STS / Target Systems Overview

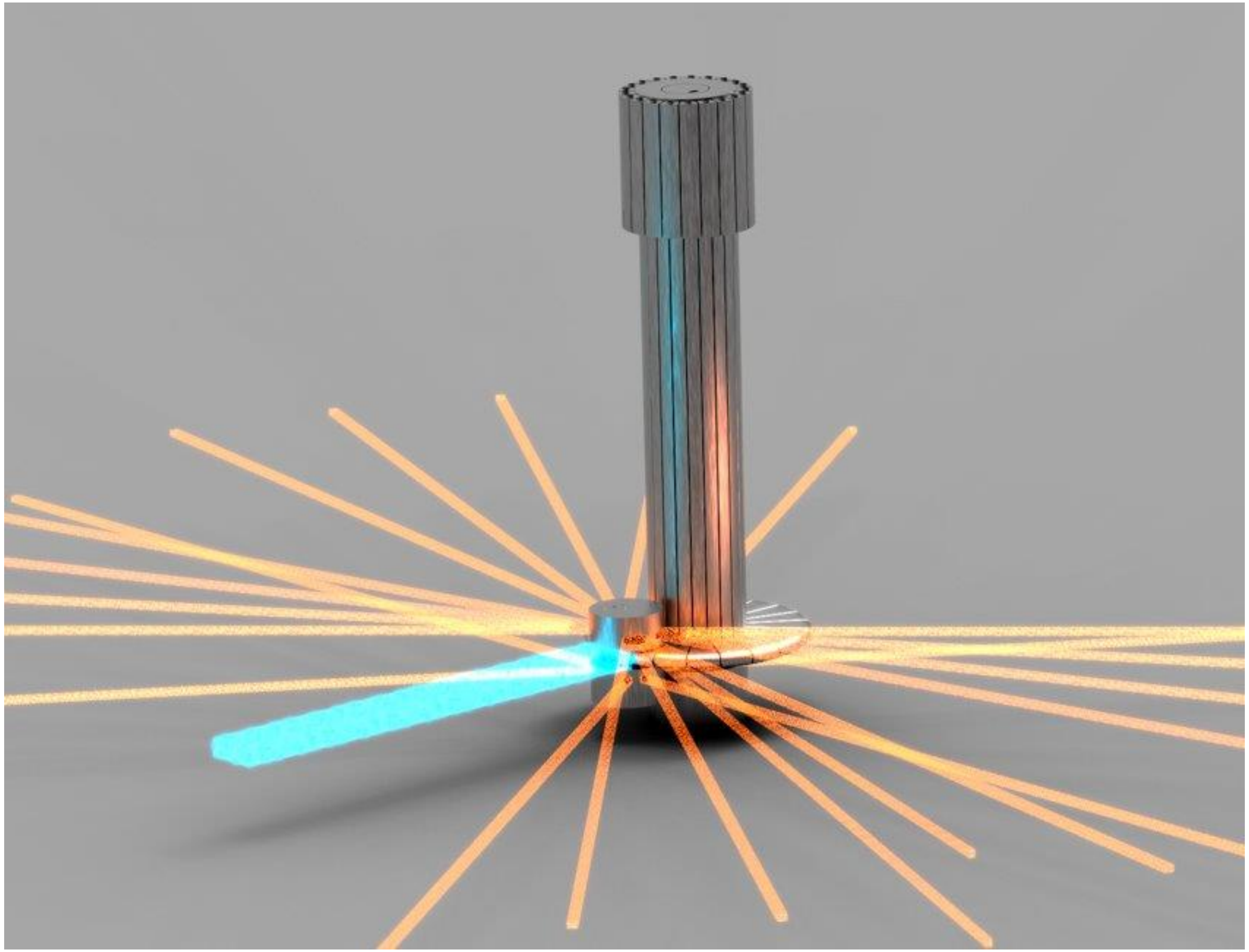
Peter Rosenblad

MRA Preliminary Design Review

3/26/2024

Topics

- **Neutrons at ORNL**
- STS Organization
- STS Schedule
- STS Requirements
- STS Technical Overview
- Target Systems Requirements
- Target Systems Overview



Today ORNL operates two of the brightest neutron sources

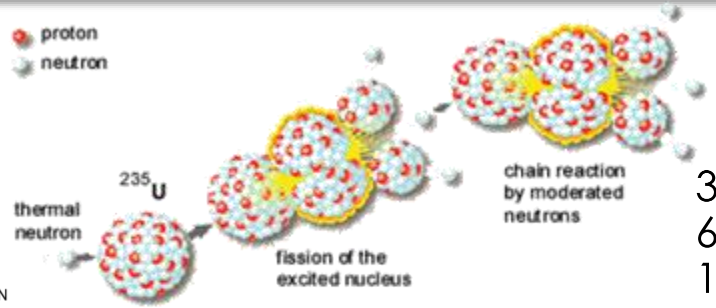
High Flux Isotope Reactor (HFIR)

Highest continuous neutron flux

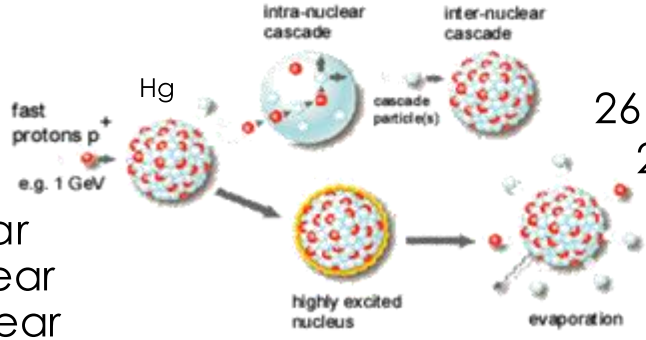
Spallation Neutron Source (SNS)

Highest peak neutron brightness

2.5 n/fission
190 MeV/useful n
Continuous



33 instruments
600 publications/year
1200 experiments/year
1200 unique users/year



26 n/proton (1 GeV)
25 MeV/useful n
Pulsed

SNS upgrades will accelerate scientific progress and deliver wholly new capabilities

PPU project: Double the power of the existing accelerator structure

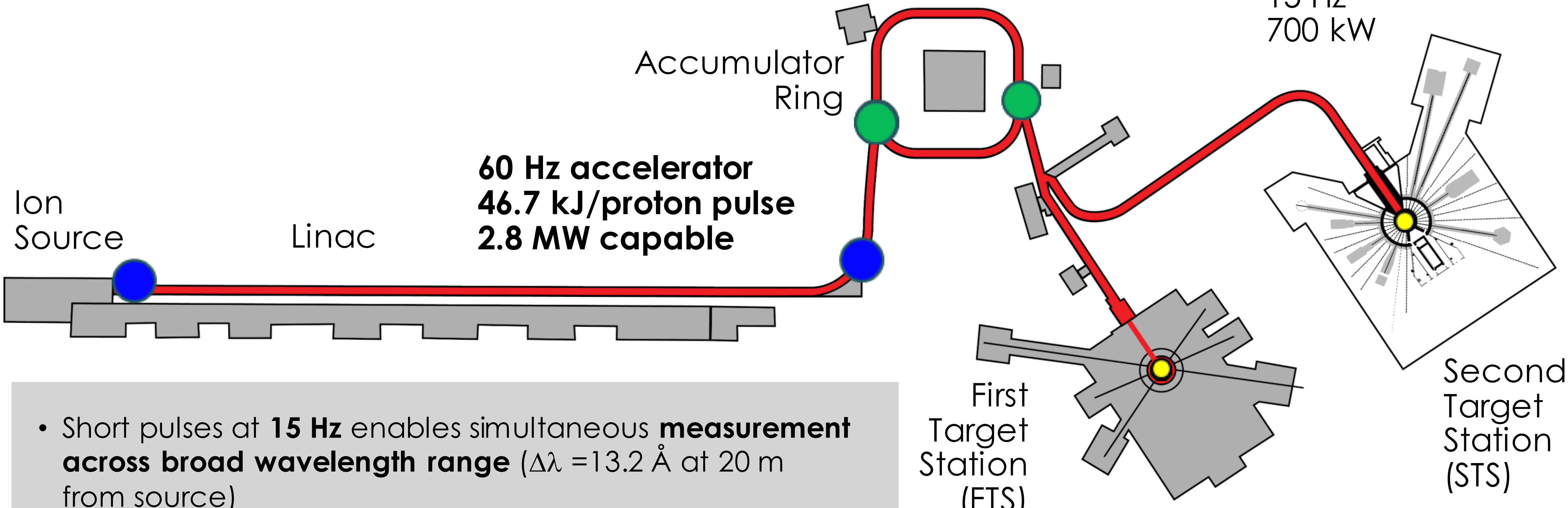
- First Target Station (FTS) is optimized for thermal neutrons
- Increases the brightness of beams of pulsed neutrons
- Provides new science capabilities for atomic resolution and fast dynamics
- Provides a platform for STS

STS project: Build the second target station with initial suite of beam lines

- Optimized for cold neutrons
- World-leading peak brightness
- Provide new science capabilities for measurements across broader ranges of temporal and length scales, real-time, and smaller samples

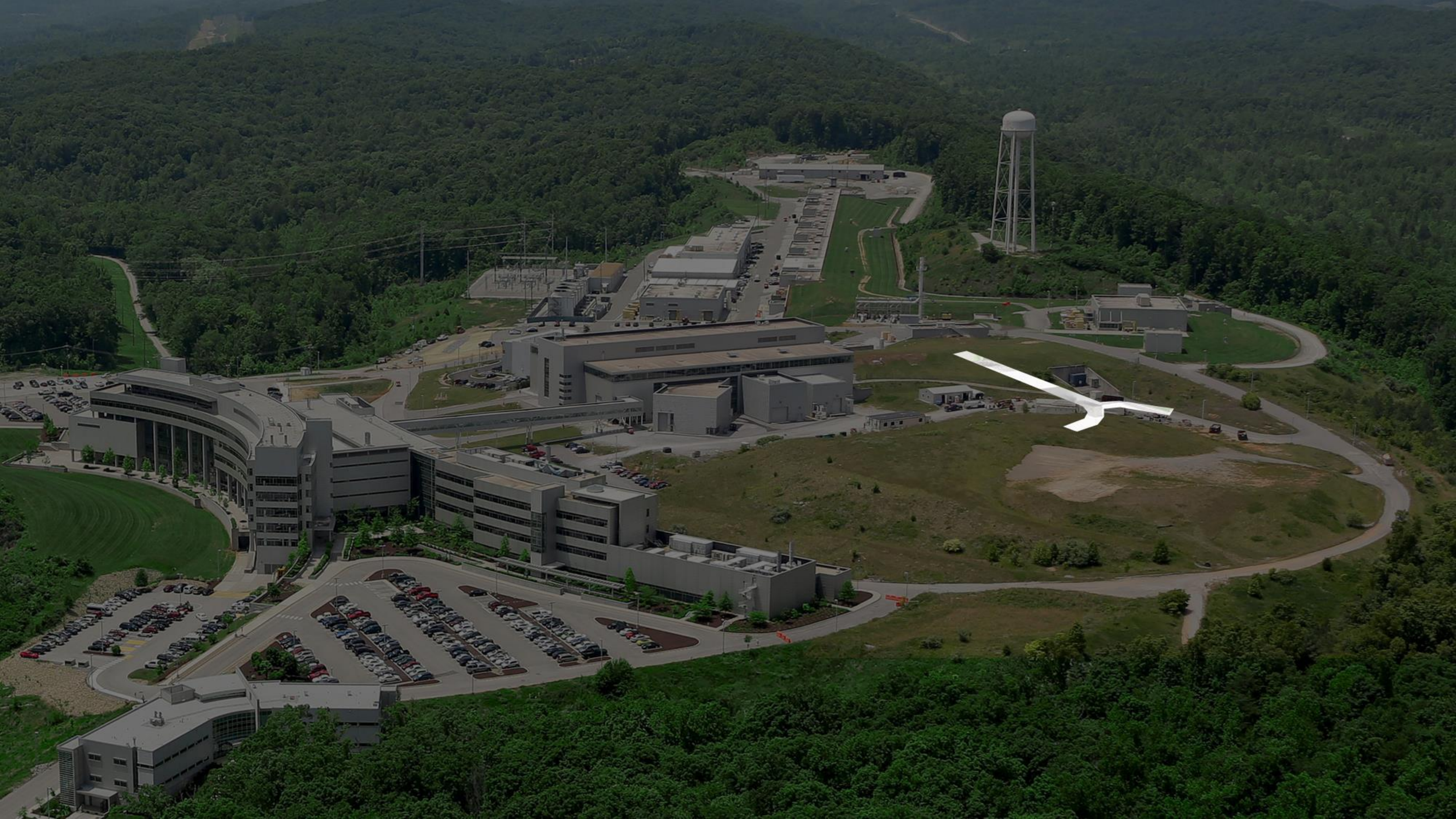
STS instruments see 4x more and 100x faster than today's similar instruments

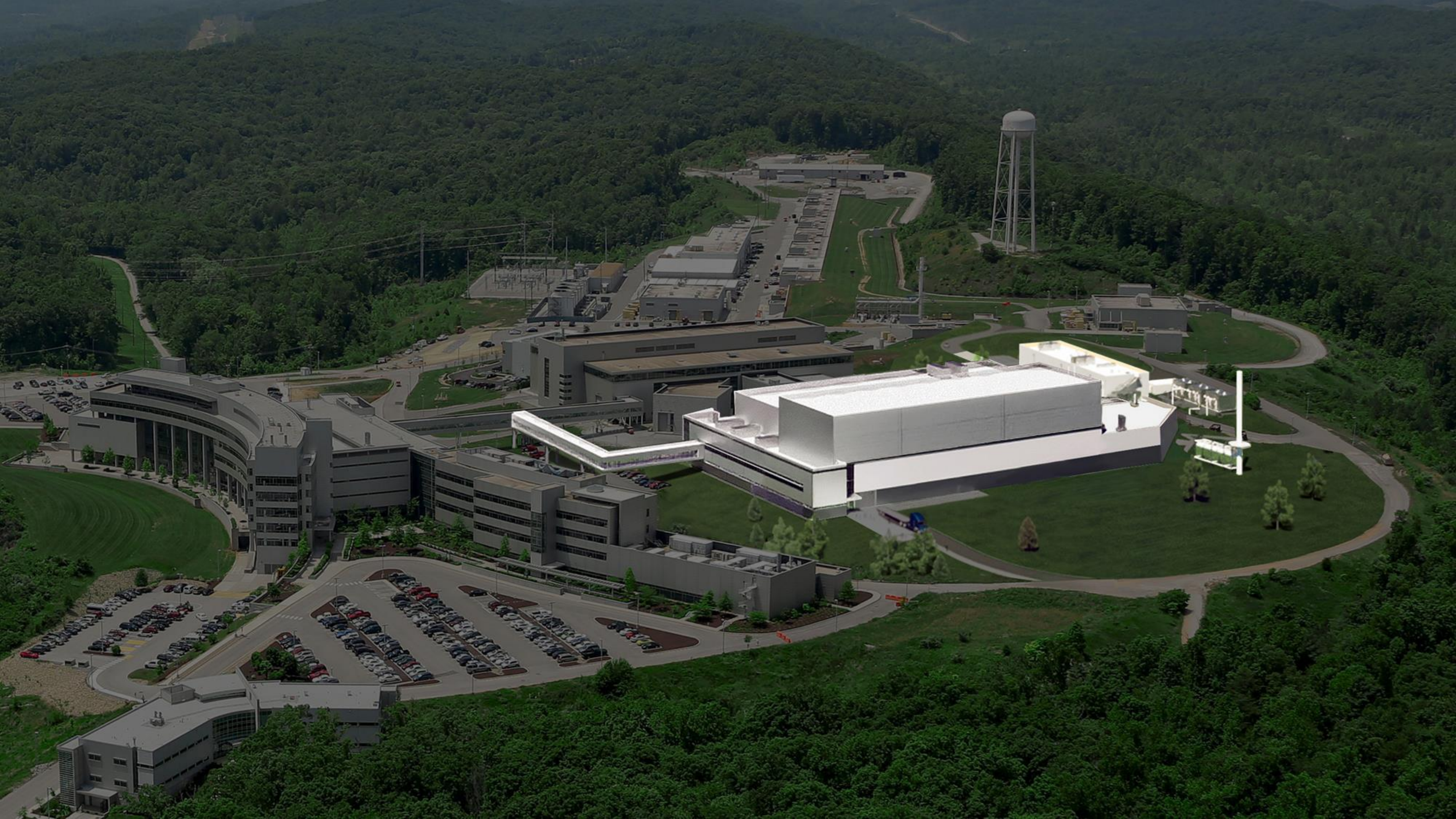
STS will make optimal use of the PPU-upgraded SNS accelerator capability



- Short pulses at **15 Hz** enables simultaneous **measurement across broad wavelength range** ($\Delta\lambda$ =13.2 Å at 20 m from source)
- Complementarity with FTS – **uses all available accelerator capability provided by PPU**
- **Flexibility** will be provided to **operate** both FTS and STS at the same time or separately if either is shutdown

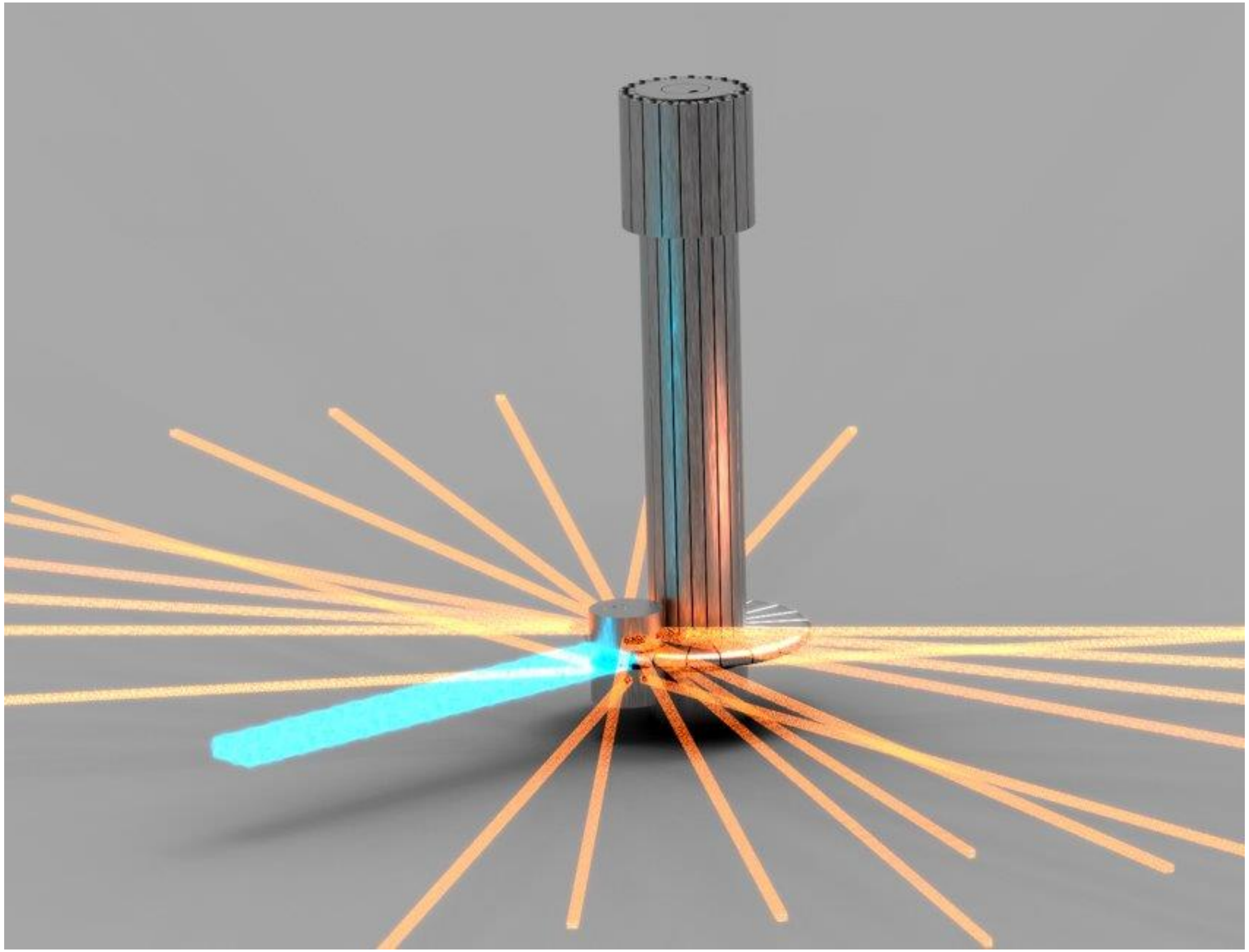
animation courtesy of Matt Stone





Topics

- Neutrons at ORNL
- **STS Organization**
- STS Schedule
- STS Requirements
- STS Technical Overview
- Target Systems Requirements
- Target Systems Overview



Oak Ridge National Laboratory

Stephen Streiffer, Laboratory Director

Susan Hubbard, Deputy for Science and Technology

Lindsey Twardy, Chief of Staff

Balendra Sutharshan, Deputy for Operations

Chief Inclusion Officer: Delphia Howze
Science–Security Integration: Shaun Gleason
Federal Affairs: Tyler Owens
Office of Institutional Planning: Jens Dilling
Office of Research Education: Moody Altamimi
Partnerships: Mike Paulus
UT-Oak Ridge Innovation Institute: David Sholl (Interim)

Communications: David Keim
Counterintelligence: Julian Rael
General Counsel: David Mandl
Internal Audit: Fred Pieper
Office of Integrated Performance Management: Dana Hewit
Project Management Office: Greg Capps

Biological and Environmental Systems Science
Paul Langan, Assoc Lab Director
Steve Cline, COO

- **Biosciences Division** – Julie Mitchell
- **Environmental Sciences Division** – Eric Pierce

Computing and Computational Sciences
Gina Tourassi, Assoc Lab Director
Fred Sudler, COO

- **Computational Sciences and Engineering Division** – Kate Evans
- **Computer Science and Mathematics Division** – Michael Parks
- **National Center for Computational Sciences Division** – Arjun Shankar (Interim)

Energy Science and Technology
Robert Wagner, Assoc Lab Director
Ron Ott, COO

- **Buildings and Transportation Science Division** – Tim Theiss (Interim)
- **Electrification and Energy Infrastructures Division** – Philip Bingham
- **Manufacturing Science Division** – Yarom Polsky

Fusion and Fission Energy and Science
Mickey Wade, Assoc Lab Director
Chris Beatty, COO

- **Fusion Energy Division** – Phil Snyder (Interim)
- **Nuclear Energy and Fuel Cycle Division** – Dave Pointer (Interim)

Isotope Science and Engineering
Jeremy Busby, Assoc Lab Director
Kenneth Engle, COO

- **Enrichment Science and Engineering Division** – Brian Anderson
- **Isotope Processing and Manufacturing Division** – Jim Placke
- **Nonreactor Nuclear Facilities Division** – Allen Smith (Interim)
- **Radioisotope Science and Technology Division** – Susan Hogle

National Security Sciences
Moe Khaleel, Assoc Lab Director
Michaela Martin, COO

- **Cyber Resilience and Intelligence Division** – Mason Rice (Interim)
- **Field Intelligence Operations Division** – Chuck Durant
- **Geospatial Science and Human Security Division** – Budhendra Bhaduri
- **Nuclear Non-proliferation Division** – Cary Crawford

Neutron Sciences
Jens Dilling, Assoc Lab Director (Interim)
Brian Weston, COO

- **Neutron Scattering Division** – Jon Taylor
- **Neutron Technologies Division** – Richard Ibberson
- **Research Accelerator Division** – Fulvia Pilat
- **Research Reactors Division** – Mike Pierce

Physical Sciences
Cynthia Jenks, Assoc Lab Director
Doug Collins, COO

- **Center for Nanophase Materials Sciences** – Karren More
- **Chemical Sciences Division** – Roger Rousseau
- **Materials Science and Technology Division** – Yutai Kato
- **Physics Division** – Marcel Demarteau

Exascale Computing Project
Lori Diachin, Project Director

Neutron Upgrades Project Office
Graeme Murdoch, Director

US ITER Project
Kathy McCarthy, Project Director

Business Services
Scott Branham, CFO
Stacy Boggs, Operations Director

- **Accounting Operations Division** – Libby Brown
- **Business Operations Division** – Andrew Petzold
- **Contracts Division** – Tina Richards

Environment, Safety, Health, and Quality
John Gearhart, Director
Jeff Ullian, Operations Director

- **Engineering Management Division** – Doug Freels
- **Environmental Protection Services Division** – David Skipper
- **Health Services Division** – Bart Iddins
- **Safety and Operations Services Division** – Jeff Ullian
- **Transportation and Waste Management Division** – Jeff Shelton
- **Nuclear Facility Safety Division** – Tony Koonce
- **Nuclear and Radiological Protection Division** – Mike Stafford
- **Quality Assurance Division** – Jill Christian

Facilities and Operations
Ann Weaver, Director

- **Fabrication, Instrumentation, and Inspection Division** – Dave Price
- **Facilities Management Division** – Jim Serafin (Interim)
- **Integrated Operations Support Division** – Katie Andrews
- **Laboratory Modernization Division** – Bart Hammontree (Interim)
- **Laboratory Protection Division** – Lantz Turner
- **Logistical Services Division** – Steve Macklin
- **Utilities Division** – Scott Wellman

Human Resources
Brian Arrington, CHRO

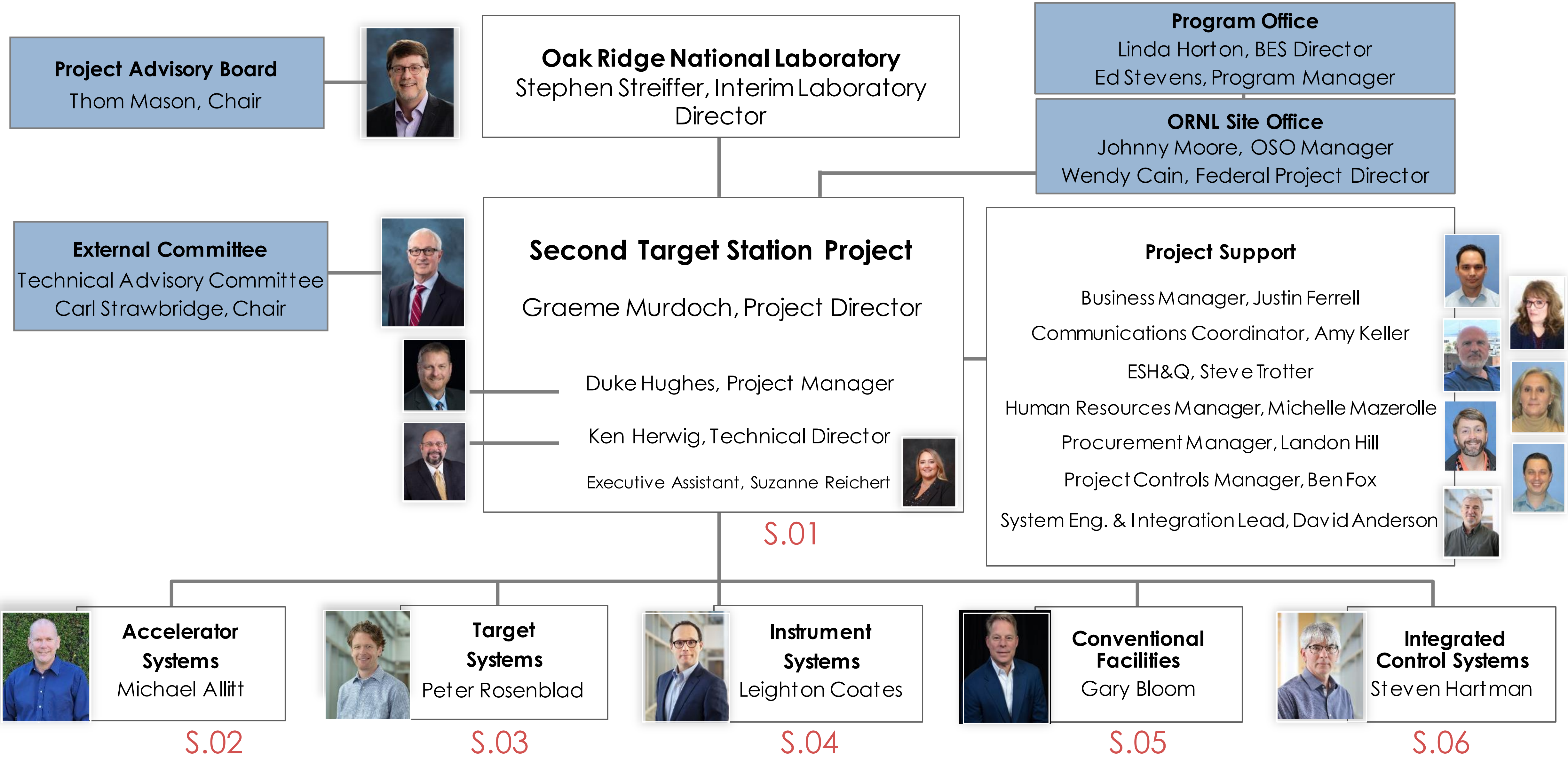
- **Benefits Division** – Scott McIntyre
- **Compensation, HRIS, and Analytics Division** – Lisa Blum
- **Learning, Engagements, and Development Division** – Joy Wilson
- **HR Partnerships Division** – Megan Fielden
- **Talent Acquisition and Mobility Division** – Matt Elam

Information Technology Services
Kris Torgerson, CIO

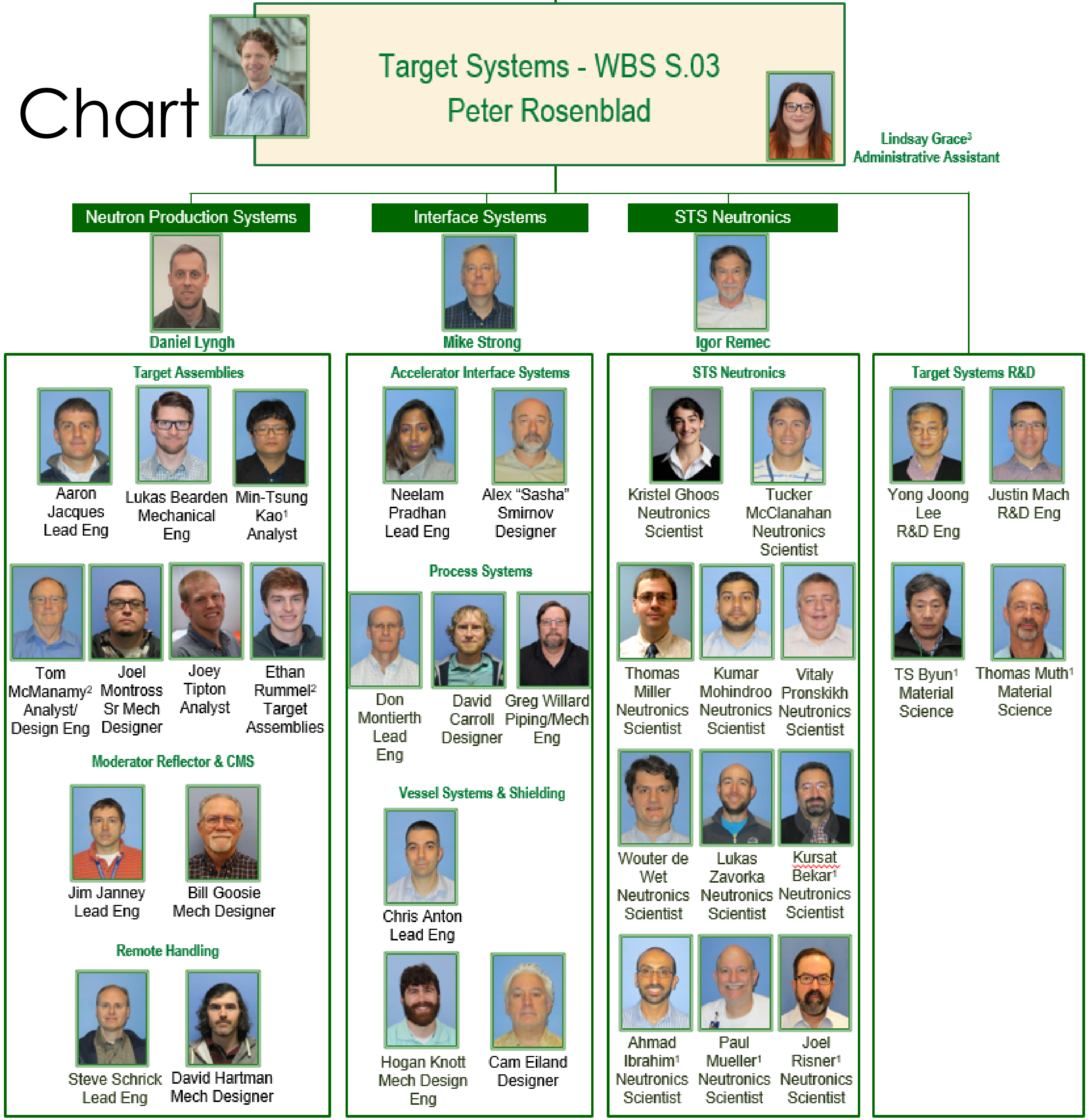
- **Application Development Division** – Jay Eckles
- **Cyber Security Division** – Maria McClelland
- **Digital Services Support Division** – Paul Chamberlain
- **Research Computing Support Division** – Brett Ellis

OAK RIDGE National Laboratory

STS Project organization chart

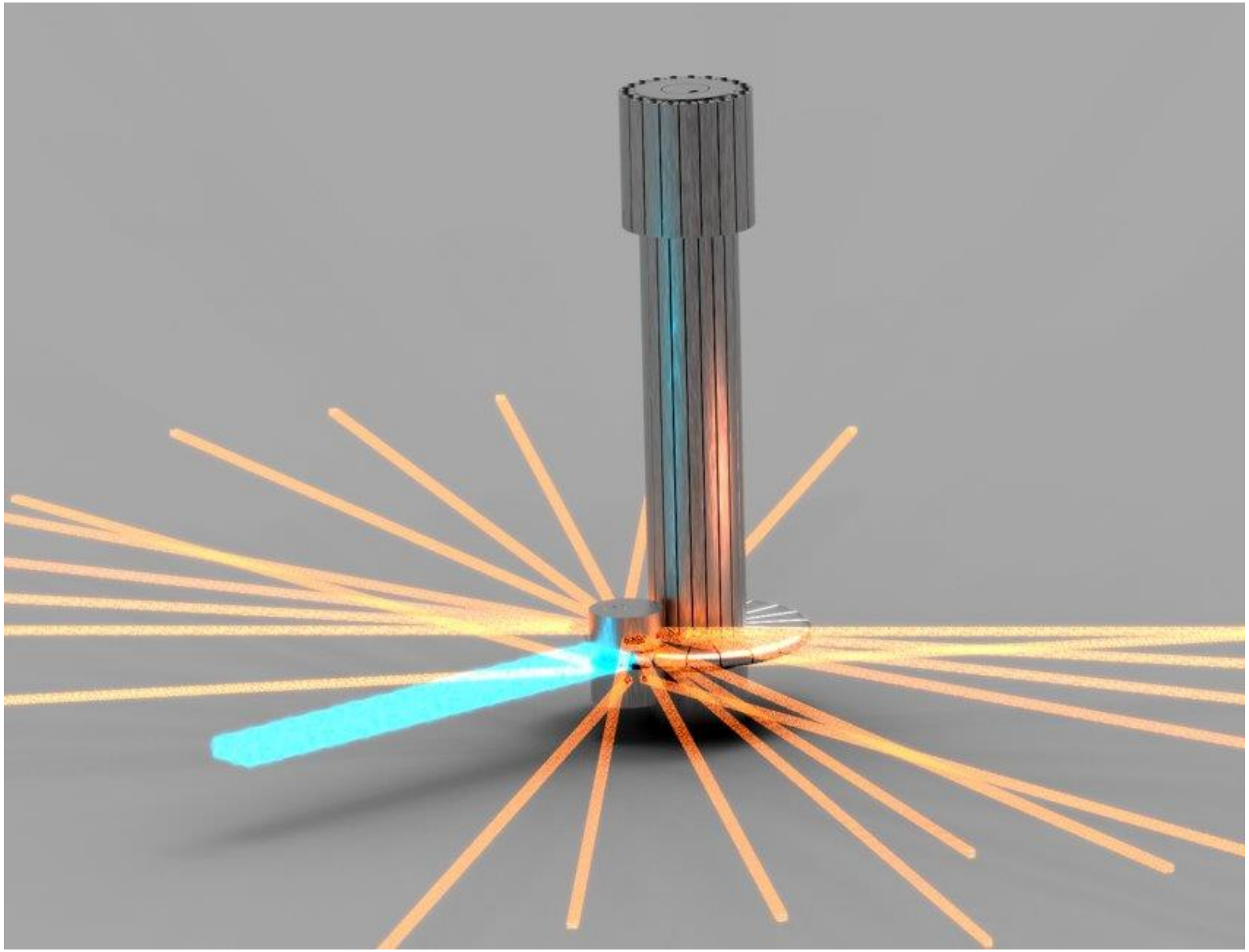


Target Systems Org Chart



Topics

- Neutrons at ORNL
- STS Organization
- **STS Schedule**
- STS Requirements
- STS Technical Overview
- Target Systems Requirements
- Target Systems Overview



Major Projects Take Time

2024

2020, November – DOE approved the project's CD-1 status

2017, April –Selection of major STS technical alternatives: 15 Hz pulse repetition rate, 700 kW proton beam power, short pulse options.

2016, January – Initiated STS conceptual design activities.

2010

2009 – DOE approved Critical Decision-0 (CD-0)

2019, October – Dedicated STS Project Office established.

2000

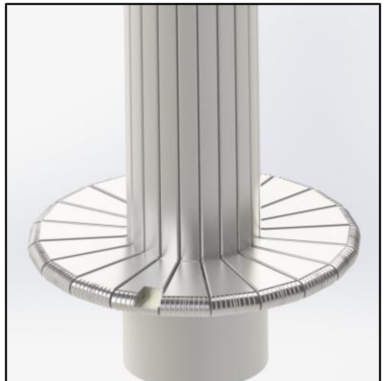
2013 – A DOE advisory committee noted STS is "absolutely central" to US leadership in science.

1996

1999 - Environmental Impact Statement for SNS included a Second Target Station (STS).

1996 – A DOE advisory committee recommended that SNS proceed and include additional target station capability.

Significant progress has been made across the project over the past 4 years



Segmented Target

2021 IPR

Segment Target Concept Selected

New proton transport lattice

Preliminary Moderator Optimization Complete

MRA/Inst. Sys. Interface Sheet issued

Lasagna Target Concept Selected

RTST & CSB design begins

Preliminary neutronic heating, structural & CFD analysis completed

TS/AS beam parameter IS Rev 2 issued

T & I bldg. design begins

PDR proton beam optics

2021 | 2022 | 2023

8 STS Project Neutron Instruments selected

Site plan established

Two beam flavors workshop report issued

Technical review of initial designs for 4 instruments complete

Requirements documents issued for all 8 instruments

Second critical device workshop for FTS target cart out of position

ICDs & ICSs with AS & SNS issued

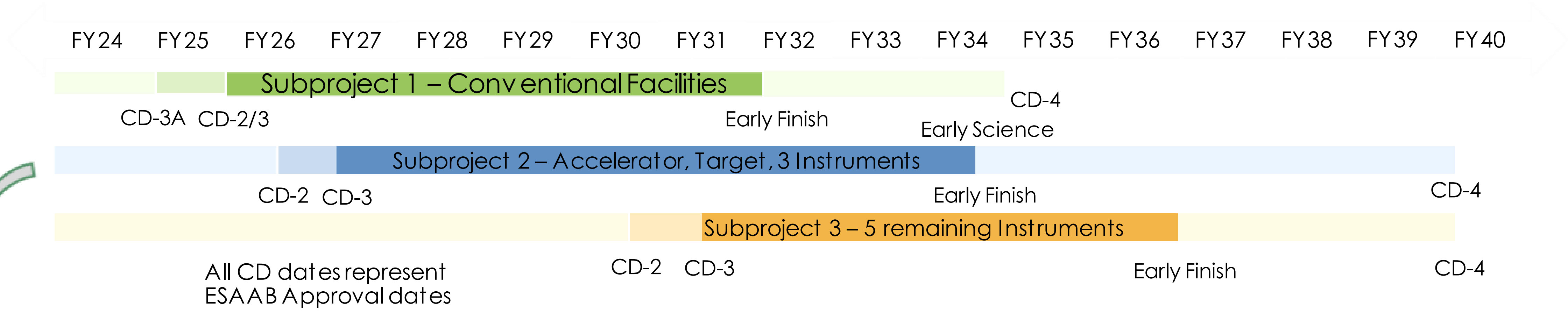
PDR Timing System, Run Permit System, & Linac LLRF controls

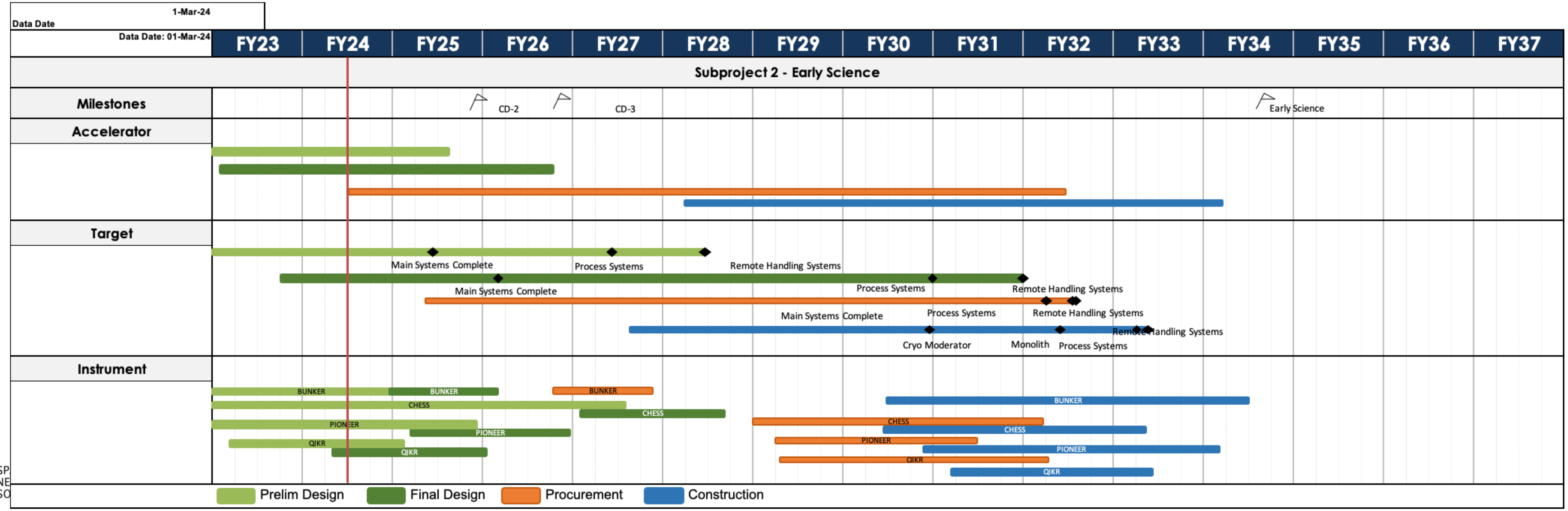
PDR for CHESS, PIONEER, & QIKR optics

Independent Control
700 kW proton beam power
Peak Brightness
≥ 8 neutron instruments

QIKR Instrument

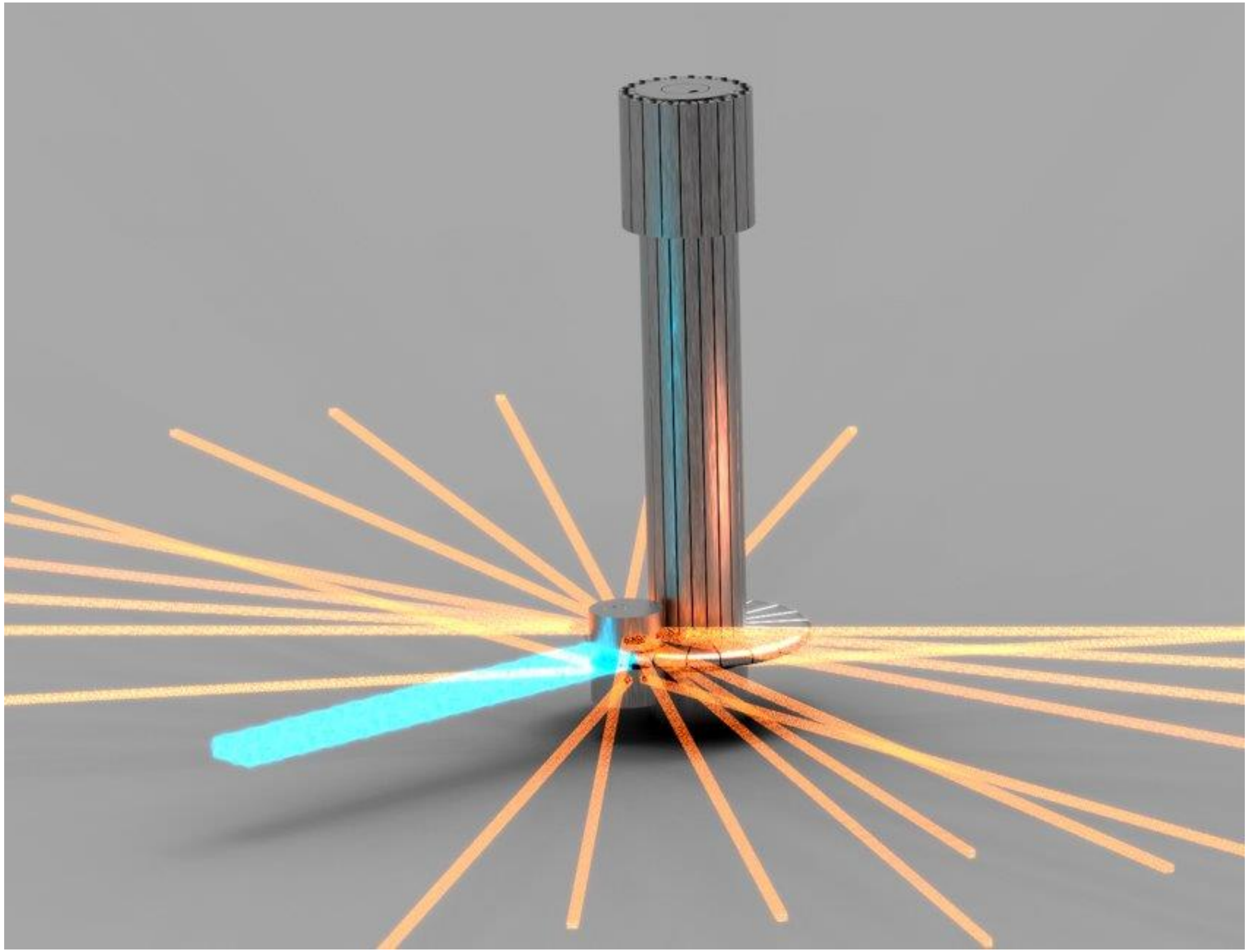
Notional Execution Strategy





Topics

- Neutrons at ORNL
- STS Organization
- STS Schedule
- **STS Requirements**
- STS Technical Overview
- Target Systems Requirements
- Target Systems Overview

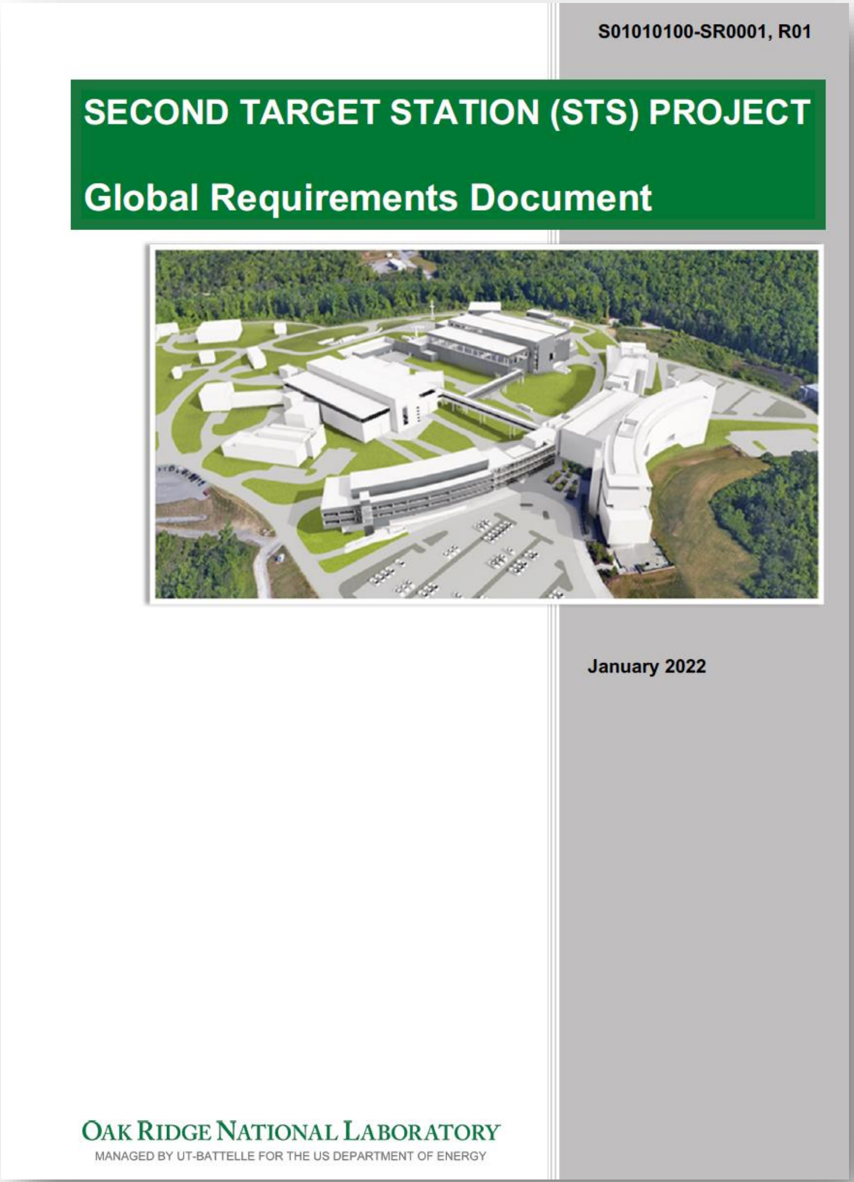


Preliminary Key Performance Parameters (PKPP) provide highest level of requirements

Key Performance Parameter	Thresholds (Performance Deliverable)	Objectives	Plan meets requirement
Demonstrate independent control of the proton beam on the two target stations	Operate beam to FTS at 45 pulses/s, with no beam to STS Operate beam to STS at 15 Hz, with no beam to FTS Operate with beam to both target stations 45 pulses/s at FTS and 15 Hz at STS		✓
Demonstrate proton beam power on STS at 15 Hz	100 kW beam power	700 kW beam power	✓
Measure STS neutron brightness	Peak brightness of 2 x 10^{13}n/cm^2/sr/Å/s at 5 Å	peak brightness of 2 x 10^{14}n/cm^2/sr/Å/s at 5 Å	✓
Beamlines transitioned to operations	8 beamlines successfully passed the integrated functional testing per the TTOP acceptance criteria	≥ 8 beamlines successfully passed the integrated functional testing per the TTOP acceptance criteria	✓

Global (Level 1) requirements are derived from PKPPs

ID	Requirement Description
R1	The STS Project will demonstrate independent controls of the proton beam on the two target stations
R2	STS Project shall deliver a facility with the capability to operate 700 kW proton beam power to STS
R3	STS Project shall deliver a facility with the capability to operate with a peak brightness of $\geq 2x10^{14} n/cm^2/sr/Å/s$ at 5 Å
R4	The STS shall provide world-leading capabilities for science using cold neutrons with more than a 10x gain relative to comparable First Target Station instruments
R5	STS Project shall transition to operations ≥8 beamlines that successfully pass the integrated functional testing per the Transition to Operations Plan (TTOP)
R6	STS facility shall be designed to accommodate 22 neutron beamlines
R7	STS facility shall be designed to support a lifetime of 40 years
R8	STS facility shall be designed to support > 5000 hrs of proton beam on target per year
R9	STS facility shall be designed to support an availability of > 90%
R10	STS facility shall be designed to maintain compatibility with the SNS Facility
R11	STS facility shall be designed in accordance with the DOE Order 420.2C Safety of Accelerator Facilities
R12	Systems, Structures and Components for the STS shall be designed for decommissioning


S01010100-SR0001, R01

SECOND TARGET STATION (STS) PROJECT

Global Requirements Document

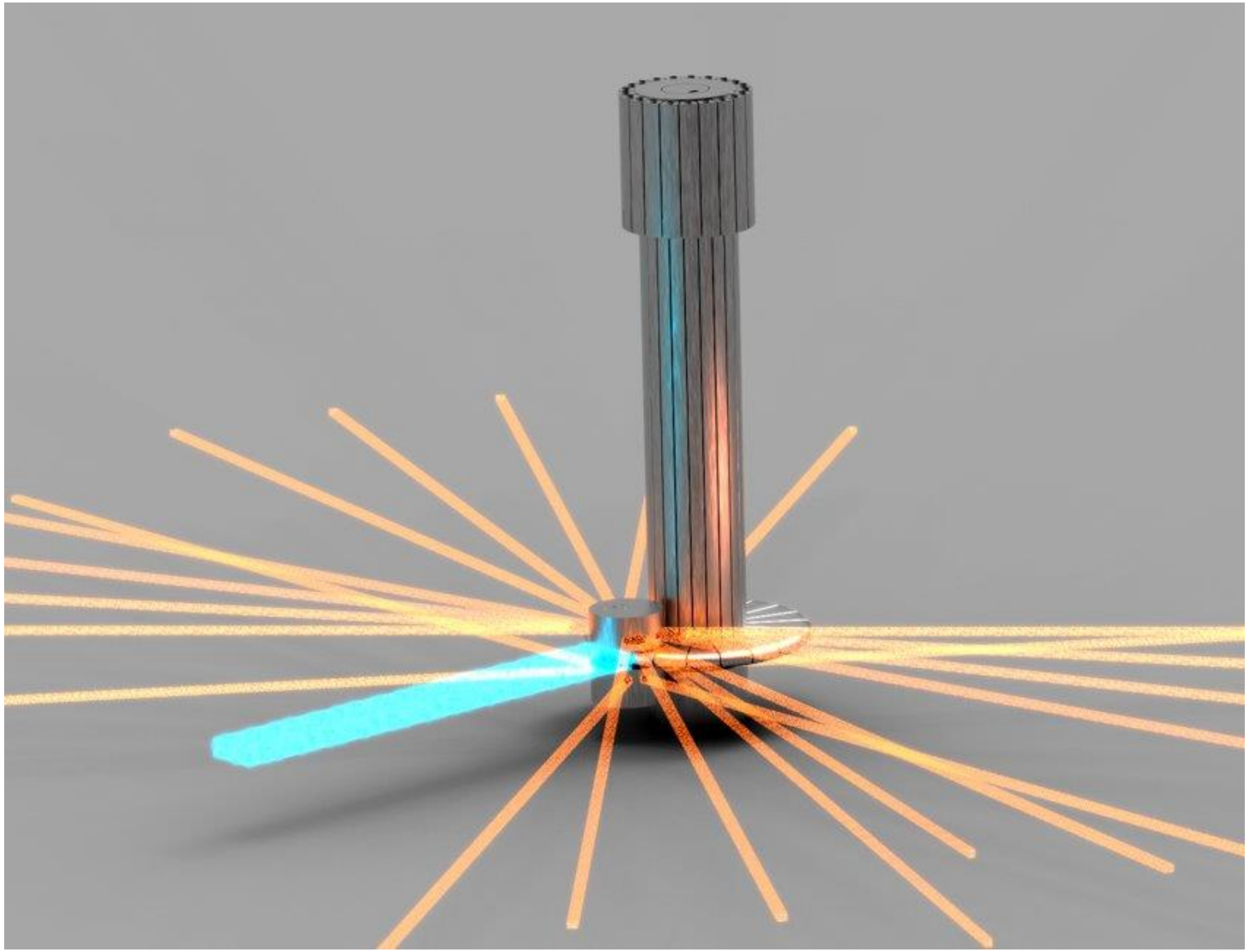
January 2022

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

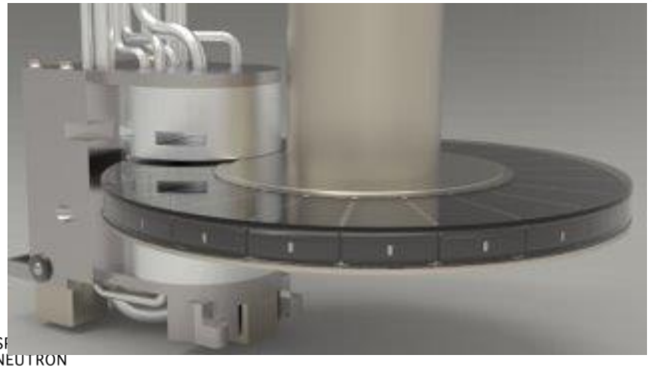
Topics

- Neutrons at ORNL
- STS Organization
- STS Schedule
- STS Requirements
- **STS Technical Overview**
- Target Systems Requirements
- Target Systems Overview

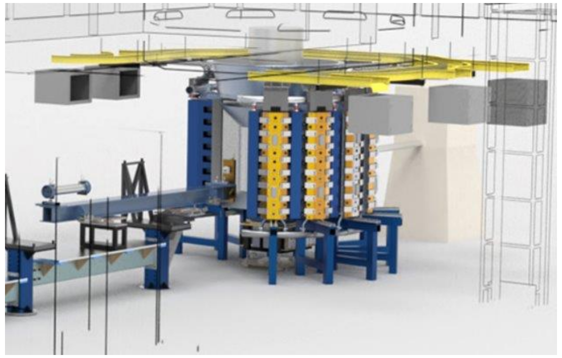


Preliminary design scope supports case for achieving world-leading capability

Accelerator	Target	Instruments	Conventional Facilities	Integrated Controls
• Transport protons to STS operating at 15Hz • Independent operation of First Target Station (FTS) and STS	• Solid rotating water cooled tungsten target • 2 high brightness, supercritical H_2 moderators	• Provide capability for ~20 instrument end stations • 8 beamline instruments included in STS scope	• ~220k square feet of new infrastructure	• Control systems and computing infrastructure • Data acquisition for neutron scattering instruments



Rotating, segmented solid-tungsten target



PIONEER diffractometer optimized for small samples

STS shown on SNS site

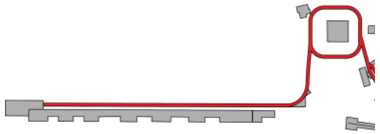
STS uniquely combines advanced technologies to deliver new science capabilities needed to understand more complex materials, processes, and devices

Start with the world's most powerful hadron accelerator – the SNS

PPU upgraded SNS
46.7 kJ/proton pulse
60 Hz, 2.8 MW capable

+

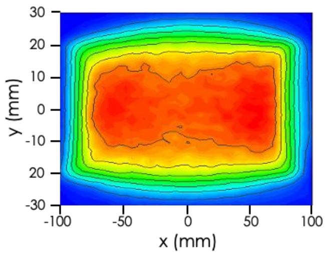
Use the accumulator ring to compress the proton pulse



1 msec linac production compressed to < 1 μsec

+

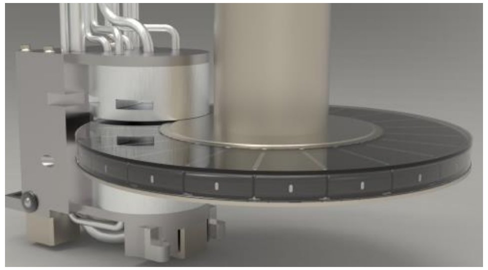
Add optics & transport to produce uniform proton spot size on the target



STS proton area = 60 cm^2
FTS proton area = 140 cm^2

+

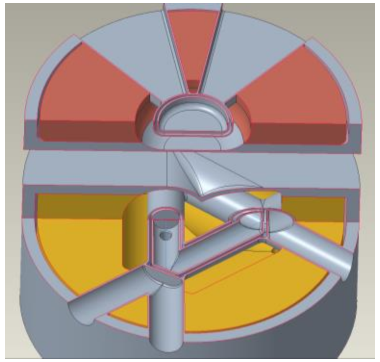
Add rotating, segmented solid-tungsten target



Spreads heat load over larger volume with longer lifetime

+

Add low dimensional moderators, tightly-coupled to neutron production zone



Two high-brightness, geometrically-optimized moderators (cylinder & tube)

+

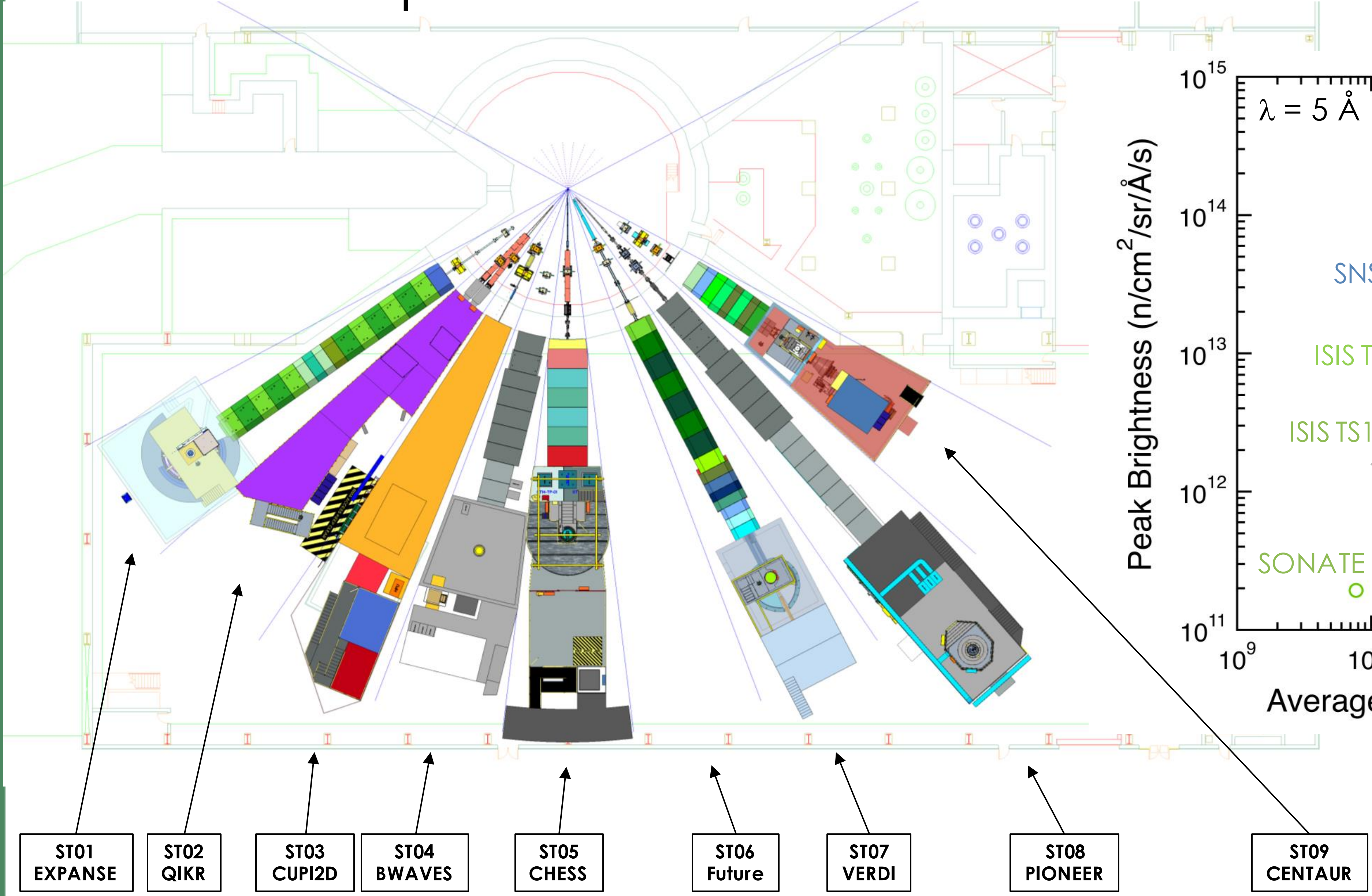
Add science-driven, optimized instrument designs

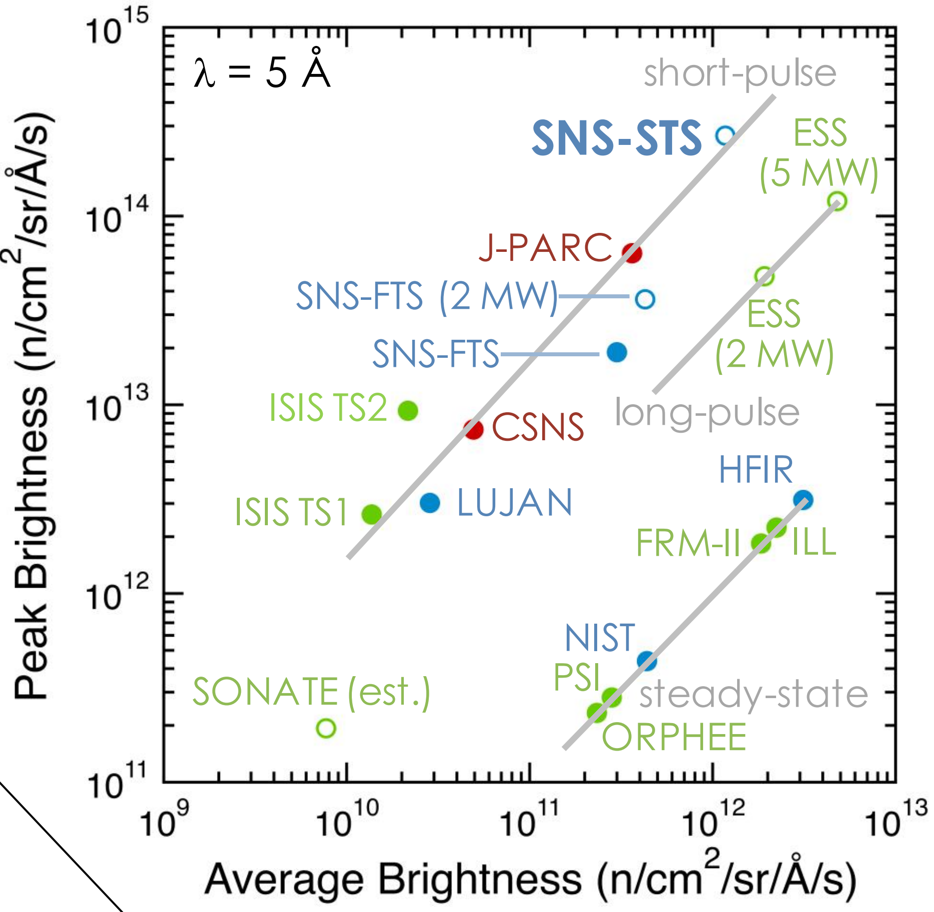
8 initial STS instrument, latest technologies, integrated controls, scientific software, proposed by and selected with the user community

=

Next generation neutron facility with science capabilities needed for materials innovation: materials discovery & materials in-action.

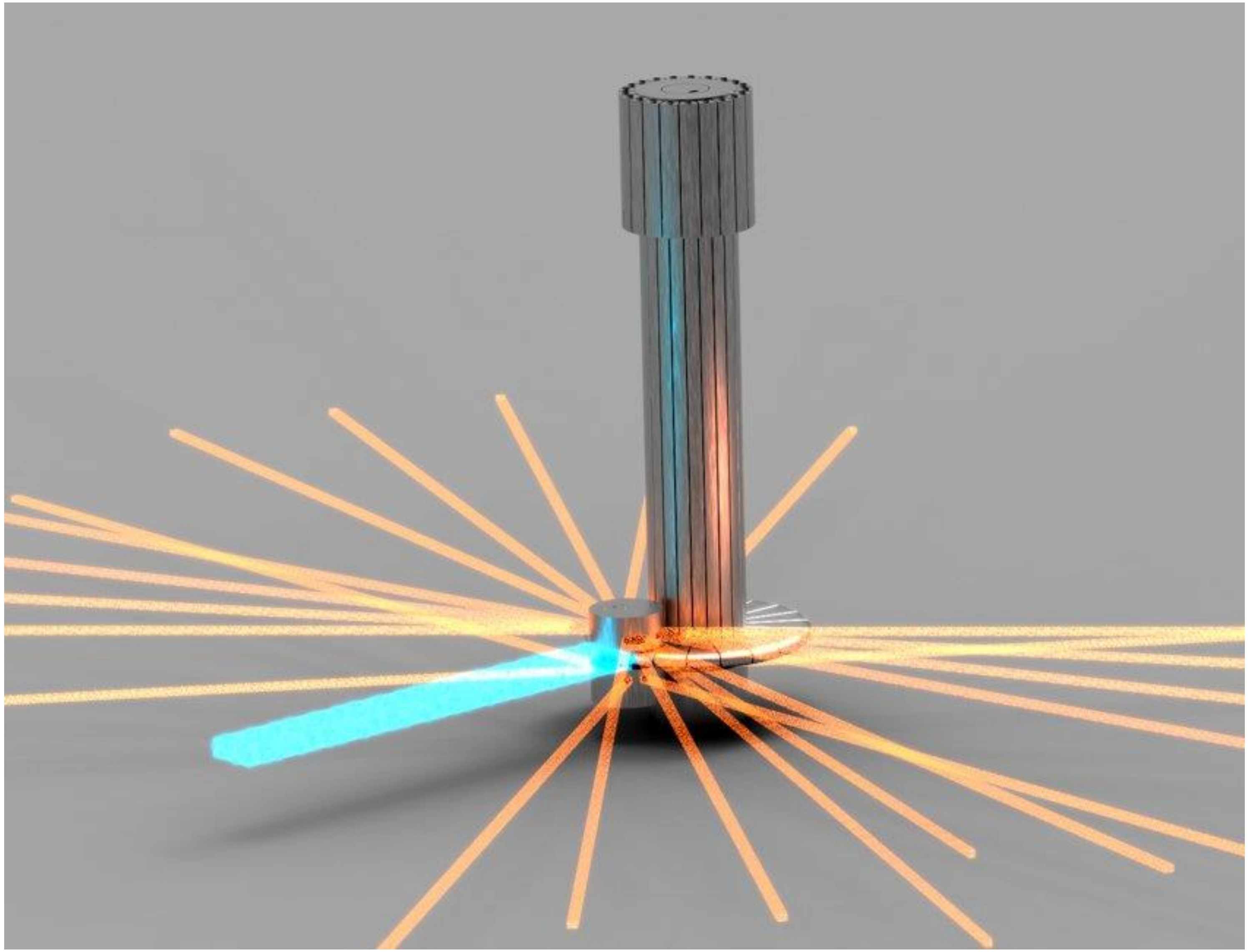
World class performance for 8 initial instruments





Topics

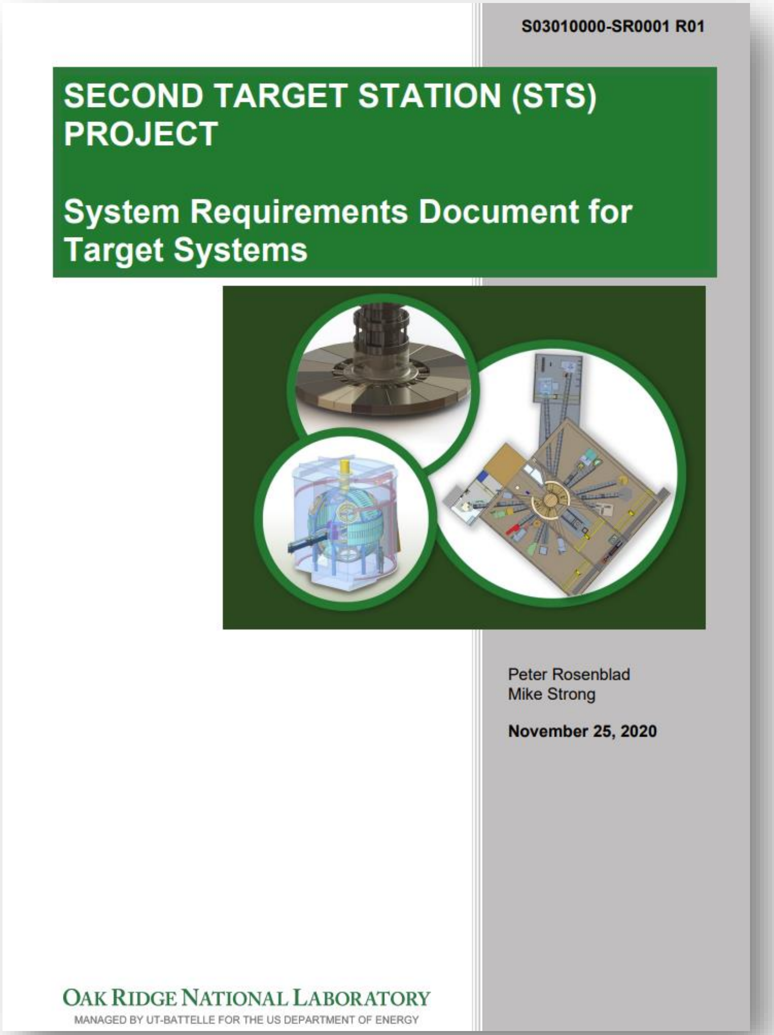
- Neutrons at ORNL
- STS Organization
- STS Schedule
- STS Requirements
- STS Technical Overview
- **Target Systems Requirements**
- Target Systems Overview



Target Systems (Level 2) requirements are established

Selected key requirements:

- Accept a pulsed proton beam of 700 kW, 1.3 GeV, 15 Hz
- Convert the proton beam pulses into cold neutron pulses using high-brightness moderators that will meet or exceed the peak brightness of 2e14 n/cm^2/sr/Å/s at the neutron wavelength of 5Å
- Distribute neutrons to 22 beamlines
- Include a service or replacement scheme and disposal path for all perishable components
- Provide connection to and isolation from the Accelerator Systems environment upstream of the Target Station Monolith for transport of the proton beam to the Target
- Operate for 40 years @ 5,000 hours/year and 95% availability for scheduled run times
- Provide the potential to respond to evaluate component failures via post irradiation examination (PIE)


S03010000-SR0001 R01

SECOND TARGET STATION (STS) PROJECT

System Requirements Document for Target Systems

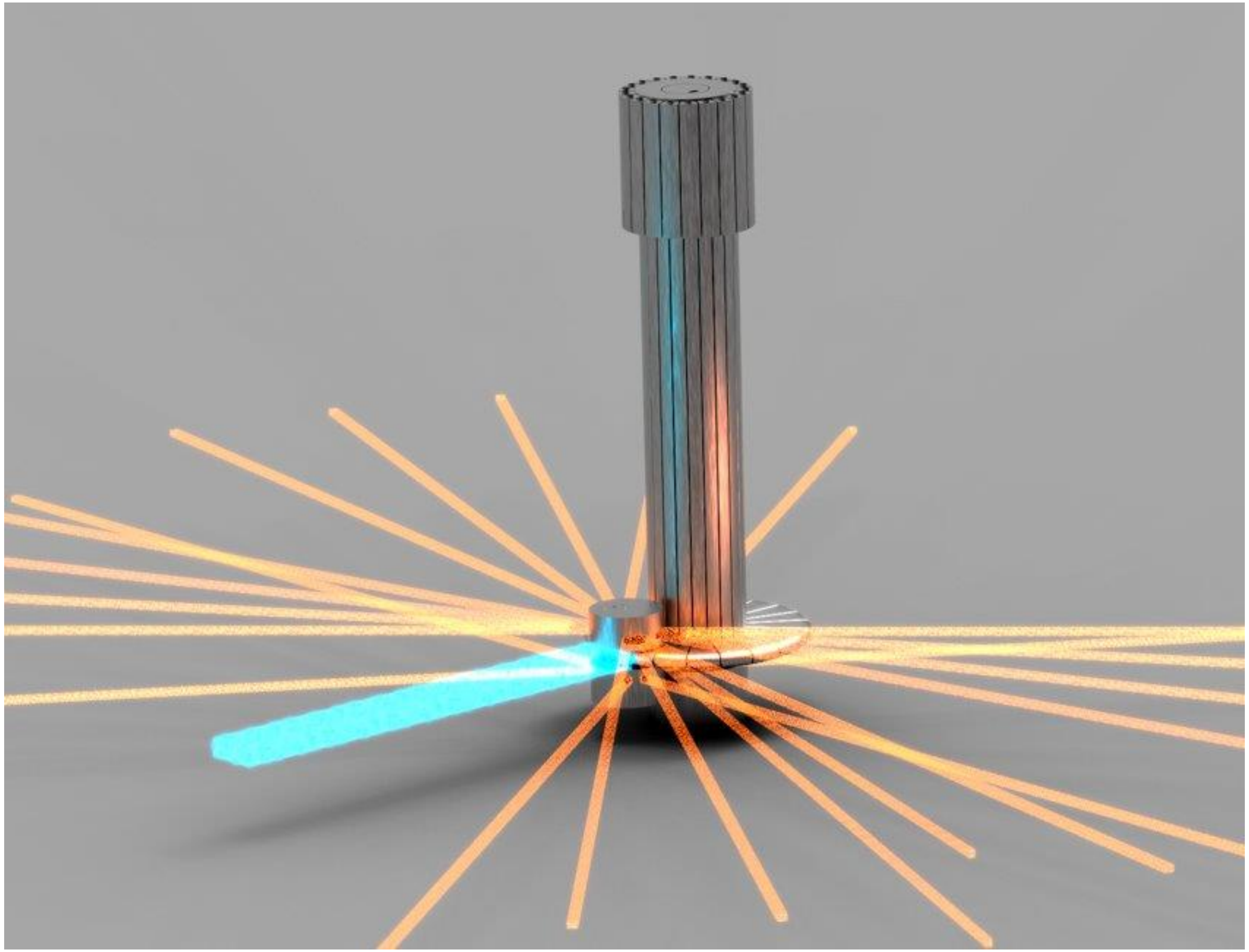
Peter Rosenblad
Mike Strong

November 25, 2020

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

Topics

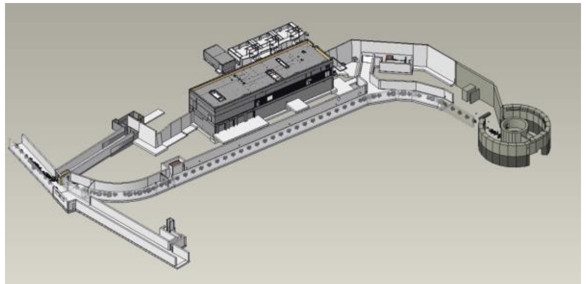
- Neutrons at ORNL
- STS Organization
- STS Schedule
- STS Requirements
- STS Technical Overview
- Target Systems Requirements
- **Target Systems Overview**



Scope is established to match requirements

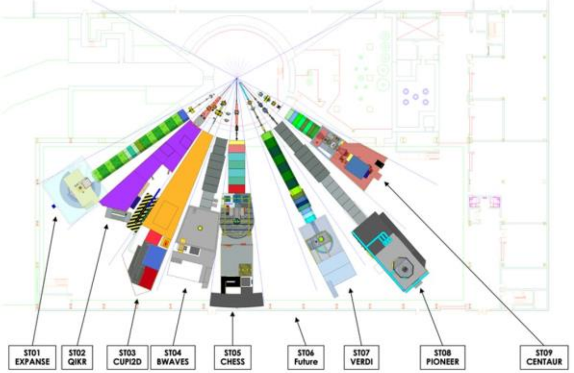
- Develop → design → manufacture → procure → install hardware necessary to convert protons into pulses of high brightness cold neutrons
- Includes all hardware within the monolith
- Includes water, cryogen, and gas systems necessary to cool the target systems in the core vessel
- Includes remote handling systems, tooling, and infrastructure necessary to maintain operation of the target systems, including the potential to perform PIE
- Includes Neutronics analysis necessary for design and operation of target systems
  - Target Systems Group also includes neutronics staff for all of STS

Key interfaces are established and actively updated

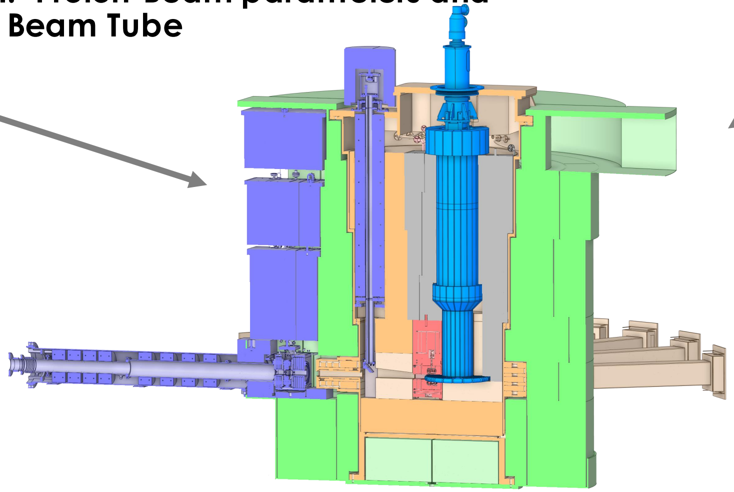


Accelerator Systems
- ICD issued, 4 interfaces identified
- **Two interface sheets in active revision control: Proton Beam parameters and Proton Beam Tube**

STS South Hall Instrument Suite



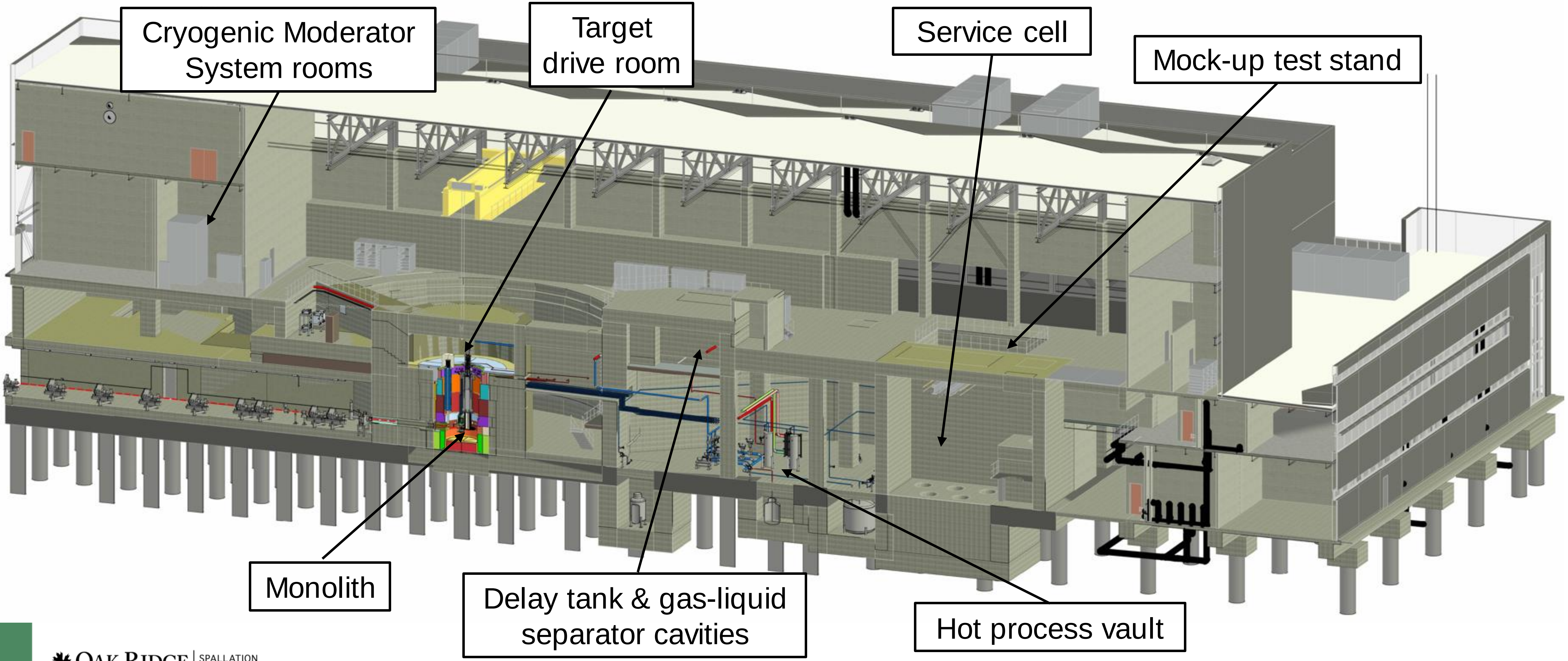
Instrument Systems
- ICD issued, 4 interfaces identified
- **One interface sheet in active revision control: Moderator Reflector Assembly**



Integrated Control Systems
- ICD issued, 14 interfaces identified
- **Six interface sheets are in active revision control: Target Viewing Periscope, Halo Monitors, Moderator Reflector Assembly, Process Systems I&C, TPS-Activated Cooling Loop 1, and TPS-Target Assembly**

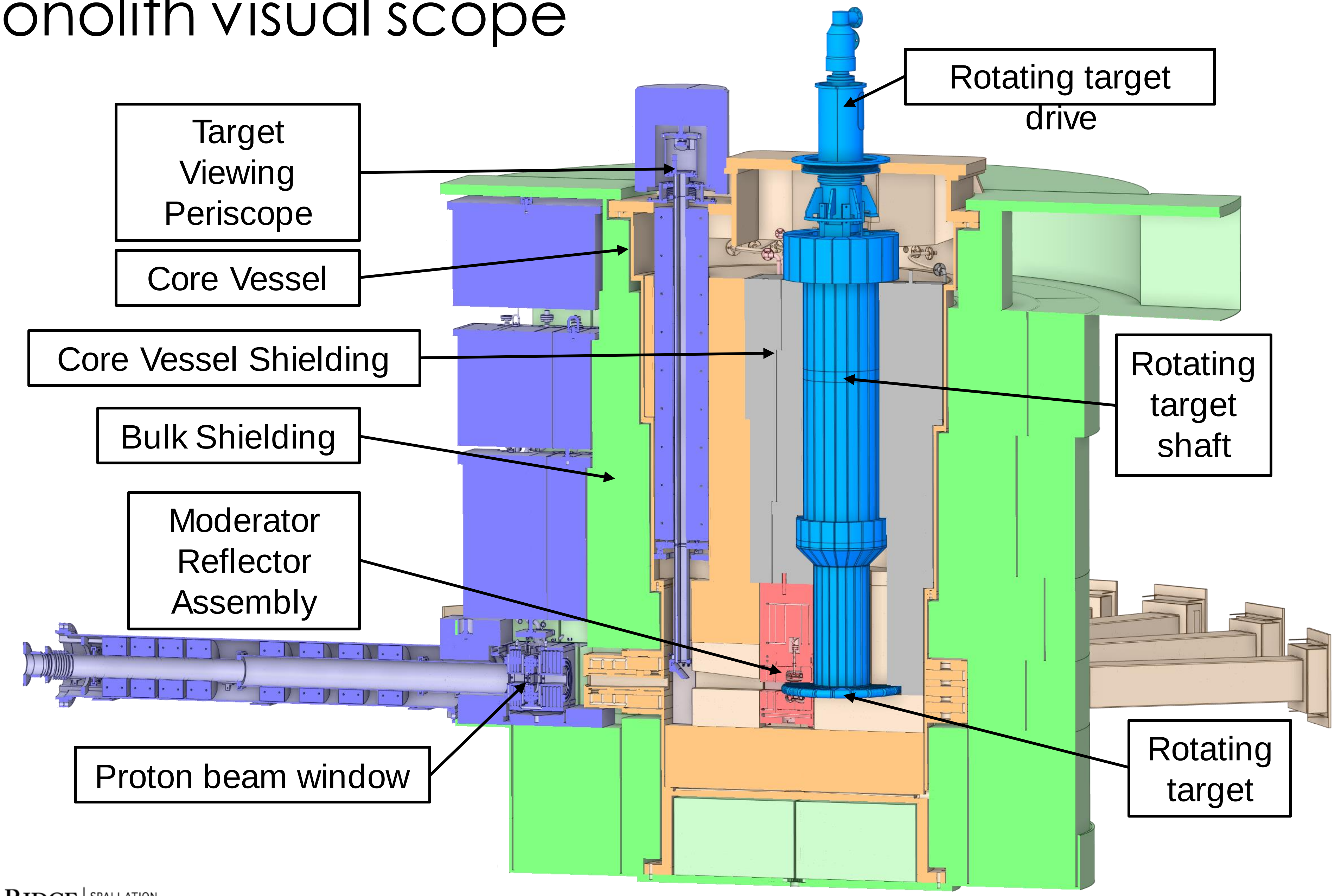
Conventional Facilities
- ICD issued, 18 IS identified

Target Systems visual scope



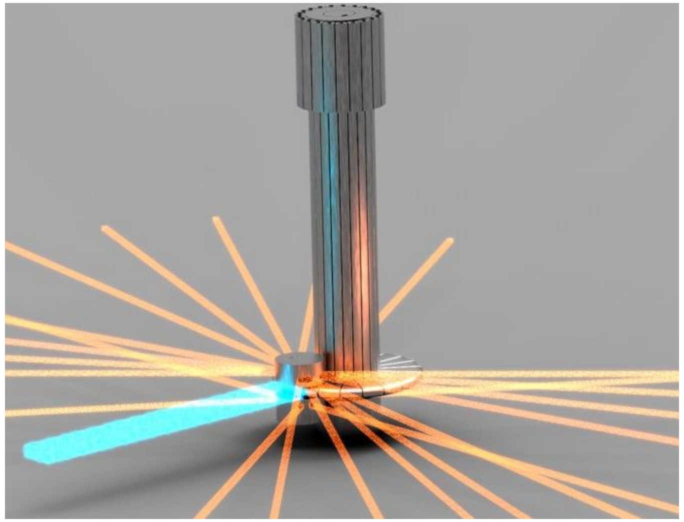
OAK RIDGE National Laboratory | SPALLATION NEUTRON SOURCE

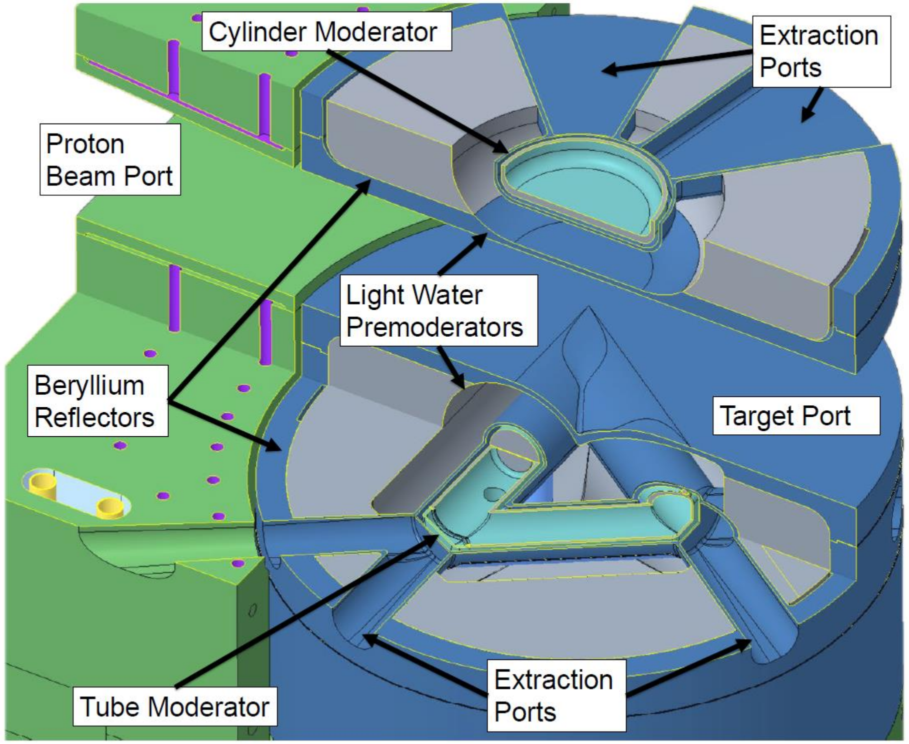
Monolith visual scope



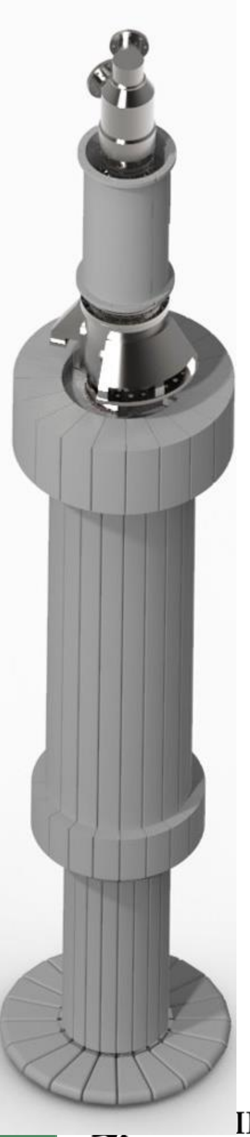
STS Target Systems key parameters / features

- 1.3 GeV, 700 kW, 15 Hz, 46.7 kJ/pulse
- Rotating tungsten target 1.1 m diameter x 60 mm tall
- Small (3 cm) 20 kelvin supercritical hydrogen moderators
  - Coupled and not poisoned
  - 2 cm light water pre-moderator
- Be reflector, no heavy water
- Aluminum proton beam window
- Core Vessel with flexibility for helium or rough vacuum operation
- Vertical only maintenance
- No heavy shutters – neutron optics close to moderator face with minimal windows



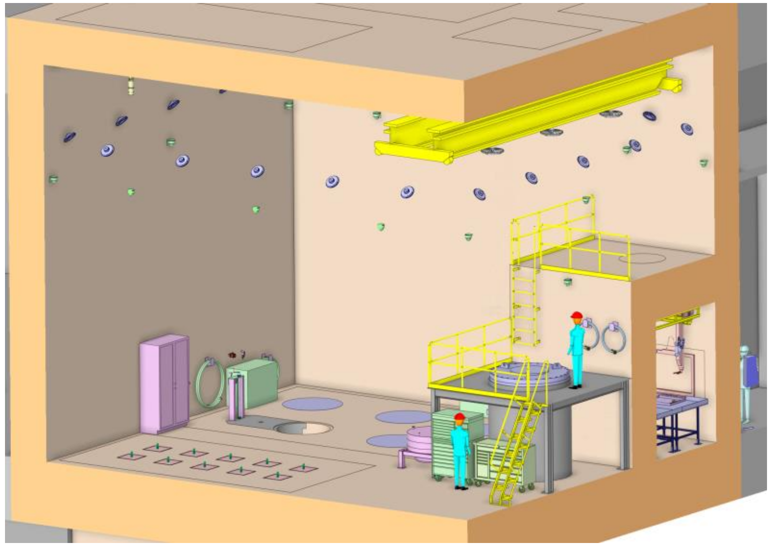


Key Target Systems decisions and relation to MRA



- Rotating Target – afterheat protection, efficiency
  - No lateral reflector material in MRA
- Vertical access to target
  - MRA "captures" target
- Segmented Target – maintenance, availability, and flexibility
  - MRA removal / installation is couples with removal of at least 3 segments
  - MRA is pure vertical removal / installation
  - Upward dose during removal is

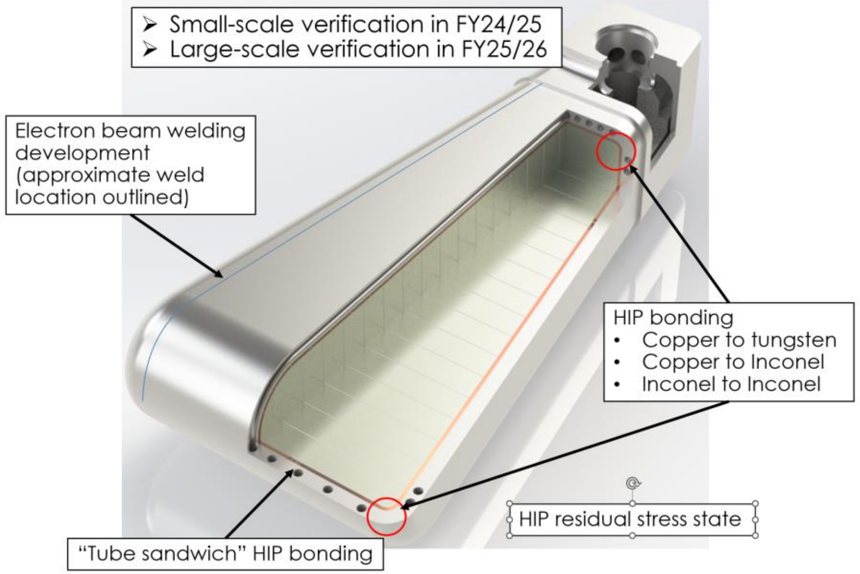
- Brightness optimization – small proton beam, small target, close moderators
  - MRA configuration, manufacturability, tolerances, and alignment
- Single hydrogen loop for both moderators – facility simplification and cost savings
  - MRA moderators in series



- Target Viewing Periscope included
  - MRA provides viewing path
- Cost effective future PIE capability included
  - Focus is target block – no requirements for MRA PIE

Remaining Target Systems key challenges

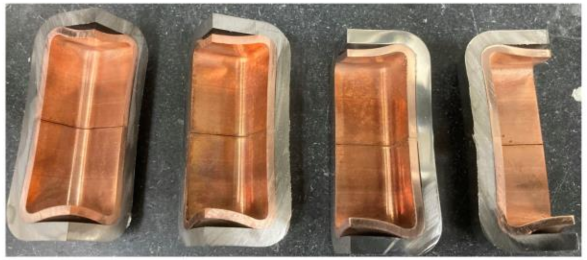
- Target block manufacturability
- Core Vessel Beltline manufacturability
- Design coordination, particularly with conventional facilities and integrated controls
- Execution!

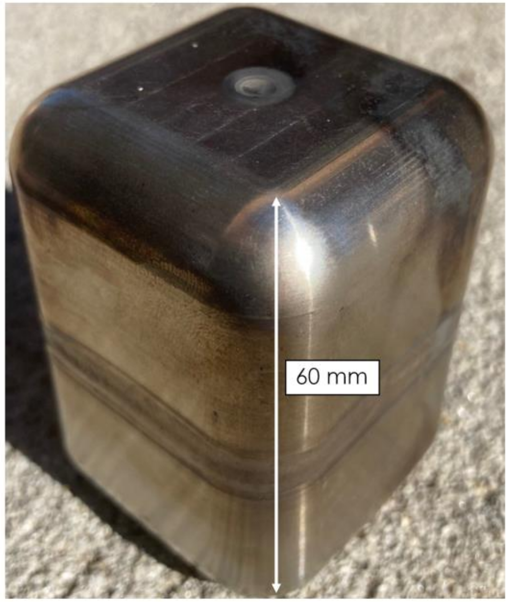


Mk. 1 small-scale HIP test article – 4 mm Inconel shell

Piece parts


Pre-HIP


Weld development



Post-HIP

Summary

- STS will provide world class neutron brightness to an initial suite of 8 instruments, expanding ORNL's leadership in neutron scattering science
- STS requirements are established, which drive project scope across 5 technical systems
- STS Target Systems requirements are established and key design decisions have been based on these requirements
- MRA preliminary design supports Target Systems and STS requirements, specifically towards:
  - Beam parameters
  - Neutron brightness
  - Number of instruments
  - Availability
  - Maintenance
  - Waste path