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Title: LANL Accelerators: History, capabilities, and Plans

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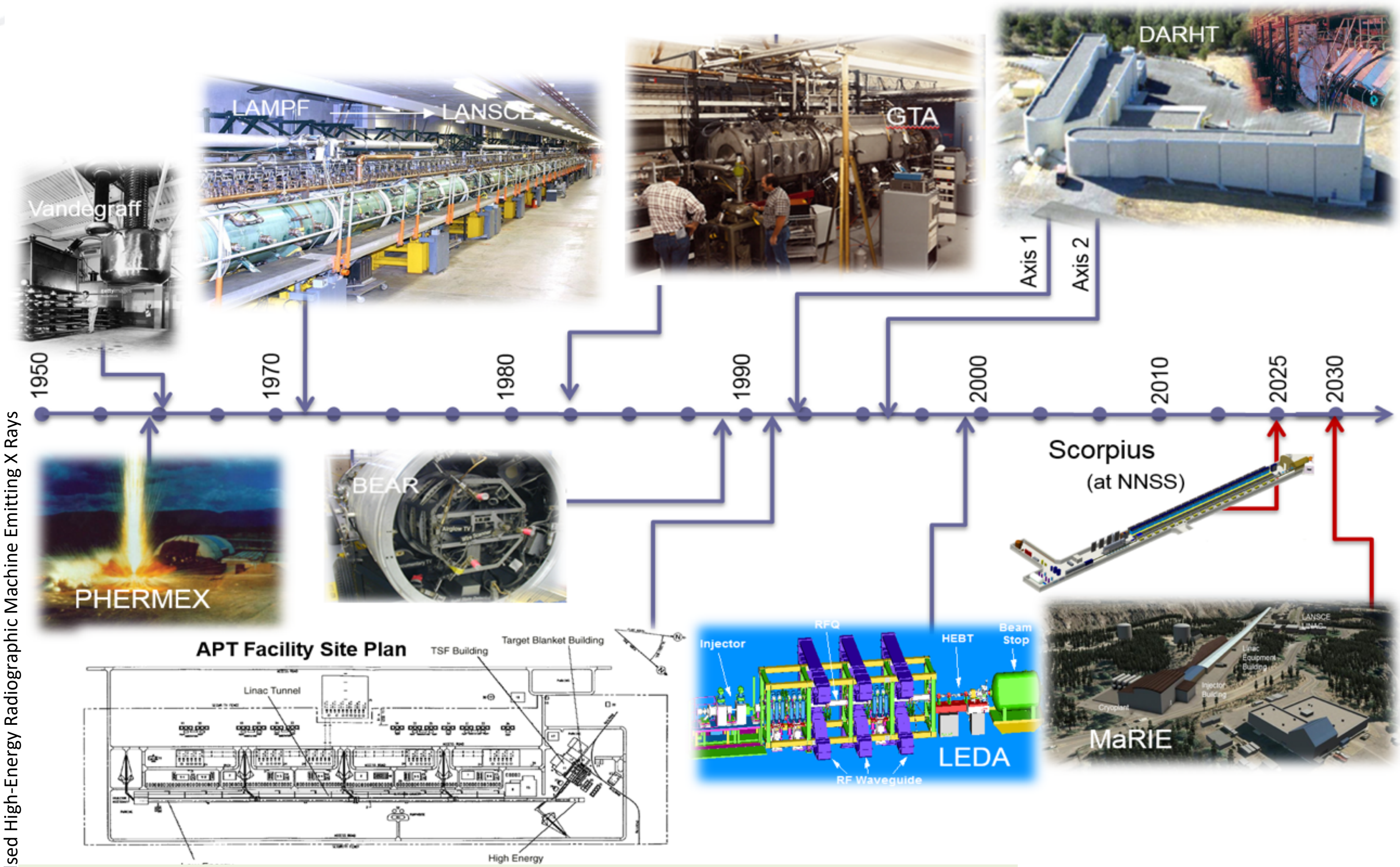
# LANL Accelerators

## History, Capabilities, and Plans

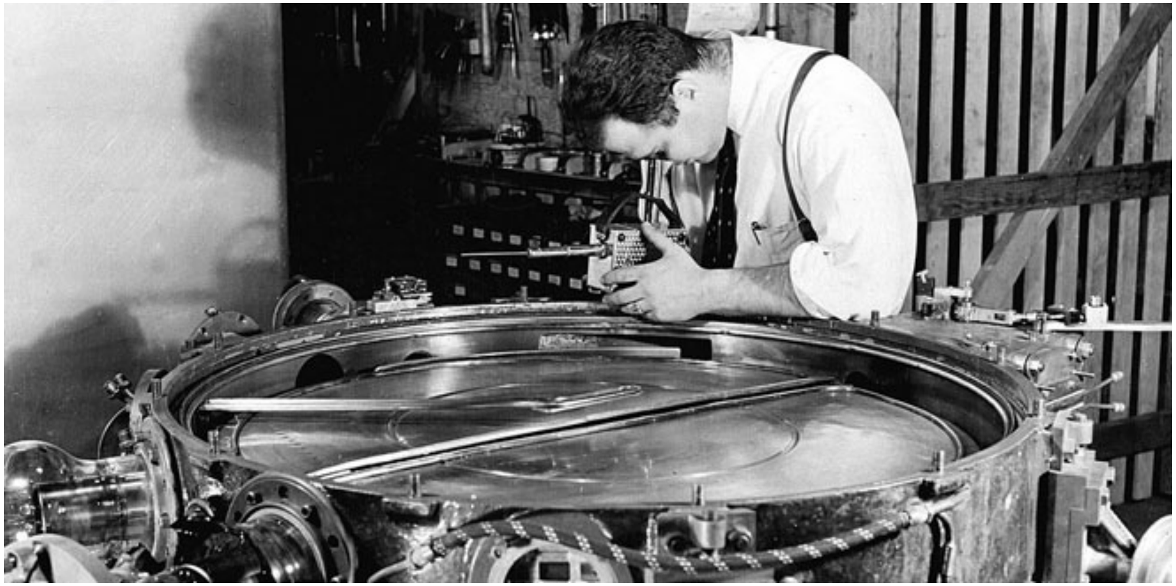
Stephen Milton

# Accelerators have always been a part of supporting national security at LANL.




**Accelerators have been and will continue to be essential to the LANL mission.**

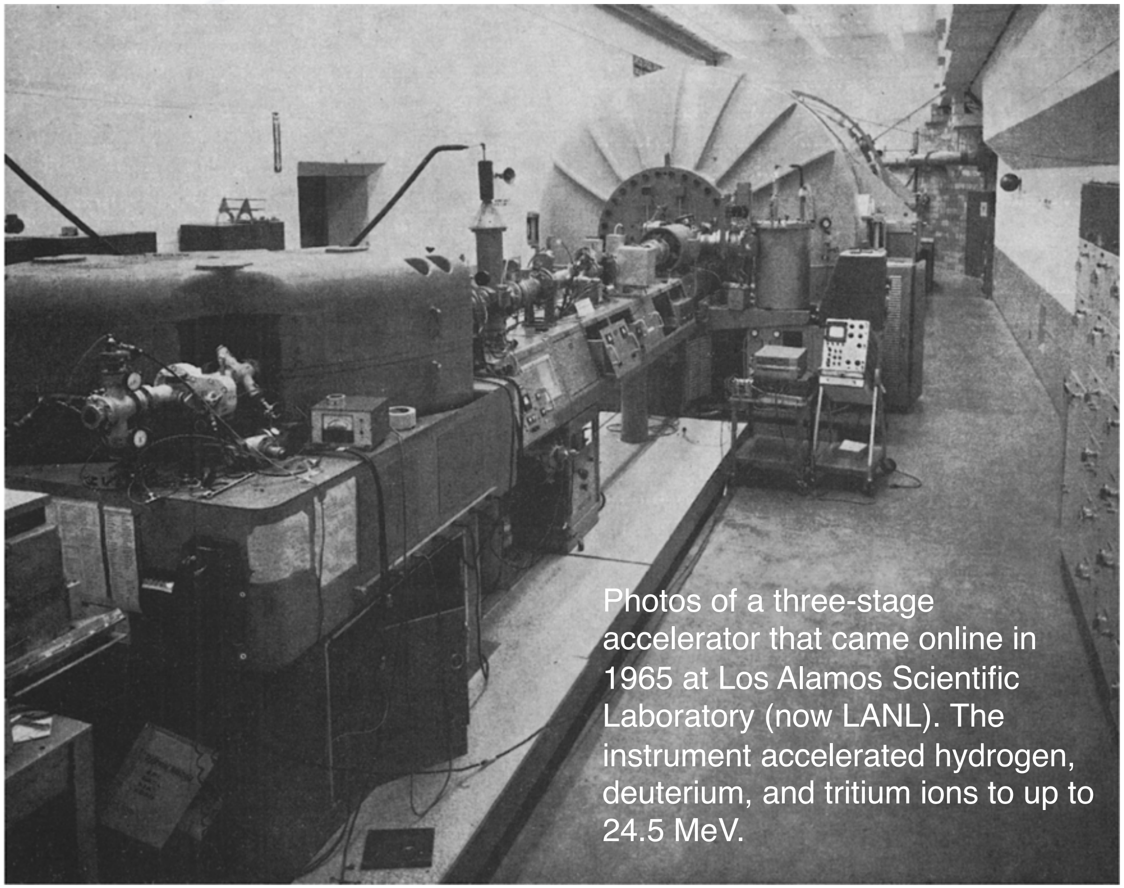
# The first accelerator at Los Alamos was the Harvard Cyclotron



The Harvard cyclotron was sent to Los Alamos in 1943.

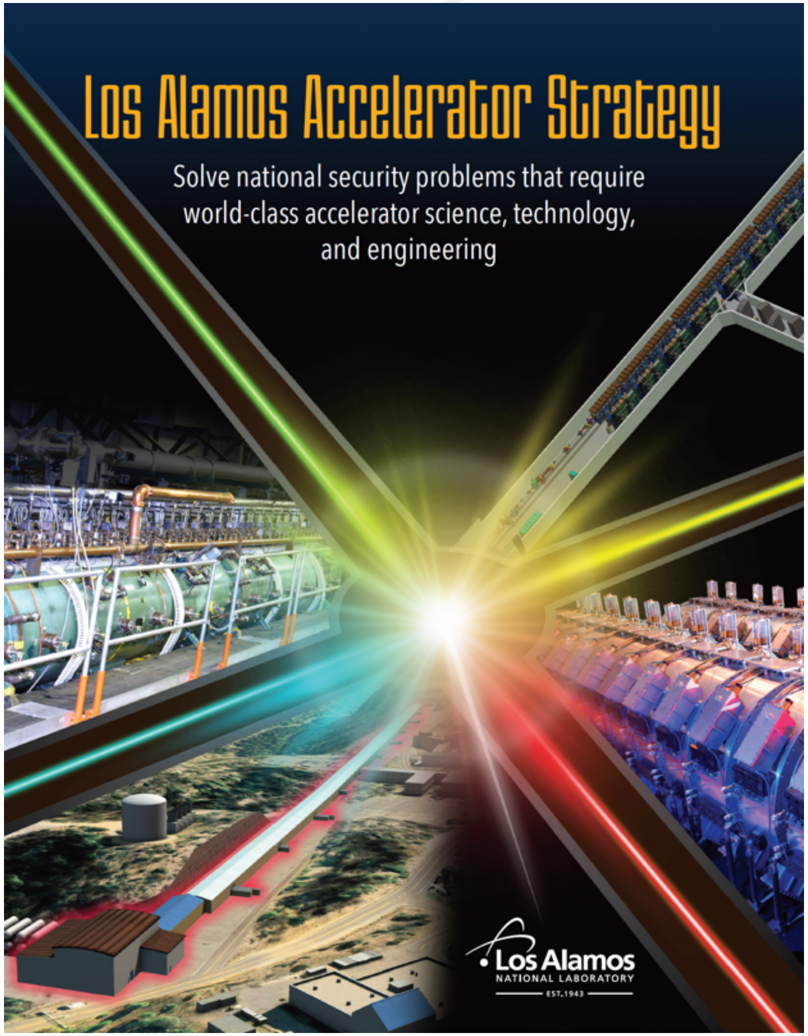
Also in 1943 Robert (Bob) Wilson was hired from Lawrence's group at Berkeley to run the cyclotron group.

# An early accelerator and an early accelerator physicist



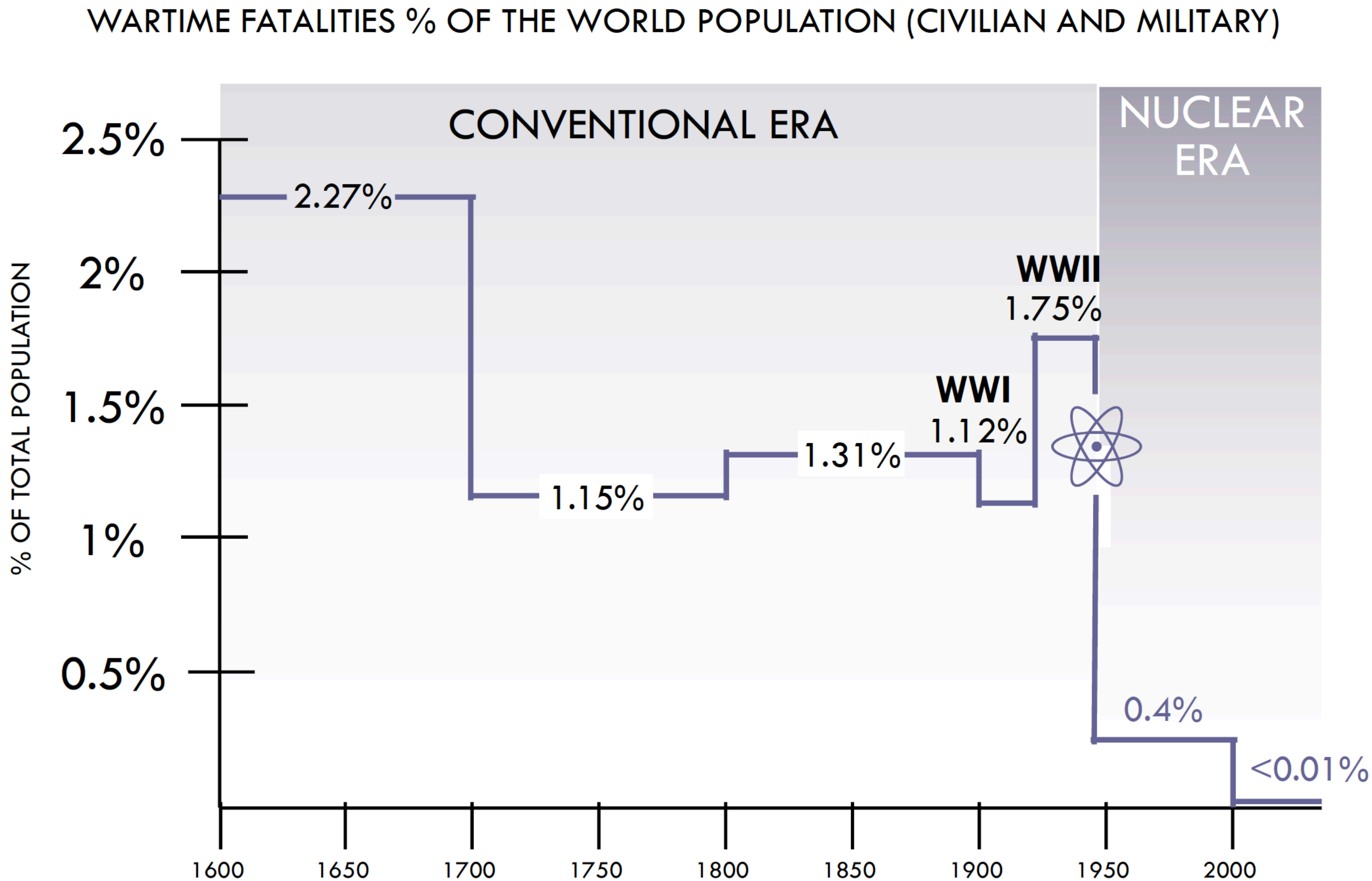
Photos of a three-stage accelerator that came online in 1965 at Los Alamos Scientific Laboratory (now LANL). The instrument accelerated hydrogen, deuterium, and tritium ions to up to 24.5 MeV.

# In 2018 we generated an Accelerator Strategy that provides a clear path on how to proceed




- **Accelerator Strategy Vision**
  - *Solve national security problems that require world-class accelerator science, technology, and engineering.*
- **Solutions to Meet Mission Needs**
  - *Diagnose dynamic experiments in weapon configurations with nuclear and surrogate materials that meet the (classified) requirements of primary designers.*
  - *Control the performance and the production of materials vital to national security missions.*
  - *Obtain nuclear data for stockpile assessment, forensics, criticality analysis, and radiochemistry.*
  - *Develop next-generation predictive physics models used to assess and certify the present and future stockpile with low uncertainty and high confidence.*
  - *Address emerging stockpile stewardship challenges and global nuclear threats.*

# The Nuclear Deterrent is Real




From the 2018 US Nuclear Posture Review

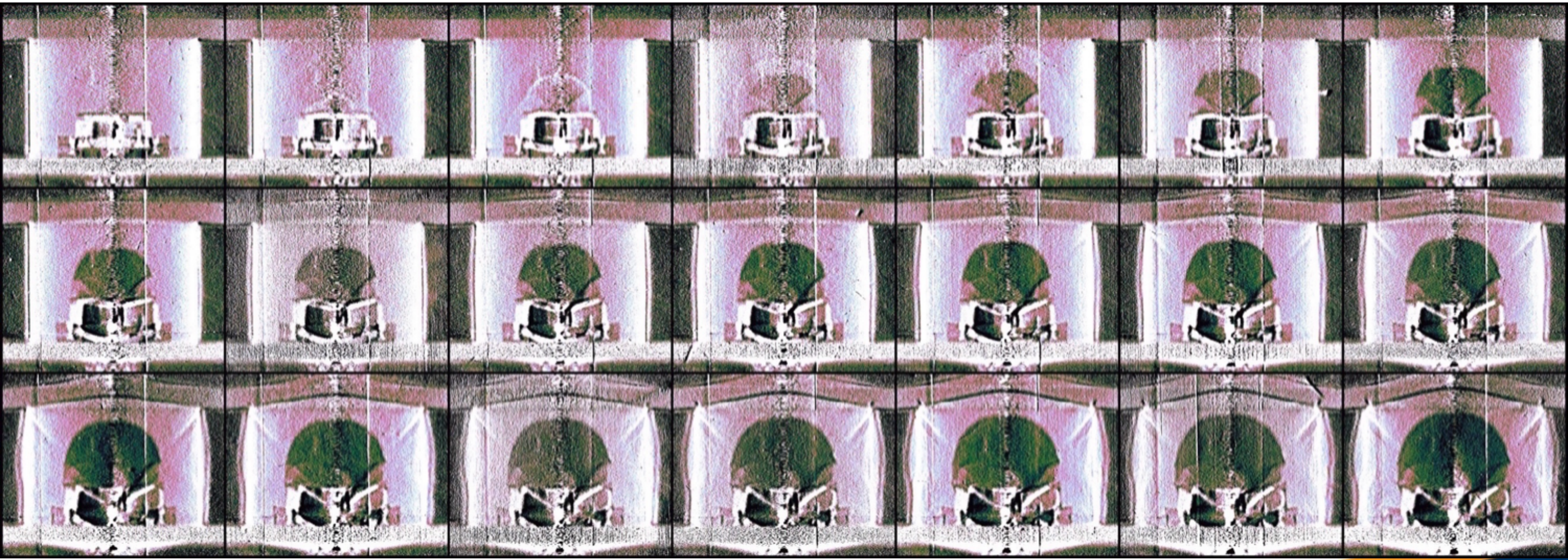
# LAMPF/LANSCE: 47 years

# The LANSCE facility has a diverse set of capabilities


- **Operations began in 1972**
  - Risk mitigation completed in 2015
- **800-MeV (1 MW) proton beam**
- **Highly capable/flexible facility**
  - 100-800 MeV proton energies
  - 5 target stations
  - 3 neutron spallation targets
  - 16 beam lines
  - Time structure of beam allows for a large dynamic range of experiments
- **Dynamic proton radiography**
- **Neutron radiography**
- **Structural material properties**
- **Nuclear properties of materials**
- **Fundamental physics**
- **Isotope production**

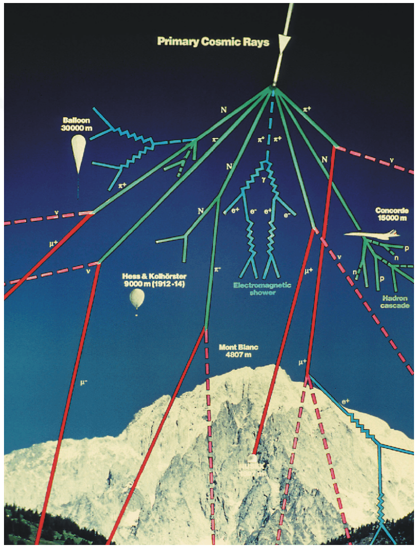
# LANSCE particles can film materials at extremes

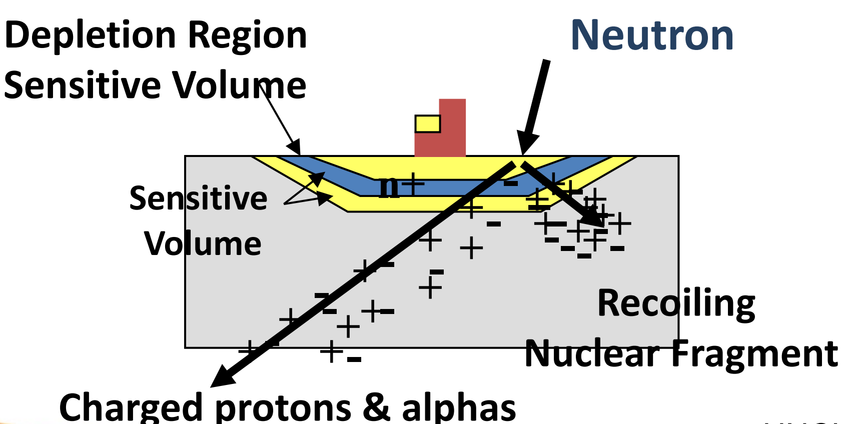
- In the 90s, nuclear physicists at LANL created lens-focused charged particle radiography, a technique that takes fast radiographs of dynamic systems (like x-rays of explosions and implosions)
- Users at the Lab's Proton Radiography (pRad) facility now use elementary particles to understand how material behaves in extreme conditions



# Neutrons for industrial users: ensuring robustness of electronics against cosmic-ray bombardment

- Neutrons produced by cosmic rays penetrate the atmosphere
- Can interact with electronics and can cause single event upsets or latch ups
- At LANSCE the neutron flux is 1 million times that experienced at 35,000 ft
- We operate 2 flight paths dedicated to industrial users paying full cost recovery

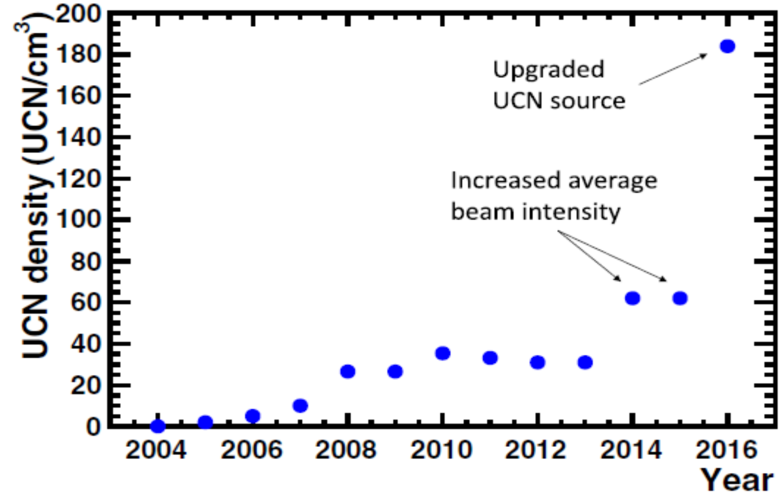


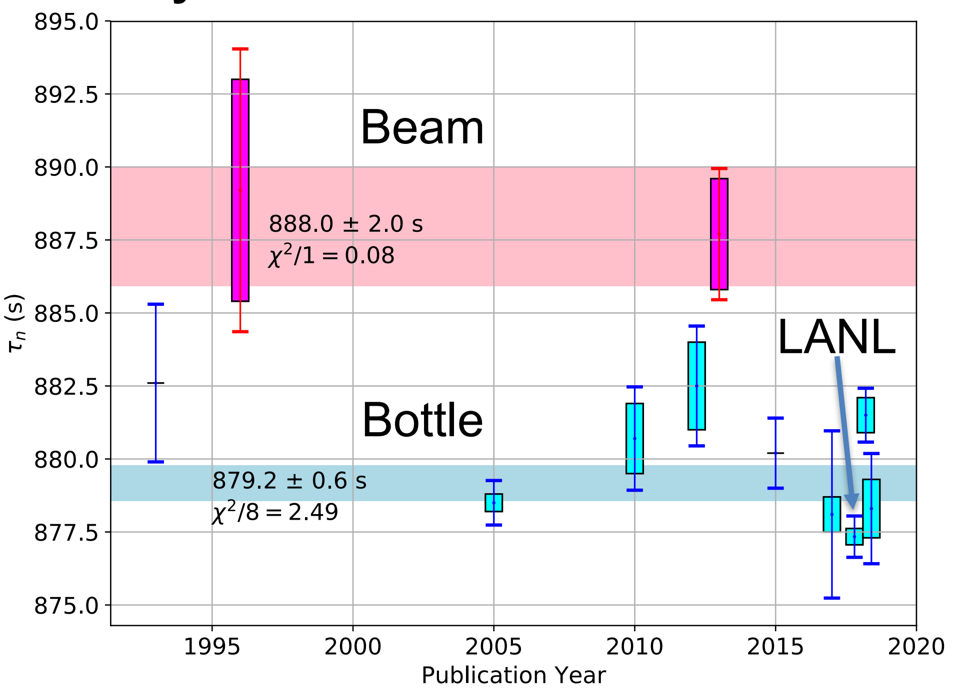



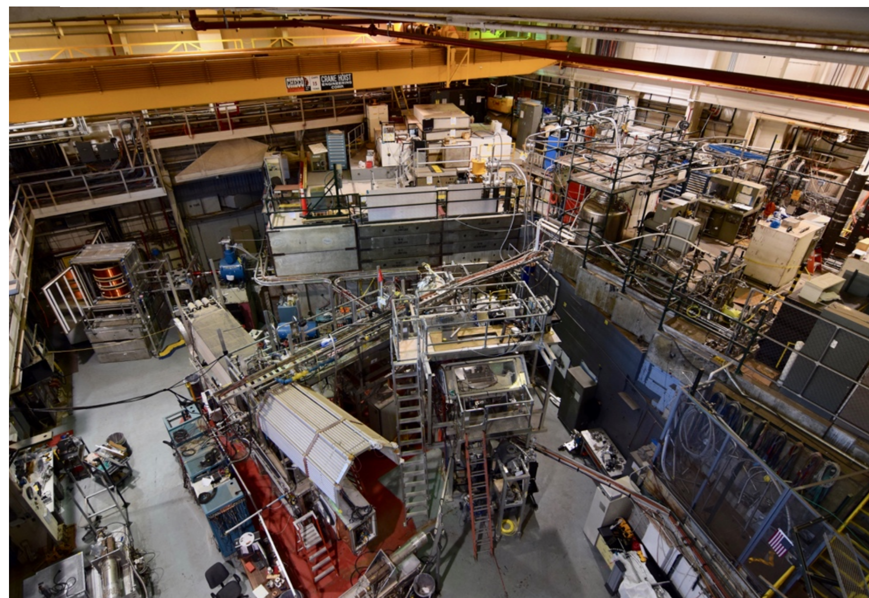

Advanced Micro Devices
Marvell Semiconductor, Inc.
Arista Networks
Prairie View A&M University
Honeywell
Infineon Technologies, AG
Rockwell Collins, Inc.
Sandia National Laboratories
KVA Engineering, Inc.
Texas Instruments
University of South Dakota

# Ultra-cold neutrons can probe fundamental symmetries of nature

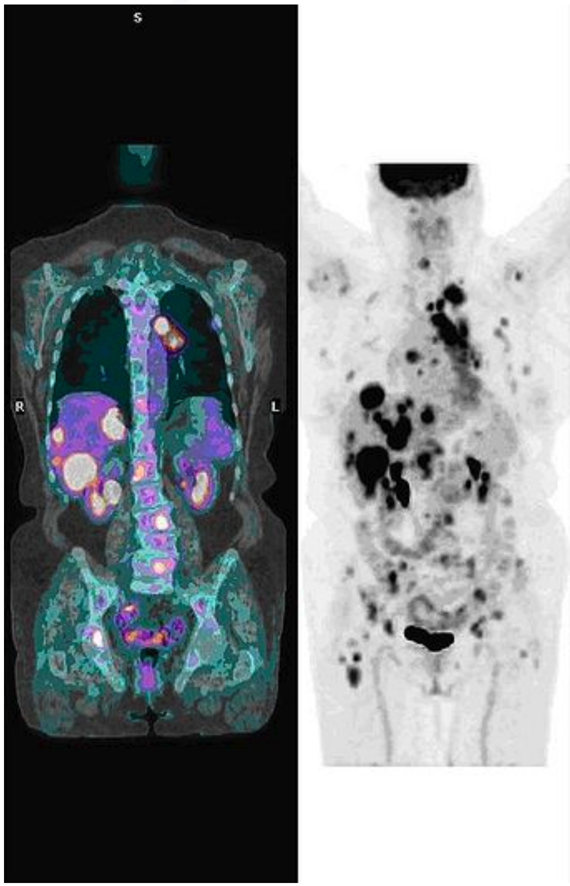
- **LANSCE has the most intense source of ultra-cold neutrons**
- **We have published the world's most precise measurement of the neutron lifetime (*Science* May 6, 2018)**
- **Developing experiment to detect non-β decay of neutrons**



# Isotopes from LANL help medical patients around the world



**Isotope Production Facility is one of the five facilities that accepts beam from the LANSCE Accelerator**

**IPF uses protons to generate radioactive isotopes that:**

- Show where diseases like cancer have taken root in the body
- Maximize damage to tumors while reducing impact to surrounding tissue
- Diagnose cardiac disease

**The Lab is a major supplier of diagnostic isotopes Sr-82 and Ge-68**

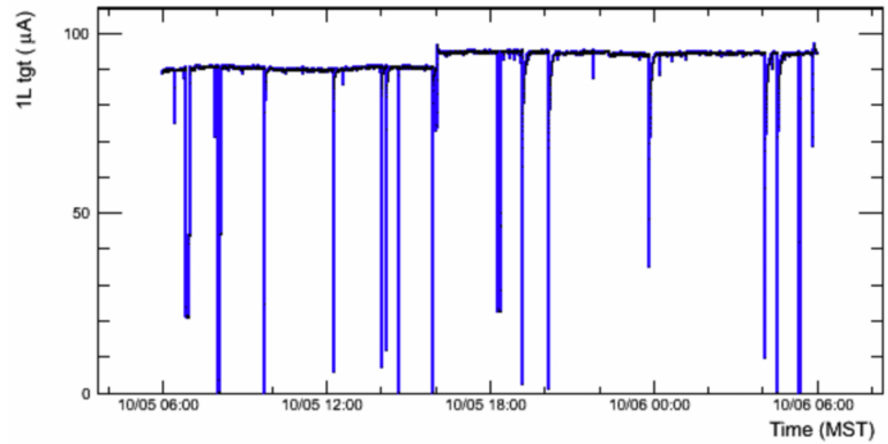
**Researchers are scaling up production of Ac-225, an alpha-emitting isotope in FDA trials for treating cancer**

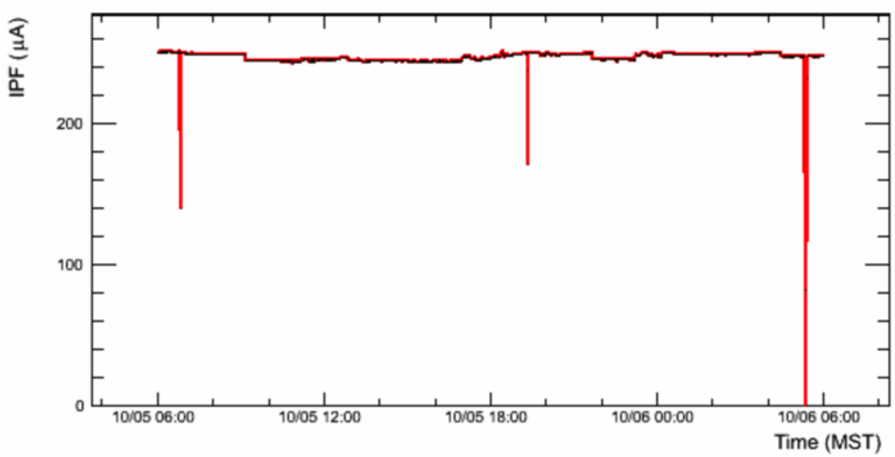
# Sometimes the performance of the machine is quite good. Other times…

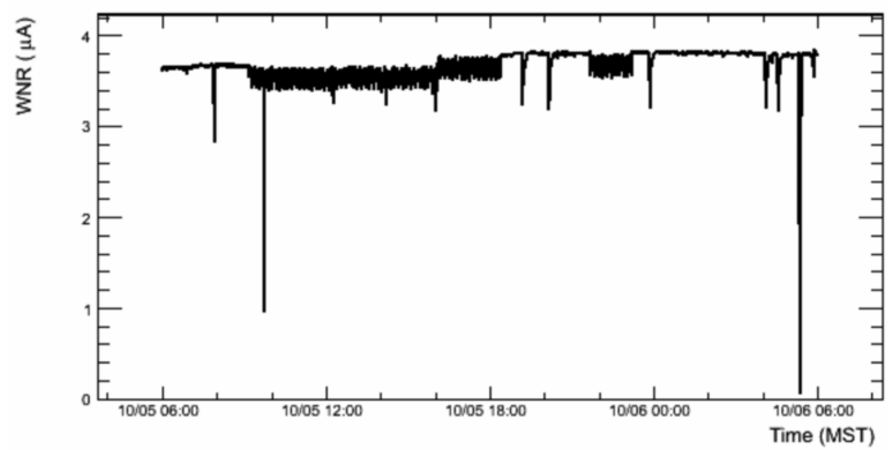
LANSCE
Los Alamos Neutron Science Center

**The Last 24 Hour Estimated Availability**

| ====== IPF ====== | == 1L target == | == WNR targets == |
|---|---|---|
| Beam UPTIME: 23.93 hours<br>Beam DOWNTIME: 0.05 hours<br>Integral current: 5.911 mA*h<br>Relative UPTIME: 99.79 %<br>Average current UP: 247 uA | Beam UPTIME: 23.54 hours<br>Beam DOWNTIME: 0.4583 hours<br>Integral current: 2.173 mA*h<br>Relative UPTIME: 98.09 %<br>Average current UP: 92.3 uA | Beam UPTIME: 23.93 hours<br>Beam DOWNTIME: 0.05 hours<br>Integral current: 87.99 uA*h<br>Relative UPTIME: 99.79 %<br>Average current UP: 3.676 uA |



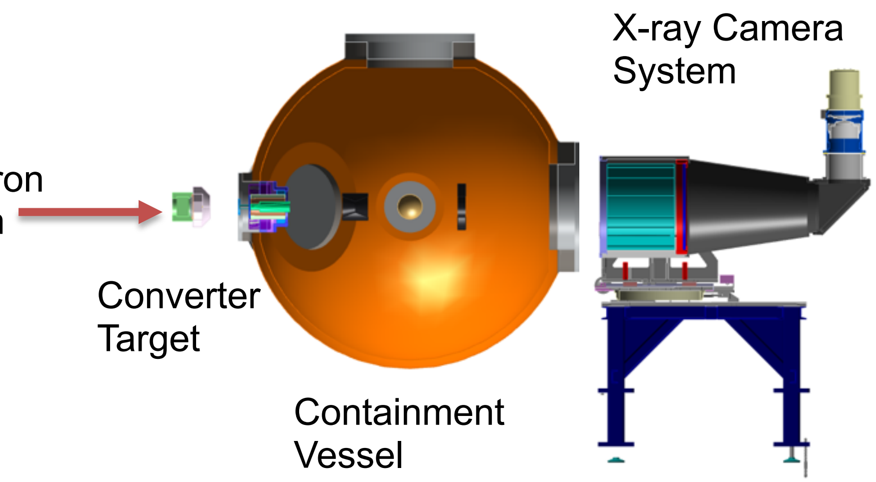
# The “Crack” of 2019

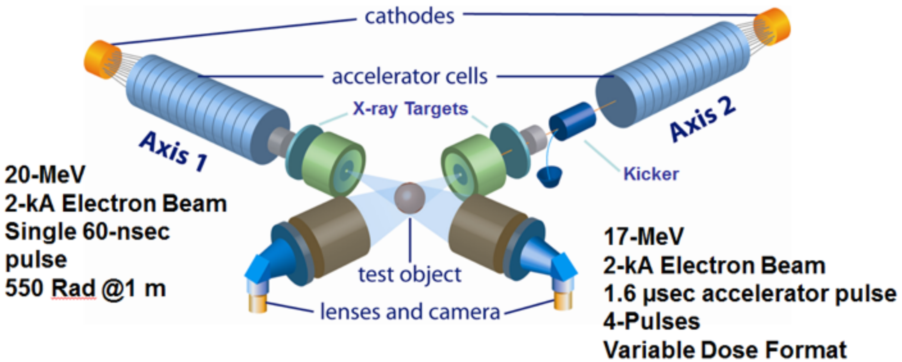

- This DTL is now working better than it has in 10 years
- However, inspection of this tank and the 3 of DTL tanks show worrisome “features” at weld joints


DARHT: 1st Axis Completed 1999
2nd Axis Completed 2003
but Operational in 2008

# The Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility supports science-based Stockpile Stewardship and large-scale Homeland Security applications


DARHT: 1st Axis completed 1999
2nd Axis completed 2003
but operational in 2008



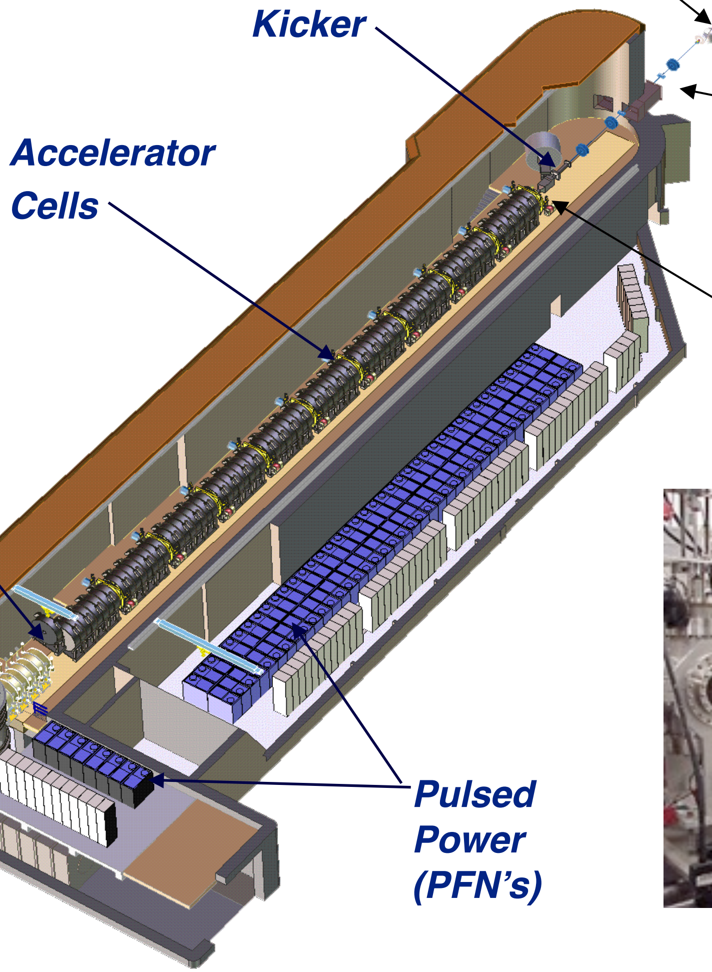



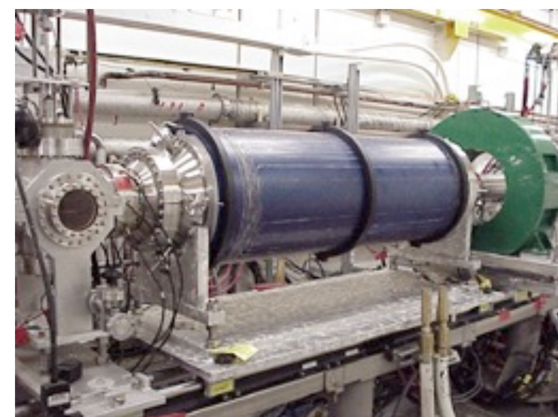

- The converter target generates a nearly point source of x-rays that propagate through the object.
- A thick, large-area, pixelated, LSO scintillator converts the x-rays to visible light.
- Multi-frame CCD cameras capture and record the images.

# The primary mission of the DARHT facility is to support national security

- Capabilities
  - The main purpose of DARHT is to provide radiographic data for verification of computer codes.
  - Radiographic images are used to evaluate nuclear weapons through non-nuclear hydrodynamic testing of full-scale mock implosions of the primary stage of a nuclear weapon system.
  - DARHT is the world's most powerful x-ray machine for analysis of mock nuclear weapon implosions.
- National Security
  - Critical tool for nuclear weapons development and stockpile stewardship.
  - DARHT provides radiographs that help ensure weapons in the stockpile are safe, effective, and will perform as designed.
  - Tests of improvised devices are also performed.

# DARHT Phase 2 Accelerator Layout



# It was once quite exciting to watch the ”shot” (experiment) at DARHT

# What's next? ECSE

- ECSE is a portfolio of projects designed to see what happens to plutonium hit with extreme pressure from explosively driven shocks
- ECSE is planned for Nevada National Security Site's U1a Complex
- President's proposed budget for the coming year fully supports the ECSE budget plan

Los Alamos NATIONAL LABORATORY EST. 1943

**NNSA approves 'Critical Decision 1' for Advanced Sources and Detectors Project, a new tool to advance stockpile stewardship**

February 14, 2019

**The project is designed to generate x-ray images of subcritical experiments for the Nation's nuclear weapons program**

LOS ALAMOS, N.M., Feb. 14, 2019—The National Nuclear Security Administration (NNSA) has approved Critical Decision-1 (CD-1) for the Advanced Sources and Detectors Project (ASD), a cornerstone of the Enhanced Capabilities for Subcritical Experiments portfolio (ECSE). ASD is a proposed 20-million electron volt (MeV) accelerator that will generate X-ray images, or radiographs, of subcritical implosion experiments for the nuclear weapons program.

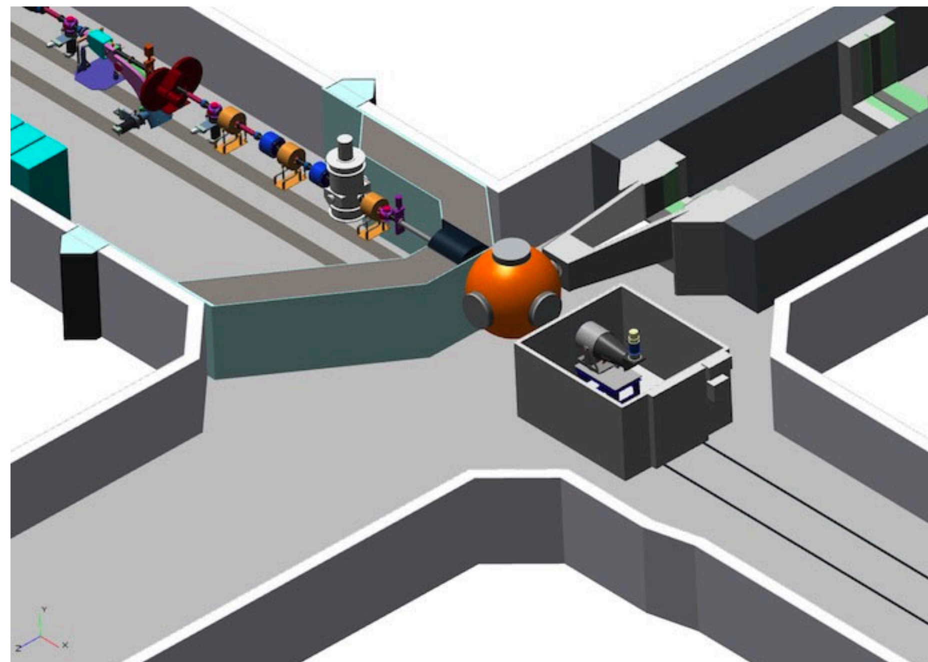
"The ECSE portfolio is designed to better understand plutonium when it is subjected to extreme pressure from explosively driven shocks, a central mission need for NNSA's science-based Stockpile Stewardship Program," said Thom Mason, Director of Los Alamos National Laboratory (LANL). "The ECSE program continues the outstanding stockpile science of the past 30 years, assuring the safety, security and effectiveness of the U.S. nuclear deterrent without the need for full-scale underground nuclear testing."

The NNSA's national laboratories are working together to pursue ECSE. Los Alamos is leading this federally-directed plan with Sandia National Laboratories, the Nevada National Security Site (NNSS) and Lawrence Livermore National Laboratory to develop new diagnostic capabilities so that scientists can study plutonium in much more detail under the conditions found inside the final stages of a nuclear weapon implosion — but without the nuclear yield — called a "subcritical experiment."

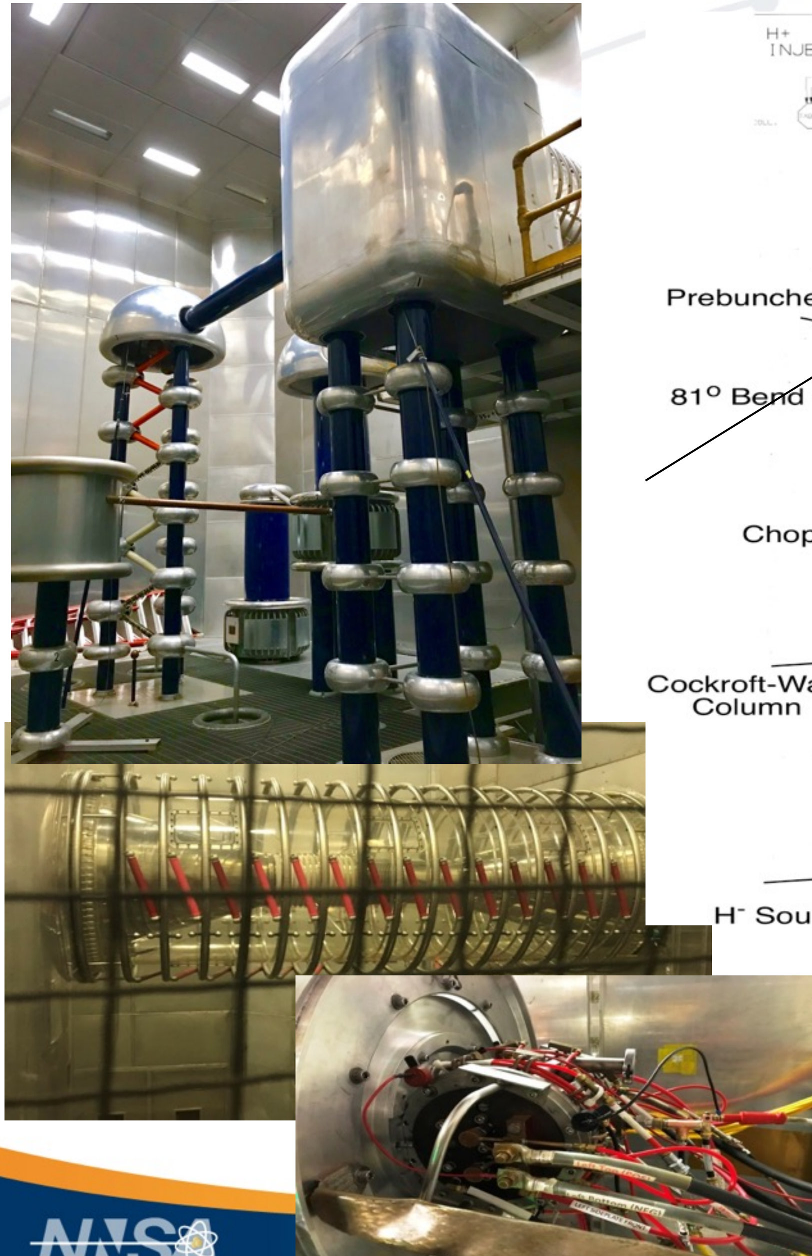
"The new diagnostics capabilities provided by ASD will significantly enhance and expand the ability to measure the dynamic behavior of plutonium under weapons-relevant conditions," said Bob Webster, Deputy Director of Los Alamos National Laboratory for Weapons.

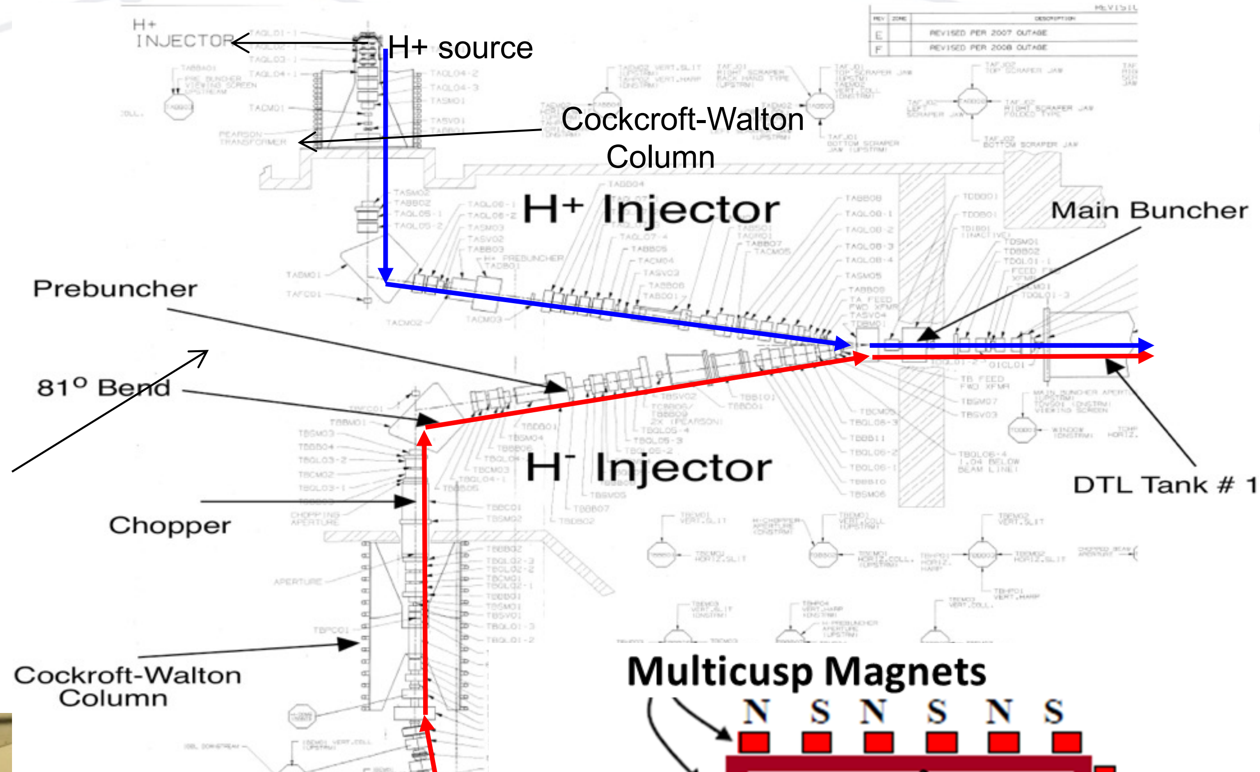
# ECSE's 'Scorpius' project will help steward the stockpile

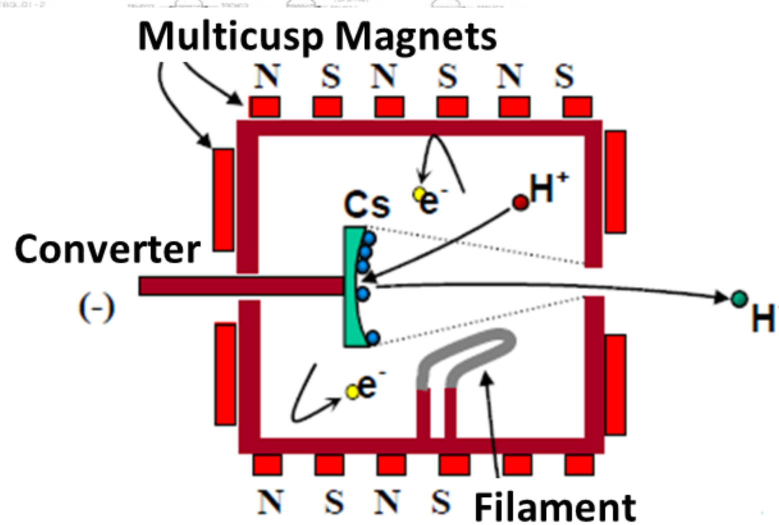
- One of the ECSE's 10 projects, nicknamed Scorpius, is a 20-MeV accelerator for x-raying subcritical implosions
- Experimental campaigns using Scorpius will radiograph subcritical implosion experiments using real plutonium



# Negative Ion Source at LANSCE
# H⁻ dome, surface converter negative ion source and 750 keV injector (80+670 kV)

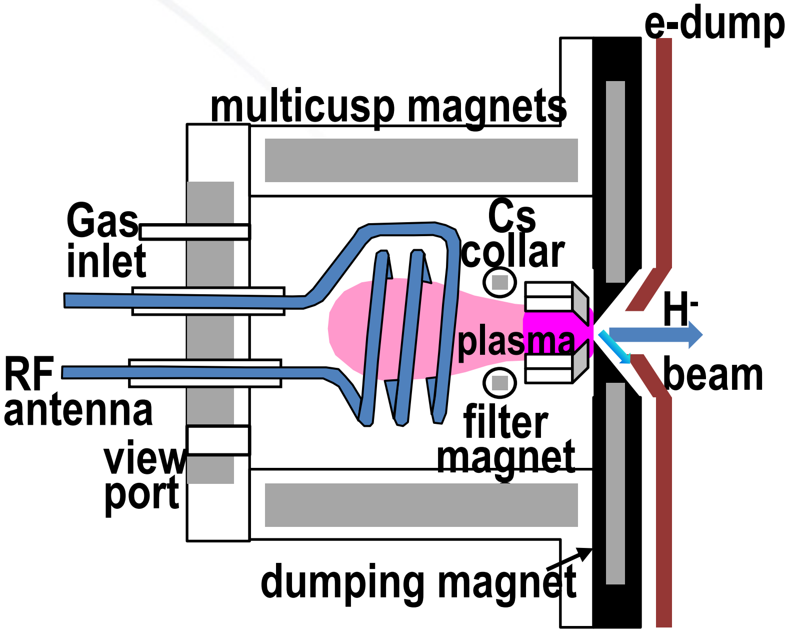




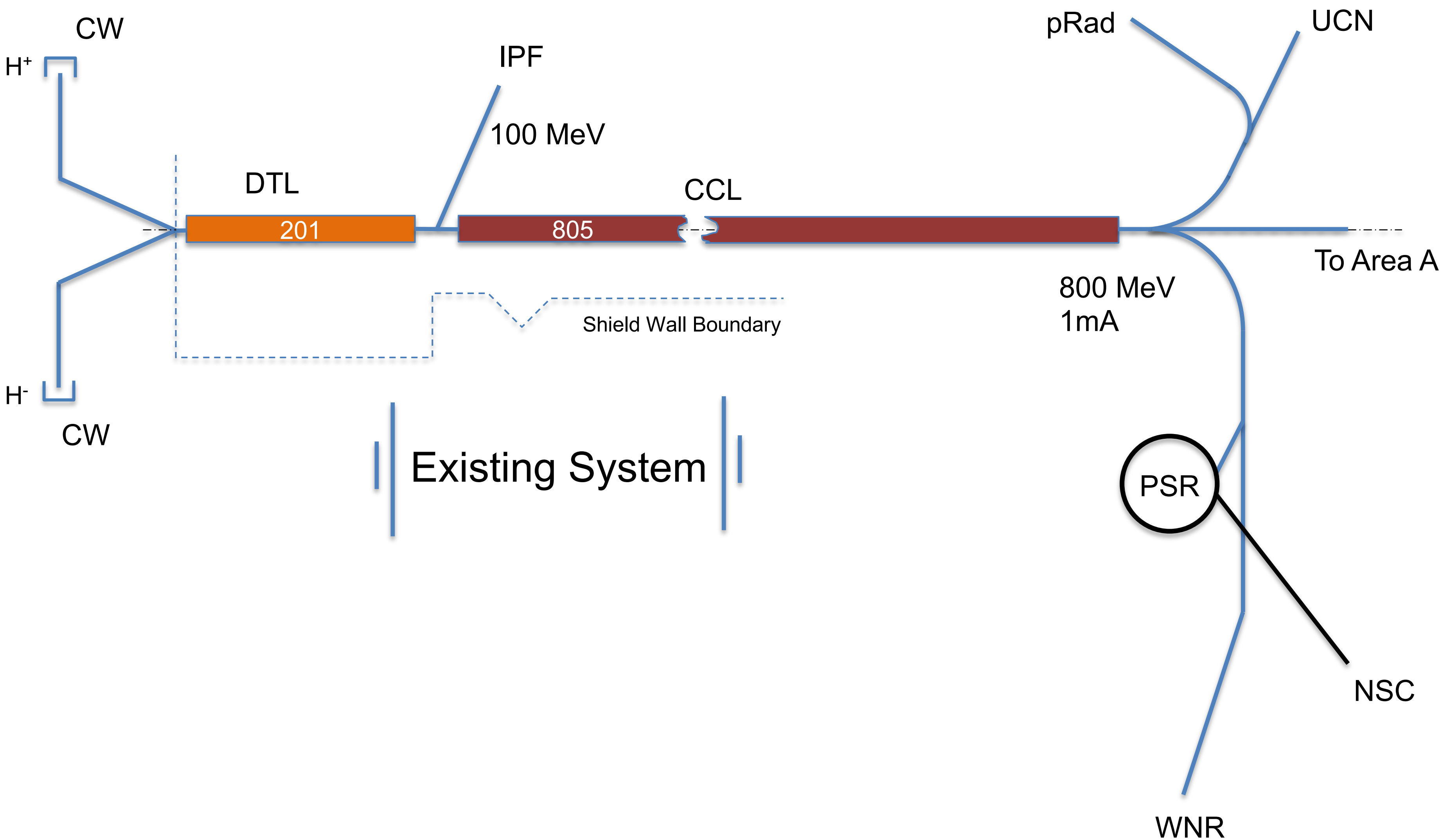



# New H⁻ ion source following the LBNL/SNS design

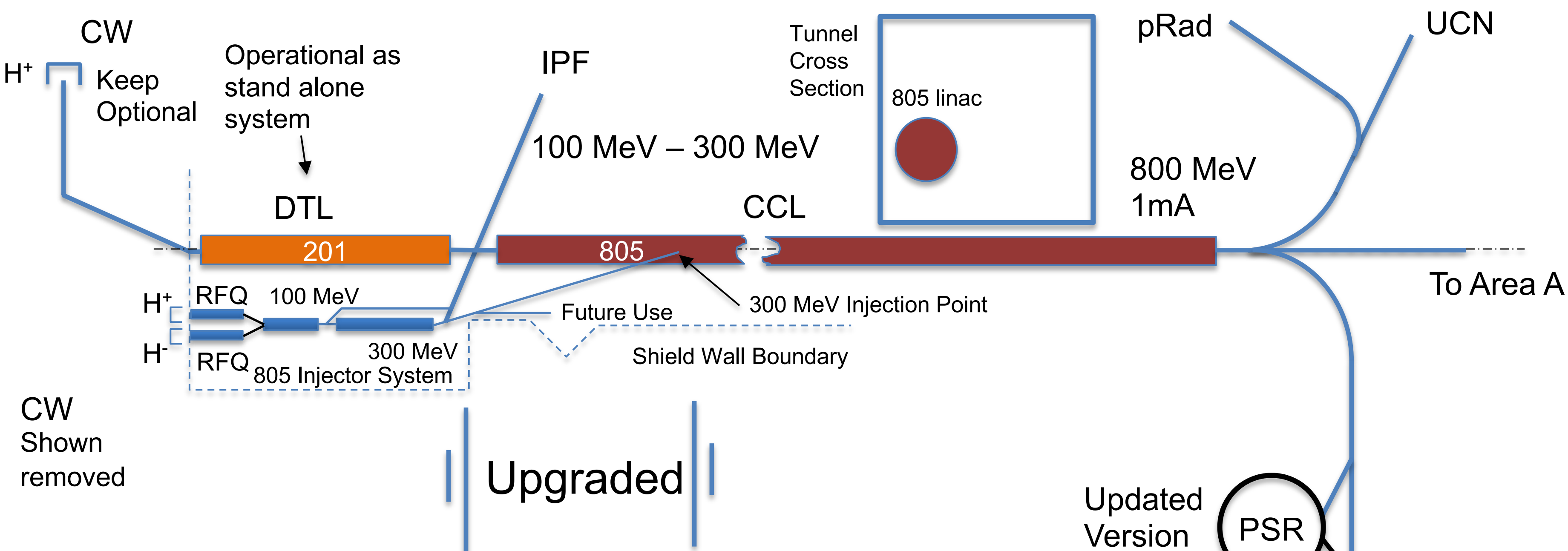
- **LBNL developed** and SNS improved the cesium-enhanced, RF-driven multicusp $H^-$ ion source, which delivers ~1-ms long $H^-$ current pulses at 60 Hz.
- LANL is working with SNS to adapt this source to our machine
  - Higher average currents
  - Significantly longer lifetimes

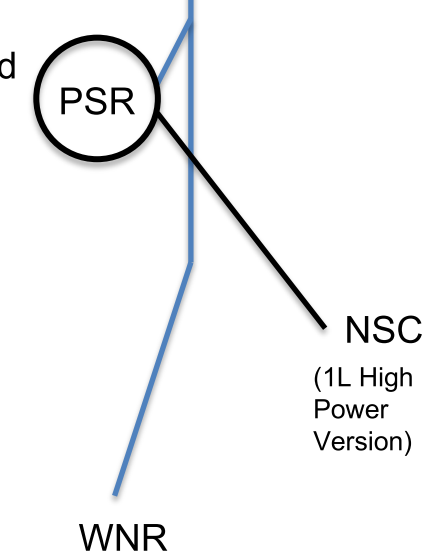


# LANSCE Facility: Present Configuration



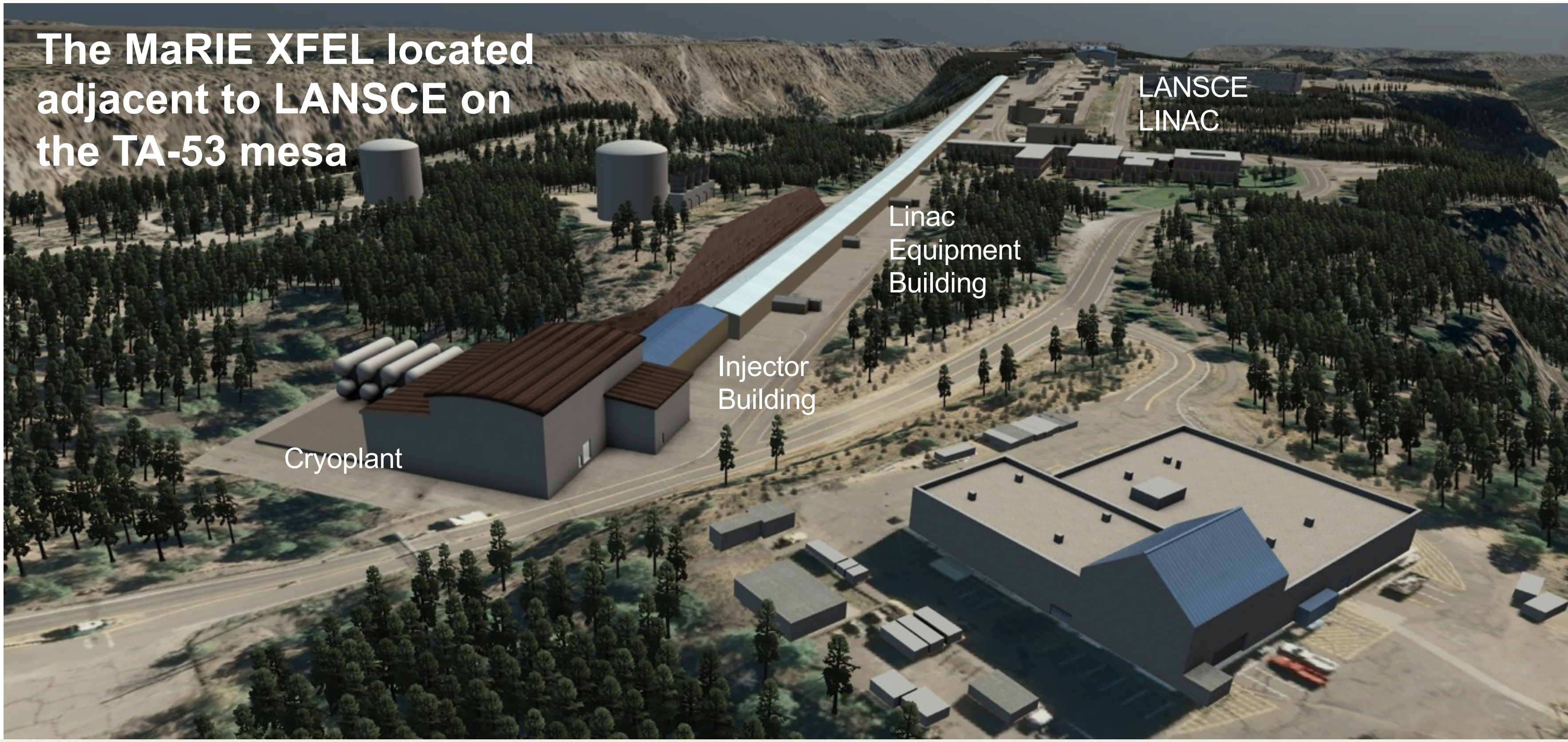
# LANSCE Facility Updated




- **Phase 2: Replace CW and DTL**
  - High current $H^-$ and $H^+$ sources feeding RFQs
  - High gradient 805 MHz Injector
    - Installed adjacent to existing DTL and made functional prior to placing into operation
    - 100 MeV to 300 MeV capable front end system
- **Phase 3: Replace PSR**
  - Large dynamic aperture
  - Large energy acceptance
  - Defined loss point
  - Rapidly serviceable
    - Allows shortening maintenance period
      - 4M on, 2M off cycle
  - > 3x current capability
  - Short pulse capability

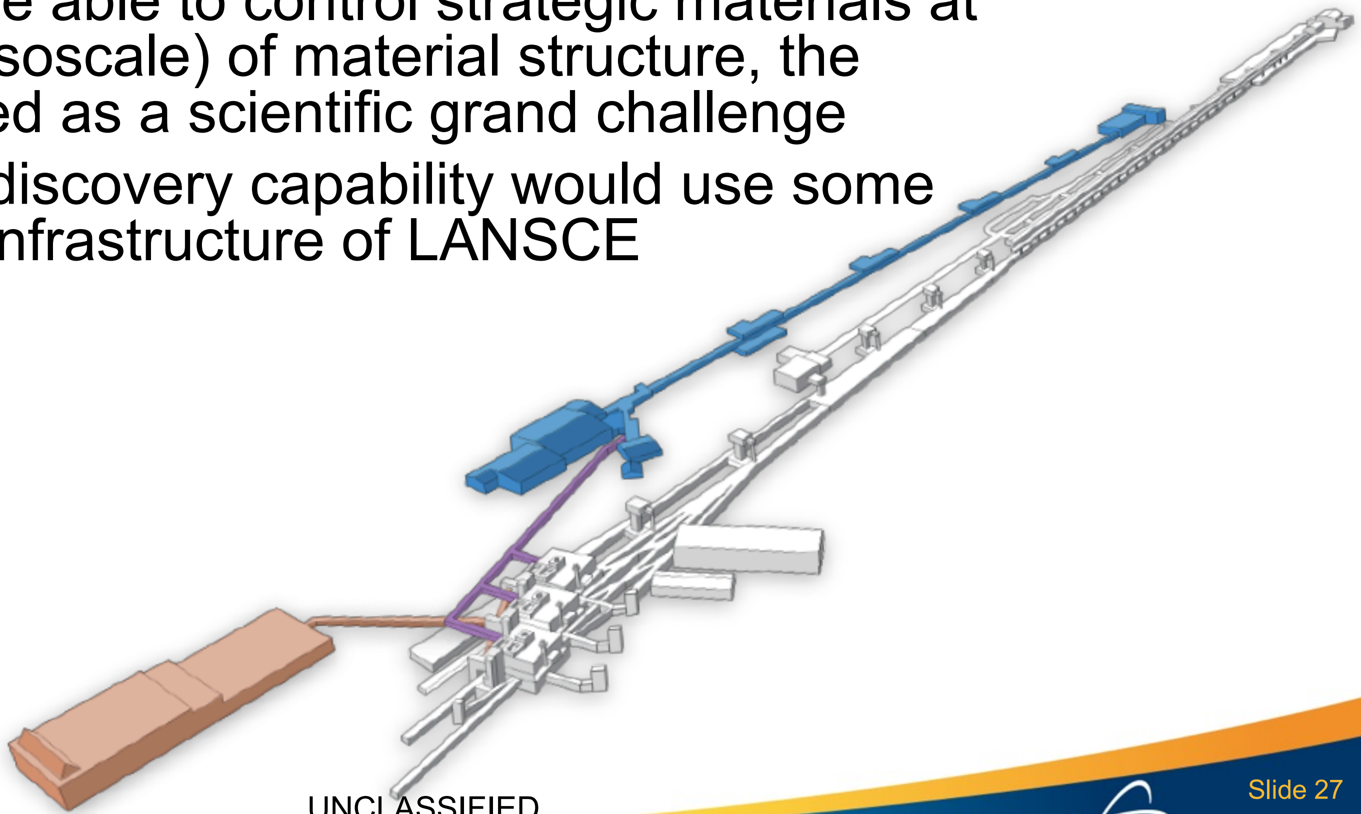
# Dynamic Mesoscale Materials Scientific Capability and one potential system architecture the MaRIE XFEL




**MaRIE will provide complementary capabilities to ESCE, advancing material qualification through an understanding of the microstructure-performance link.**

# MaRIE is LANL's high-tech proposal to fill the DMMSC need

- Matter-Radiation Interactions in Extremes (MaRIE) would be a laser-like, brilliant x-ray source with flexible, fast pulses that are so energetic they can study critical materials
- MaRIE would be able to control strategic materials at the middle (mesoscale) of material structure, the scale recognized as a scientific grand challenge
- This materials discovery capability would use some of the existing infrastructure of LANSCE



# Summary

- LANL has an extensive history in the development and use of accelerators for defense, security, and stockpile stewardship.
- We continue to operate and improve our existing machines.
- We have a clear strategy forward.
- By developing and implementing checks and balances, in this case through the use of accelerator science, technology, and engineering, we continue to strive to ensure the world is a safe place.