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Title: The Los Alamos Neutron Science Center (LANSCE): Essential data for stockpile stewardship

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The Los Alamos Neutron Science Center (LANSCE): Essential data for stockpile stewardship

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March 10, 2021

LANSCE Overview Agenda

LANSCE
Los Alamos Neutron Science Center

1. The LANSCE facility
2. Managing LANSCE
3. LANSCE missions
4. Responding to the challenges at LANSCE

… to be followed by additional briefings on particular aspects of LANSCE

The LANSCE Facility

LANSCE is a 48-year-old 800-MeV linear accelerator sending two beams (H^+ and H^-) to five areas

Operations began in 1972. LANSCE currently supports:

- 100-800 MeV proton energies
- 6 target stations
- 3 neutron spallation targets
- 16 beam lines
- Time structure of beam allows for a large dynamic range of experiments

- **Significant investment (~$115M)** to sustain accelerator over the last fifteen years; risk mitigation completed in 2015
- **Ongoing projects to upgrade utilities**, fire protection, controls, electronics, and targets
- **Additional investment is urgently needed** to address deferred maintenance, end-of-life components, and future capabilities

View of the LANSCE accelerator complex from the west

To meet its variety of mission needs, LANSCE requires a particularly flexible accelerator

Proton Radiography (pRad Facility)

- Dynamic radiography for NA-10 and -80

Lujan Neutron Scattering Center (Lujan Center)

- Neutron scattering and imaging for NA-10, DOE NE, and DOE FE

Weapons Neutron Research Facility (WNR)

- Nuclear physics for NA-10, -80, and -511 (also done at Lujan Center)

Ultra-Cold Neutron Facility (UCN)

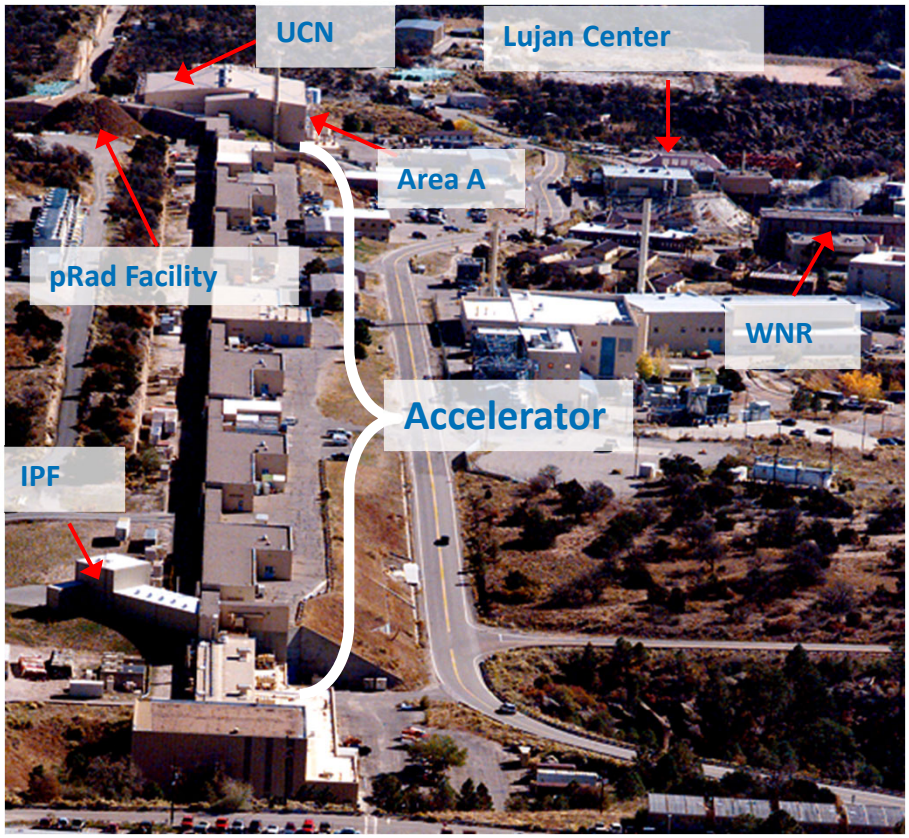
- Unique probe for DOE NP and NSF, possible future NA-10 uses

Isotope Production Facility (IPF)

- Medical isotopes for DOE IP, short-lived isotopes for NA-11, -20/80, and -511

Area A

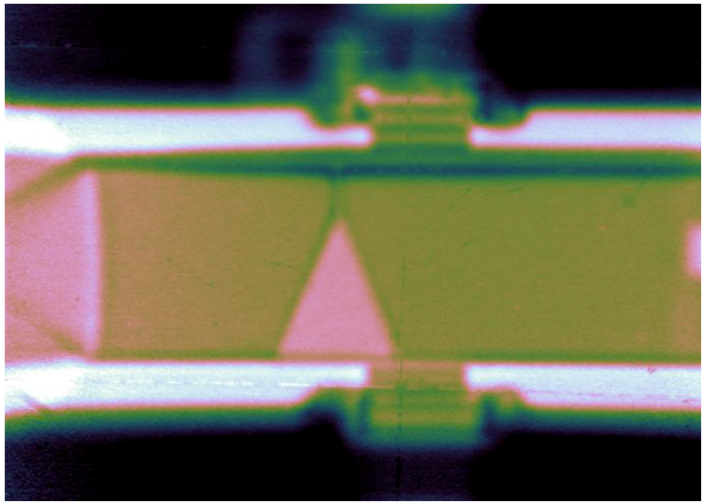
- Future experimental possibilities to ensure that we can meet advanced experimental needs



View of the LANSCE accelerator complex from the west

The pRad Facility provides a unique capability for dynamic radiography

- **pRad is able to take dynamic movies of the structure of shock and detonation events, with a unique ability to image high explosive detonation.** Data have been crucial to LEPs, ALTs, MODs, SFIs, and manufacturing
- pRad drivers include **high explosives, a powder gun, and pulsed power**
- **Data acquired at pRad:**
  - 21 radiographs of areal density
  - Up to 16 channels of velocimetry
  - Multiple custom diagnostics,
    - visible imaging, x-rays, pins, etc.
- **Future plans include Pu@pRad experiments**
- **pRad is oversubscribed by ~2x**, with most users granted less beam time than they request

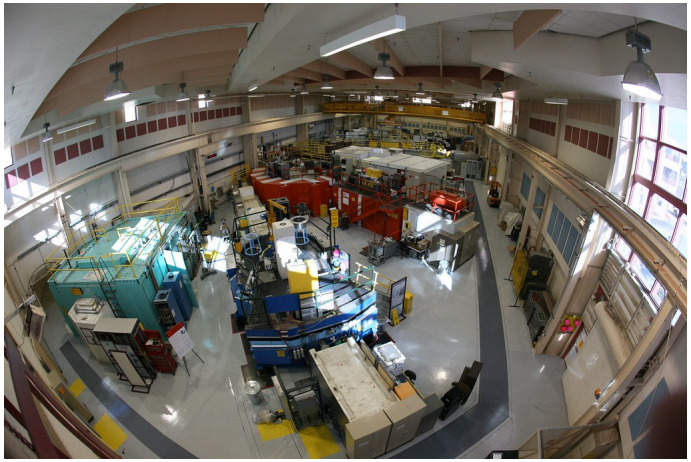


AWE high explosive burn
past plastic wedge shot

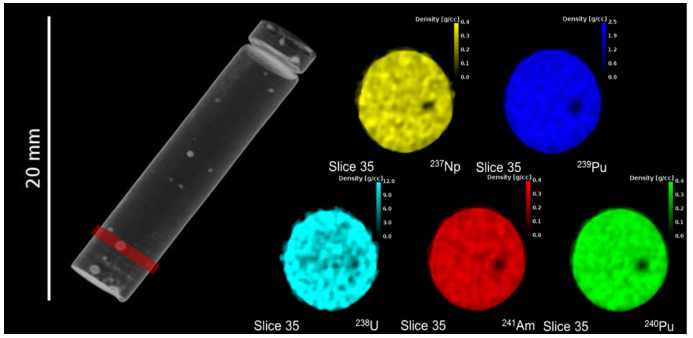
LANL material properties
of processed copper shot

The Lujan Center characterizes NNSA materials for qualification

- **Neutron scattering provides experimental microstructural characterization used to advance models**
  - Uses the unique properties of neutrons on four flight paths
  - Used by predictive manufacturing and performance calculations
- **Unique mandate and ability to study classified, toxic, radioactive materials under extreme conditions**
  - Weapon components
  - Nuclear fuels
  - Special nuclear material and high explosives both authorized
- Recent highlights:
  - **Plutonium aging**
  - Isotope-specific imaging
  - Characterization of **additively-manufactured LANL/LLNL/SNL/KCNSC components**
- **Beam time constraints mean that only ~2/3 of proposals receive time**



Lujan Center experimental hall

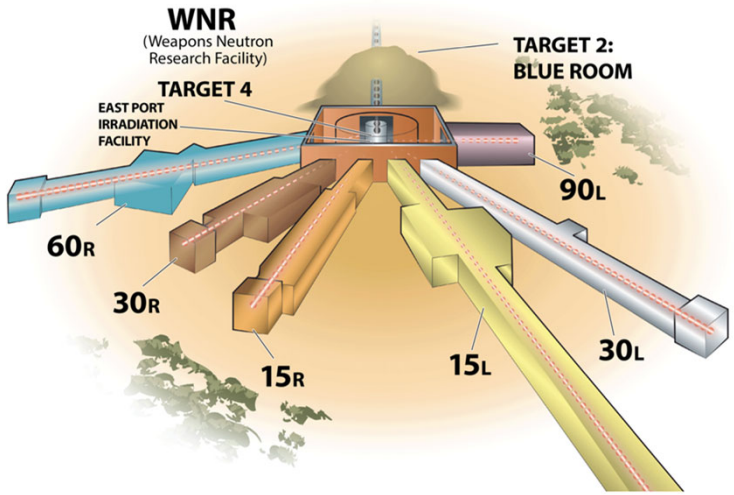


Elemental distribution in nuclear fuels

Note that nuclear physics done in the Lujan Center is discussed below

The Weapons Neutron Research Facility is NNSA's center of excellence for nuclear physics

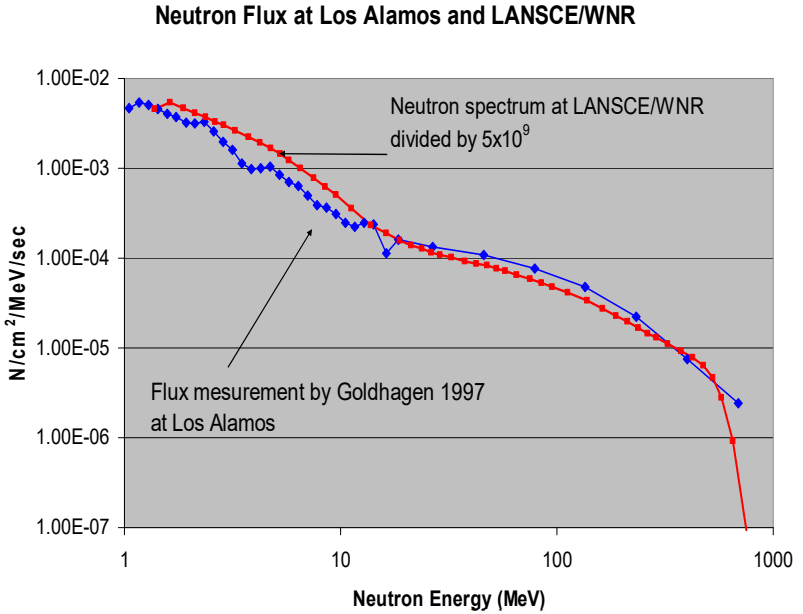
- The WNR Facility produces neutron beams for seven stations conducting a range of experiments **from fundamental measurements of the nuclear properties of materials to applied measurements acquiring radiographic and radiation effects data**
  - predicts the performance of **nuclear weapons primaries;** recent work made the **first credible uncertainty estimate of a key primary performance parameter**
  - **radiography** complements x-rays and protons to 'see' low-density, low-Z features obscured by high-density, high-Z material
- **WNR is oversubscribed by 2-3x**

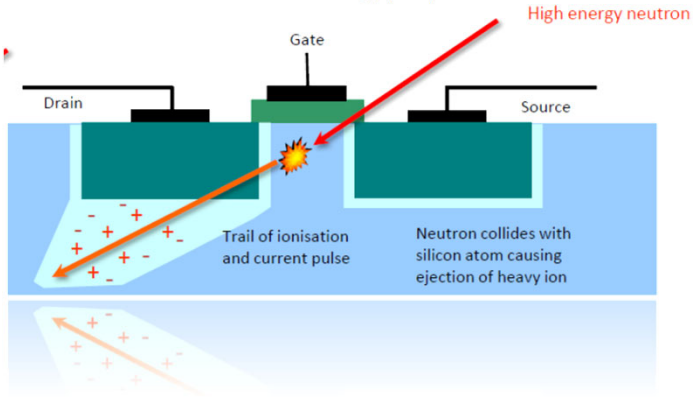


Neutron radiography enables imaging that is impossible with x-rays

Neutron radiation effects testing (at WNR) is critical for both defense and civilian applications

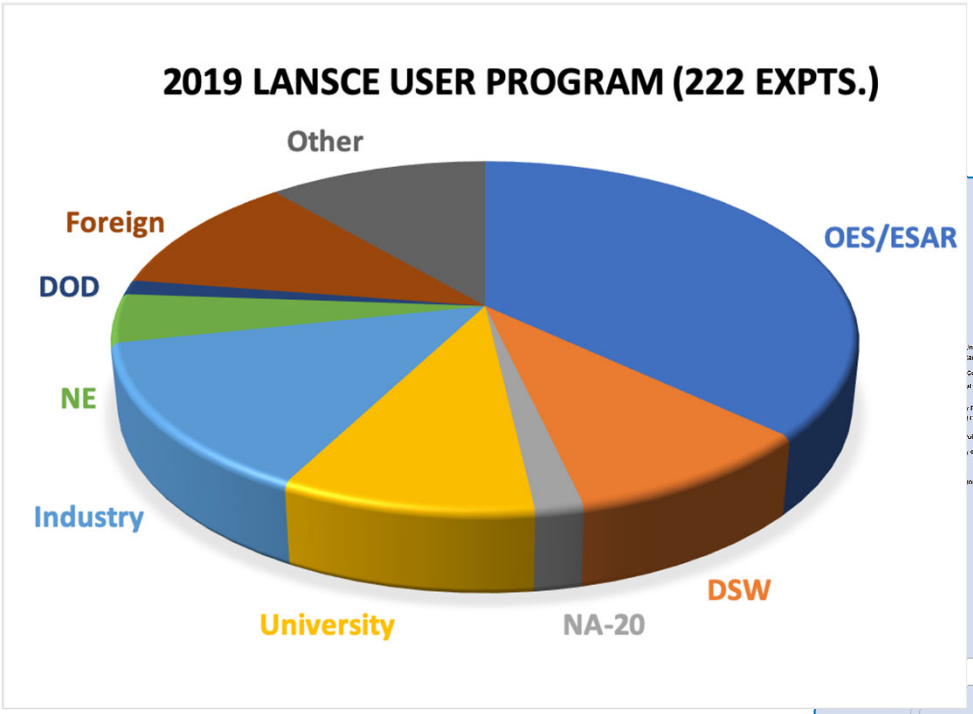
- **LANSCE is the best – and only U.S. - facility for electronics testing and certification**
  - Avionics, high-performance computing, self-driving vehicles, weapon components, and medical devices
  - ISIS just opened ChipIR facility in the UK
  - ORNL is proposing a 3rd target station

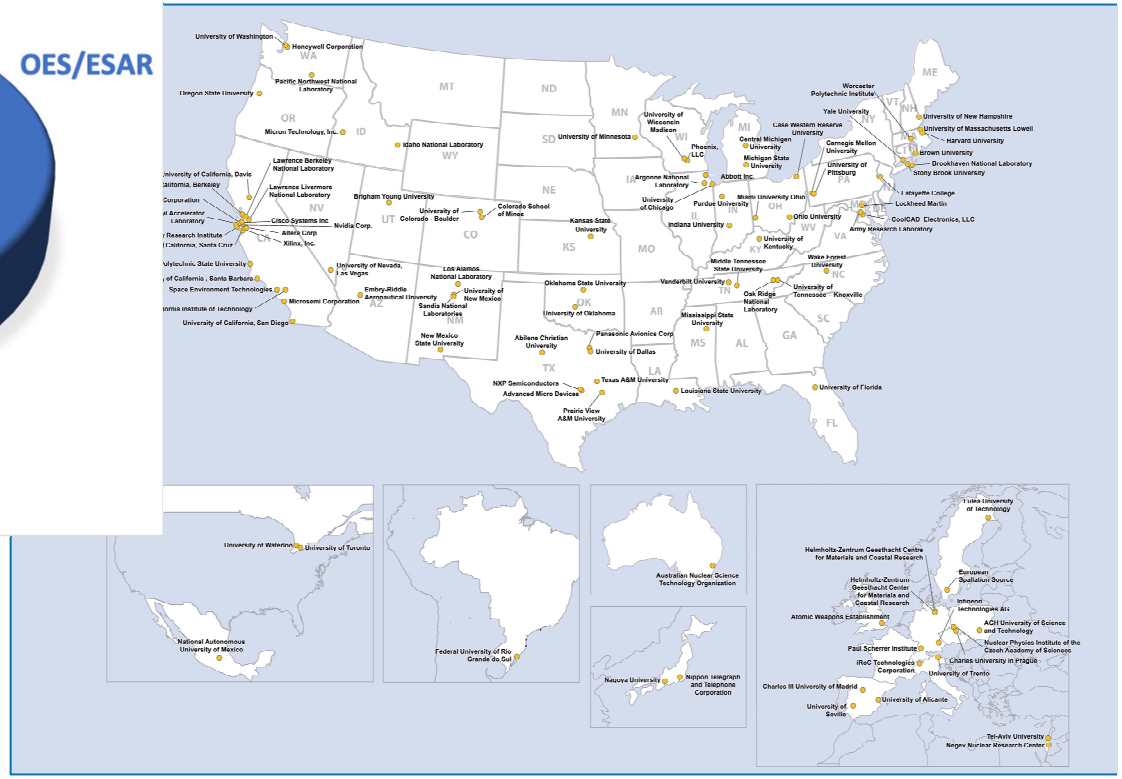




pRad, Lujan, and WNR constitute the NNSA LANSCE User Facility

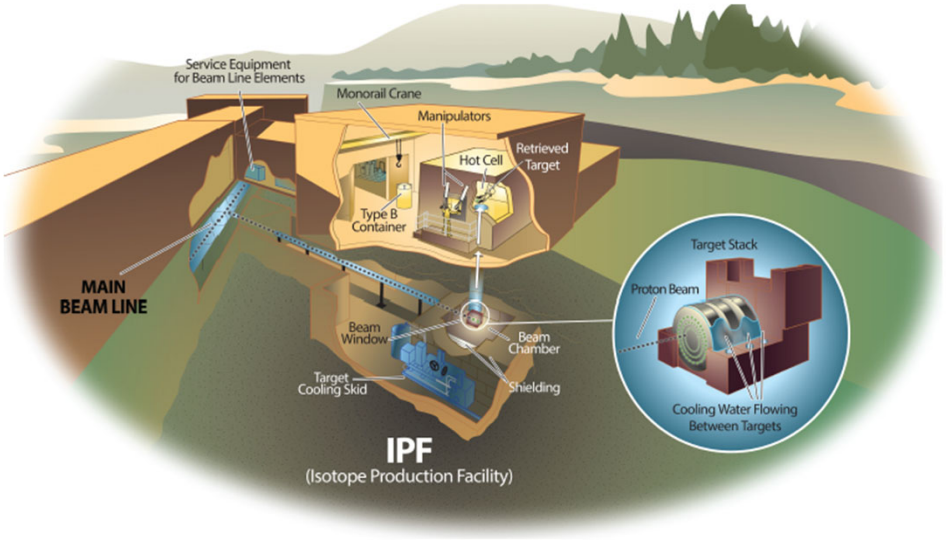
2019 run cycle: 591 users, 101 institutions, 16 countries

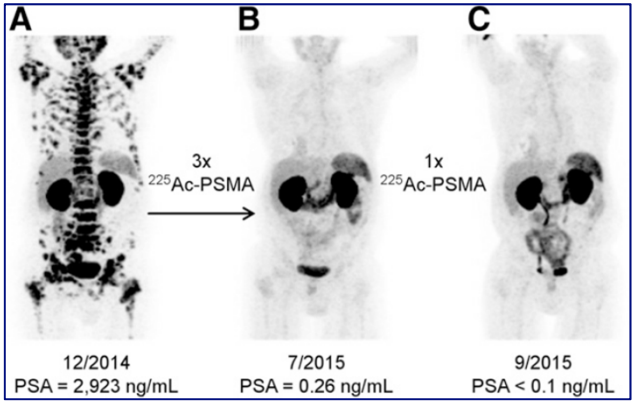




The Isotope Production Facility delivers time-sensitive medical isotopes to patients around the US

- **The Isotope Production Facility (IPF) is designed to produce large quantities of isotopes for medical, industrial and research users**
  - The IPF does not compete with commercial suppliers, but instead uses its unique capabilities to supply isotopes that are more challenging to produce or for which market demand is still emerging
  - The IPF, along with the BLIP at BNL, ensures a steady supply of essential short-lived isotopes throughout the year
  - Isotopes for targeted alpha therapy (^{225}Ac) are future thrusts
  - Funded by the Isotope Program in the DOE Office of Science, which supports operations of the IPF beamline
- **IPF has been producing isotopes of interest to NA-11 for study at WNR – unique capability to deliver the quantities and purities needed**

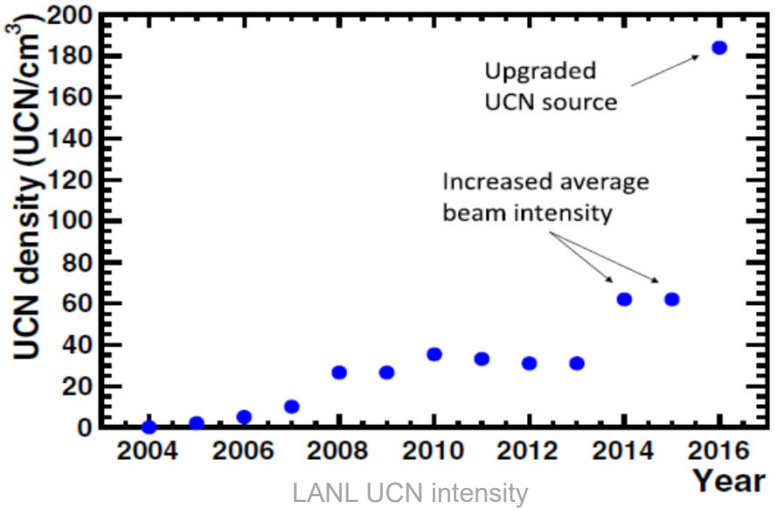




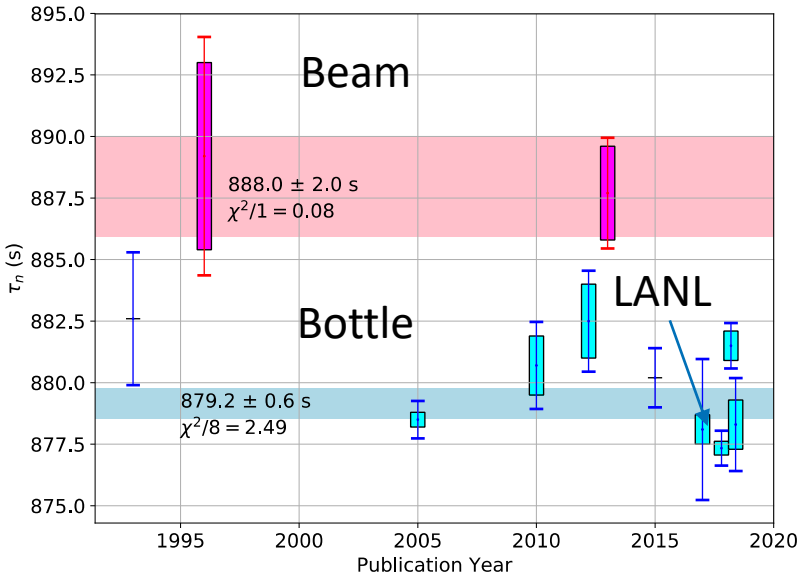
Treatment of metastatic prostate cancer with ^{225}Ac: C. Kratochwil, J. Nuc. Med, **57**, 2016 p1971

Ultra-cold neutrons can probe fundamental symmetries of nature

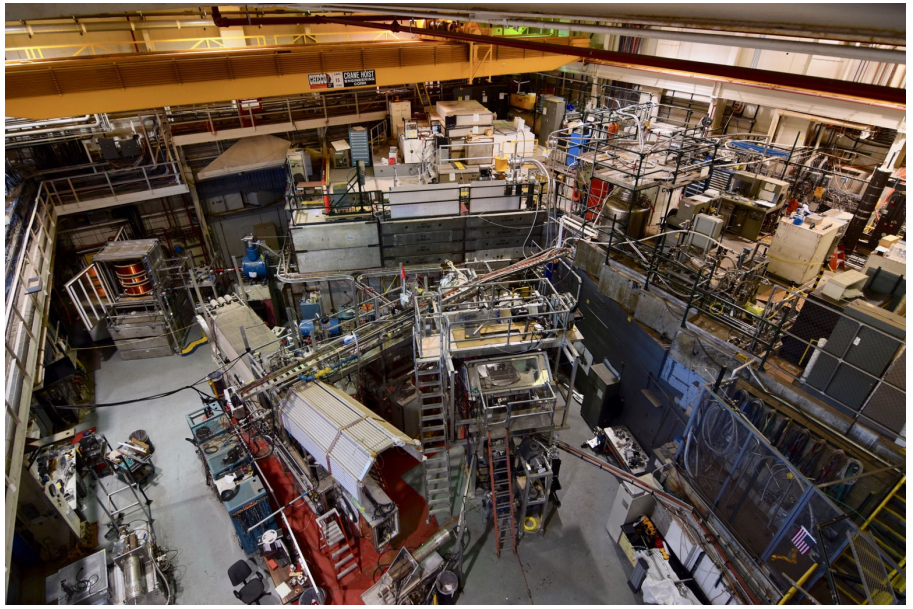
- **LANSCE has the most intense source of ultra-cold neutrons**
- We have published the world's **most precise measurement of the neutron lifetime** (*Science* May 6 2018)
- Developing experiment to detect non-β decay of neutrons



LANL UCN intensity



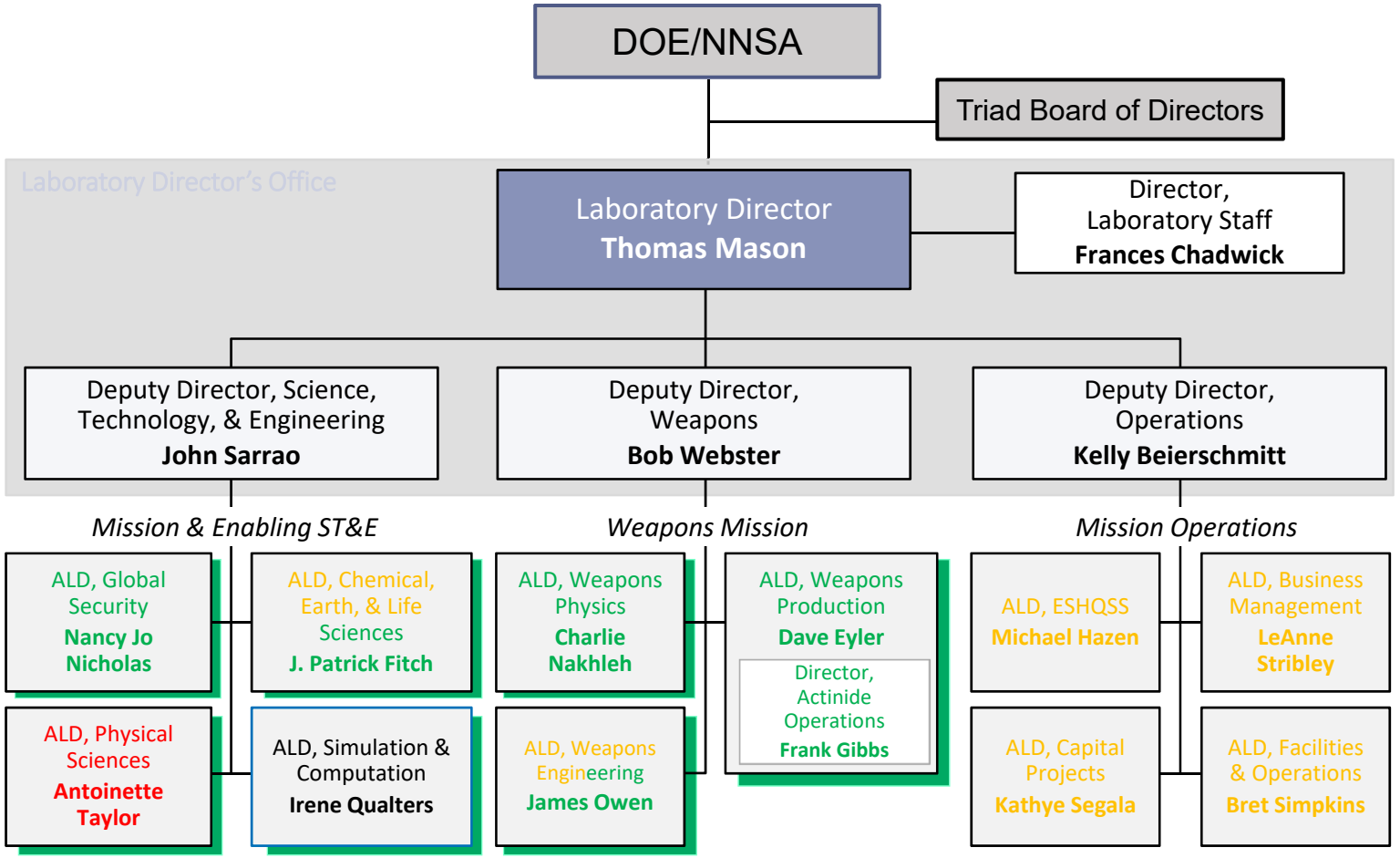
Neutron lifetime measurements



UCN experimental hall

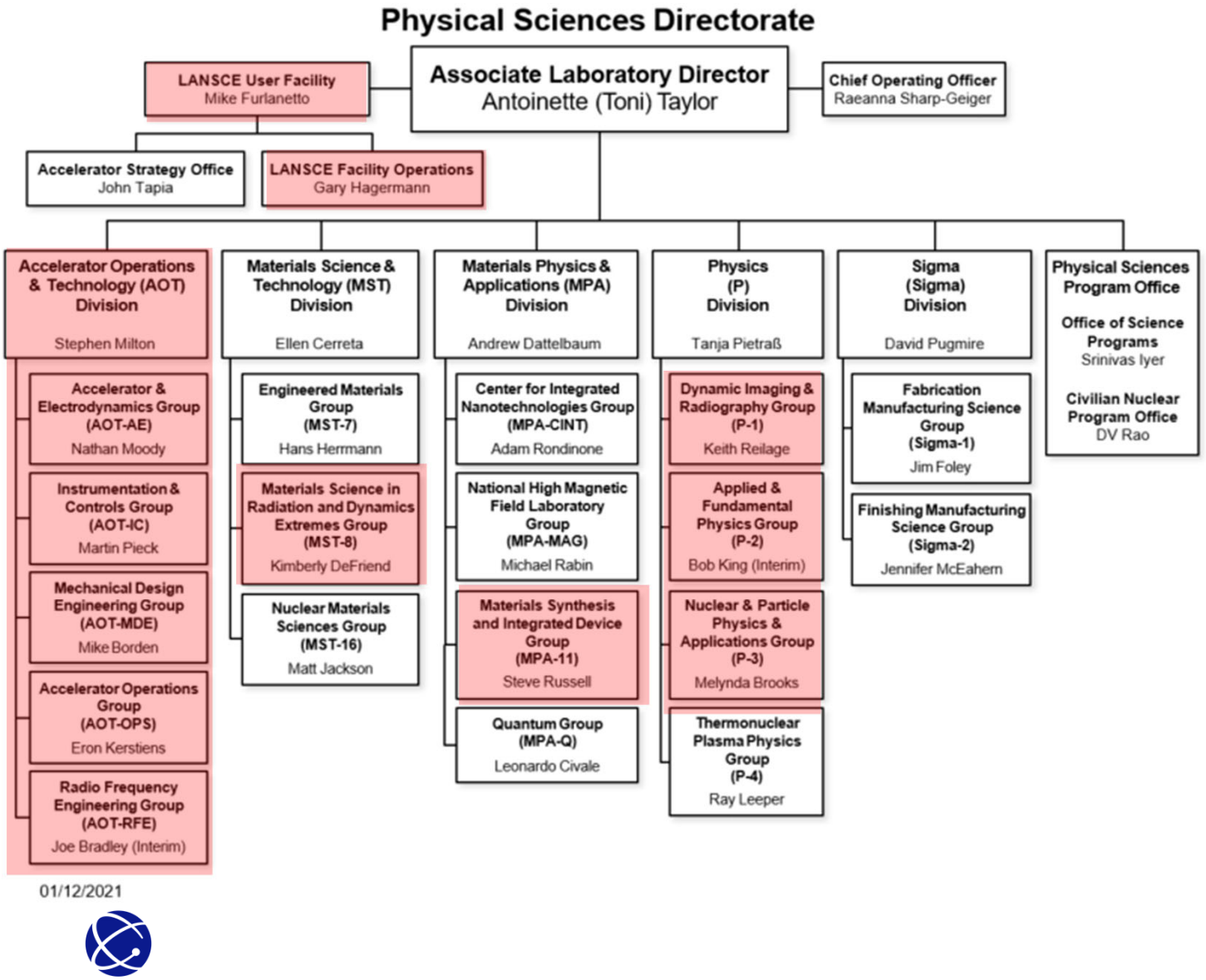
Managing LANSCE

Work at LANSCE spans much of the Laboratory



Key:
Steward
Operations
Users

ALDPS is responsible for stewarding LANSCE



Regular field office interactions highly valued!

- **Integrated FOD** helps us apply consistent institutional policies to the unique safety and security environment of LANSCE
- **Annual budget ~$125M, primarily from NA-50 and NA-113**
- **Staff ~400**
  - 155 AOT
  - 150 P
  - 75 LFO
  - 20 other

We have developed and are refining metrics for the long-term health of LANSCE

LANSCE Science Capability	IF LANSCE is not able to deliver on its national security science missions, THEN the complex will lose unique capabilities in multi-frame dynamic radiography, neutron scattering, and nuclear science and LANL will lose its flagship experimental facility.	Accelerator General Health, Accelerator Long-Term Viability, LANSCE Facility Health, LANSCE Disciplined Operation, ALDPS Talent Management Planning, LANSCE Mission Sponsor Index	Medium	High	Moderate
Accelerator General Health	IF the accelerator is not sufficiently monitored and maintained, THEN we are unable to execute critical mission deliverables.	Availability data, hours operated/hours scheduled, component data, cycle time to get beam up and running, maintenance completed/maintenance planned, number of call-ins, mean time between failures, mean time to recover	Medium	High	Moderate
Accelerator Long-Term Viability	IF there is not a plan to recapitalize significant portions of the accelerator (e.g. front end), THEN the loss of expertise in accelerator science is likely.	Recap projects data, line items data, Pu@pRad data schedule compliance, new beam line capabilities/improved capacity- track success rate in funding new beam lines	Low	High	Moderate
LANSCE Facility Health	IF facilities, utilities, and infrastructure investment does not substantially improve THEN the accelerator will not be able to operate.	CM, PM data, DM buy-down (% of deferred maintenance completed per time period, compliance against Get Well Plan data- time to complete variance, schedule compliance-schedule data & compliance with PM data, funding portfolio vs. work portfolio data, comprehensive Site-Wide Plan data, capture enhancements	High	High	High
LANSCE Disciplined Operations	IF deficiencies in disciplined operations at LANSCE are not addressed, THEN worker safety and security are at risk and the program will not be successful.	Percent training data, Safety Share data, Hot wash issues, events, pRad CoO, number of users responding, response trends, LSS data	Medium	High	Moderate
ALDPS Talent Management Planning	IIF ALDPS does not have a systematic process to support the recruitment, retention, and succession planning for key capabilities and skills, THEN compromises in quality, safety, and security of operations will be realized.	5 Year Staffing Plan Metric for LANSCE Portfolio (ALDPS) Succession plan execution Execution to plan (current)	High	High	High
LANSCE Mission Sponsor Index	IF LANSCE is unable to execute mission deliverables, THEN we risk losing sponsor confidence and steward support	Number of proposals submitted vs. accepted, Experiments completed vs. experiments planned by sponsor, Number of reports, papers, presentations per run cycle by sponsor SRO – reports and papers (current), Beam experiment days delivered per run cycle, L1, L2,…milestones contributed to – program office is source, Mean time to providing data – modification to LIMs for IE to complete, User data by characteristics per run cycle – program, location, institution, Voice of the program manager	Low	High	Moderate

ALDPS ensures that LANSCE is fully integrated into the Laboratory's accelerator strategy (and beyond)

SIMULTANEOUS EXCELLENCE	1.0 NUCLEAR SECURITY	2.0 MISSION-FOCUSED SCIENCE, TECHNOLOGY & ENGINEERING
Strategic Objective (10–20 years)	Excellence in Nuclear Security	Excellence in Mission-Focused Science, Technology & Engineering
Critical Outcomes (5–10 years)	Design, produce, and certify current and future nuclear weapons and reduce global nuclear threats	Deliver scientific discovery and technical breakthroughs that support DOE and NNSA missions
Major Strategic Initiatives (1–5 years)	1.1 Execute LANL's Manufacturing mission to deliver 30 plutonium pits per year 1.2 Transform nuclear weapons warhead design and production 1.3 Anticipate threats to global security; develop and deploy revolutionary tools to detect, deter, and respond 1.4 Support modernization of LANL warhead systems 1.5. Assess the stockpile as it ages and project weapon systems lifetimes	2.1 Refresh and refine the LANL capability pillar framework 2.2 Advance accelerator science, engineering, and technology to enable future stewardship capabilities 2.3 Advance the frontiers of computing to exascale and beyond 2.4 Assert leadership in the national quantum initiative 2.5 Develop and implement an integrated nuclear energy and nuclear materials initiative 2.6 Develop and implement an integrated initiative for plutonium and actinide missions based on FY29 strategy 2.7 Implement a national security life sciences initiative

Key:
Central
Contributor

LANSCE Missions

LANSCE continues to be essential for stockpile stewardship

"LANSCE has been a key and crucial collaborator for physics certification of the W88-0/Mk5 ALT 370 primary. These data and assessments **give us high confidence that the W88 system will meet its MCs and STS requirements well into the future."**

Donald Sandoval,
W88-0/Mk5 ALT 370 Primary Physics Lead

"The **most significant safety enhancement** within the B61-12 nuclear explosive package is the use of new detonators to reduce handling risk during assembly. LANSCE pRad data and simulations indicated that the B61-12 performs as intended and maintains a **strong link to the B61 UGT history** with the new main charge detonators."

Langdon Bennett,
B61-12 Primary Physics Lead

View of the LANSCE accelerator complex from the west

LANSCE's unique material and nuclear data are critical for stockpile assessment and certification

The LANSCE accelerator complex is a unique NNSA resource that acquires an enormous range of physics and engineering data required by the Los Alamos, Livermore, and Sandia weapons programs

- Authorization basis to **perform classified experiments with special nuclear material** using protons and neutrons
- **Unique capability to measure nuclear data** supporting initial conditions for boost, nuclear forensics, and criticality safety
- **Provides qualification and characterization** of new and aged materials, components, and high explosives **for Life Extension Programs (LEPs), Alterations**, and **Modifications**, as well as to **qualify new manufacturing methods**

	LANSCE	Brookhaven	FermiLab	SNS
Proton Radiography	●	●	●	●
High Explosive Drive	●	●	●	●
Classified Experiments	●	●	●	●
Dynamic Plutonium Capability	●	●	●	●
Low-Energy Nuclear Physics	●	●	●	●
Isotope Production	●	●	●	●
Neutron Diffraction	●	●	●	●
Static Plutonium	●	●	●	●
Neutron Radiography	●	●	●	●
Energy-Resolved Tomography	●	●	●	●
Neutron Irradiation for Defense and Civilian Applications	●	●	●	●

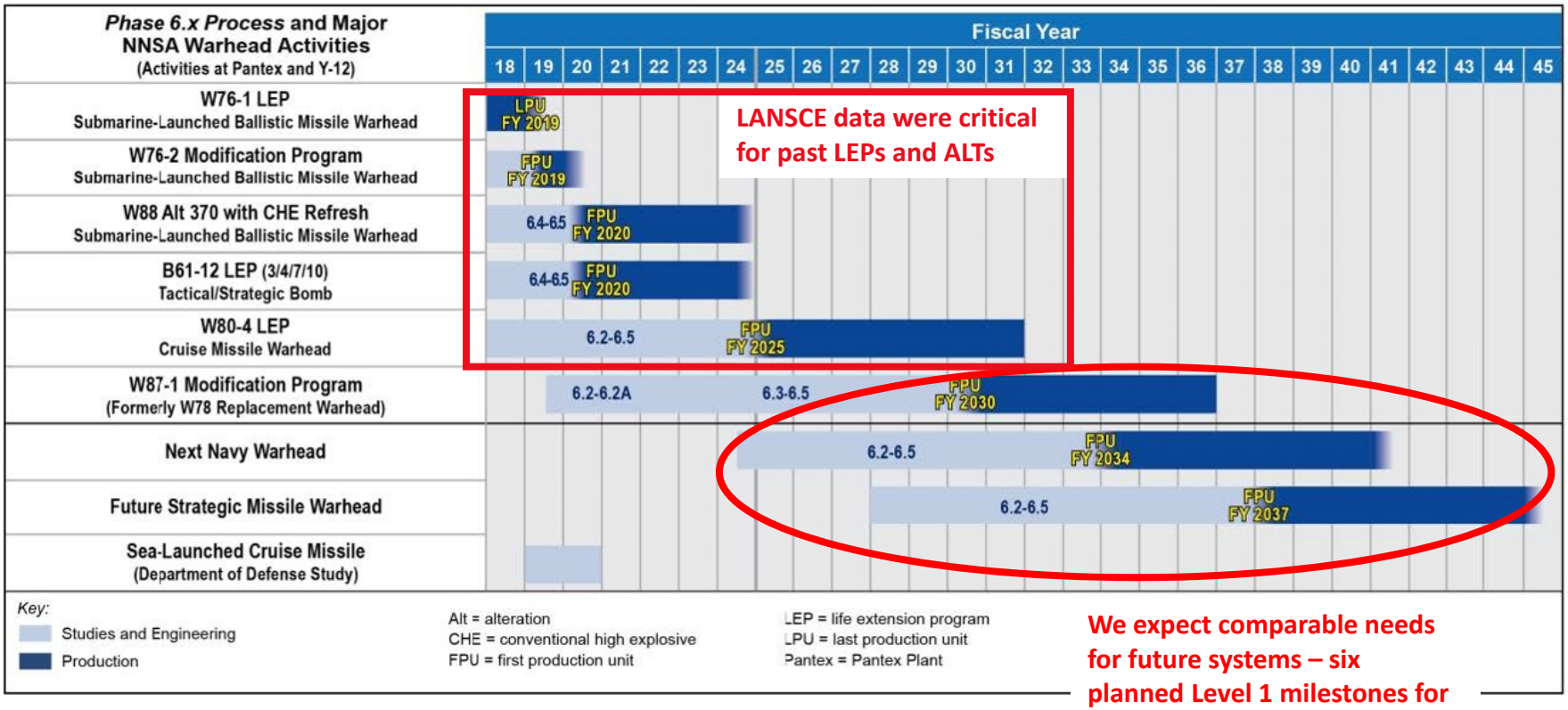
Mission space available at various US accelerators

LANSCE's experimental areas support all parts of NNSA's mission space

Mission/Area	Dynamic radiography	Neutron scattering	Nuclear physics	Neutron radiography
Stockpile Sustainment	SFI resolution; hydro interpretation; *Pu aging studies*	Pu aging studies	UGT analysis	Component surveillance/ inspection
Future Deterrent	Explosive and subsystem characterization/ design; subcritical experiment interpretation; *safety/surety*	Advanced model development	2018 Level 1 pegpost; subcritical experiment interpretation	Advanced inspection technique development
Modern Materials and Manufacturing	New explosive formulation/ characterization; *plutonium manufacturing*	Direct cast U; advanced manufacturing	Criticality assessments for safety and efficiency; effects quantification	Component inspection
Threat Mitigation	Render safe design; foreign materials		Nuclear data for foreign threats; effects quantification	

Italics show planned future capabilities

LANSCE expects increasing demand over the coming decades, for both stockpile systems and production

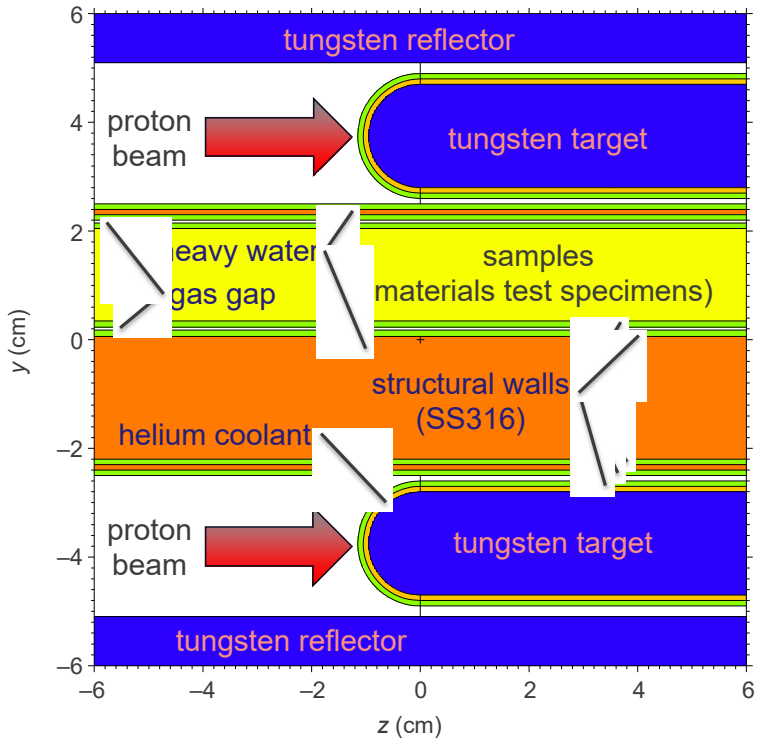


FY2020 Stockpile Stewardship and Management Plan

Non-NNSA sponsors also foresee increasing needs

- **FES**: LANSCE is one of the finalists for a Fusion Prototype Neutron Source (FPNS)*
- **NE**: increasing demand for characterization of fuels at Lujan and WNR
- **Isotope Program**: examining options for increased production and higher-power isotope sources*
- **NSF**: considering proposals for advanced UCN sources*
- **Irradiation**: industry requests for increased capacity and for a proton irradiation for space environments*

* possible options for Area A



Pre-conceptual design for LANSCE spallation target for FPNS

For LANL, LANSCE also provides crucial connections to the academic and industrial communities

- **User Program:** major source of graduate student and postdoctoral researcher recruiting
- **Rosen Scholar:** academic-in-residence program strengthens our scientific ties and reputation
- **Irradiation and Isotope Programs:** build ties to industry
- **Accelerator Operations (and futures):** ties to other accelerators and the academic community
- **Testbed** for diagnostics and experiments

- **LANSCE contributes strongly to three of our capability pillars**

Materials for the Future	Defects and Interfaces Extreme Environments Emergent Phenomena
Nuclear and Particle Futures	Applied Nuclear Science & Engineering Nuclear & Particle Physics, Astrophysics & Cosmology Accelerator Science & Technology High Energy Density Physics & Fluid Dynamics
Integrating Information, Science, and Technology for Prediction	Computing Platforms Computational Methods Data Science
Science of Signatures	Nuclear Detonation Nuclear Processing, Movement, Weaponization Natural and Anthropogenic Phenomena
Complex Natural and Engineered Systems	Human–Natural System Interactions: Nuclear Engineered Systems Human–Natural System Interactions: Non-Nuclear
Weapons Systems	Design Manufacturing Analysis

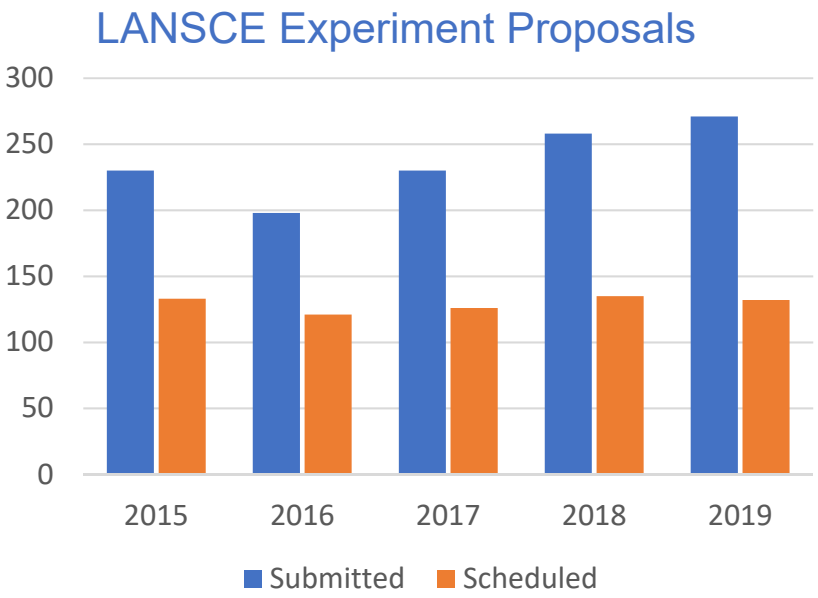
LANL capability pillars

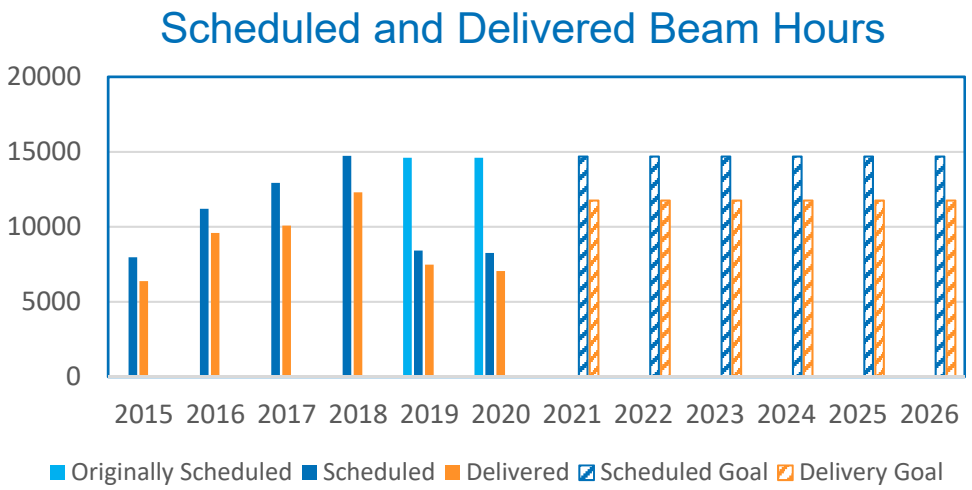
Responding to the Challenges at LANSCE

To sustain an aging facility, we are pursuing improvements on several fronts

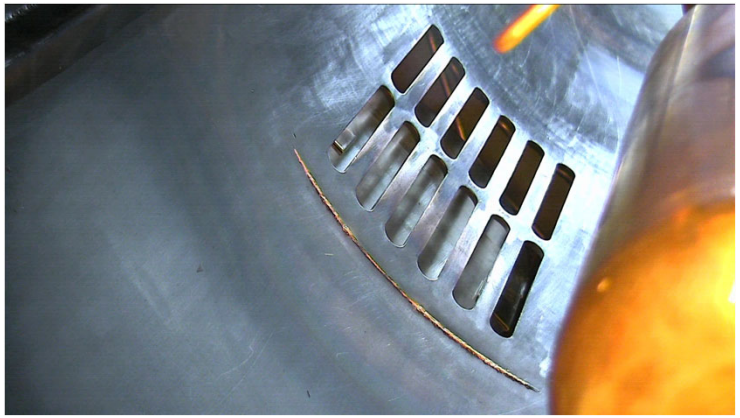
- **System-level risk-informed management**
  - Asset management assessment, pilot, and training
  - ”Get well” plans to address underinvestment
- **Capability enhancements**
  - Mark IV 1L target (2022)
  - Light Manufacturing Laboratory (2023)
  - Pu @ pRad (2025)
- **Capital investments:**
  - LANSCE Modernization Project (LAMP): ~2023-2030
  - LANSCE Enhancements Project (LANE): ~2027-2032
- **<u>Expectation</u>: increase data throughput by ~50% with reduced maintenance needs and stable staffing levels**

Aged infrastructure makes meeting current demand reliably difficult, and risks catastrophic failure

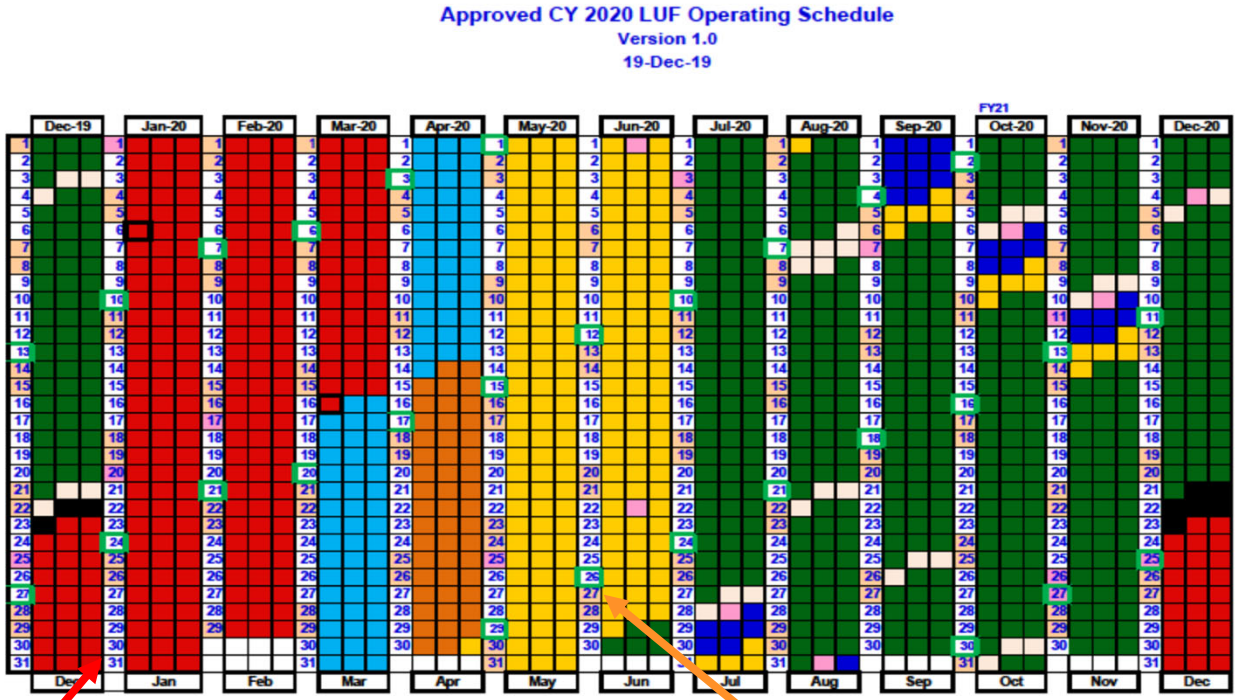




End-of-life components with uncertain repair paths



LANSCE beam availability significantly lags behind its peers



Key:
Maintenance
Startup
Experimental operations

Beam reliability only 60-85%; industry standard 95%

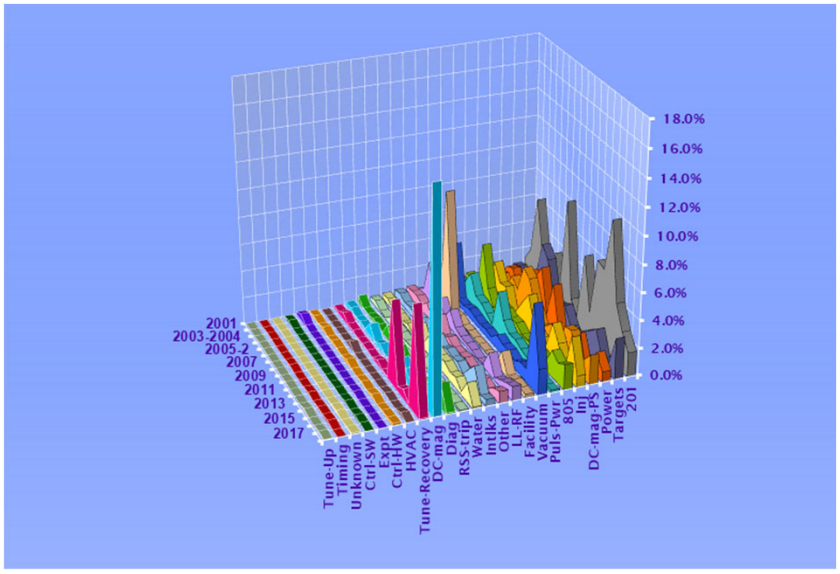
Long maintenance period determined by work required and obsolete designs

Startup ~6 weeks; other accelerators ≤ 2 weeks

Low availability is particularly problematic in light of LANSCE's chronic oversubscription.

We are managing LANSCE at the system level through a risk-based asset management and "get well" approach

- **Asset management assessment (Oct. 2020)**
  - Identified areas where we could improve
  - Looked at the best practices of our peers (*e.g.*, SNS)
- **A risk-based approach lets us prioritize investment**
  - Asset management pilot in 2021-2022 will demonstrate early successes and train the team
- **Working with NA-50 and other sponsors on a risk-informed "get well" plan to buy down deferred maintenance**
  - Fire protection improvements, roof and HVAC enhancements, and both facility and accelerator electrical upgrades are already underway

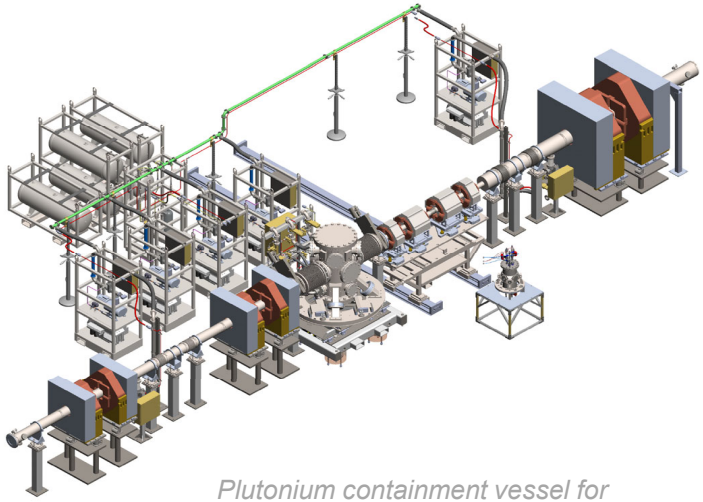


LANSCE downtime data by system

Several important capability improvements are planned for the next few years

- **Mark IV 1L target will improve nuclear physics at Lujan by ~10-100x in 2022**
- **Light Manufacturing Laboratory will enable radioactive sample processing in 2023**
- **Plutonium experiments at pRad will resume by 2025**

1L spallation target-reflector-moderator system



Plutonium containment vessel for pRad

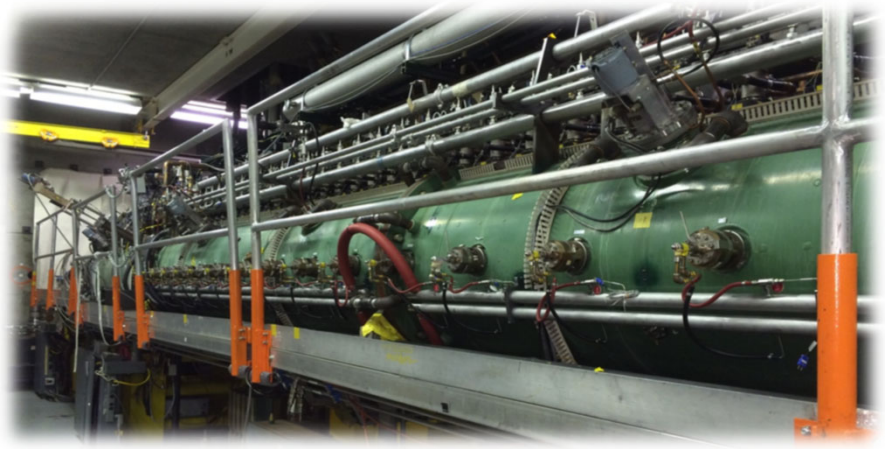
Light Manufacturing Laboratory

The LANSCE Modernization Project (LAMP) is a critical upgrade required to ensure LANSCE readiness and reliability

The timeline for LAMP is driven by several factors:

- We have already started to experience **end-of-life failures** that have reduced beam availability
- Data from LANSCE will be required to support assessment and certification at least **through 2050**
- We have developed a **high-TRL pre-conceptual upgrade design** which would take ~7 years to complete. It would replace everything from the ion sources through the drift-tube linacs
- We are investigating alternatives involving multiple projects, potentially with a raised GPP limit, to allow **more options** for completion of this work

Obsolete Cockcroft-Walton generators

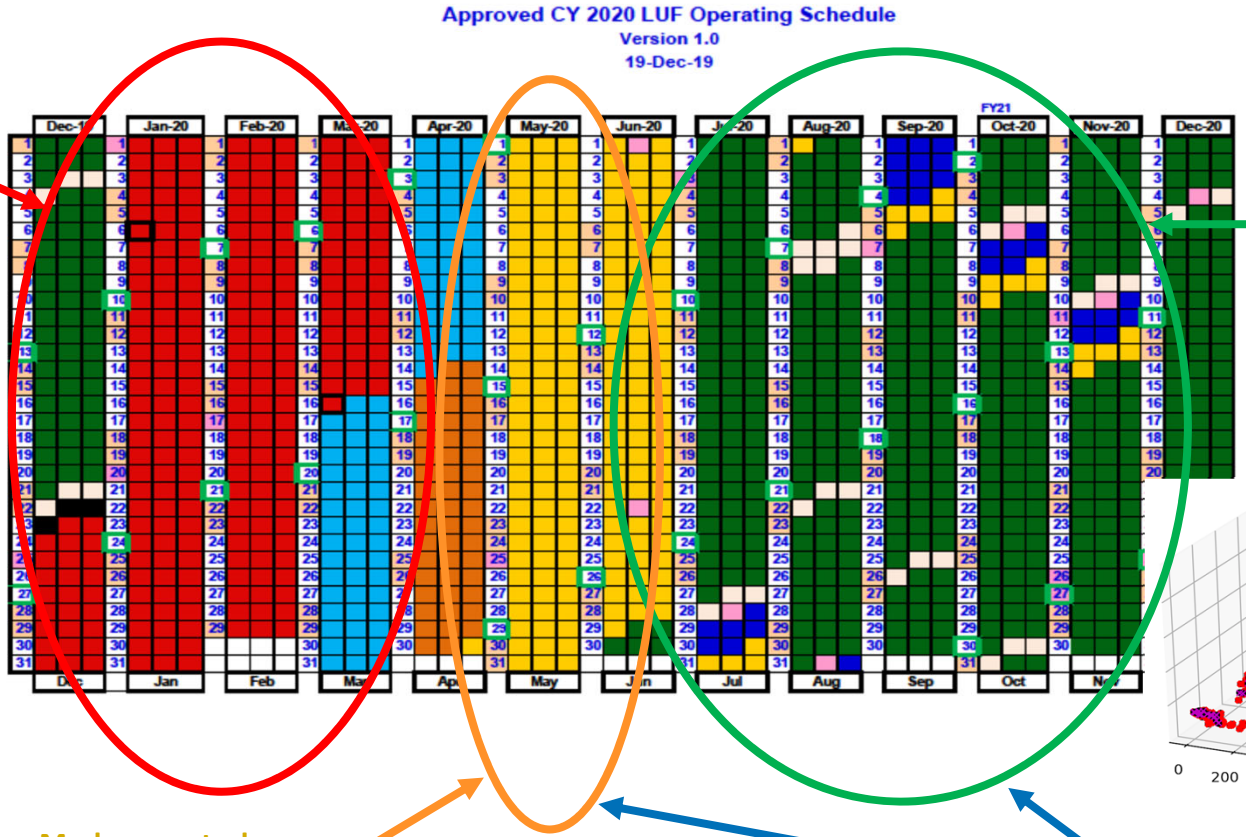


End-of-life drift tube linac

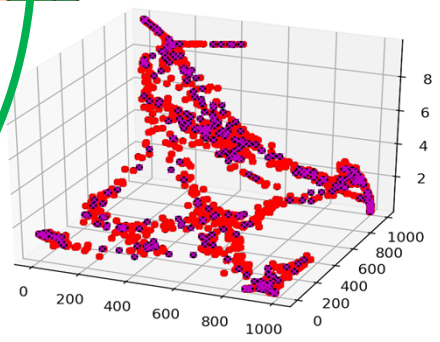
The reliability and maintainability delivered by asset management, get well planning, and LAMP will immediately increase experimental throughput

New systems reduce the down time needed for maintenance

Key:
Maintenance
Startup
Experimental operations



Increased reliability will improve beam availability from 60-85% to 95+%

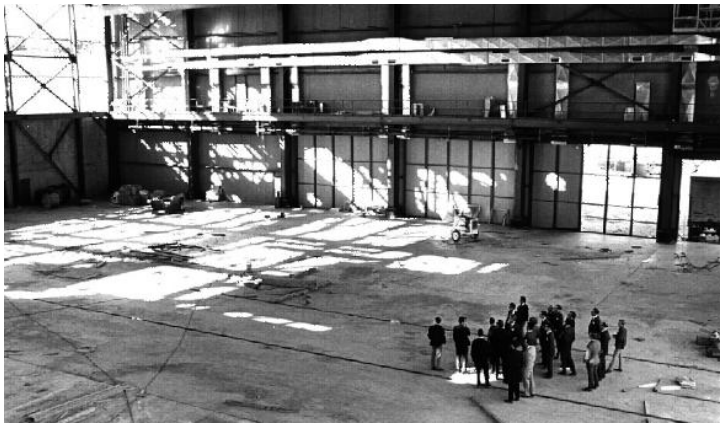


Modern controls will reduce the time needed for startup from days to hours

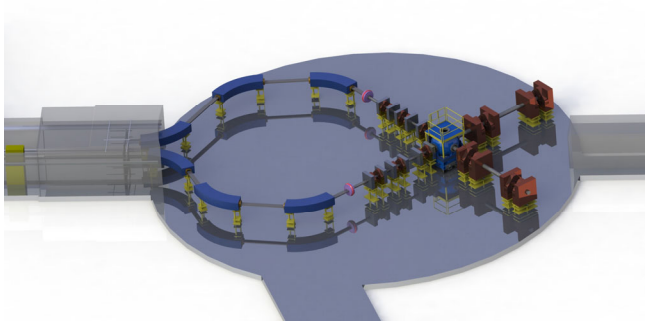
Machine learning could enable faster startup and more stable operations

Modest investments in experimental areas can deliver even more impactful data (LANSCE Enhancements/LANE)

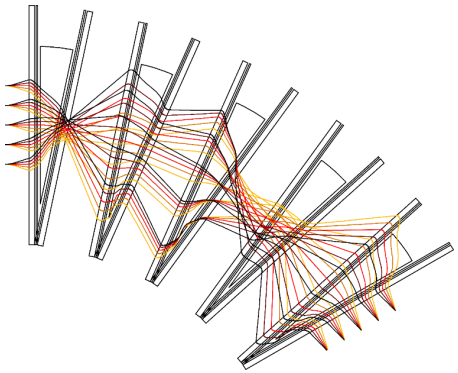
- To deliver the **data needed to support simulation advances in the 2030s**, we are examining options for Area A.
- Area A provides a **high-quality experimental facility**
- Its existing infrastructure enables the installation of several new capabilities relatively quickly and cheaply. **NA-10 relevant options include:**
  - Increased capacity, enhanced resolution, and/or multiple axis pRad
  - Revolutionary nuclear physics
  - Enhanced effects characterization



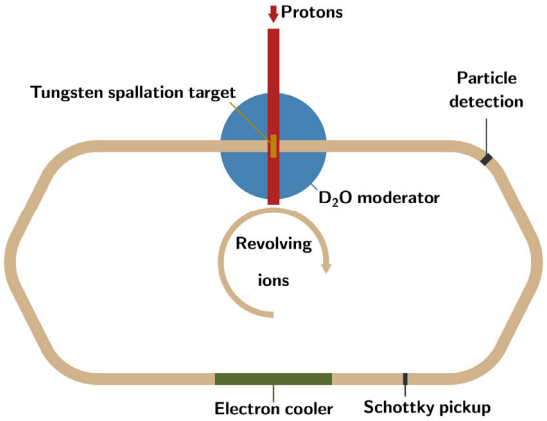
Area A is ready for experiments … in 1970 and today



Dual-axis pRad in Area C



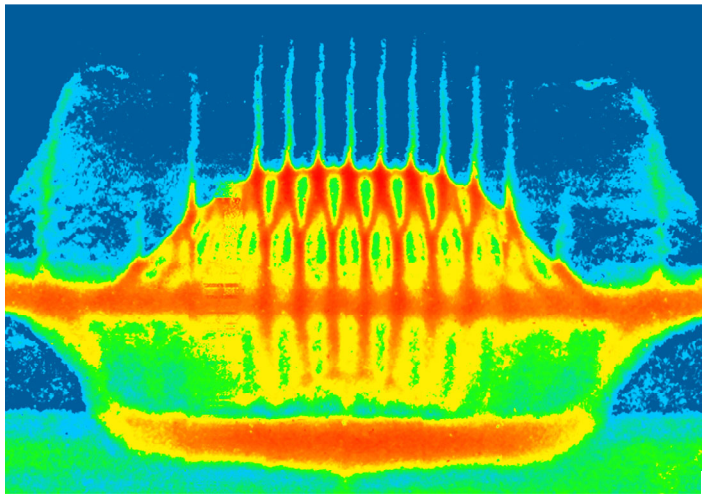
Higher-resolution achromatic lens design for pRad



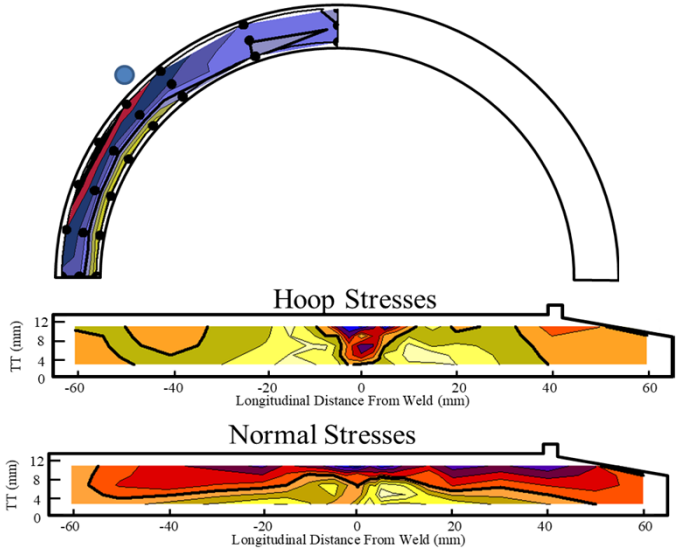
Innovative neutron target

To ensure that we can meet the need for LANSCE for decades to come, we need to invest in the facility and its experiments

- **LANSCE data will be needed over the next 30+ years** for crucial material and nuclear data, stockpile sustainment, certification of the future stockpile, meeting external threats, delivering crucial medical isotopes, and fundamental scientific discovery
- **Aging facilities make it a challenge to deliver** even the current level of data reliably
- We are identifying the **most important investments** using a system-level risk-based asset management approach, building upon the support provided by NNSA over the last fifteen years



Fluid mechanics studies at pRad



Characterizing AWE hydrotest components