SAND2008-2902C

Z-Pinch Fusion Energy Technology

Gary E. Rochau
Fuel Cycle Experiments and Analysis
Nuclear Energy and Global Security Technologies
Sandia National Laboratories
Albuquerque, New Mexico USA
gerocha@sandia.gov (505)845-7543

*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.

Sandia National Laboratories

Z-IFE Power Plant Baseline Parameters

Target Yield	3 – 20 GJ
Rep. Rate (per chamber)	0.1 – 0.3 Hz
Fusion Power per chamber	0.3 - 6 GWth
Number of Chambers	10 - 1

Chamber

Shape	Spherical or Ellipsoidal
Dimension	4 m internal radius
Material	F82H Steel
Wall Thickness	15-30 cm

Coolant

Coolant Choice	Flibe
Jet Design	Circular Array
Standoff (Target to First Jet)	0-2 m
Void Fraction	0.05 – 0.67
Curtain Operating Temperature	950 K
Average Curtain Coolant Flow	12 m^3/s
Heat Exchanger Coolant Flow	0.47 m^3/s
Heat Exchanger Temp. Drop	133 K
Pumping Power	1.3 MW/chamber
Heat Cycle	Rankine
Heat Exchanger Type	Shell and Tube

Tritium Recovery

Breeding Ratio	1.1
Tritium Recovered per Shot	0.017 g
Extraction Type	Countercurrent

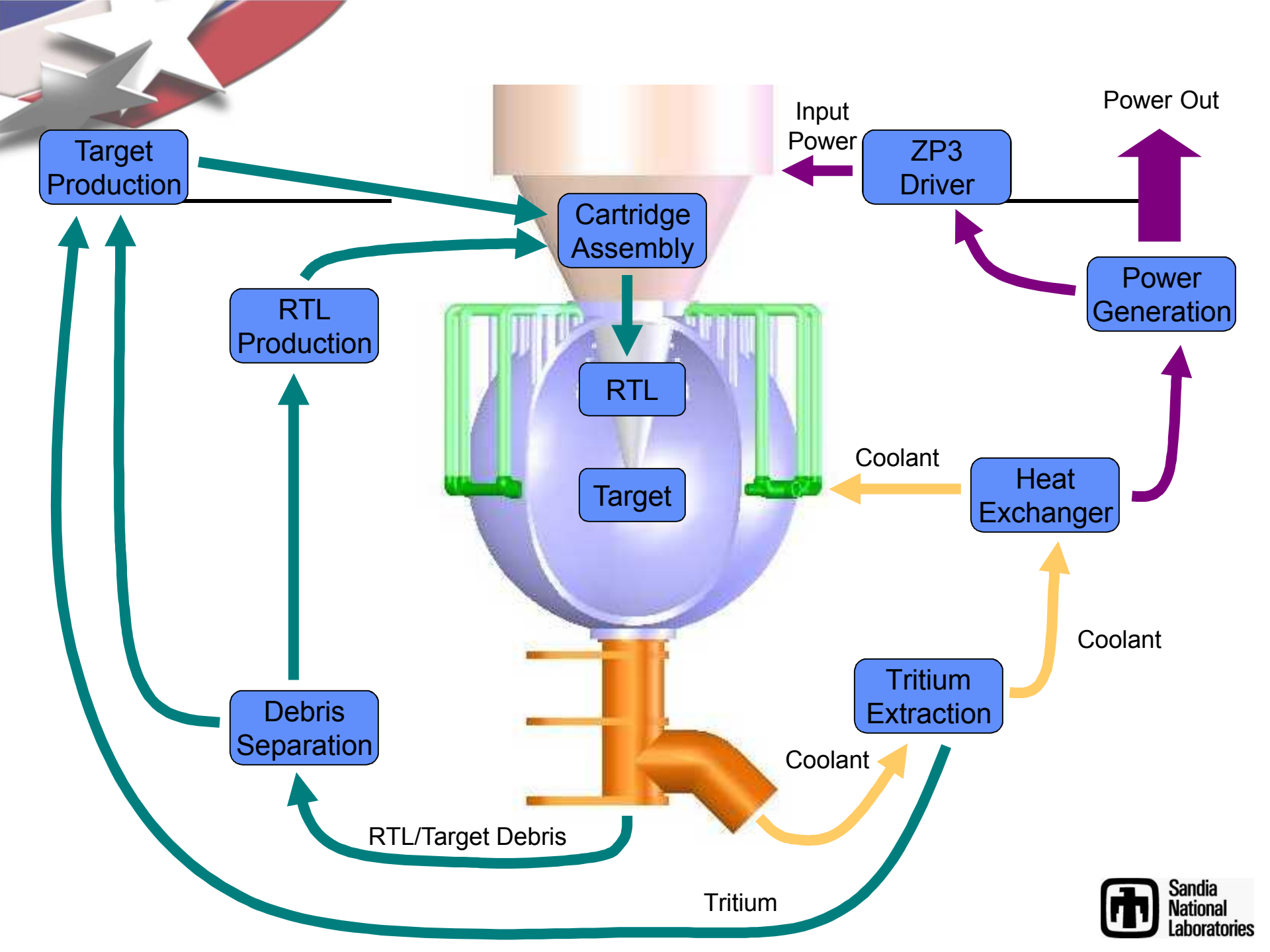
RTL(Steel)

RTL Material	1004 Carbon Steel
Cone Dimensions	1 m Ø x 0.1 m Ø x 2 m h
Outer Cone Thickness	0.9 mm → 0.52 mm
Inner Cone Thickness	0.52 mm
Mass per RTL (2 cones)	50 kg → 34 kg

RTL Manufacturing

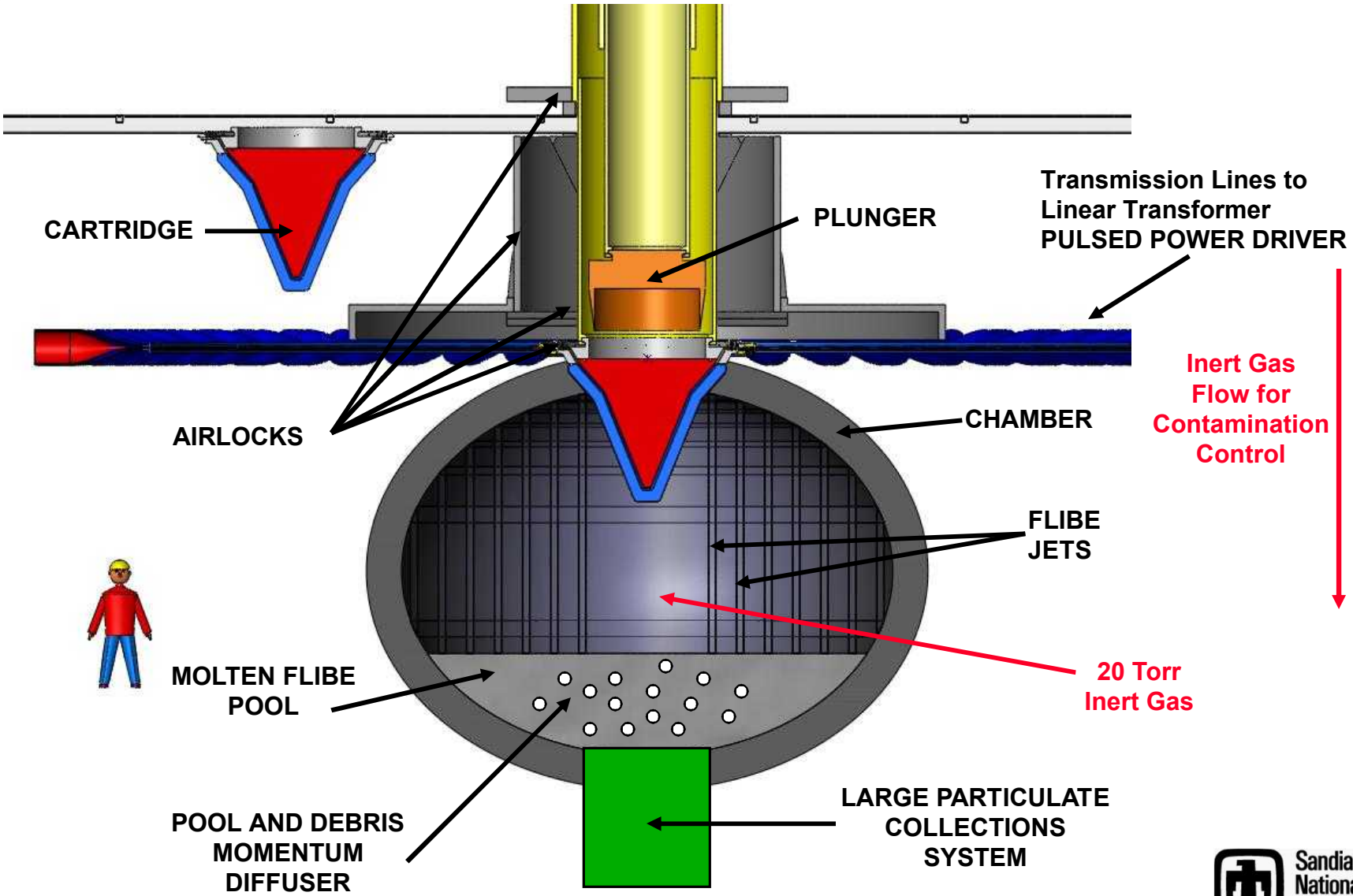
Furnace	Electric Arc or Flibe Cast
Production	Sheet Metal/Deep Draw Or Cast
Energy Demand	~5-200 MW for ten chambers

Sandia National Laboratories

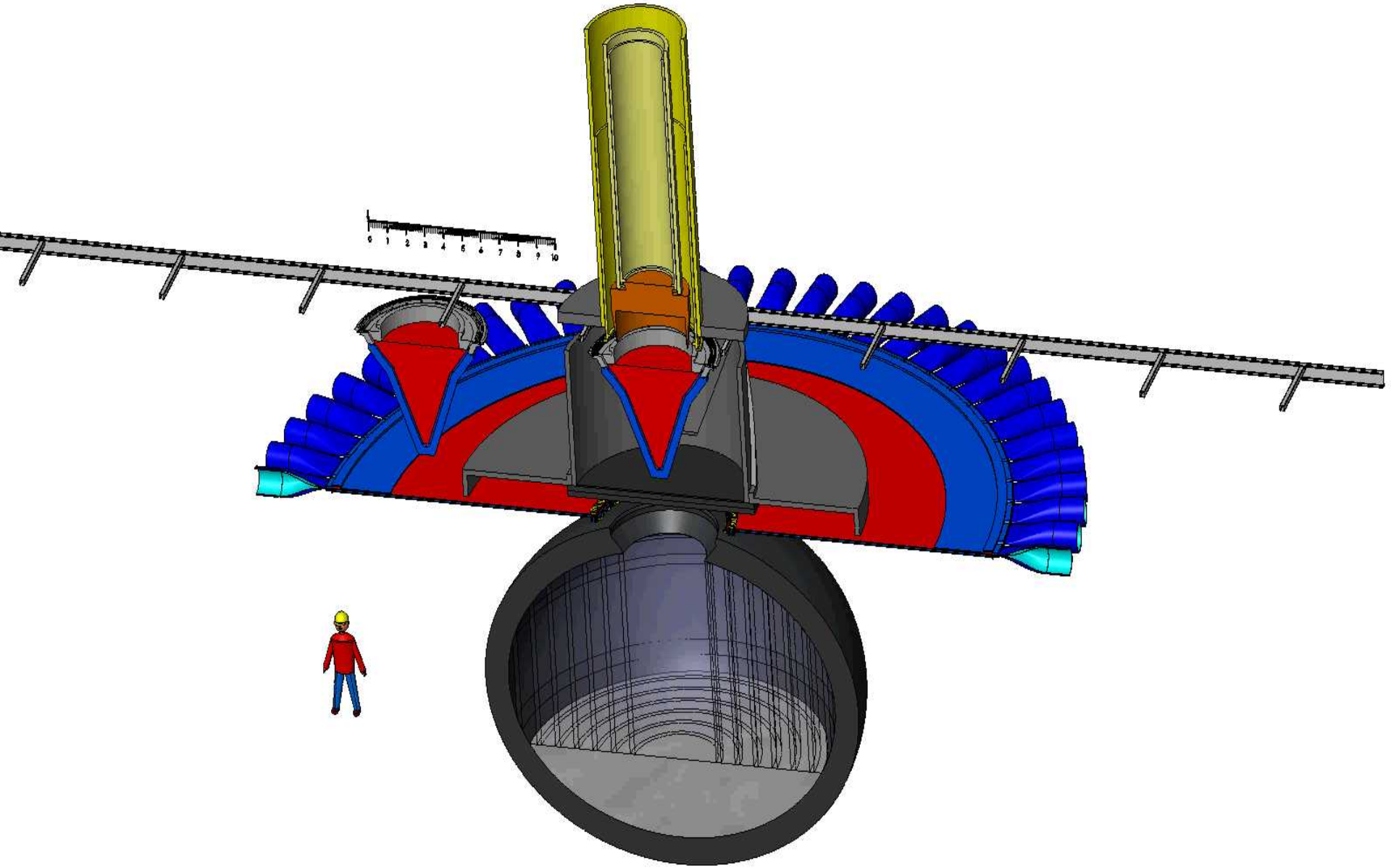


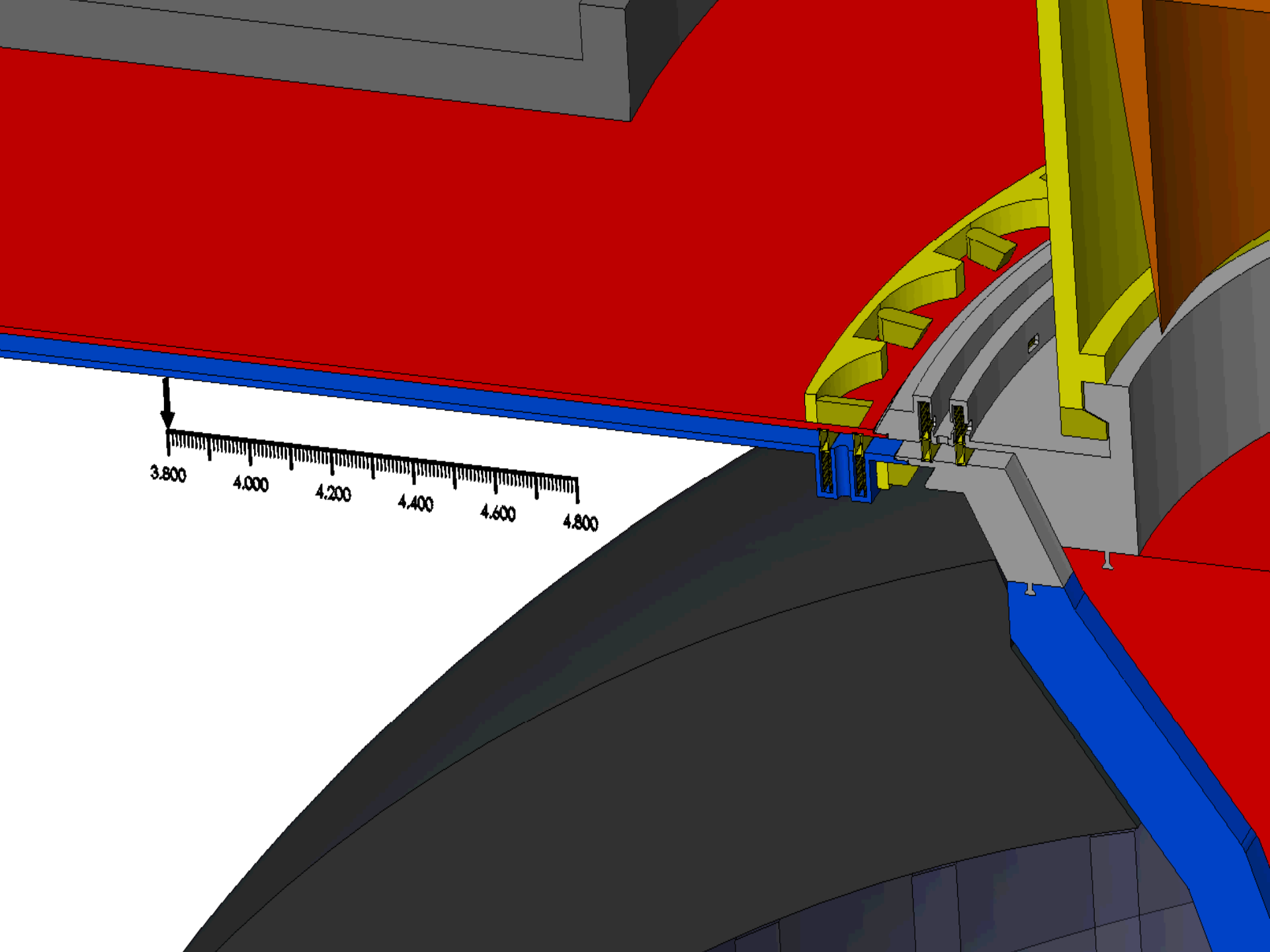
Sandia National Laboratories

BASE Z-IFE UNIT



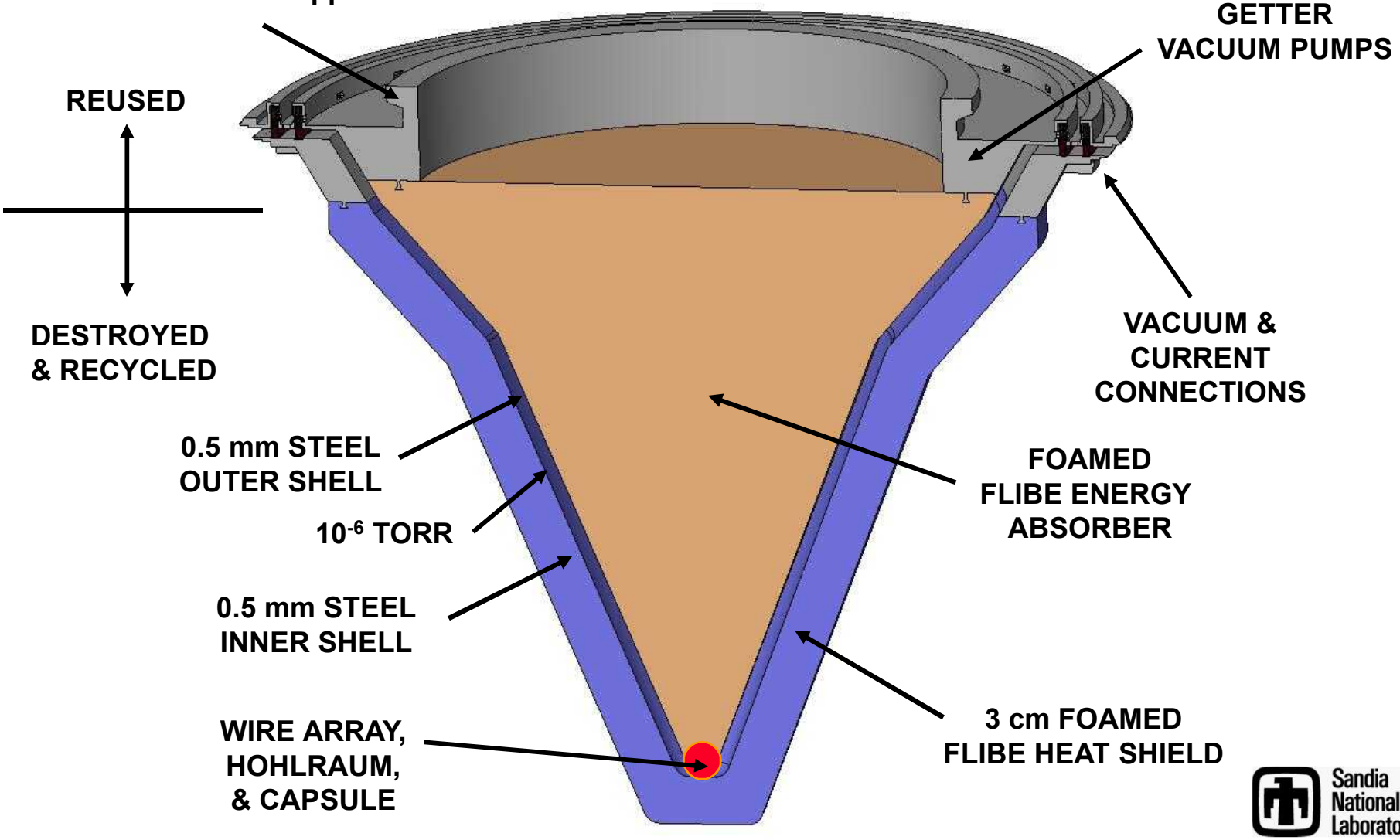
Sandia National Laboratories




3.800
4.000
4.200
4.400
4.600
4.800

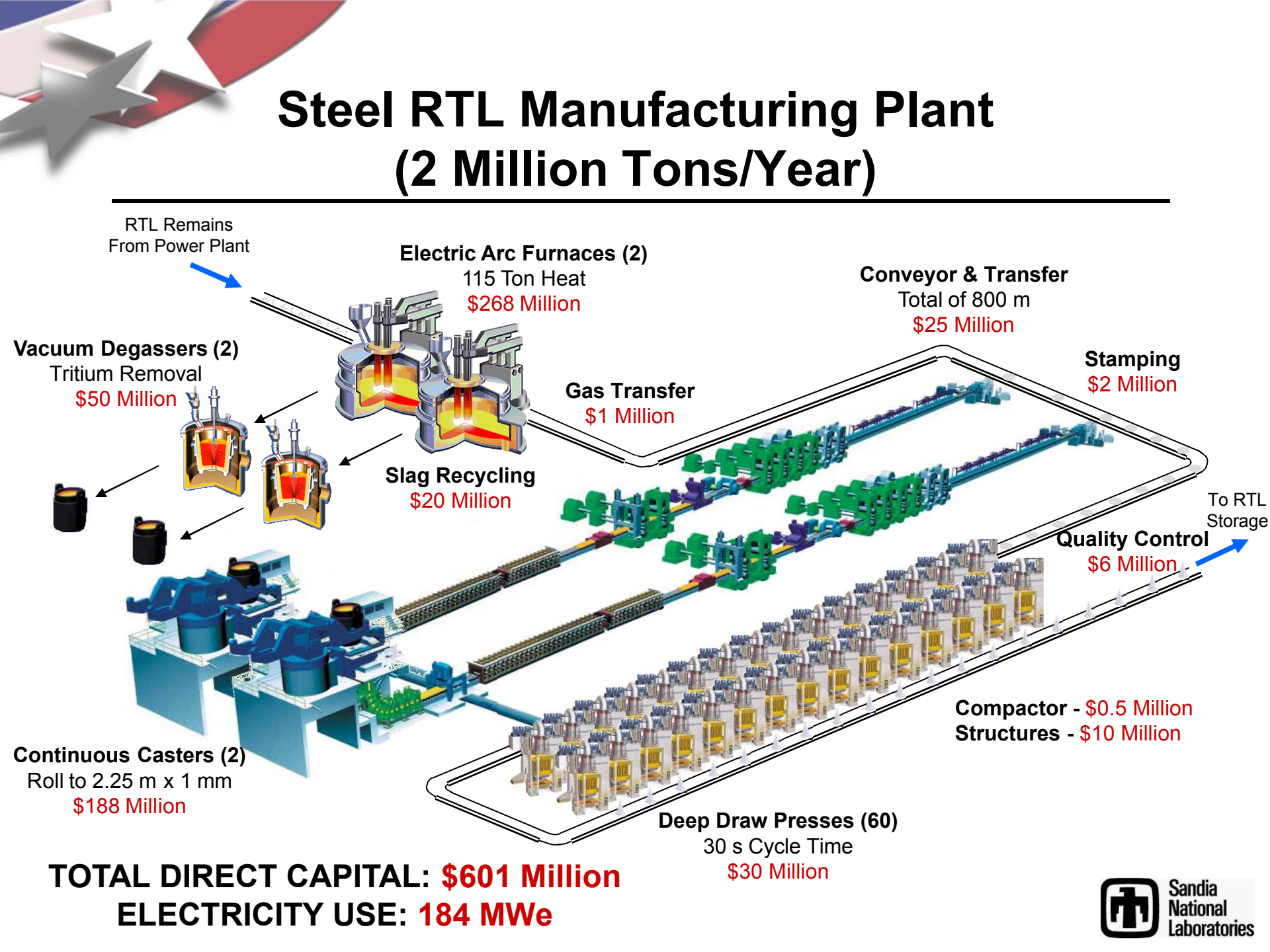
Not to Scale

Recyclable Transmission Line Configuration



Sandia National Laboratories

Steel RTL Manufacturing Plant (2 Million Tons/Year)

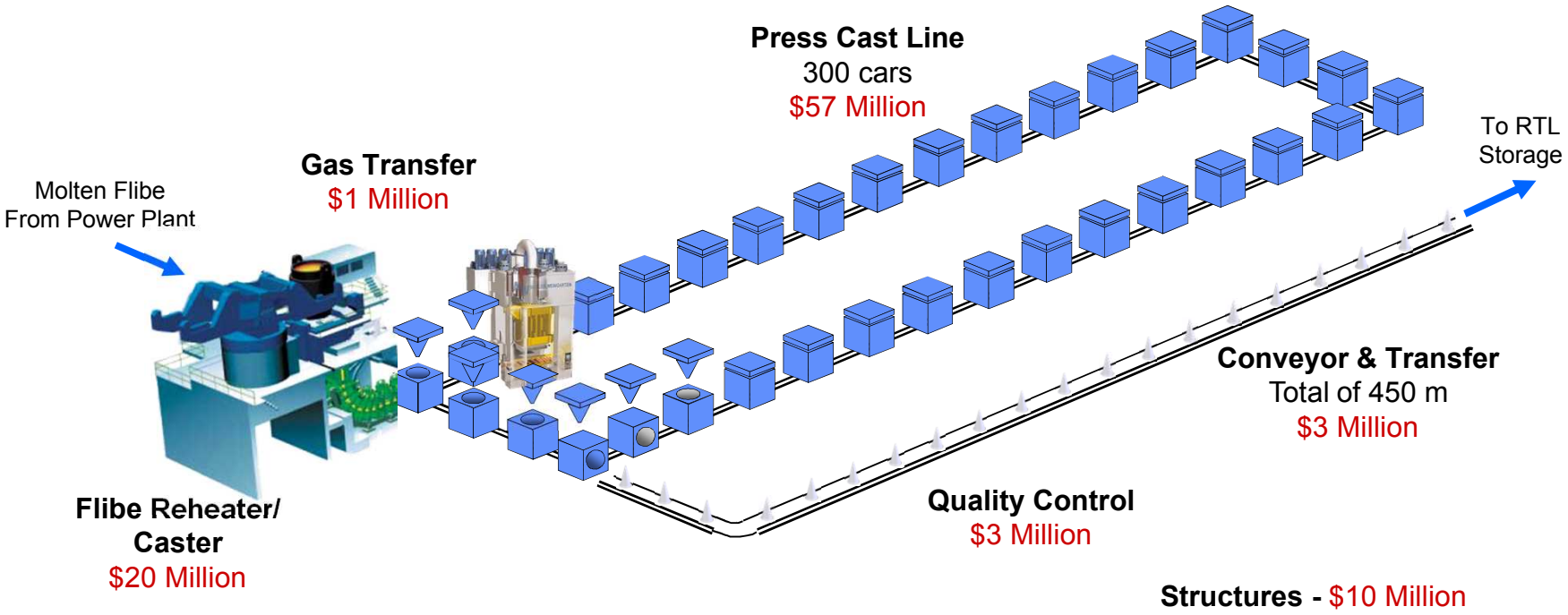


TOTAL DIRECT CAPITAL: $601 Million

ELECTRICITY USE: 184 MWe

Sandia National Laboratories

Cast Flibe RTL Manufacturing Plant

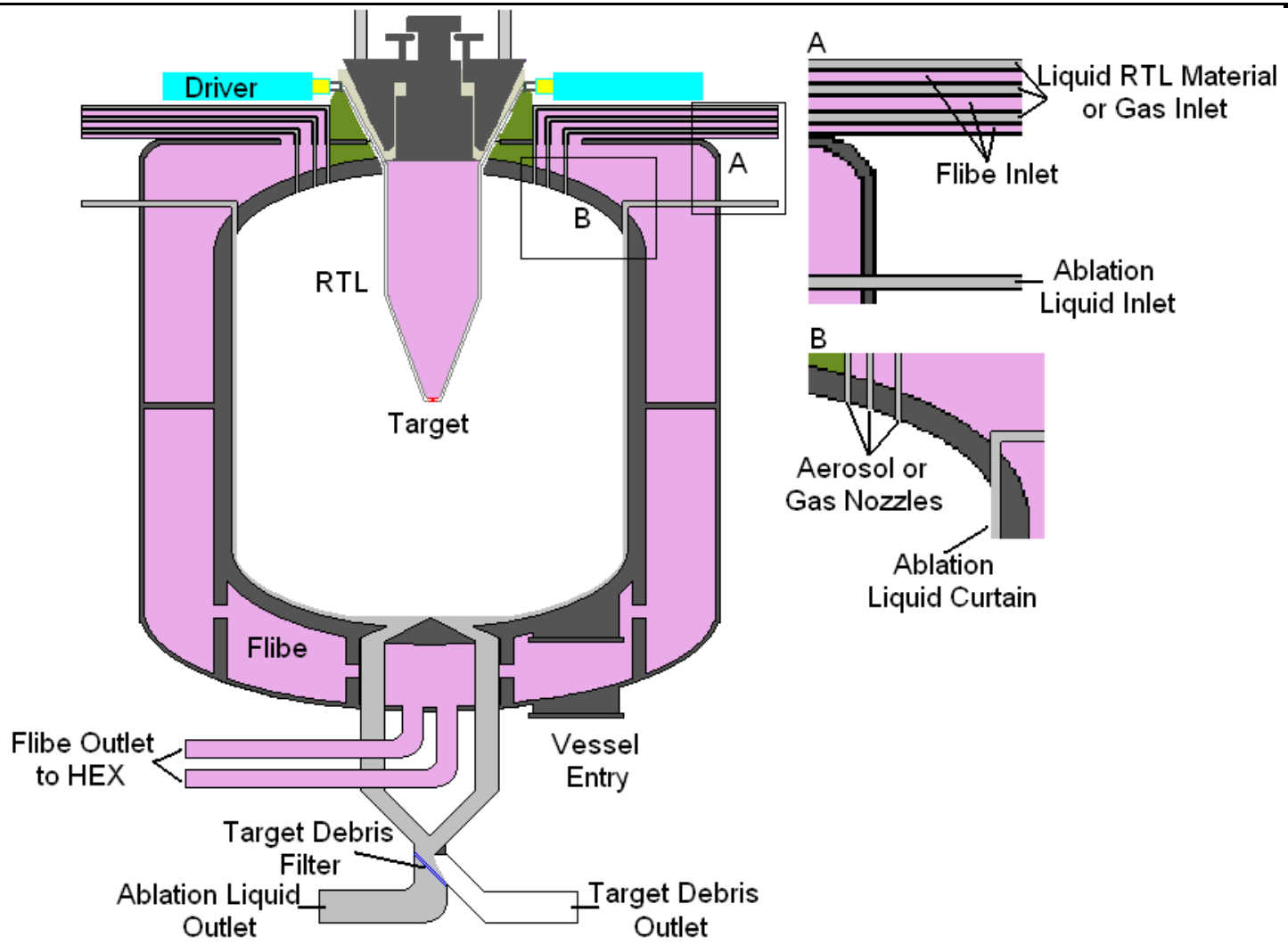


TOTAL DIRECT CAPITAL: $94 Million

ELECTRICITY USE: 5 MWe

Sandia National Laboratories

Power Plant Vessel Concept (1)



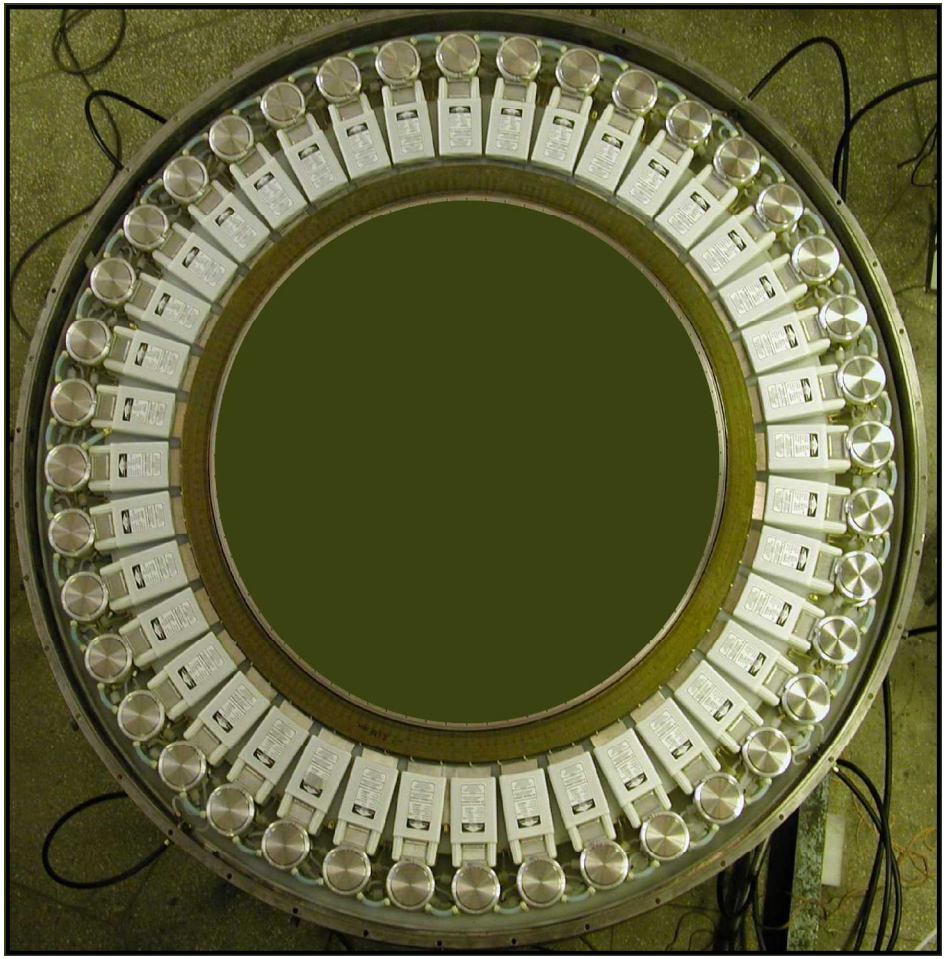
Sandia National Laboratories

Immediate Science Issues to be Addressed

- High Yield Inertial Confinement Fusion in the laboratory
- Increasing energy density and efficiency of pulsed power systems
- Understanding the mitigation of high intensity x-rays and the resulting shrapnel generation
- Material science of FLiBe as an engineered solid material as well as a large volume coolant
- Intermediate applications of fusion neutrons to provide a basis for large scale designs

Sandia National Laboratories

Linear Transformer Driver

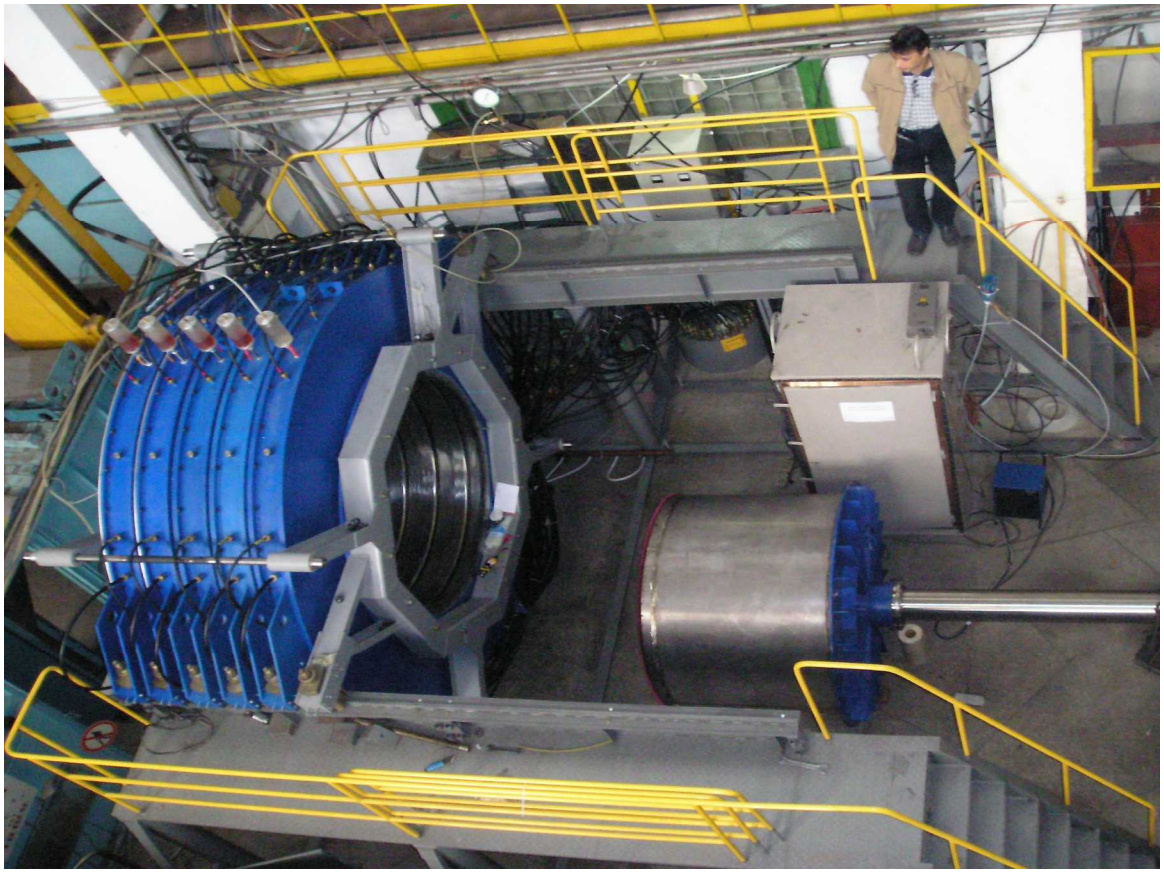


Sandia National Laboratories

Linear Transformer Driver Test

Sandia National Laboratories

5-cell Linear Transformer Driver

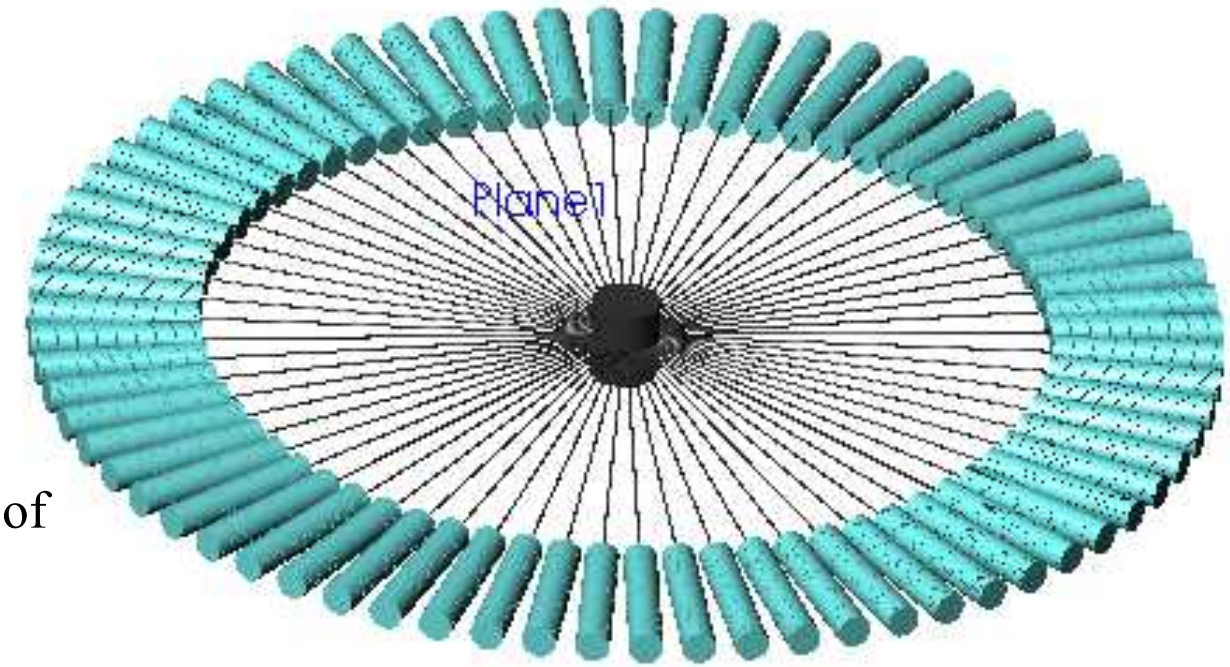


Sandia National Laboratories

Z-POP Simulation

Driver Configuration

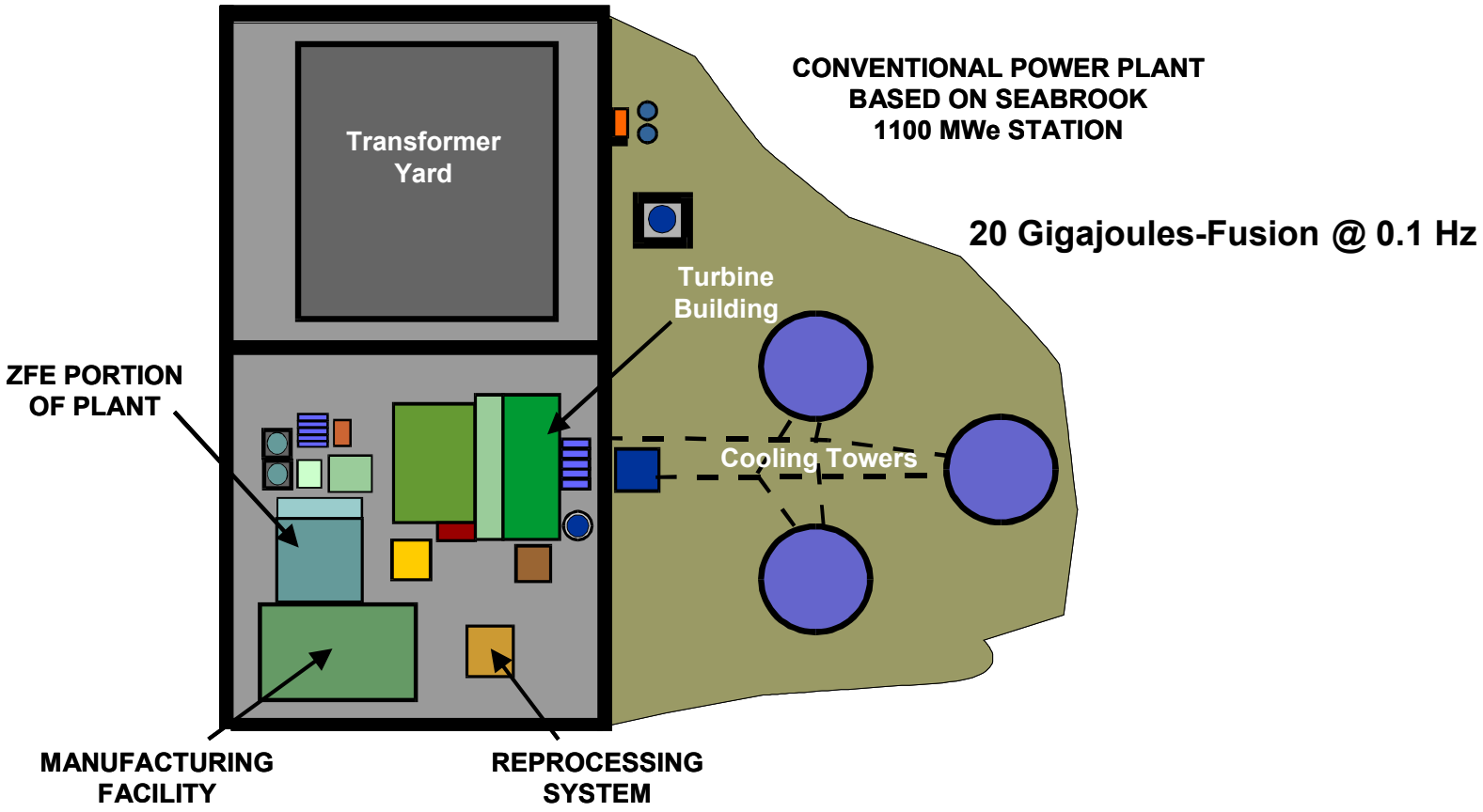
104 m



70 modules of
70 Cavities

Sandia National Laboratories

Conceptual Z-IFE Facility

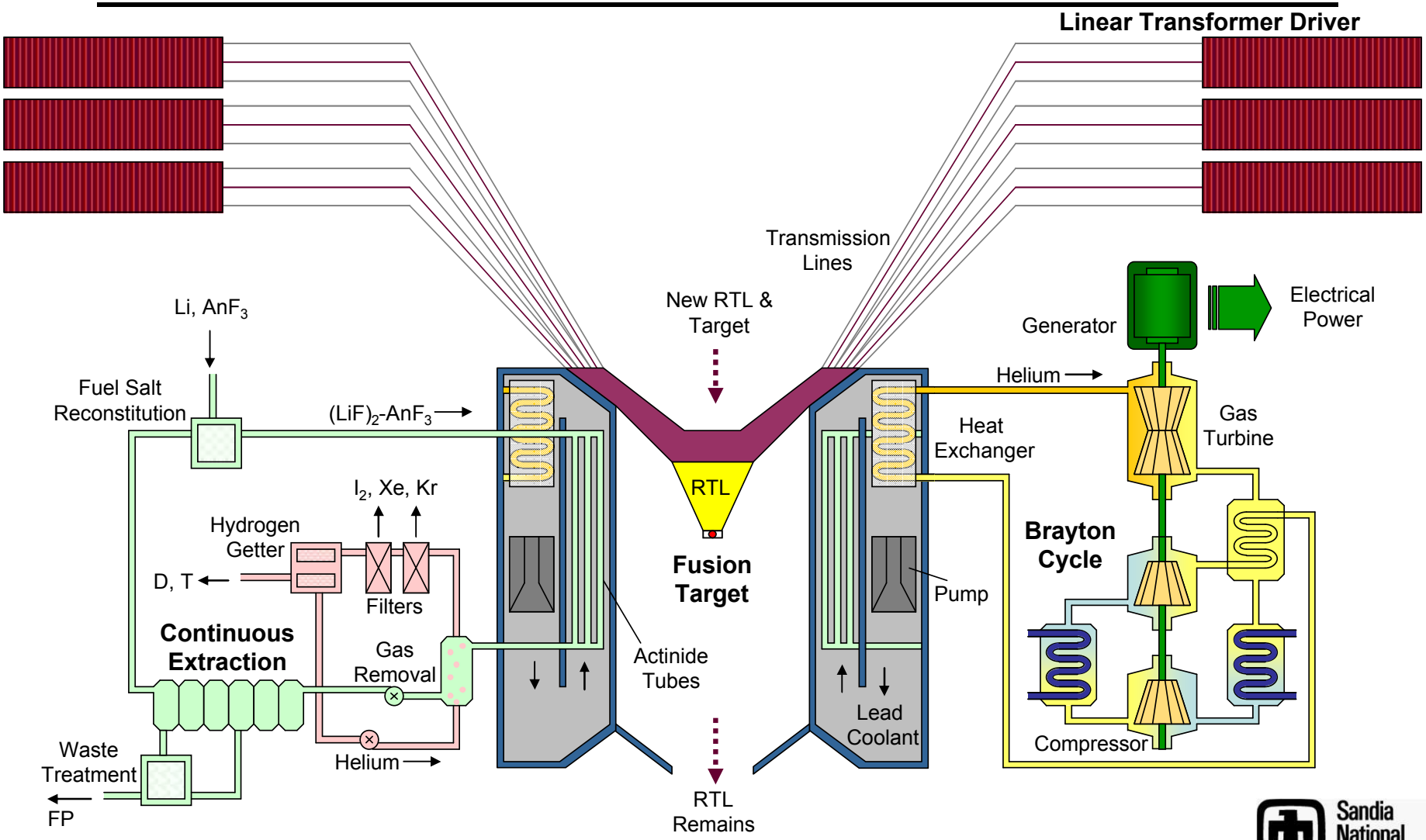


Sandia National Laboratories

Possible Intermediate Path Forward

Sandia National Laboratories

In-Zinerator Power Plant Concept: A Fusion-Fission Hybrid



Sandia National Laboratories

Transmutation Yield Requirements

- **Full Scale TRU Burner**
  - 20 transmuters required to burn TRU as fast as the current LWR fleet can produce it:

    200 MJ target fired every 10 seconds
- **Full Scale Am/Cm Burner**
  - 2 transmuters required to burn Am/Cm as fast as the current LWR fleet can produce it (assumes Pu/Np burned in LWRs):

    240 MJ target fired every 10 seconds

Experiments on ZR

- X-ray Mitigation Experiments
  - Gas
  - Aerosol
  - Ablation liquid curtain
- Tritium Containment Experiments
  - Little or no tritium permeation through the RTL opening in the vessel
- RTL and chamber sealing experiments
  - Test the concept of an RTL connecting the MITLs to the target.
  - Ensure contents within the vessel remain in the vessel after fusion event.

Sandia National Laboratories

Potential Option for Integration with ZR

Solid insert for MITL snout

Flange for ready replacement

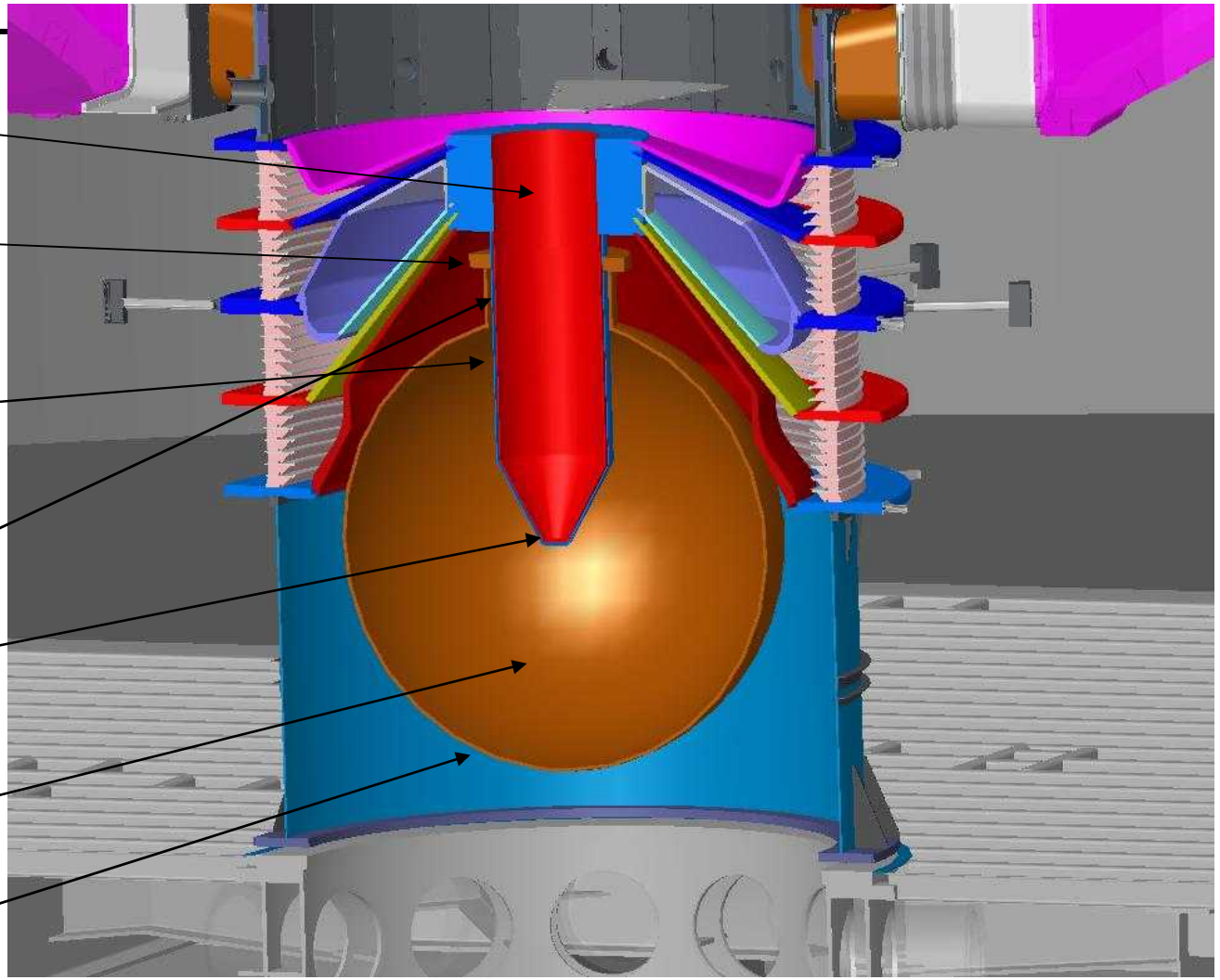
Annular Coax MITL for power transfer

Narrow gap with explosive closure

Z-pinch target

Gas to absorb x-rays & protect wall

Blast and gas containment



Sandia National Laboratories

Z Initiated Power Systems: ZIPS

- Goal: Determine steps to achieve early demonstration of high-energy and rep-rated shots
- Challenges
  - Contain the radioactive gases
  - Survive the blast of x-rays, pressure, and shrapnel
  - Engineer a system that can be rep-rated
- Potential solution for first-step demo
  - Low-pressure gas to absorb x-ray pulse and convert the 100-ns pulse to milliseconds at the wall
  - MITL “snout” to provide standoff
  - Explosive closure to protect permanent MITL
- Goal of 1 shot per hour would enhance ZR utility