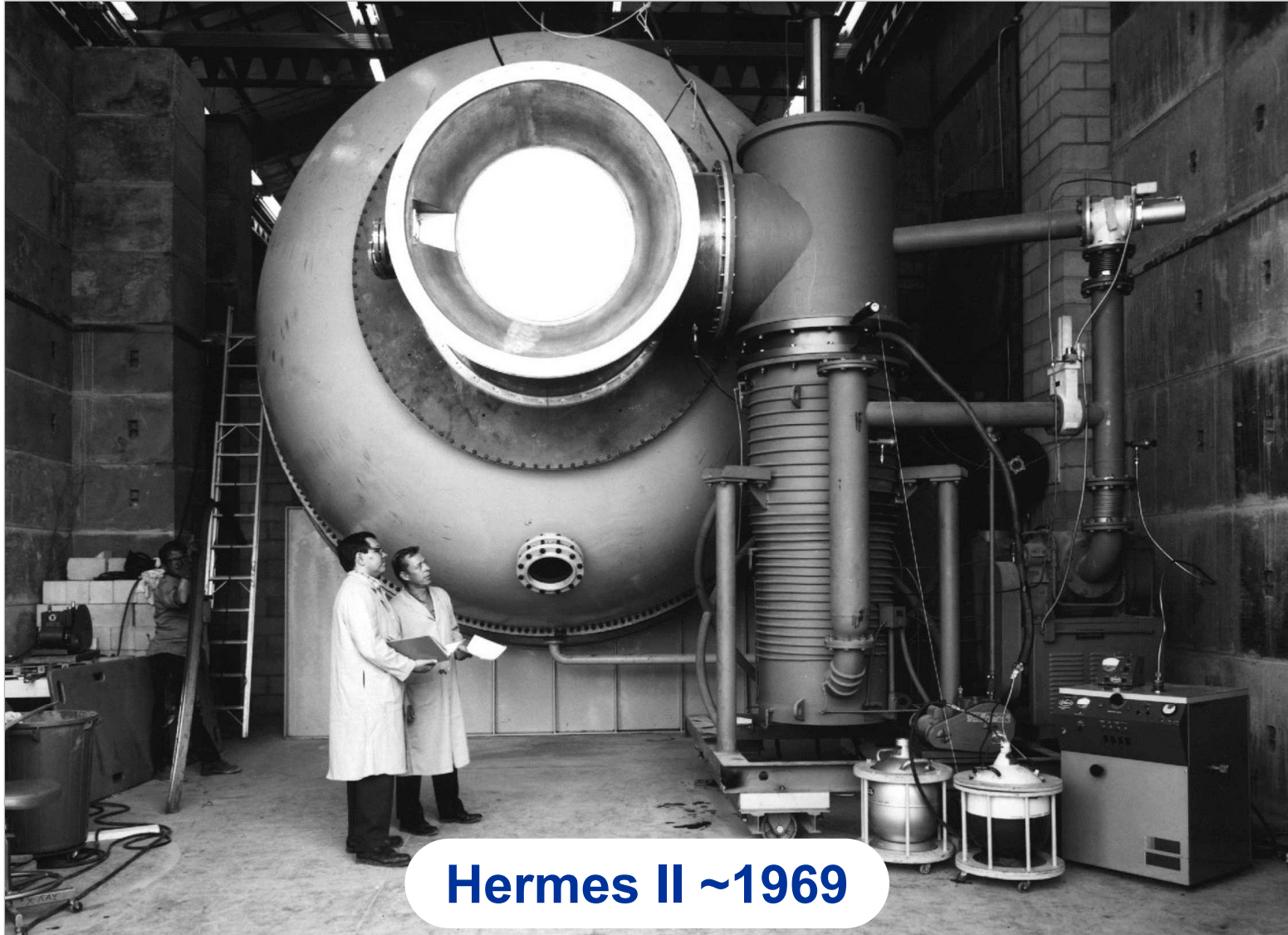


History

Z: Steeped in History



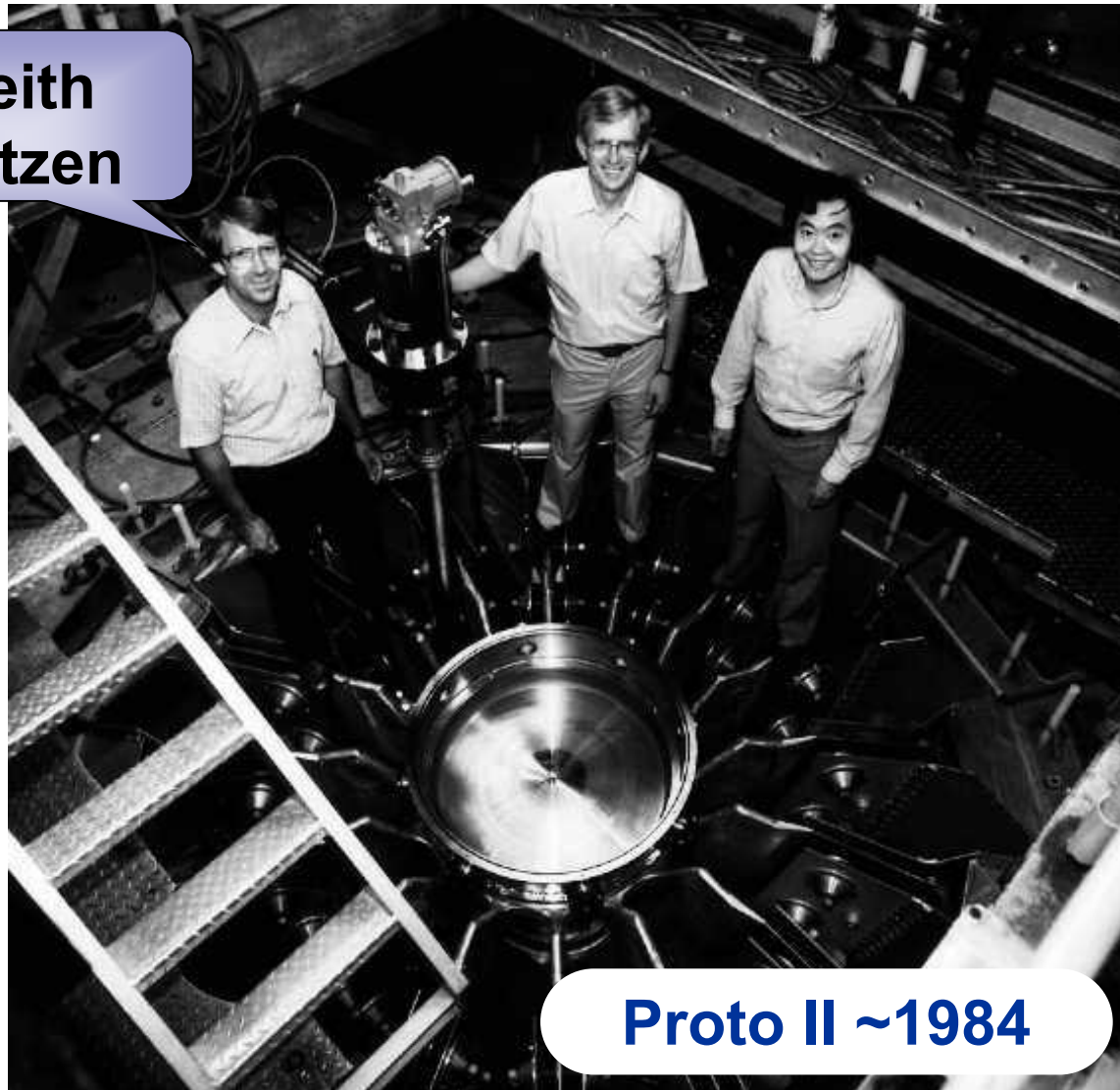
Z: Steeped in History



Hermes II ~1969

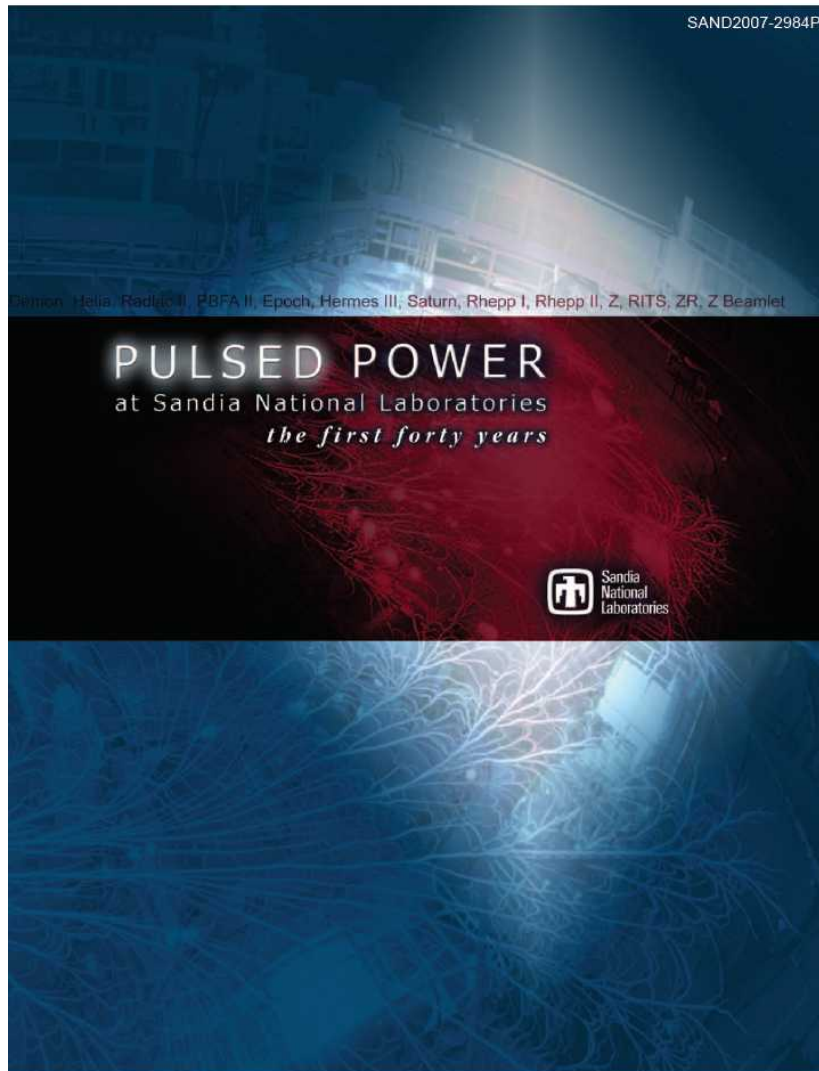
Z: Steeped in History

Keith
Matzen



Proto II ~1984

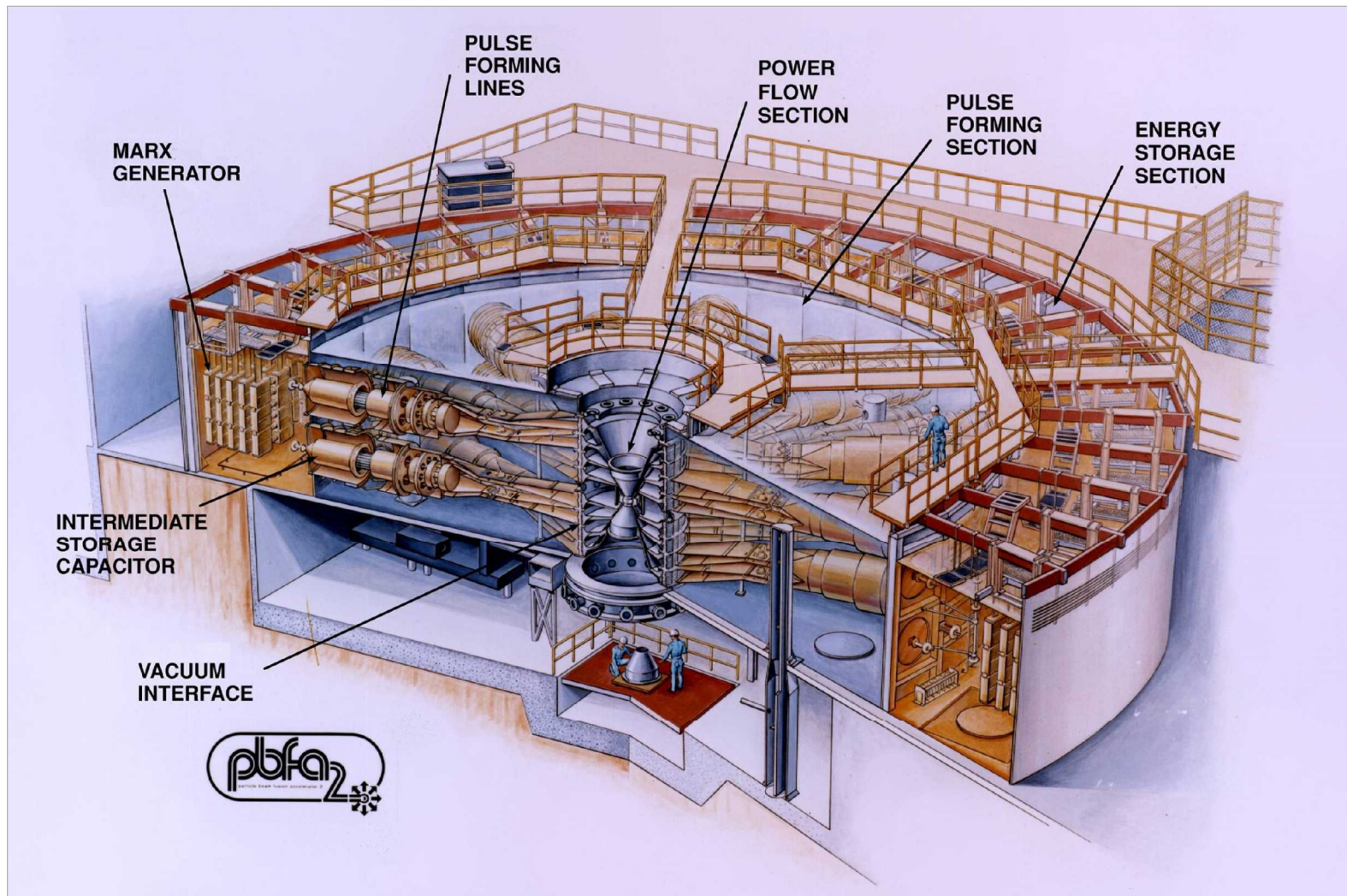
Wonderful History Resource



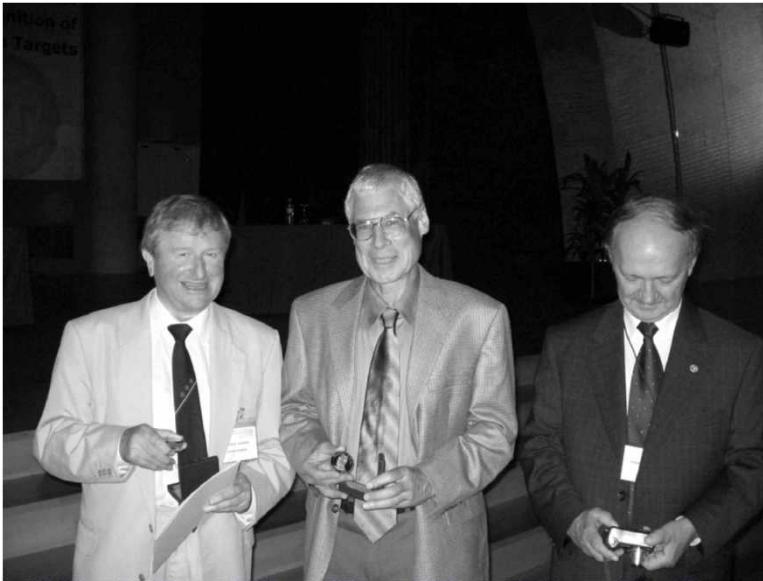
Compiled by
Ann Van Arsdall

With support from:
Myra O'Canna
Rebecca Ullrich
Laura Martinez
Also Ramona Abeyta
Shirley Aleman
Anna Nusbaum
Michael Ann Sullivan
Peggy Warner

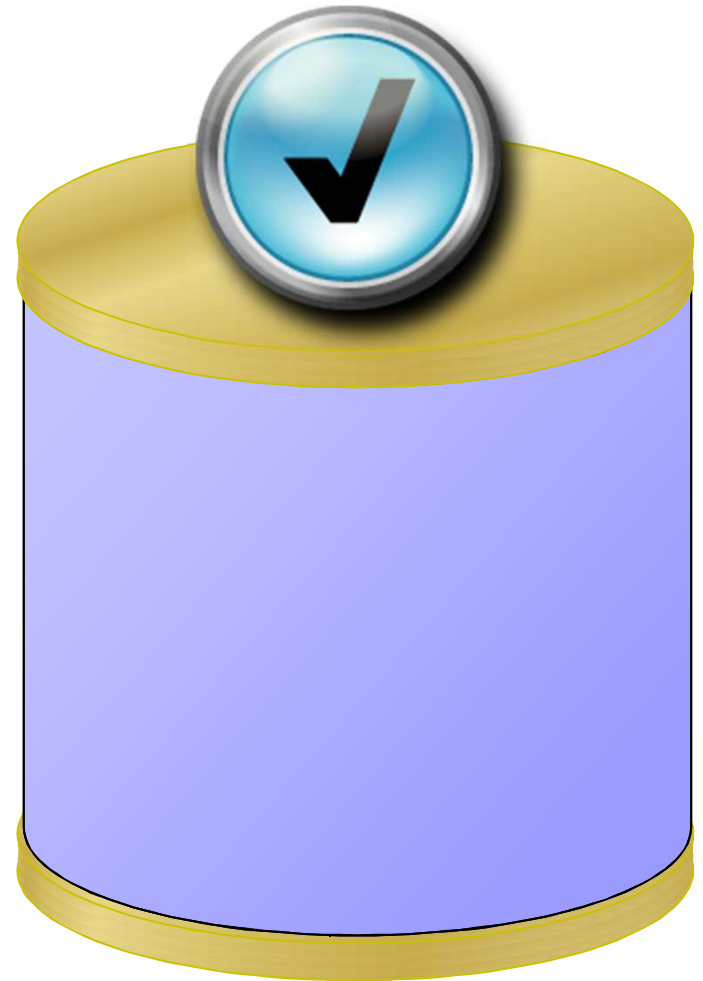
1985: Z Began Service as PBFA II



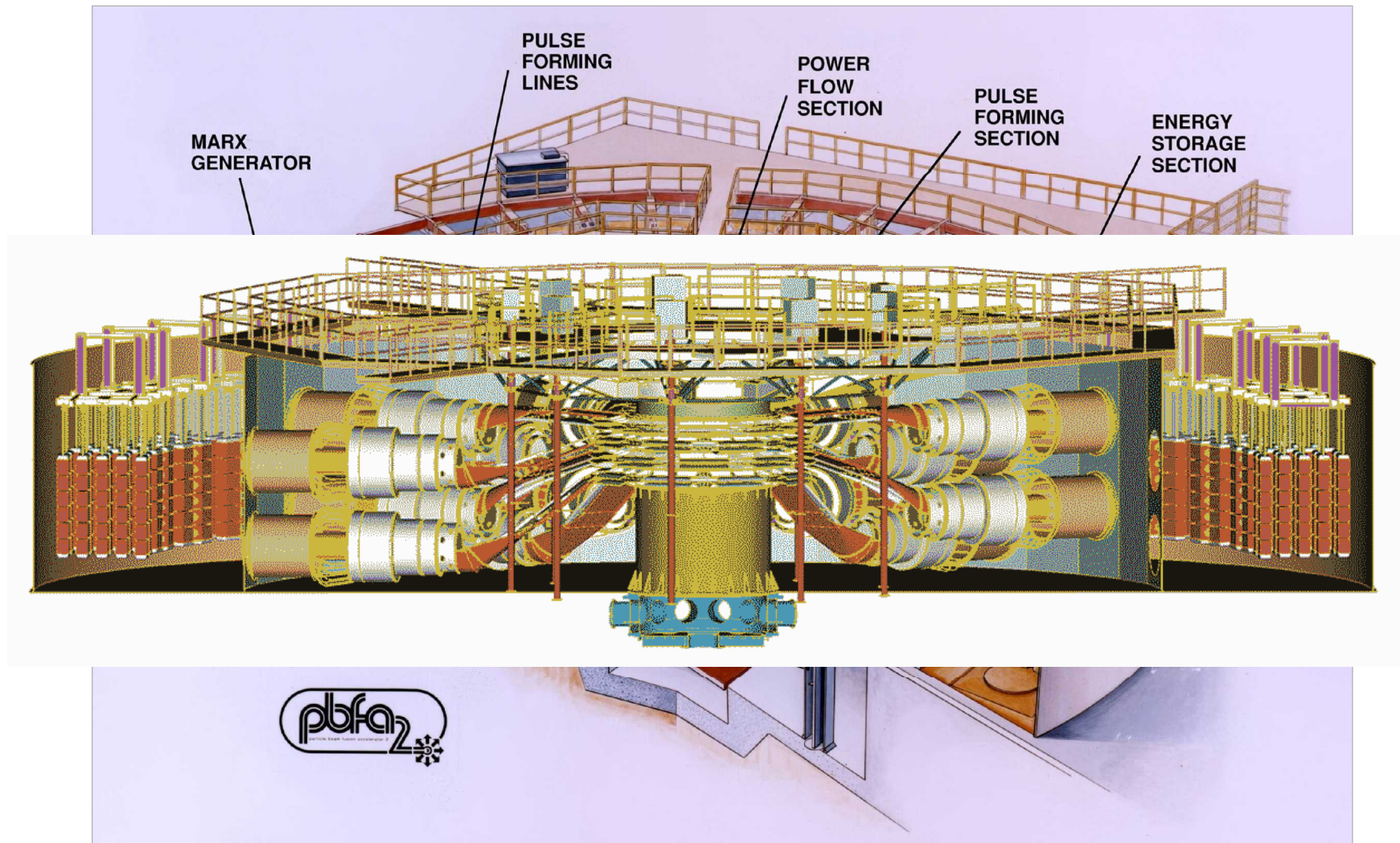
1995: Z-Pinch Breakthrough



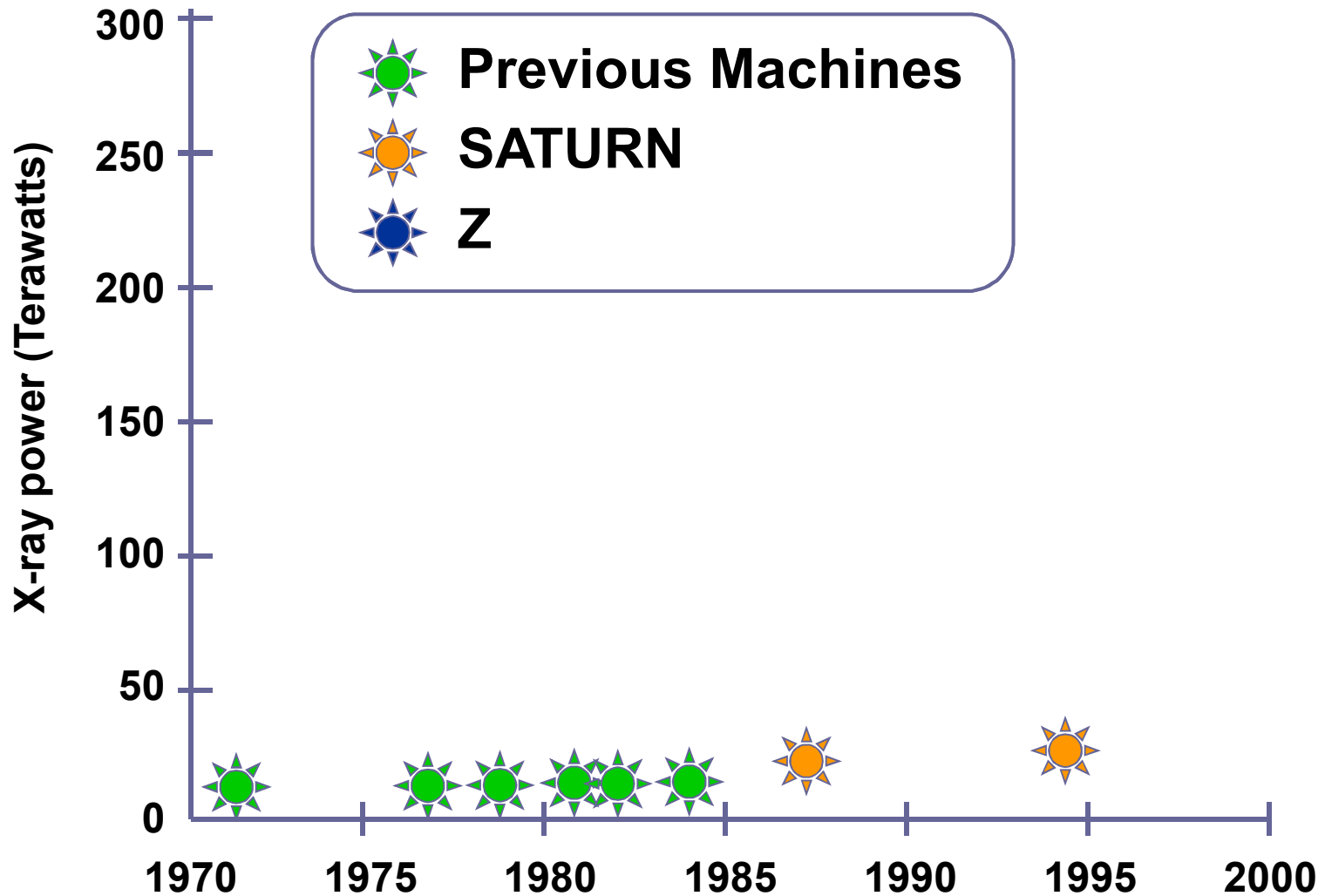
**Sanford, Haines, Smirnov
receive
European Physical Society
Hannes Alfven Prize, 2005**



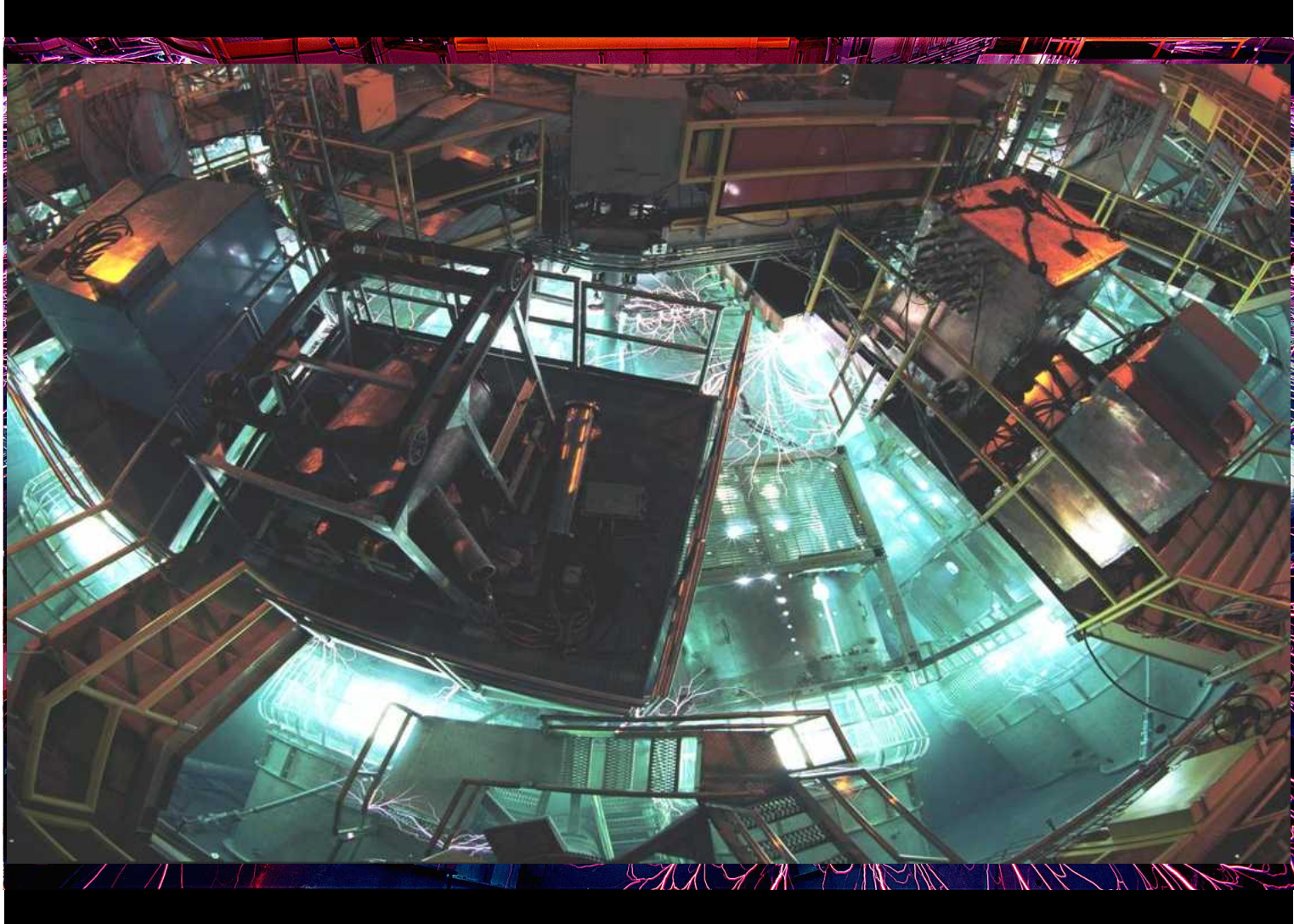
1996: PBFA -- Z Pinch Version



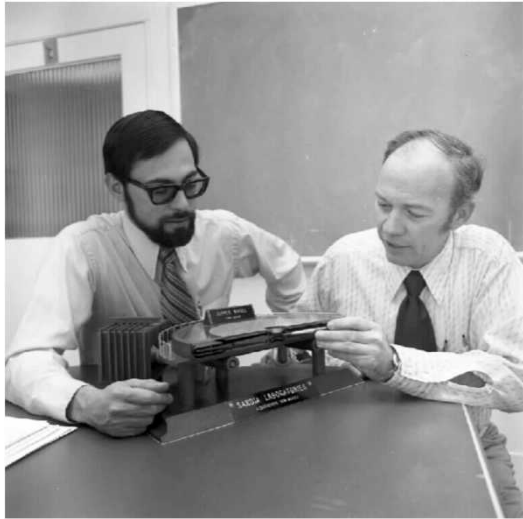
Stunning Results



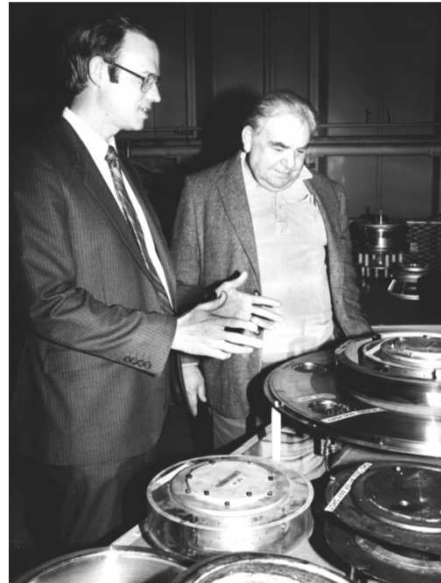
“Arcs and Sparks” thru the Years



Directors thru the Years



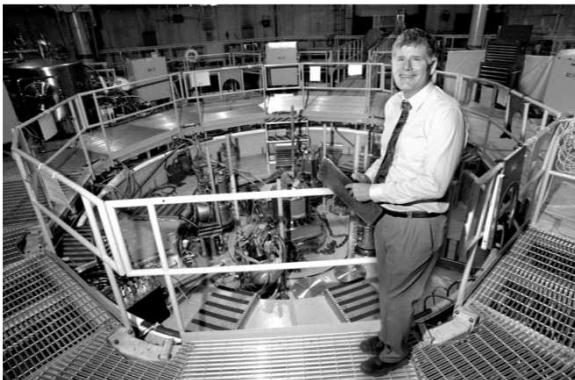
Yonas



VanDevender



Cook



Quintenz



Matzen




Pulsed Power 101

What is Pulsed Power?

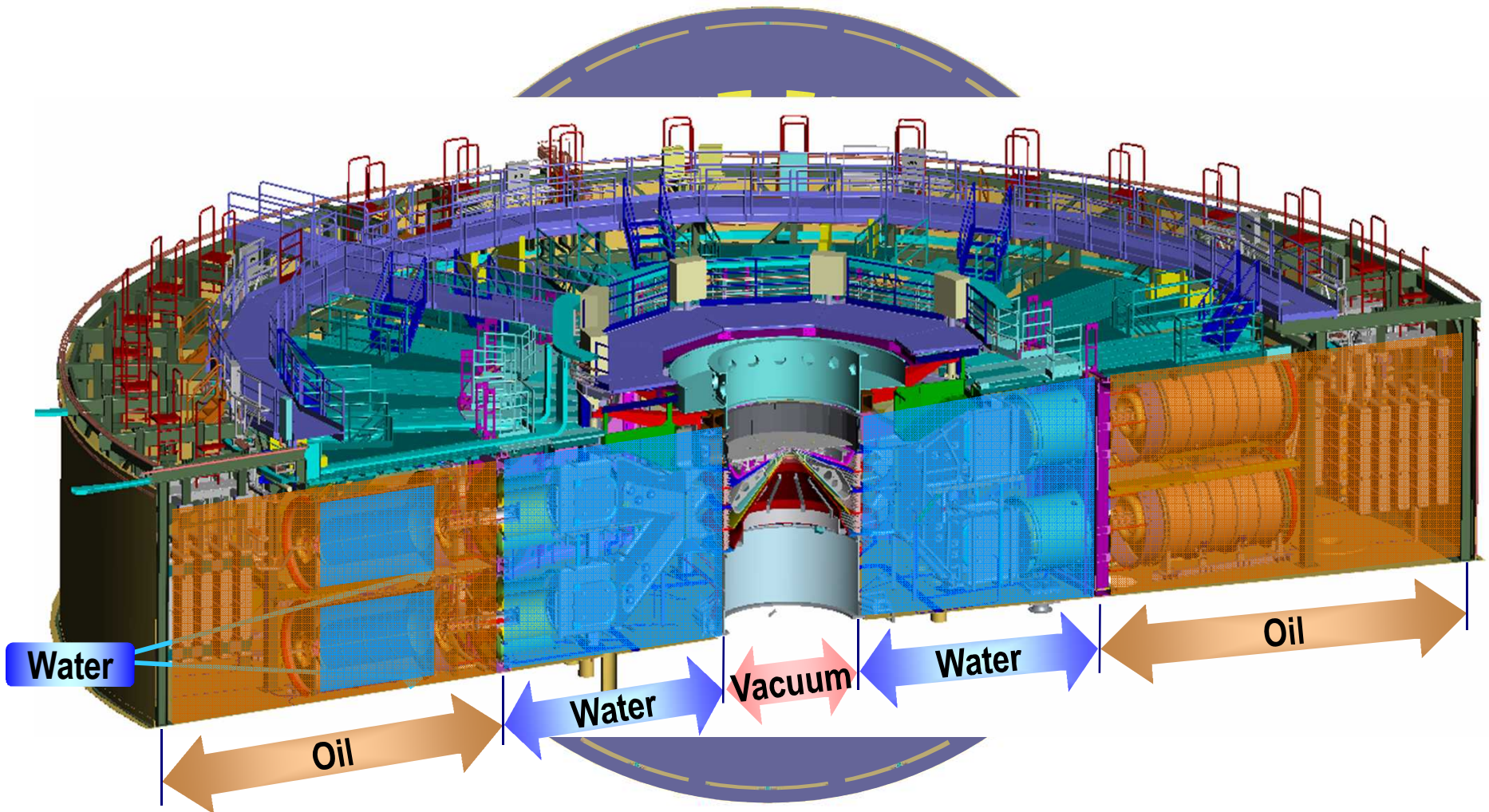
pulsed power (pŭlsd) (pou'ar), *n.* compression of energy in time and space, resulting in large instantaneous power levels

$$Power = \frac{Energy}{Time}$$

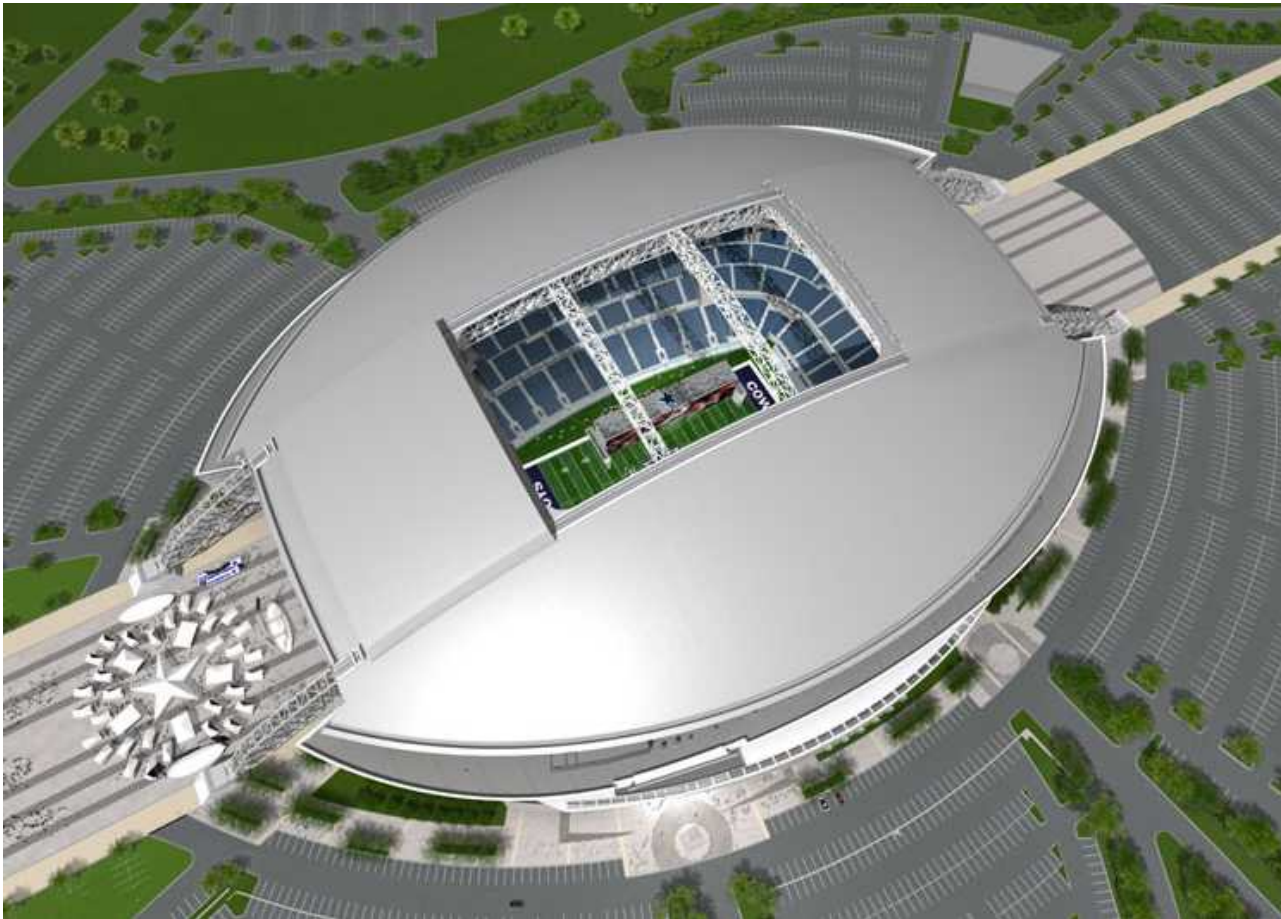
Fast Pulsed Power $\approx < 1$ microsecond


$$\left[\frac{1}{1 \text{ million sec}} \right]$$

Z's Pulsed Power Architecture



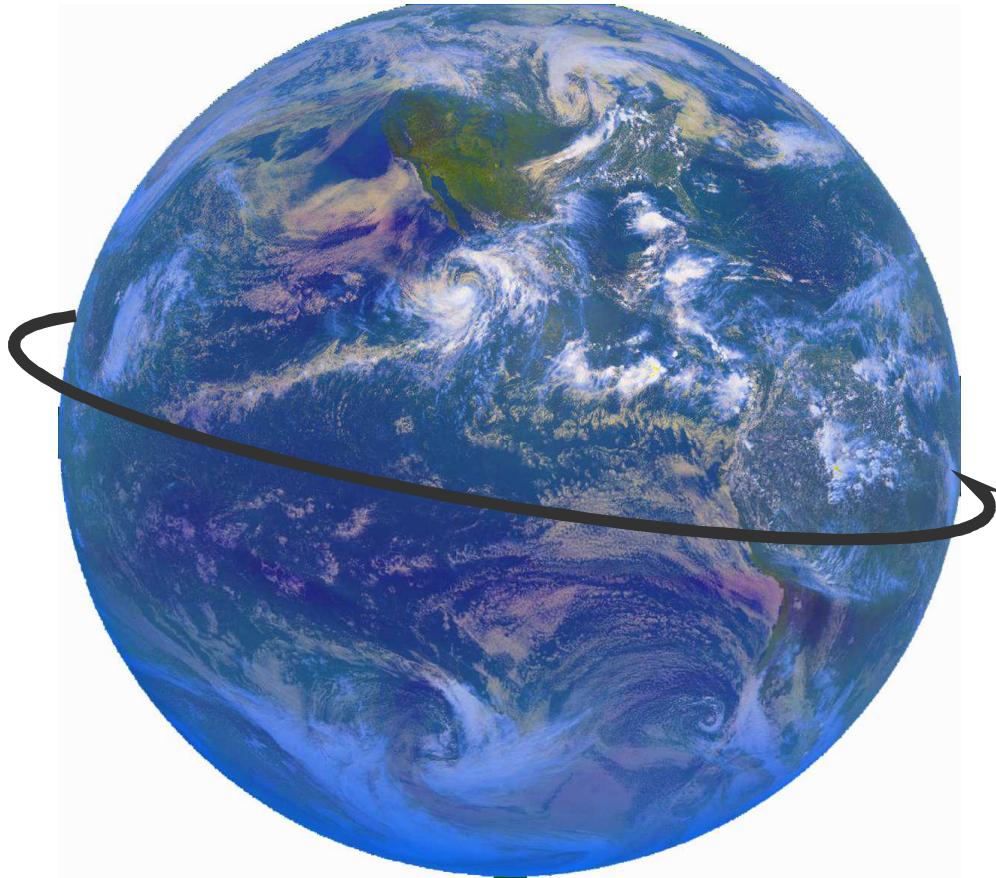
Compression in Space



New Dallas Football Stadium Under Construction
104,000,000 ft³



Compression in Time

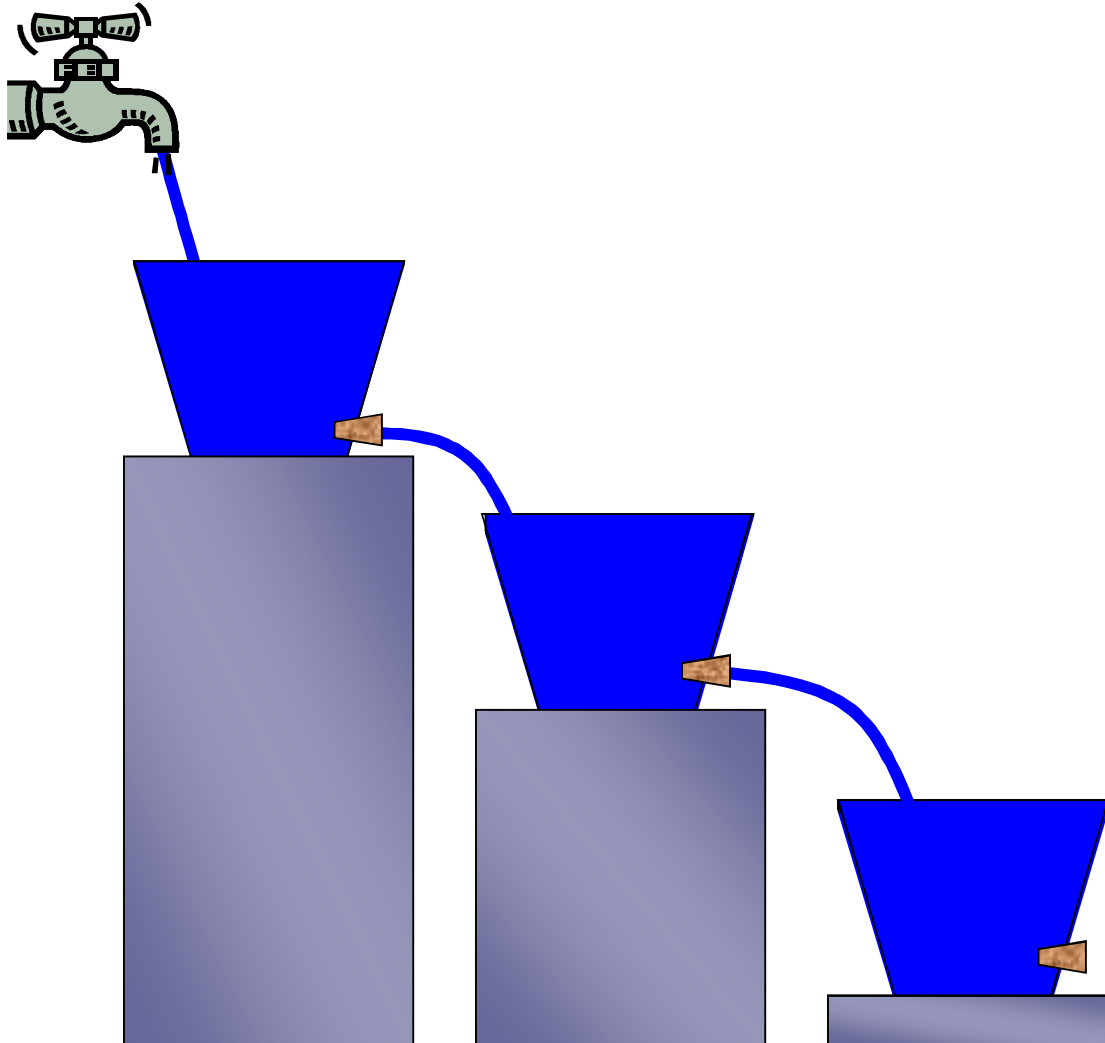


24,900 miles

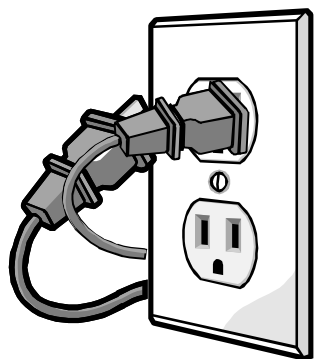


1 1/2 "

Capacitor Charge/Discharge

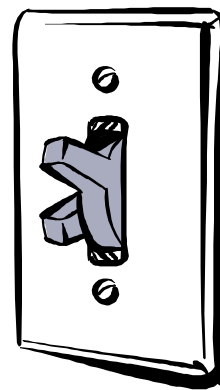


Pulse Compression

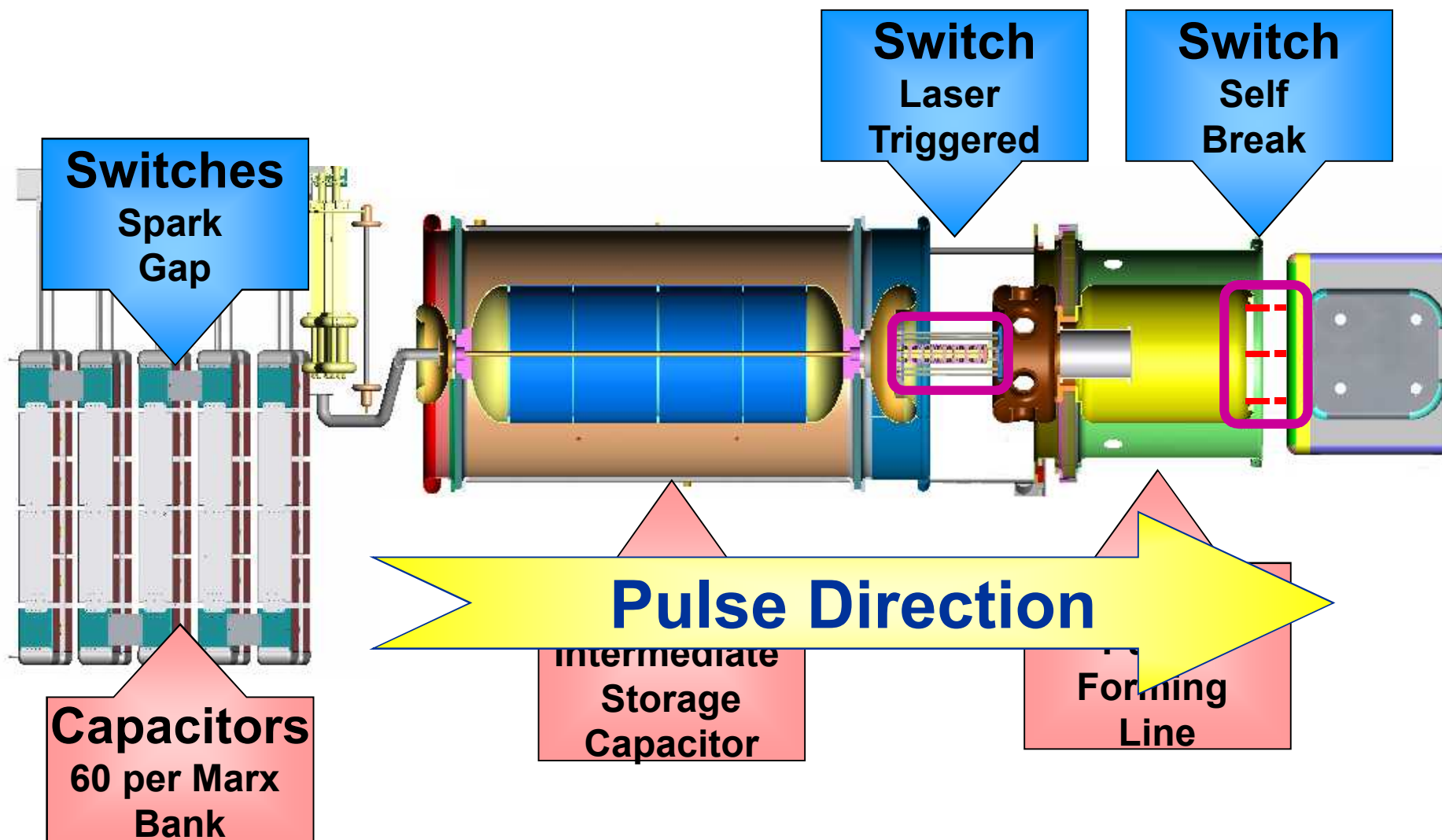


Energy

Time



Z's Capacitors & Switches

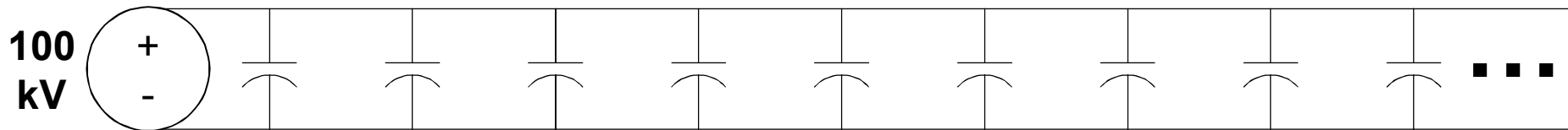


Marx Generators

~90% of pulse compression is here...



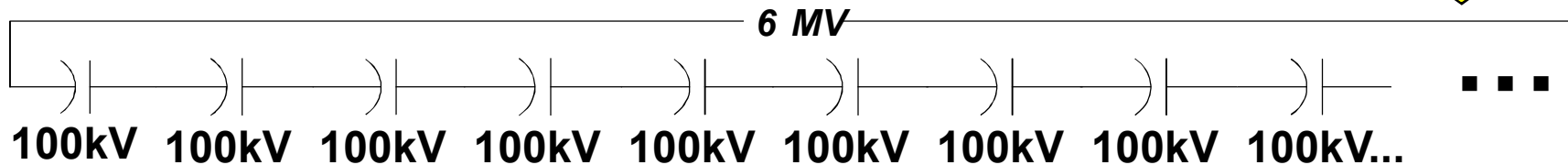
Charge in parallel



120
second
charge



1 micro
second
discharge



Discharge in series

Intermediate Storage Capacitor



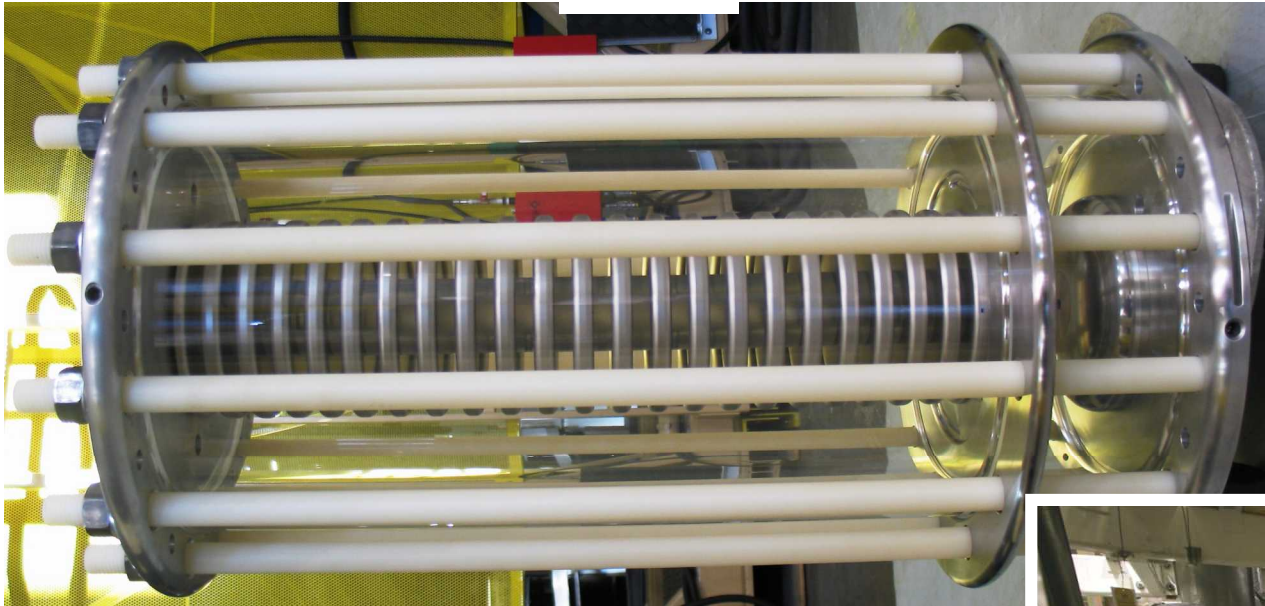
1 micro
second
charge

350 nano
second
discharge

Each capacitor holds 2,900 gallons of water

Laser Triggered Gas Switch

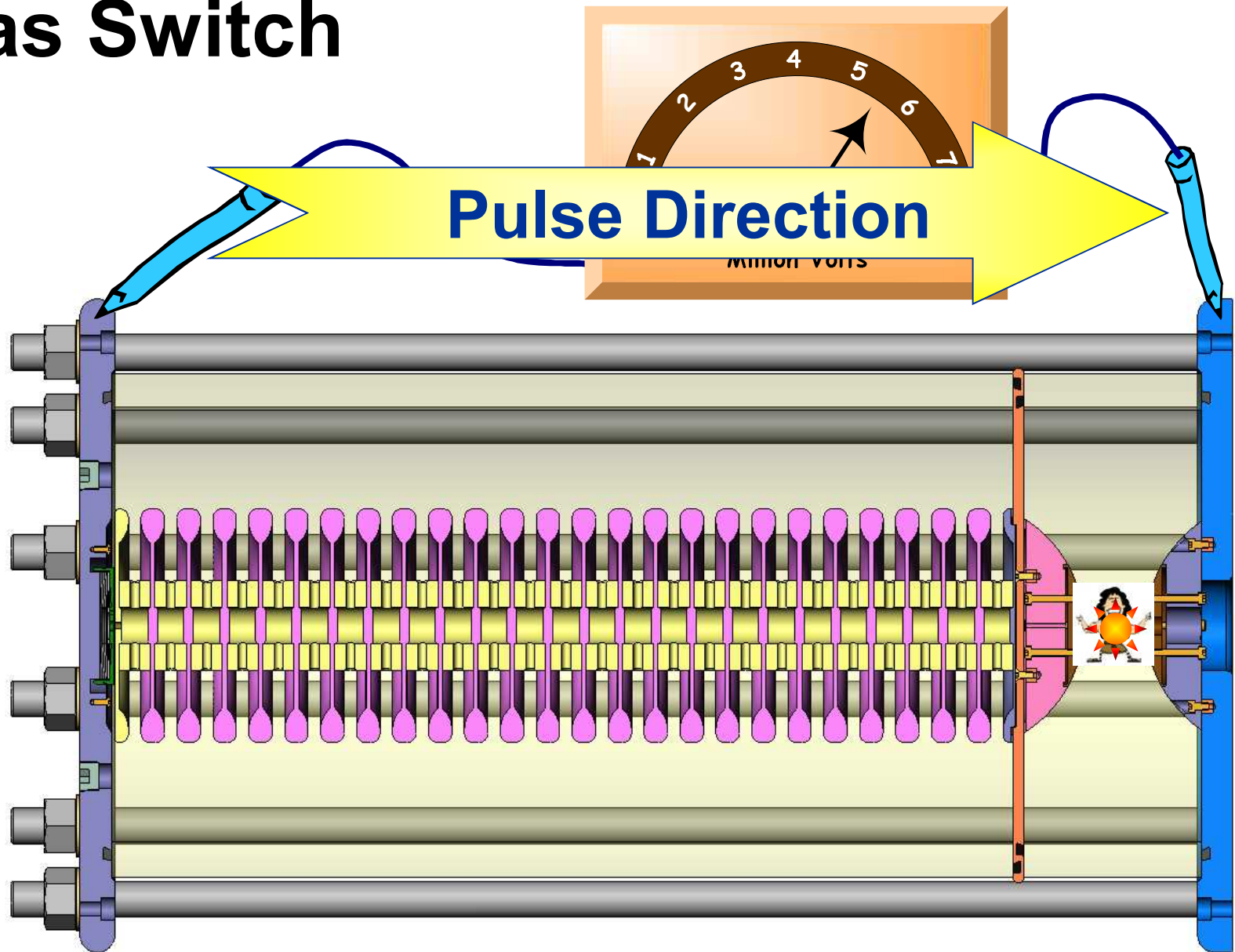
← ~30" →



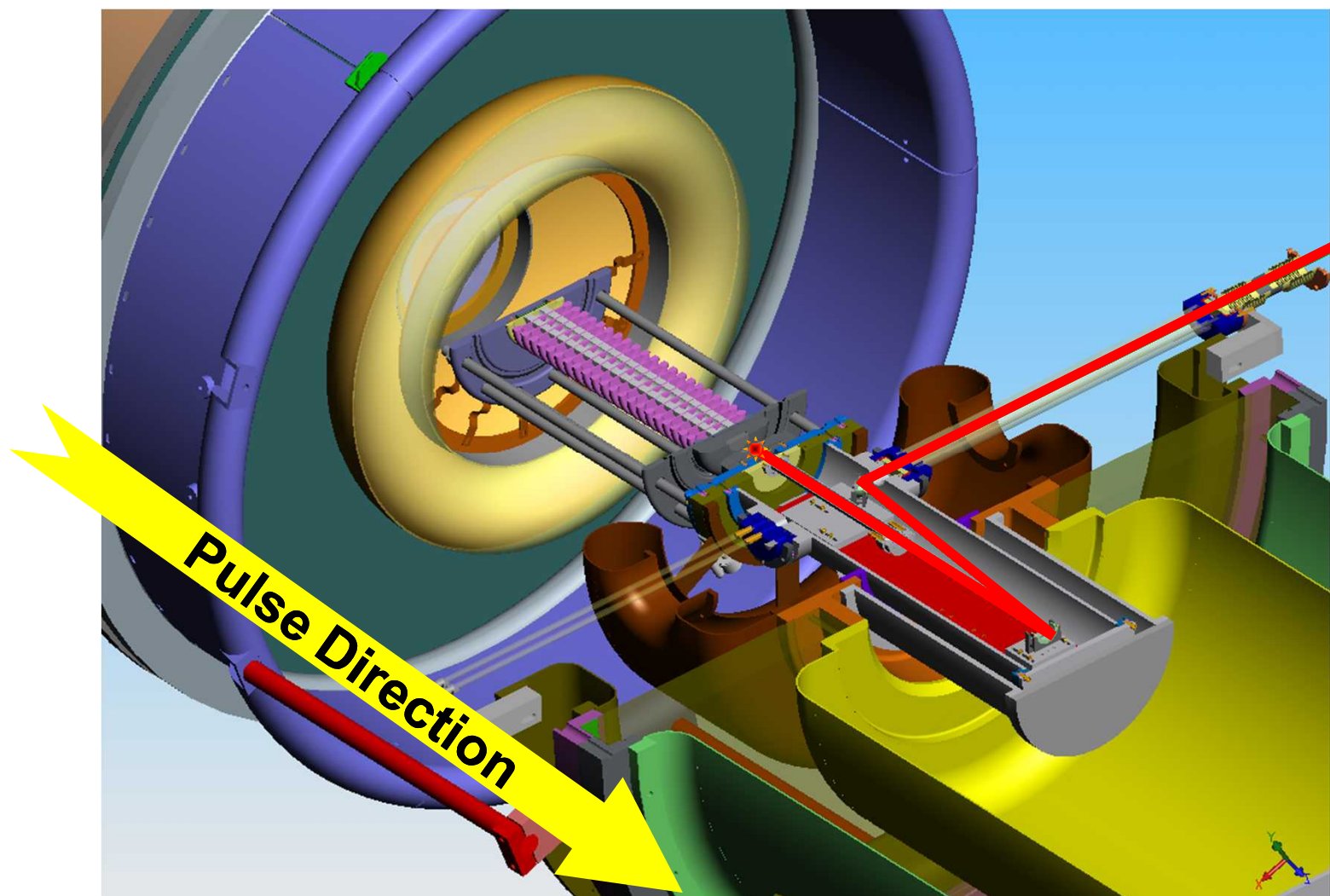
Synchronizes the 36 Modules



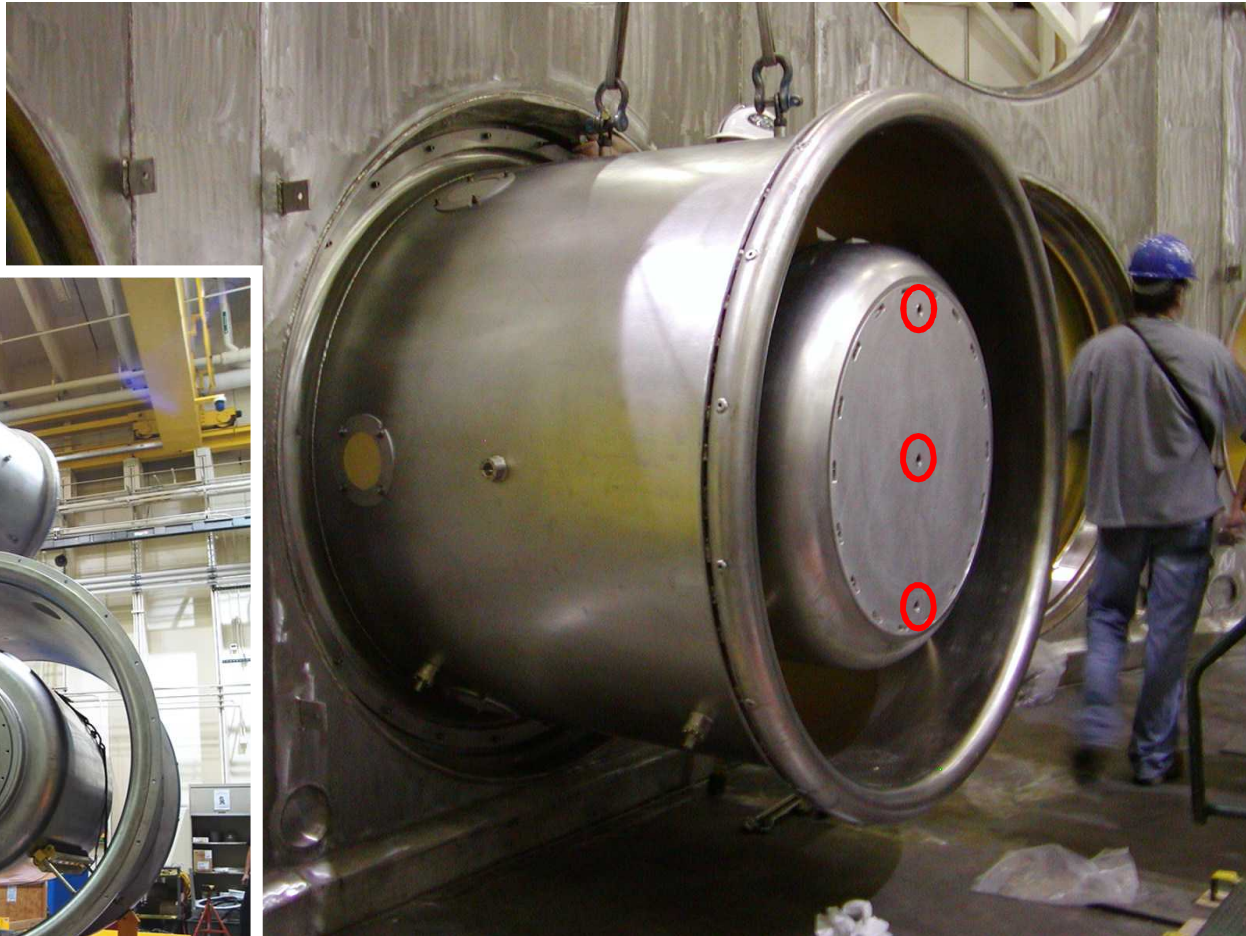
Gas Switch



Getting Laser Light Into the Switch



Pulse Forming Line



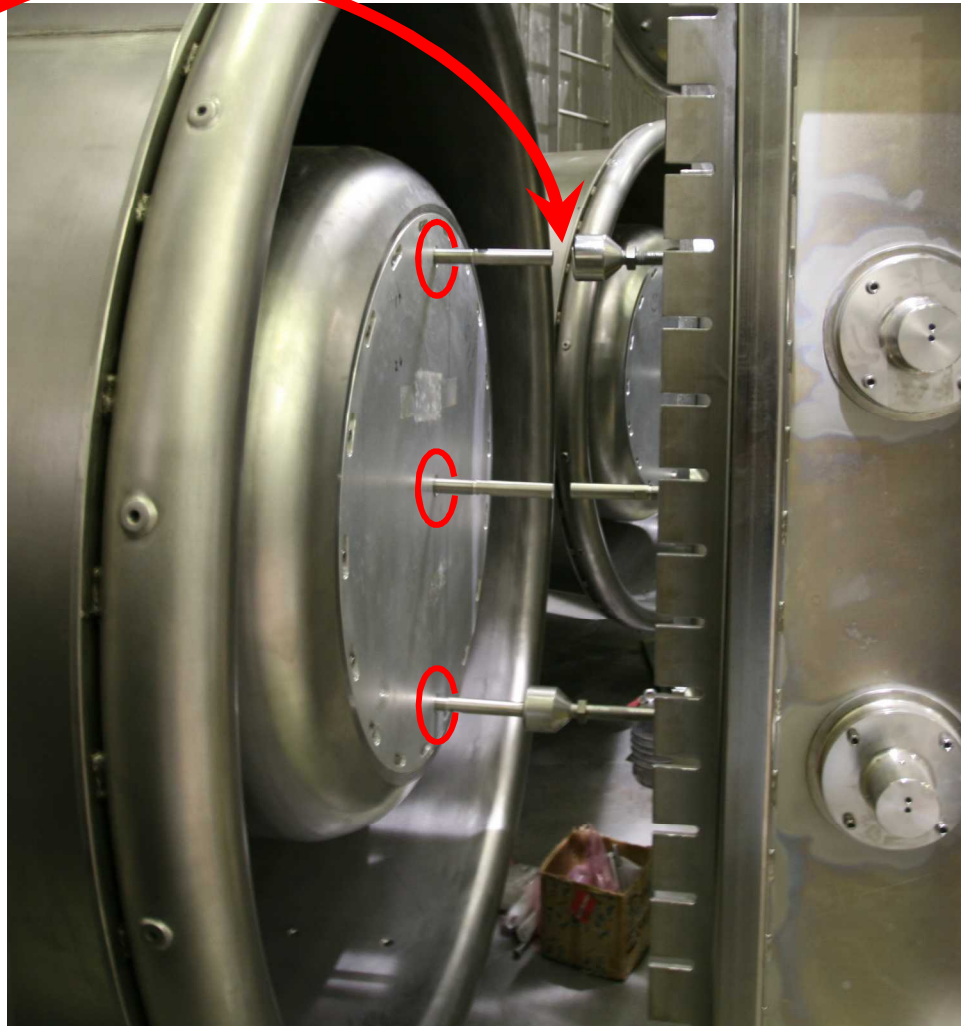
350 nano
second
charge

120 nano
second
discharge

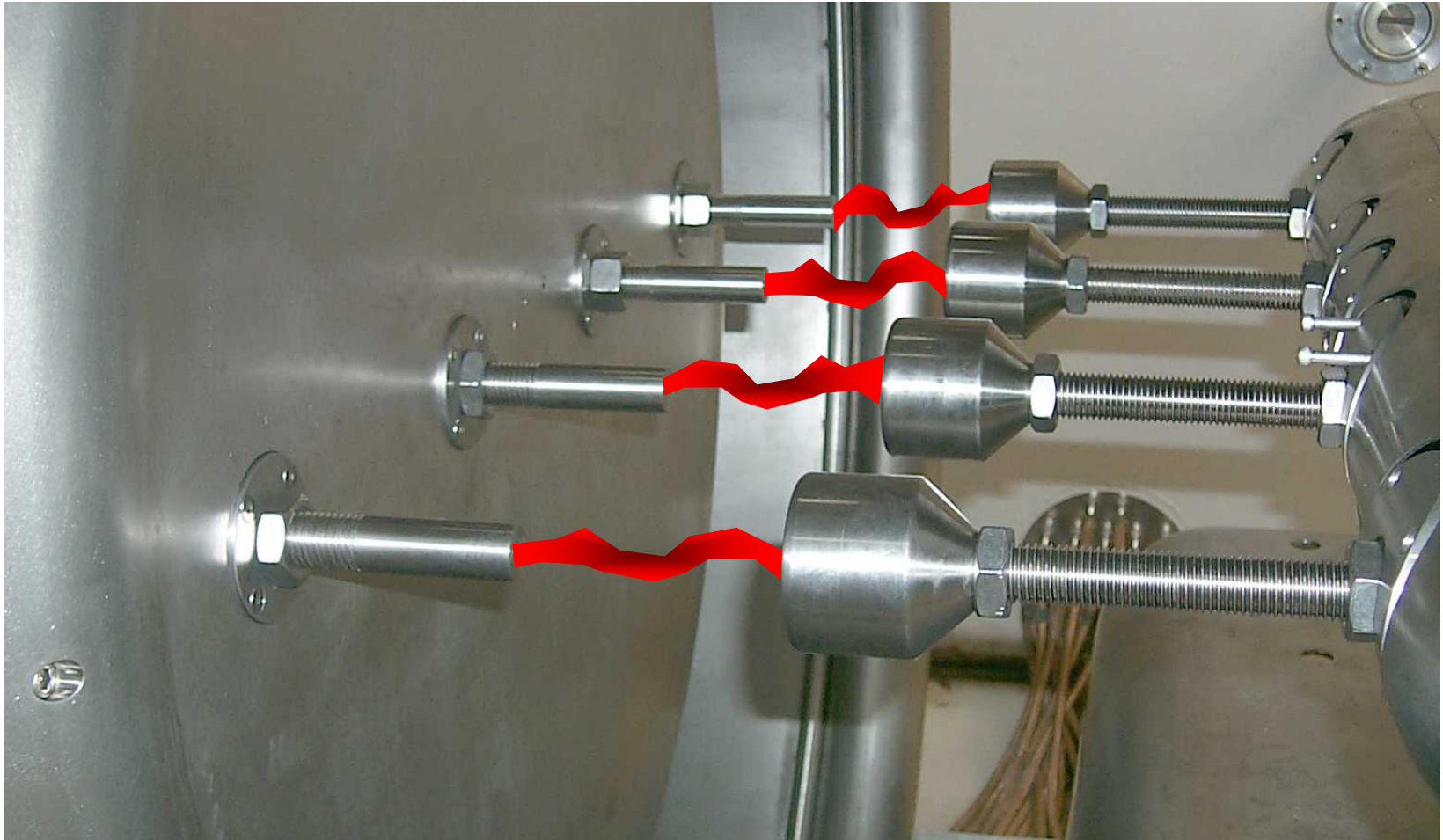


Z Self-Break Water Switch

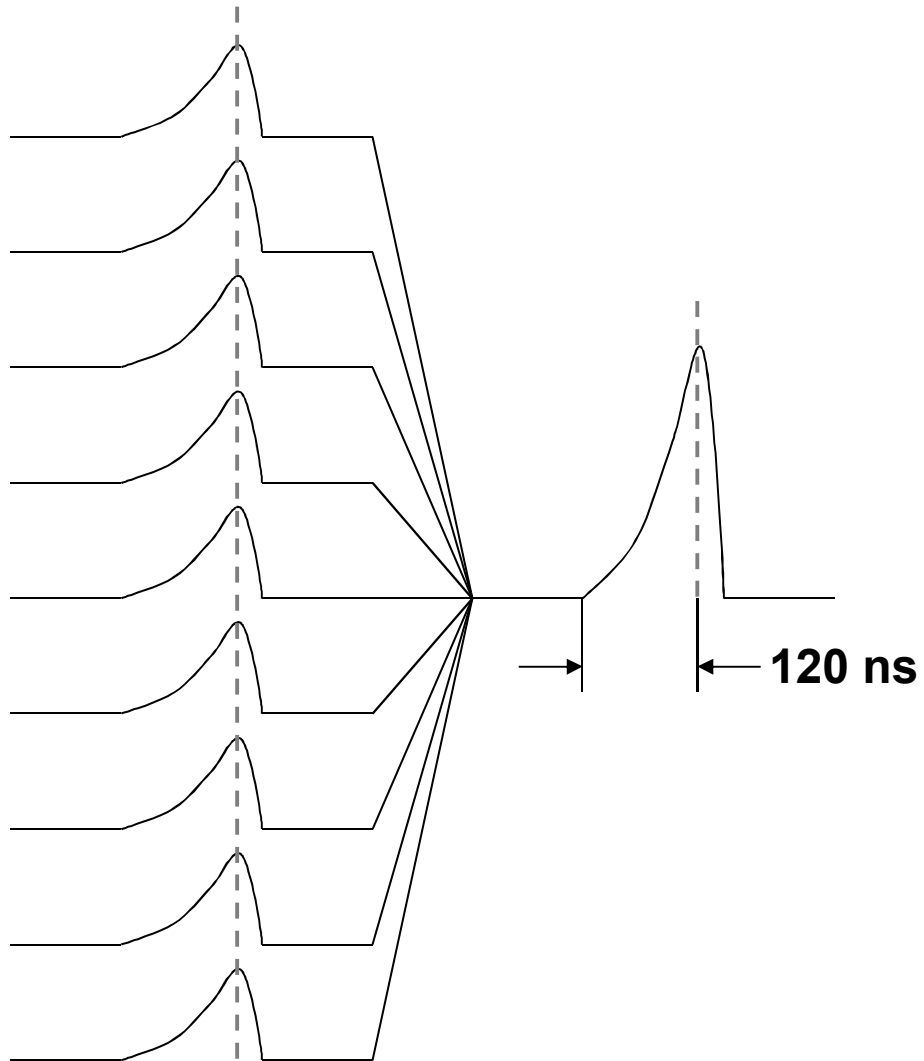
Gap is set
to ~2 to 5"



Gap Predictably Breaks Down



Pulse Shaping on Z



1 Machine – Many Applications

Z Delivers:

20–26 million amps current
2-3 million joules electrical energy
100–400 nanosecond pulse width

**Z-Pinch Wire Array
for
Magnetic Implosions**

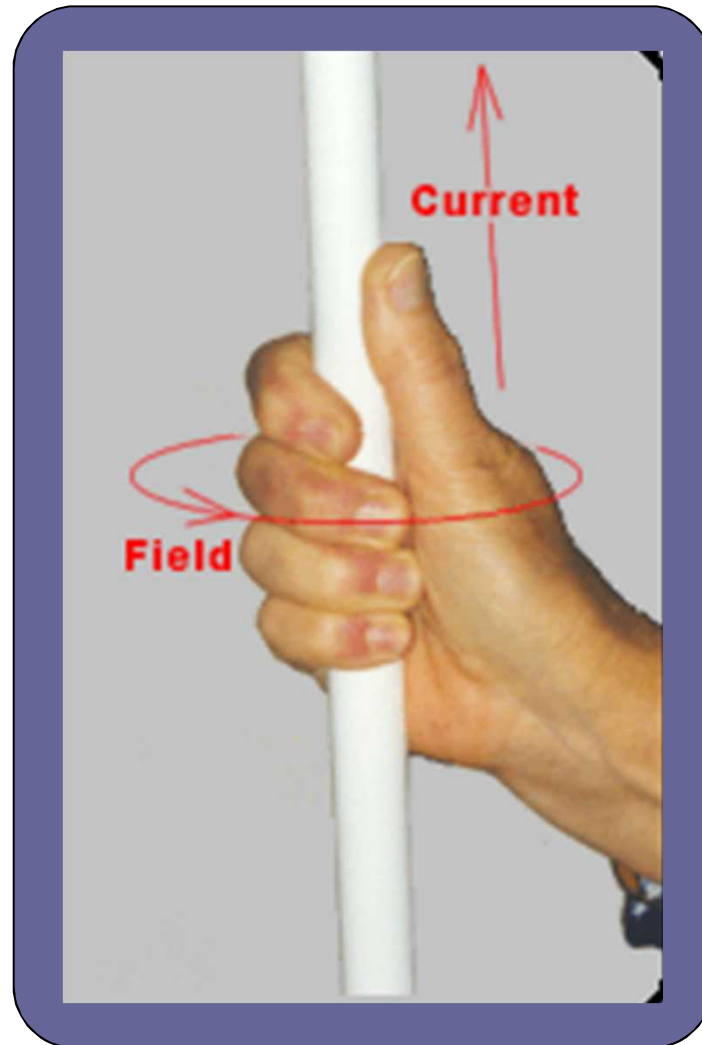
X-Rays

**Short Circuit
for
Dynamic Materials**

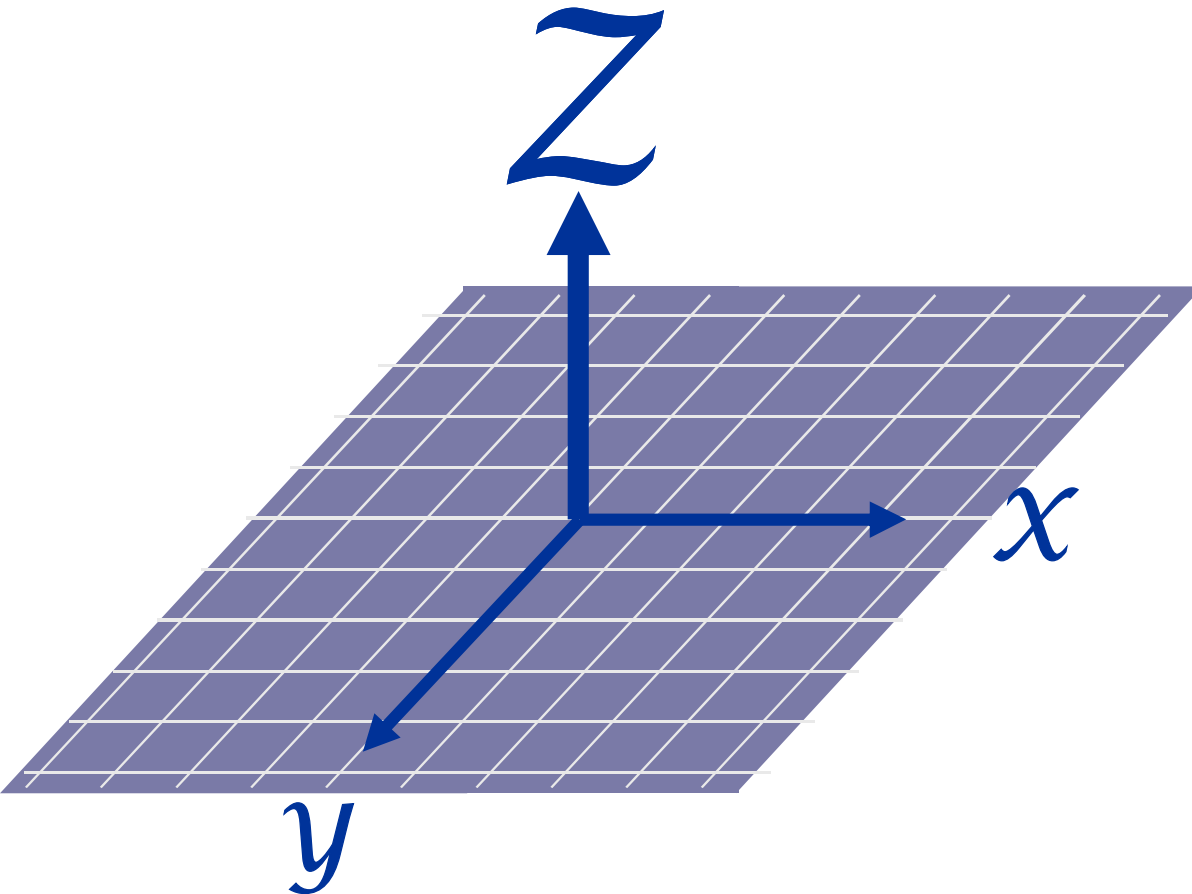
**Continuous
Compression
Curves**

**High Velocity
Flyer Plates**

Right Hand Rule is Key to Z Pinch

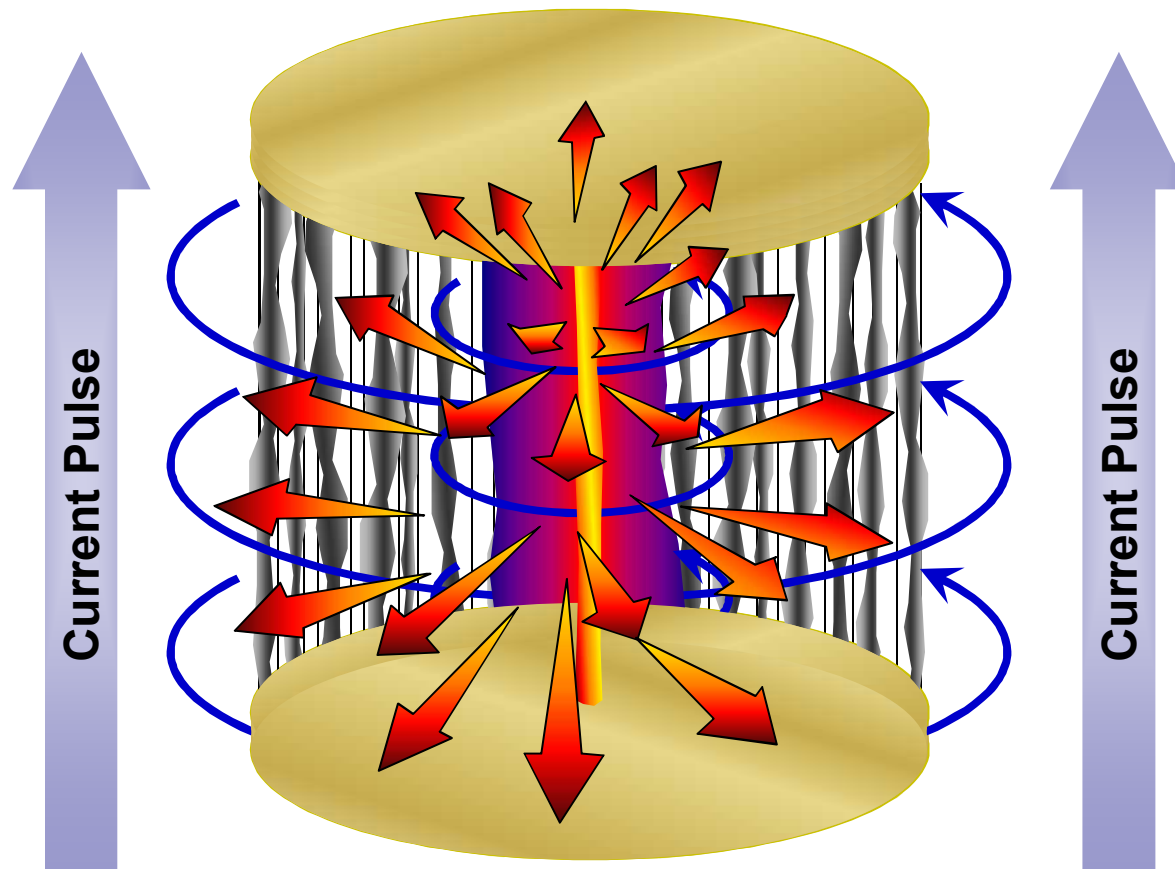


Why is  called “Z”?

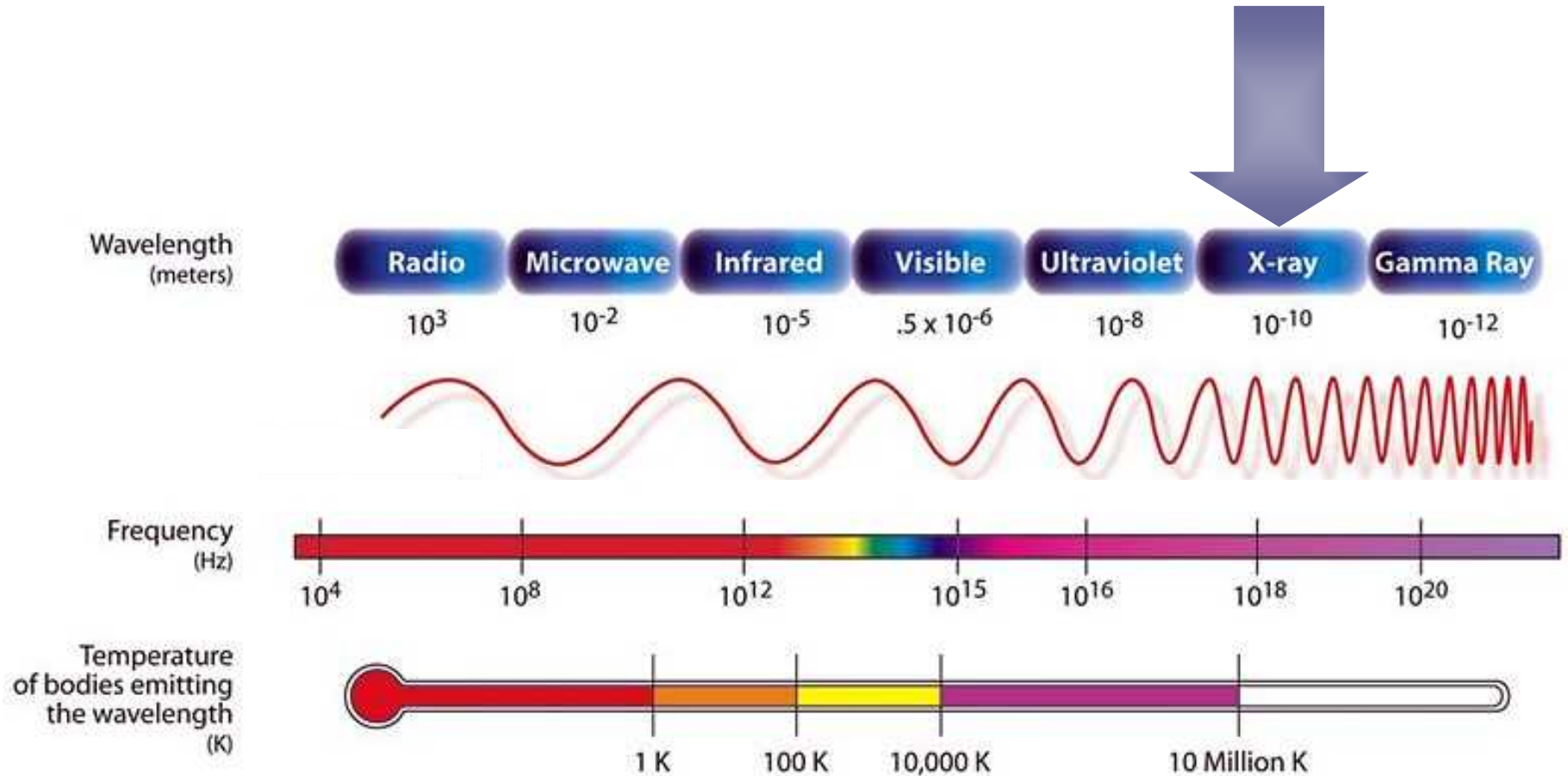


Current at the load flows in the “Z” (\uparrow) direction

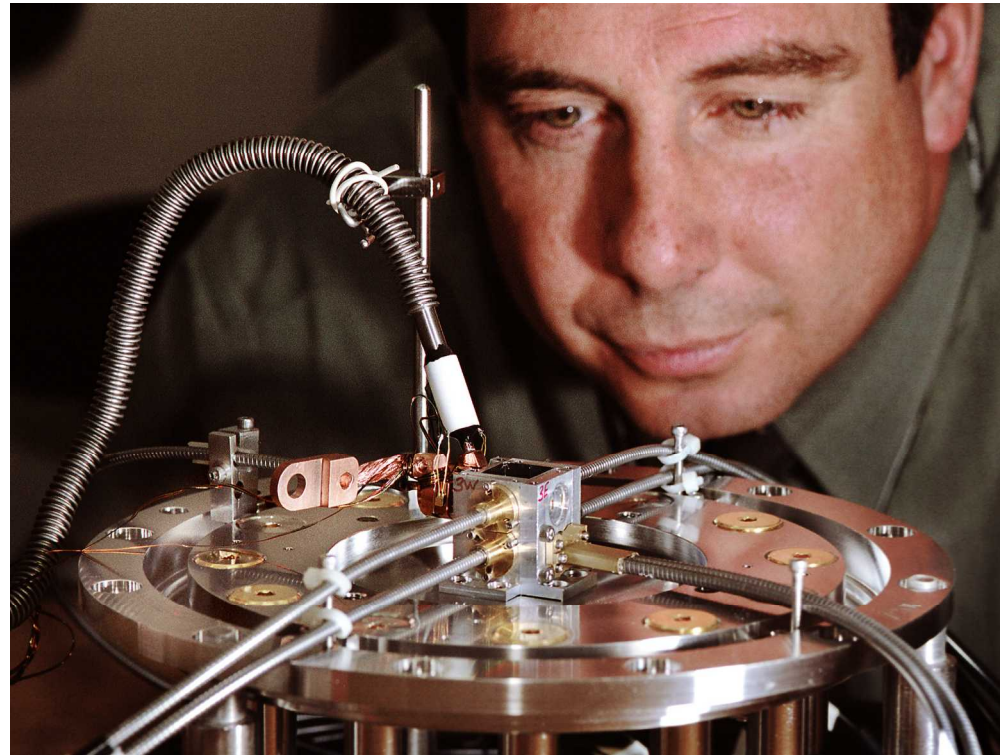
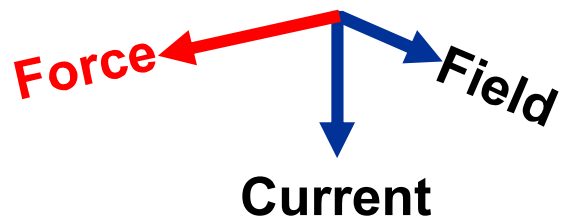
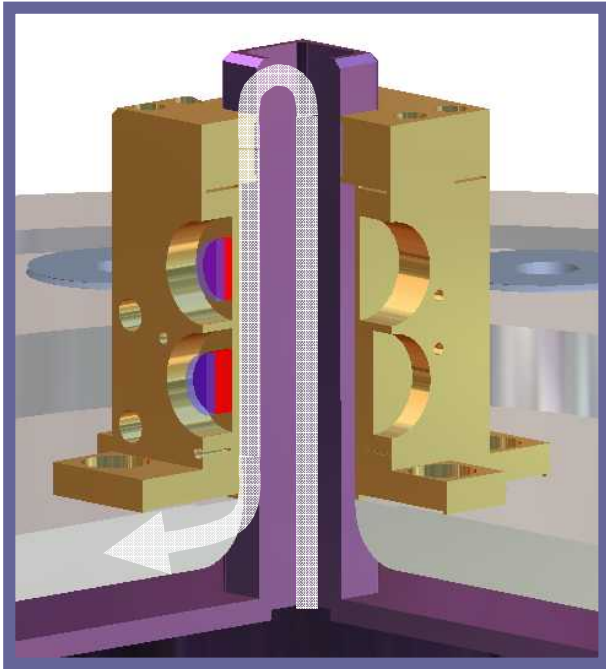
Z-Pinch → Magnetic Implosion



Kinetic Energy Becomes X-Rays

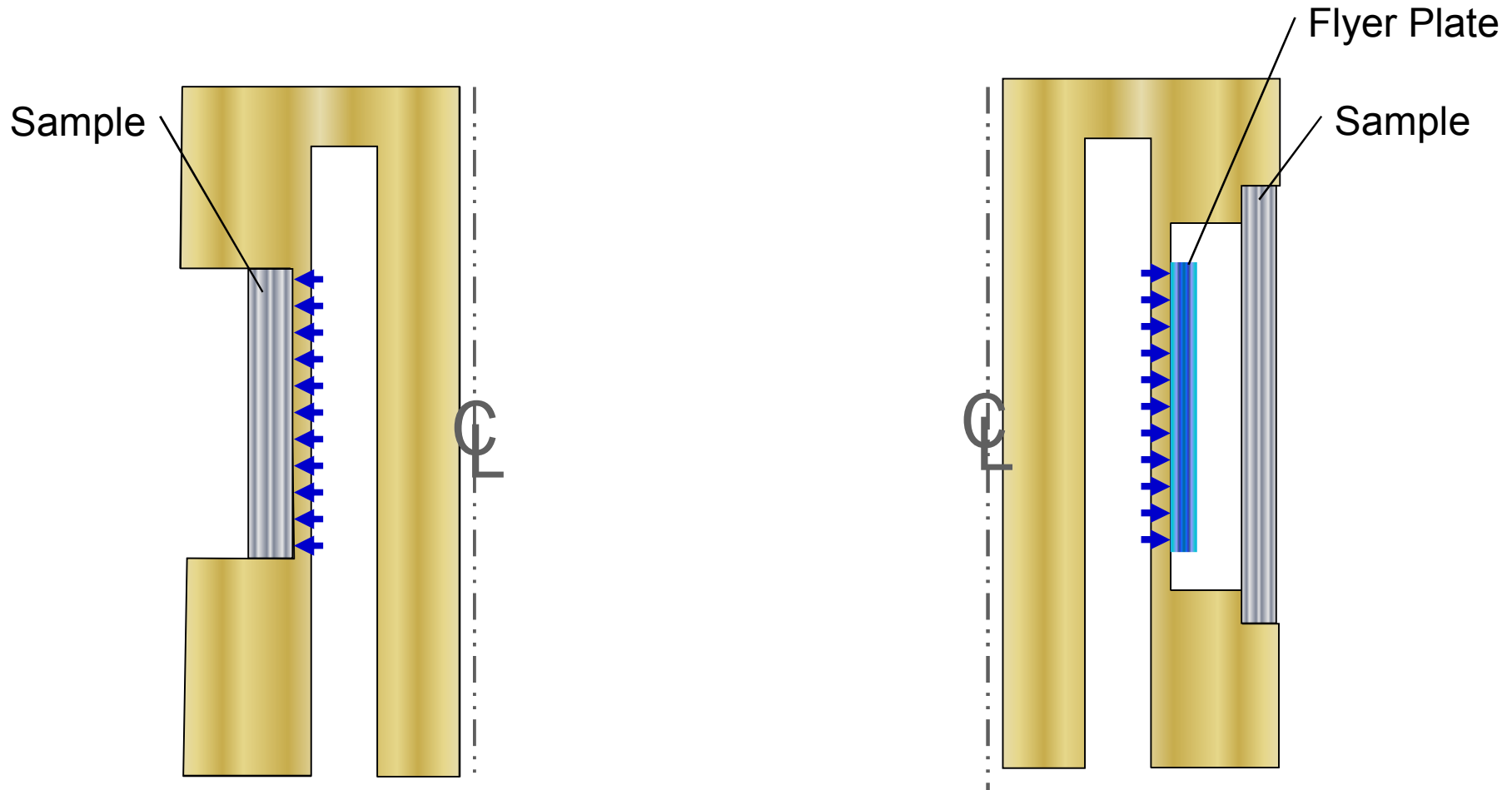


Short Circuit → Magnetic Pressure




Clint Hall with an early "ICE Cube"

Dynamic Material Properties



Isentropic Compression Experiments:
direct pressure wave through sample

Shock Hugoniot Experiments:
flyer plate launched to impact sample



ZR Project

ZR: Balanced Objectives

Capability

More Energy & Current Delivered

- ✓ Double energy stored
- ✓ Design for z-pinch and material property applications

Capacity

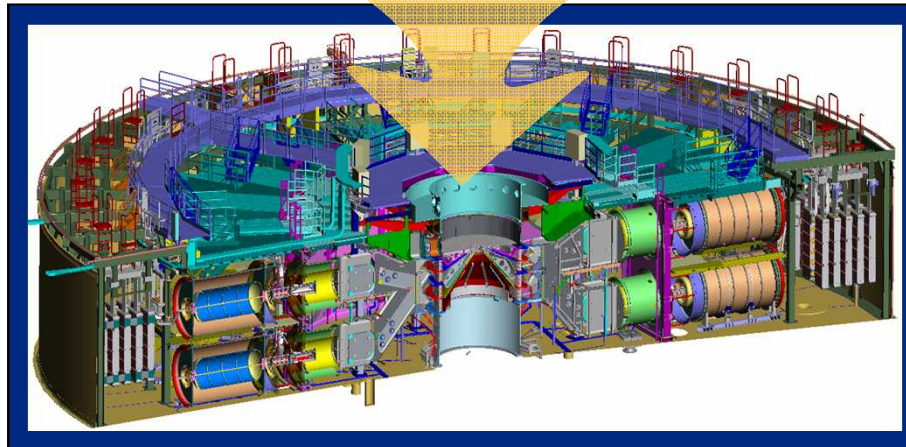
High Operational Reliability

- ✓ Design drive system conservatively
- ✓ Fabricate parts from stainless steel

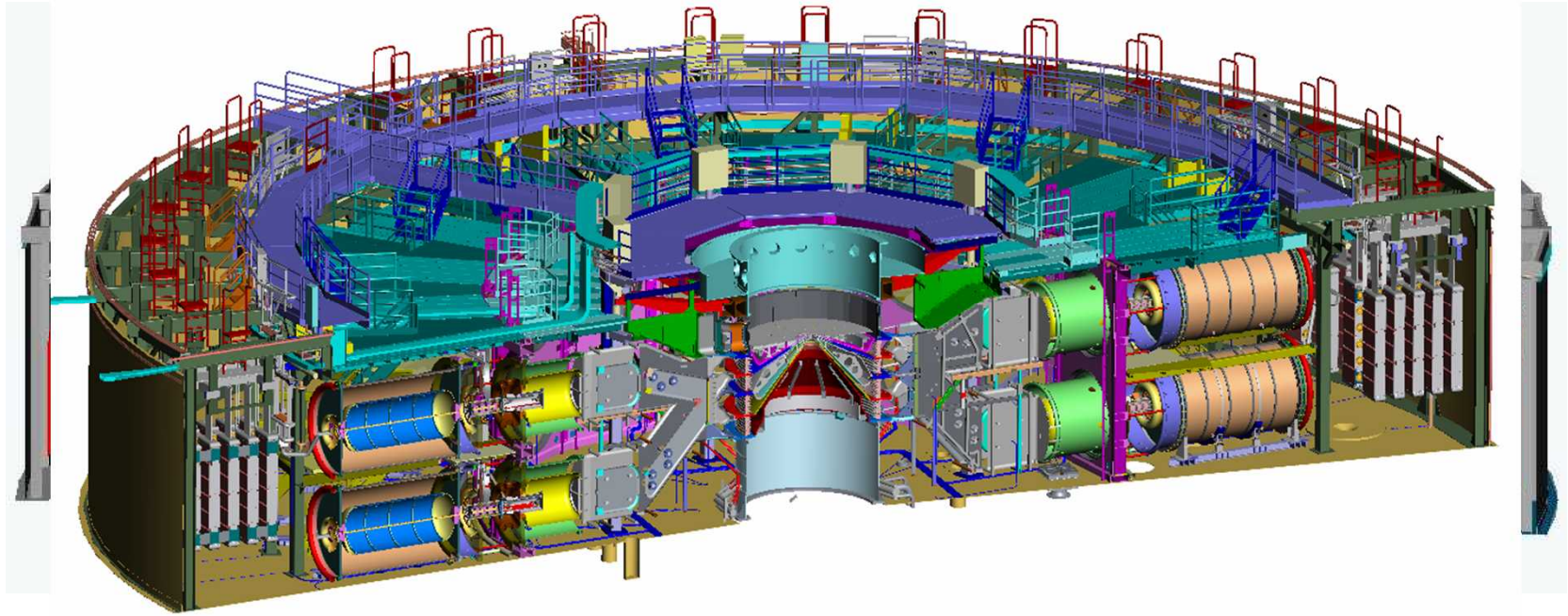
Precision

Better Repeatability, Pulse Shaping

- ✓ Individual lasers
- ✓ Longer Intermediate Storage Capacitors



ZR Project Timeframe



**Planning &
Architecture
Development**

**Single
Line
Design &
Fab**

**Single
Line Test**

**Production
Design & Fab**

**Installation
& Test**

2000

2001

2002

2003

2004

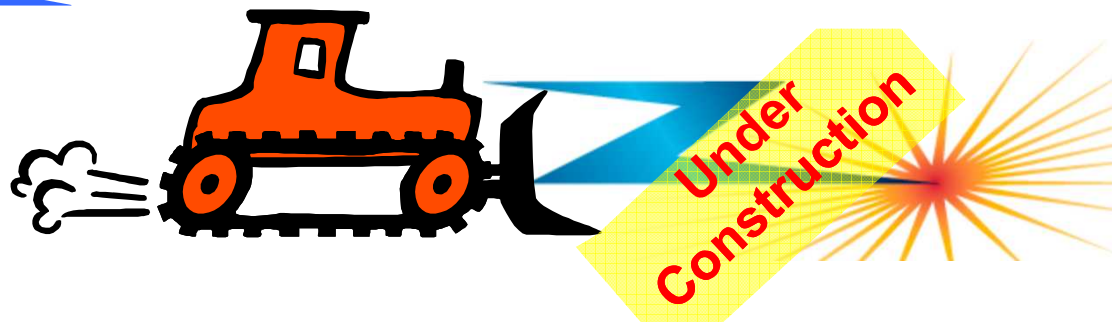
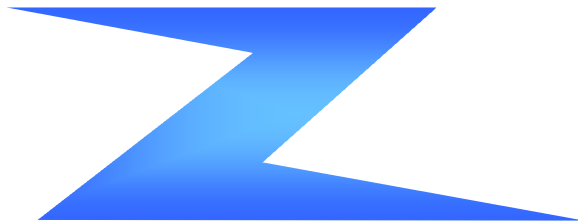
2005

2006

2007



Extreme MAKEOVER ~~HOME EDITION~~



“Family” in Need



The Vacation



Design Teams



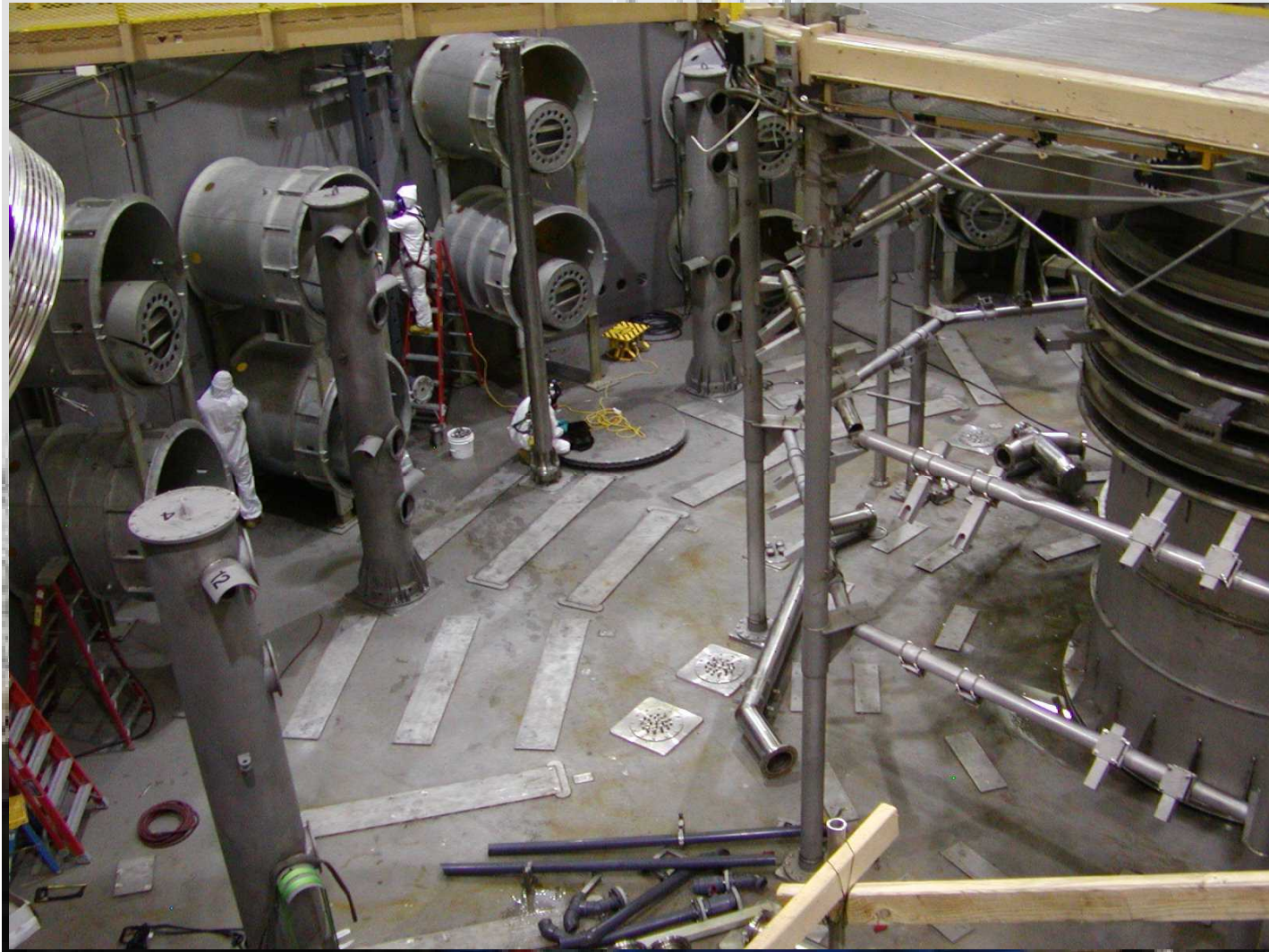
Construction Teams



Guy



Demolition



“Resources”



Appreciation to Many



“Move That Bus”



The image shows a DVD cover for the 'Z Refurbishment Project'. At the top, there is a blue stylized 'Z' logo next to a red starburst graphic. Below this, the title 'Z Refurbishment Project' is written in a bold, yellow, sans-serif font. The background of the DVD is a dark, high-contrast photograph of an industrial facility, likely a nuclear reactor, with various structures and piping visible. In the center of the DVD is a large white circle representing the hole. To the left of this circle, there is a list of contents under the heading 'Comprehensive DVD'. A blue arrow points from the left edge of the image towards the 'Short version' item in the list. To the right of the central circle, there is a 'DVD VIDEO' logo and the date 'January 2008'. At the bottom of the DVD, there is a Sandia National Laboratories logo (a stylized 'S' inside a square) followed by the text 'Sandia National Laboratories' and 'A DOE/NNSA National Laboratory'. At the very bottom, there is a copyright notice: 'Copyrighted. Please contact Video Services at (505) 844-7167 for copies or footage.'

Z Refurbishment Project

Comprehensive DVD

- Long version
- Medium version
- Short version
- Long version 2
- Construction time lapse

DVD
VIDEO

January 2008



Sandia National Laboratories

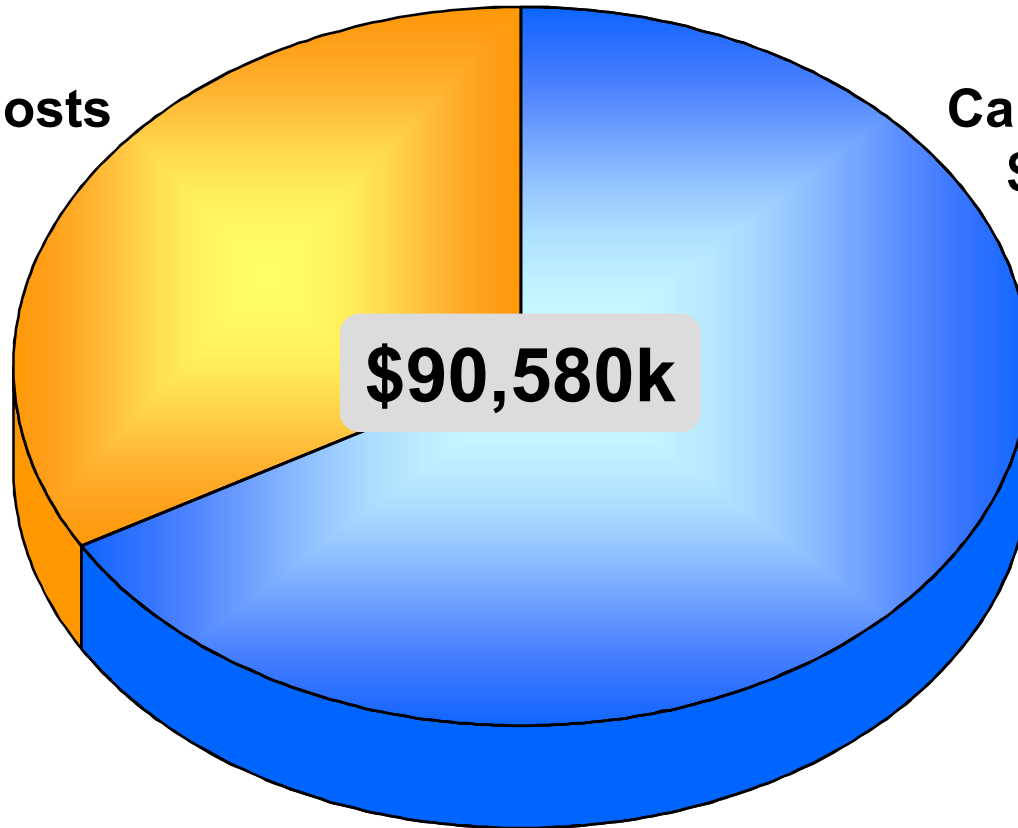
A DOE/NNSA National Laboratory

Copyrighted. Please contact Video Services at
(505) 844-7167 for copies or footage.

ZR Costs

Operational Costs
\$30,200k

Capital Costs
\$60,380k

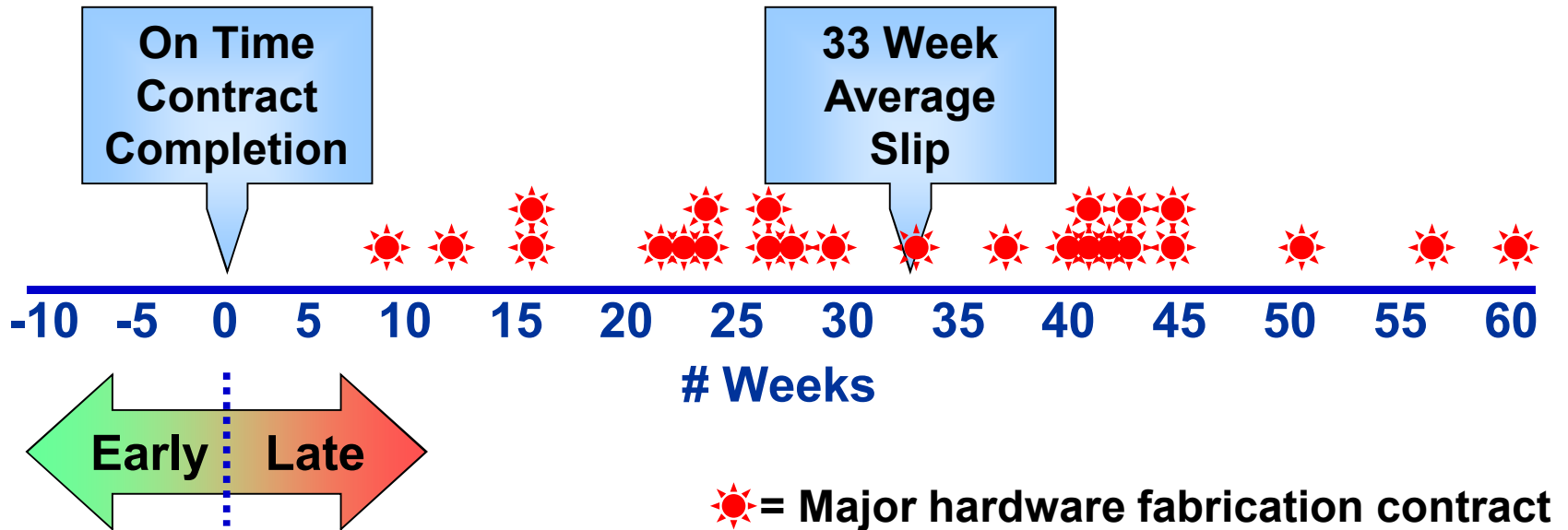


Over 70% of \$34M in manufacturing was with small businesses

Challenge: Tank Modifications



Challenge: Fabrication Deliveries



- Quality generally good
- Required agility during installation phase

Challenge: Workforce Coordination

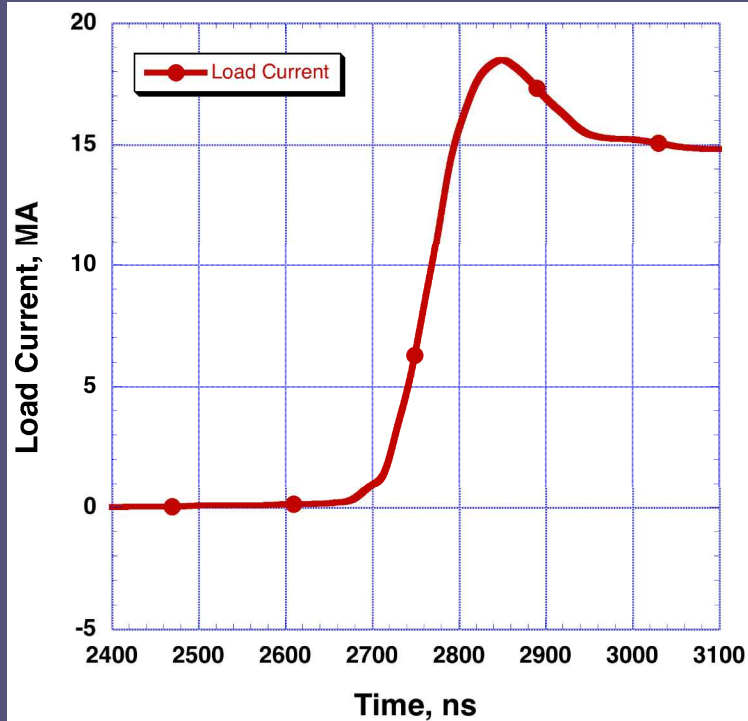




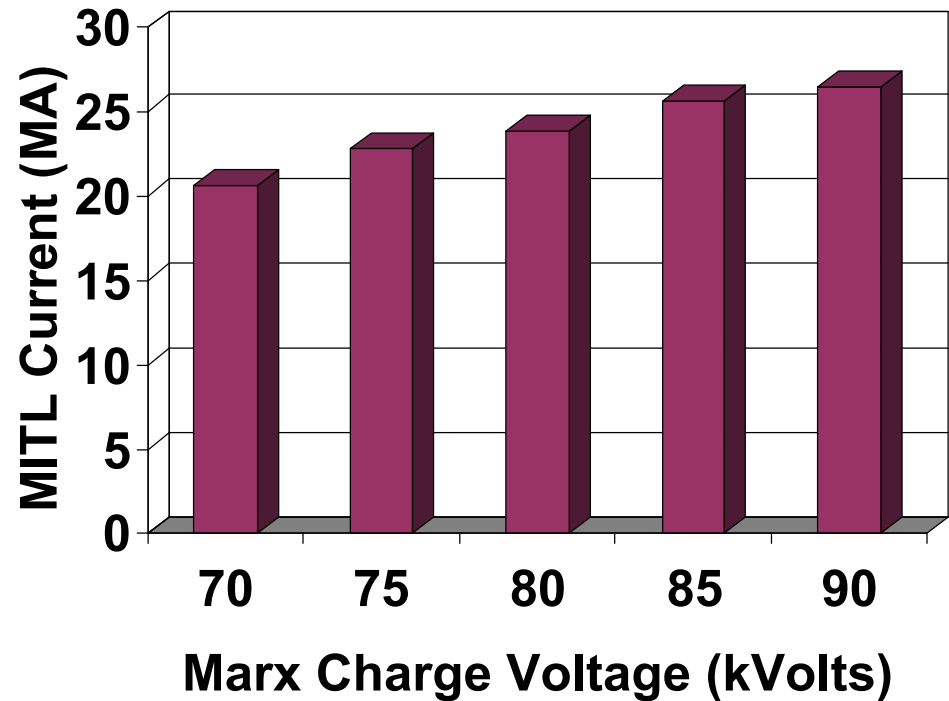
Success: Lasers & Pulse Shaping


- **Individual lasers installed early 2003**
- **Key experiments 3 years ahead of upgrade**

Success: In the End, It Works...



First Shot
September 17, 2007





Future

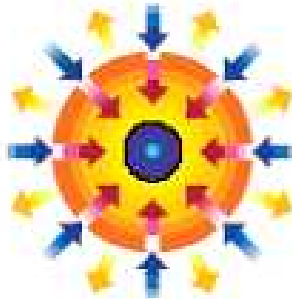
Inertial Confinement Fusion

Target heating



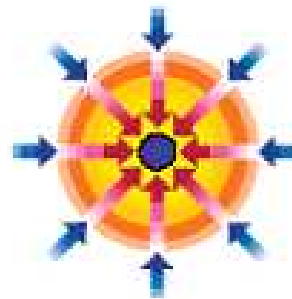
X-rays rapidly
heat surface,
forming plasma
envelope

Compression



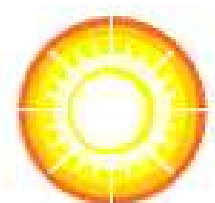
Fuel
compressed by
blowoff of hot
surface

Ignition



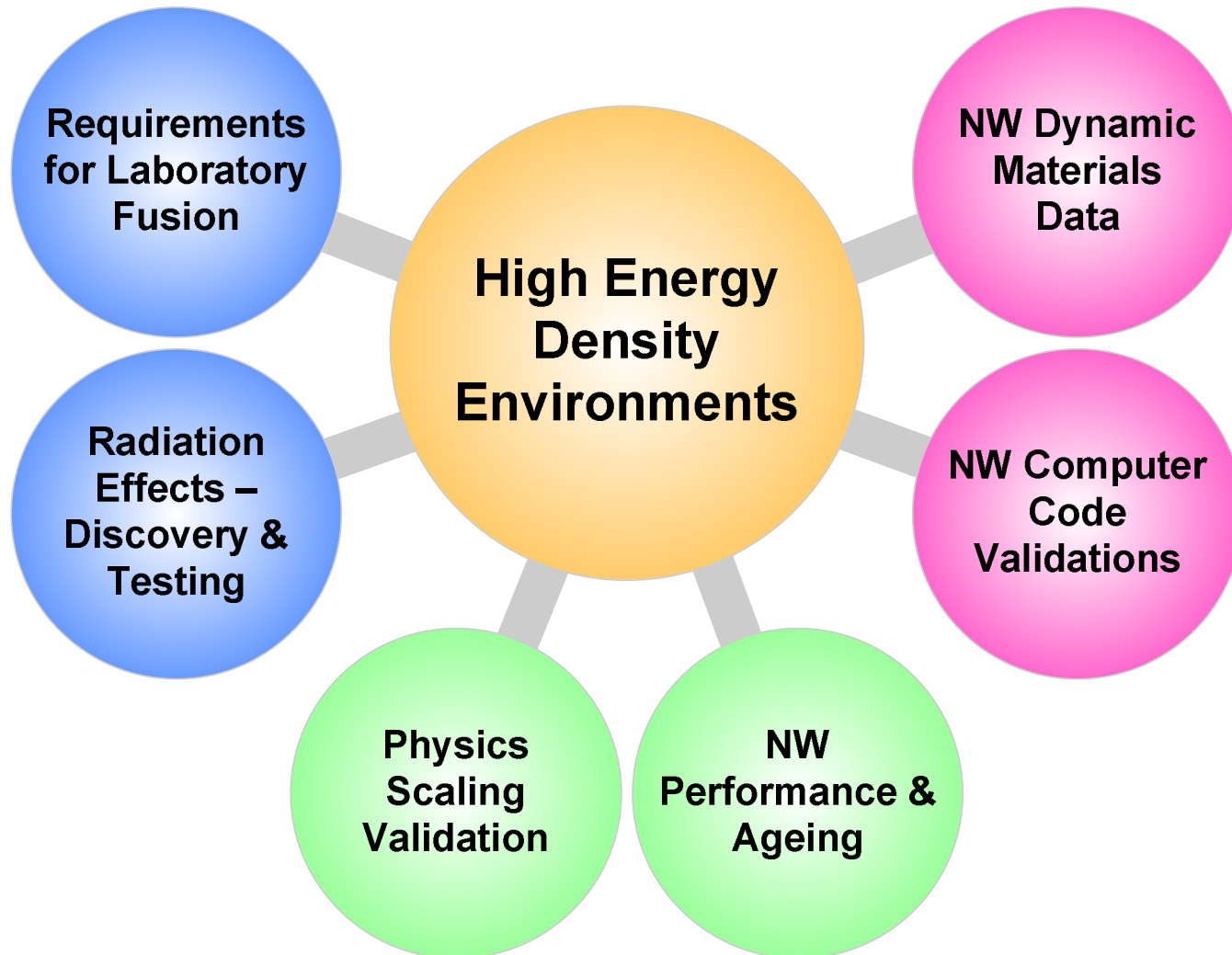
Density and
temperature
reach fusion
ignition levels

Burn

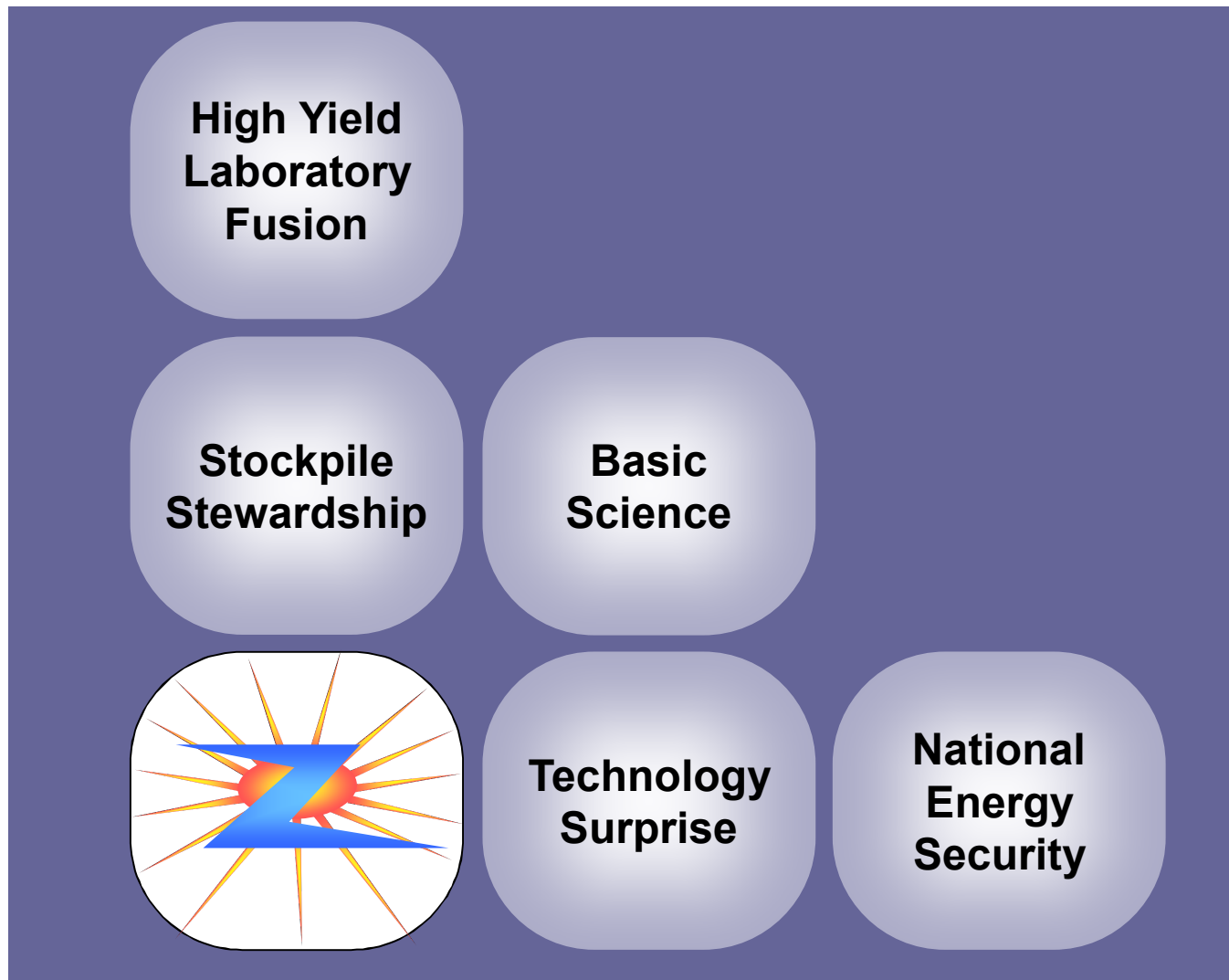


Thermonuclear
burn spreads
rapidly through
fuel

Z's Near-Term NW Mission Support



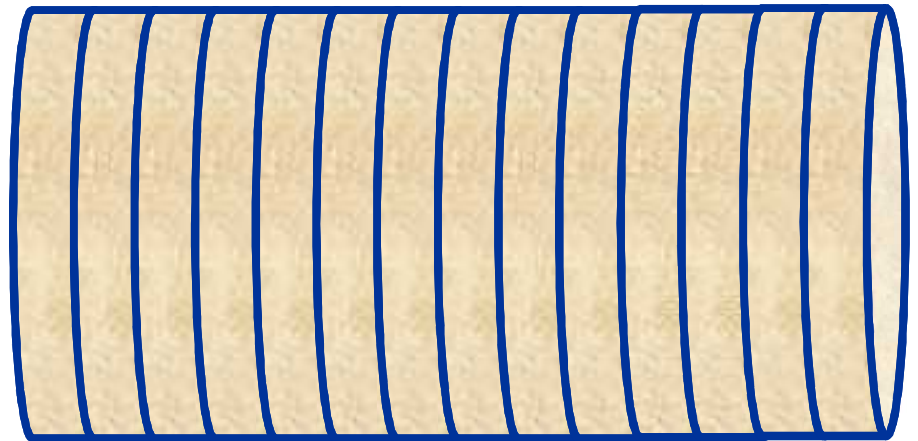
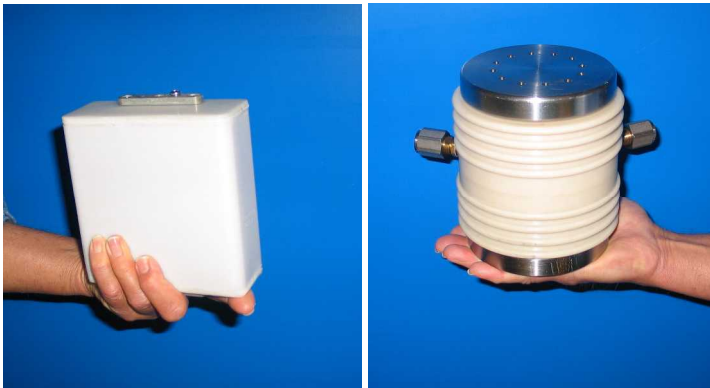
Stockpile in Focus, Fusion in View



Linear Transformer Driver



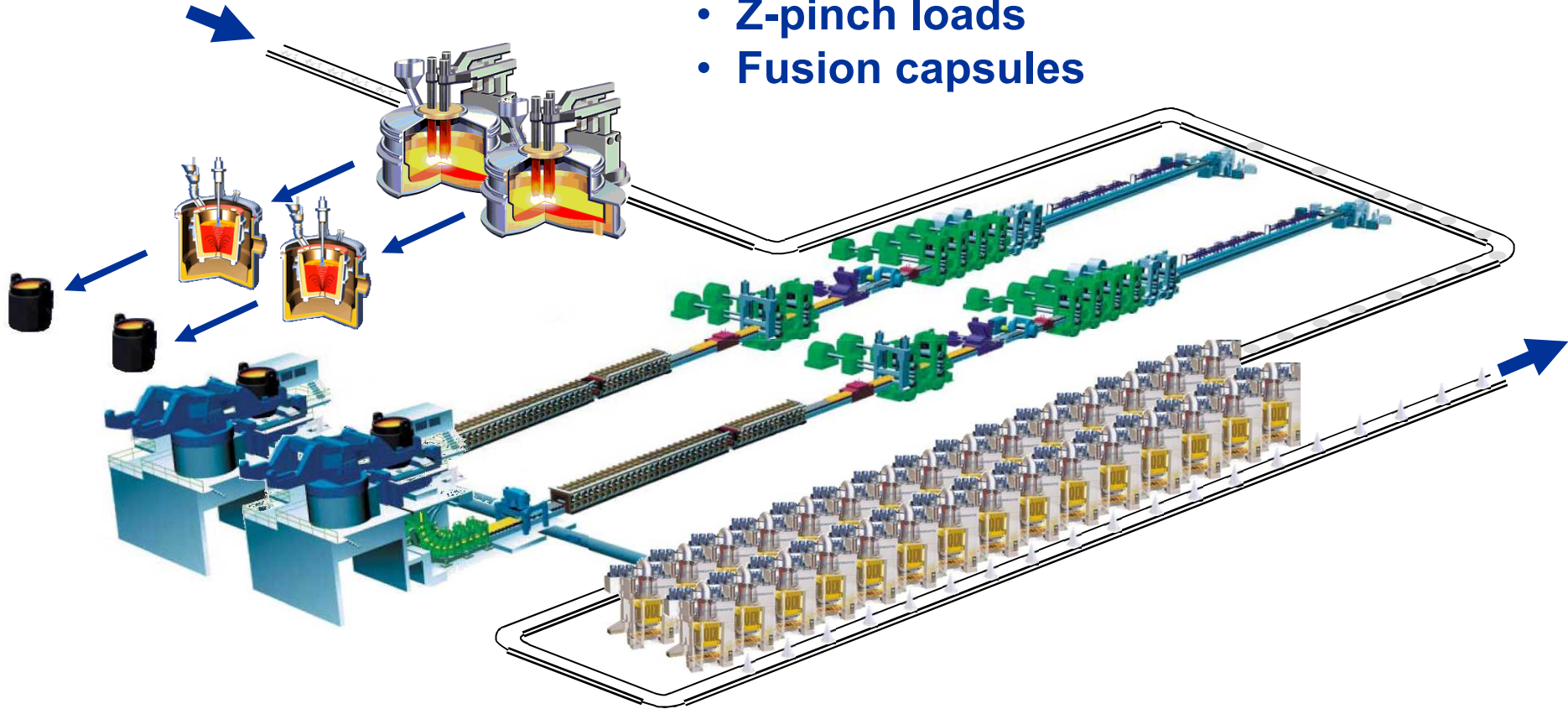
- May be revolutionary
- Compresses in 1 stage
- Simple modules
- Efficient
- Shoots 6 times/minute



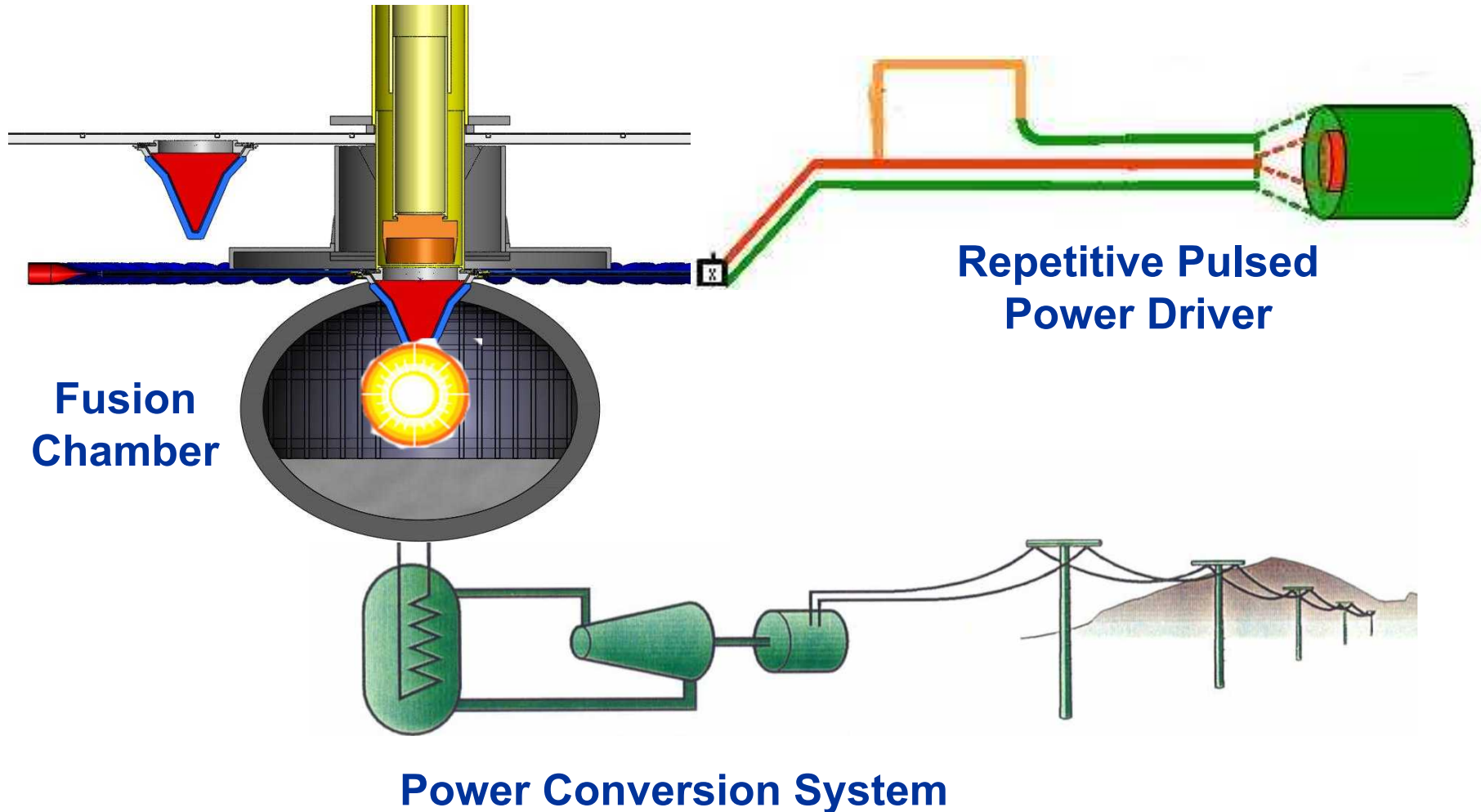
Practical Hurdles to Fusion Future


Consumables Factory

- Recyclable Transmission Lines
- Z-pinch loads
- Fusion capsules



Practical Hurdles to Fusion Future





Thanks!

Questions?