OAK RIDGE National Laboratory

STS / Target Systems Overview

Peter Rosenblad

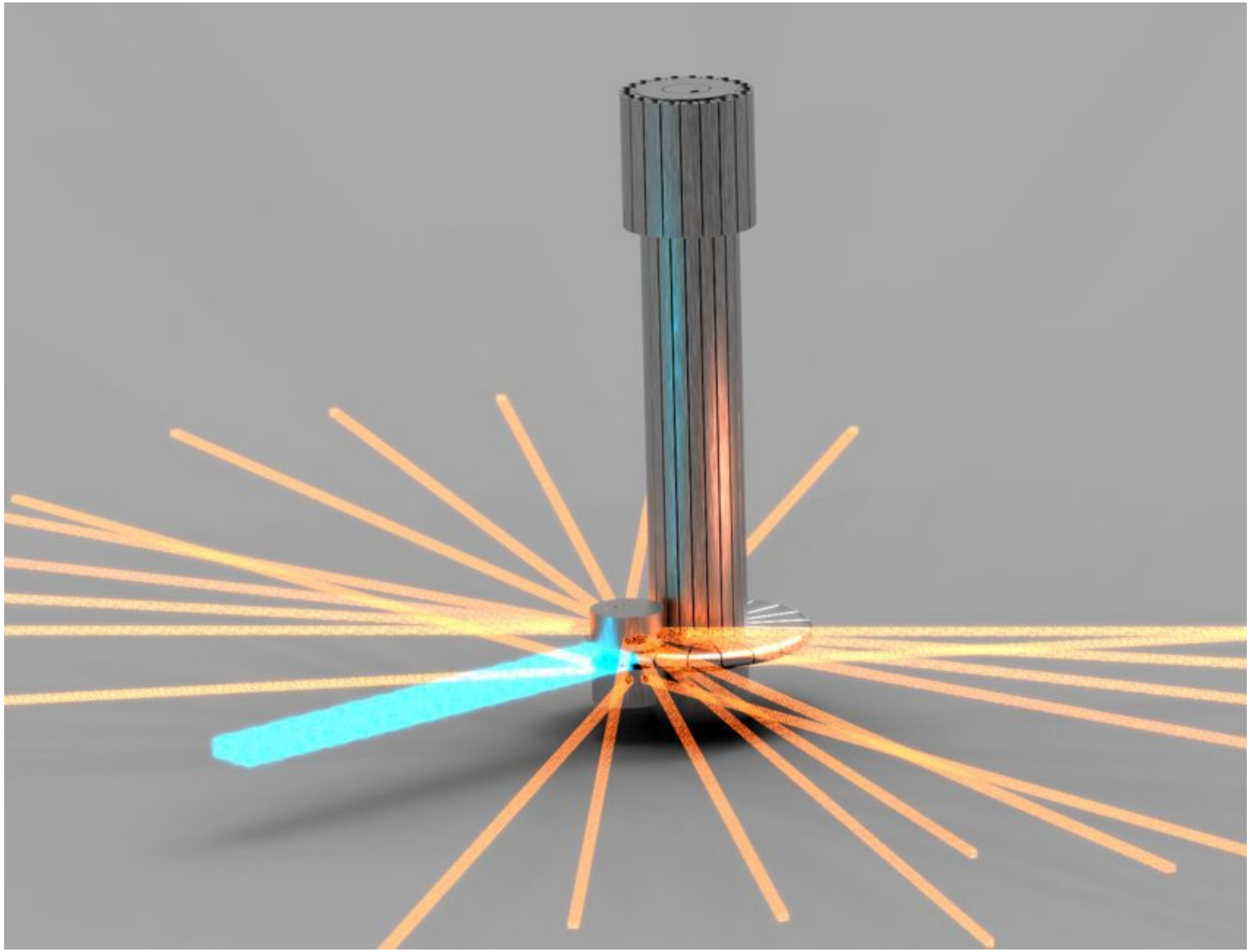
MRA Preliminary Design Review

3/26/2024

U.S. DEPARTMENT OF ENERGY

Topics

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



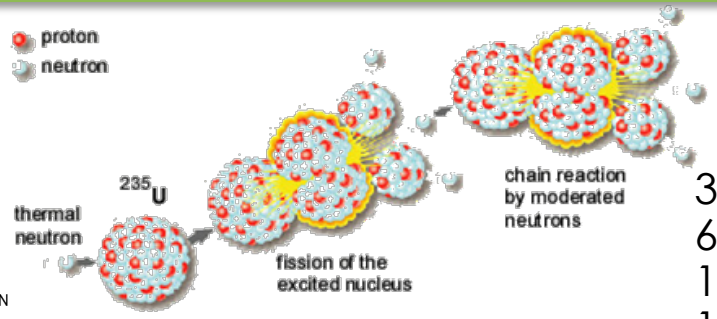
Today ORNL operates two of the brightest neutron sources

High Flux Isotope Reactor (HFIR)

Highest continuous neutron flux

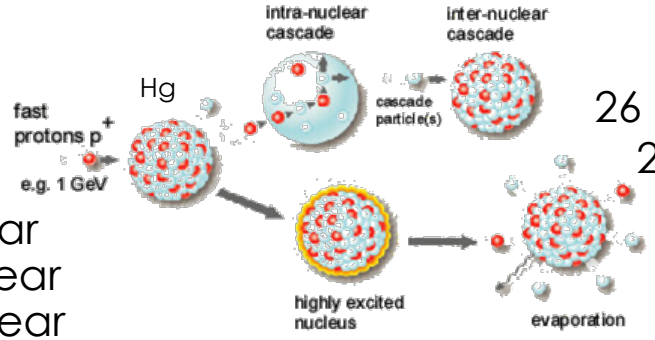
Spallation Neutron Source (SNS)

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

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SNS upgrades will accelerate scientific progress and deliver wholly new capabilities

PPU project: Double the power of the existing accelerator structure

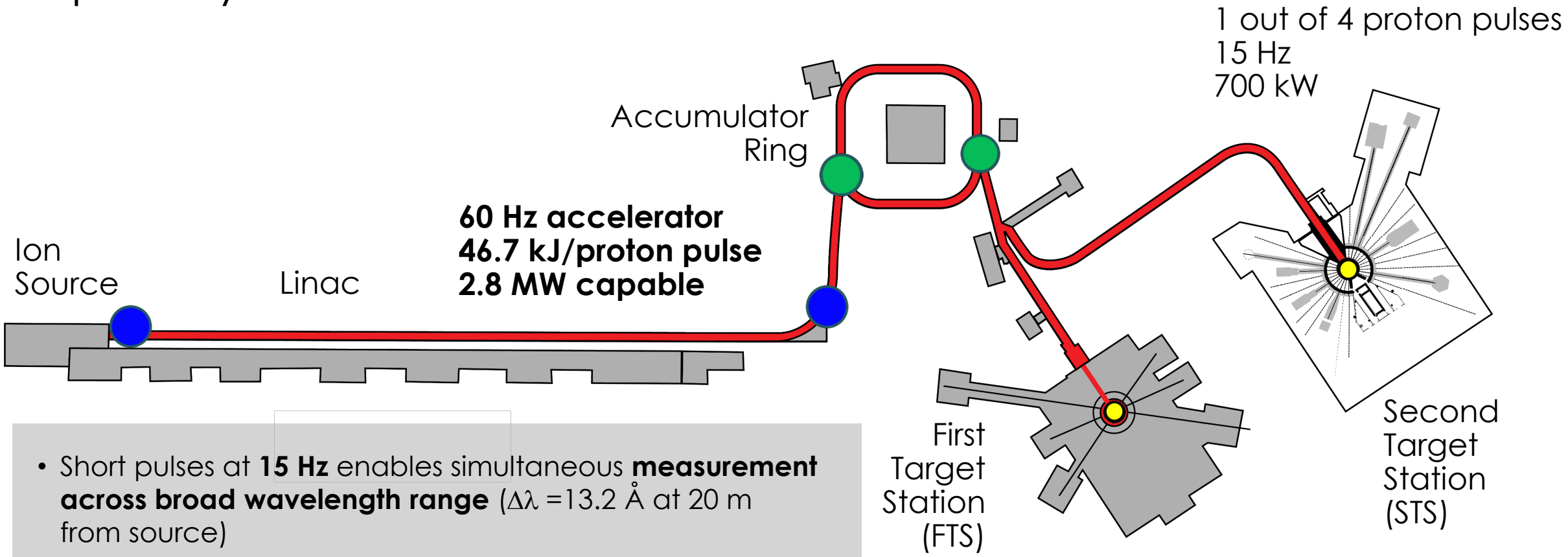
- First Target Station (FTS) is optimized for thermal neutrons
- Increases the brightness of beams of pulsed neutrons
- Provides new science capabilities for atomic resolution and fast dynamics
- Provides a platform for STS

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

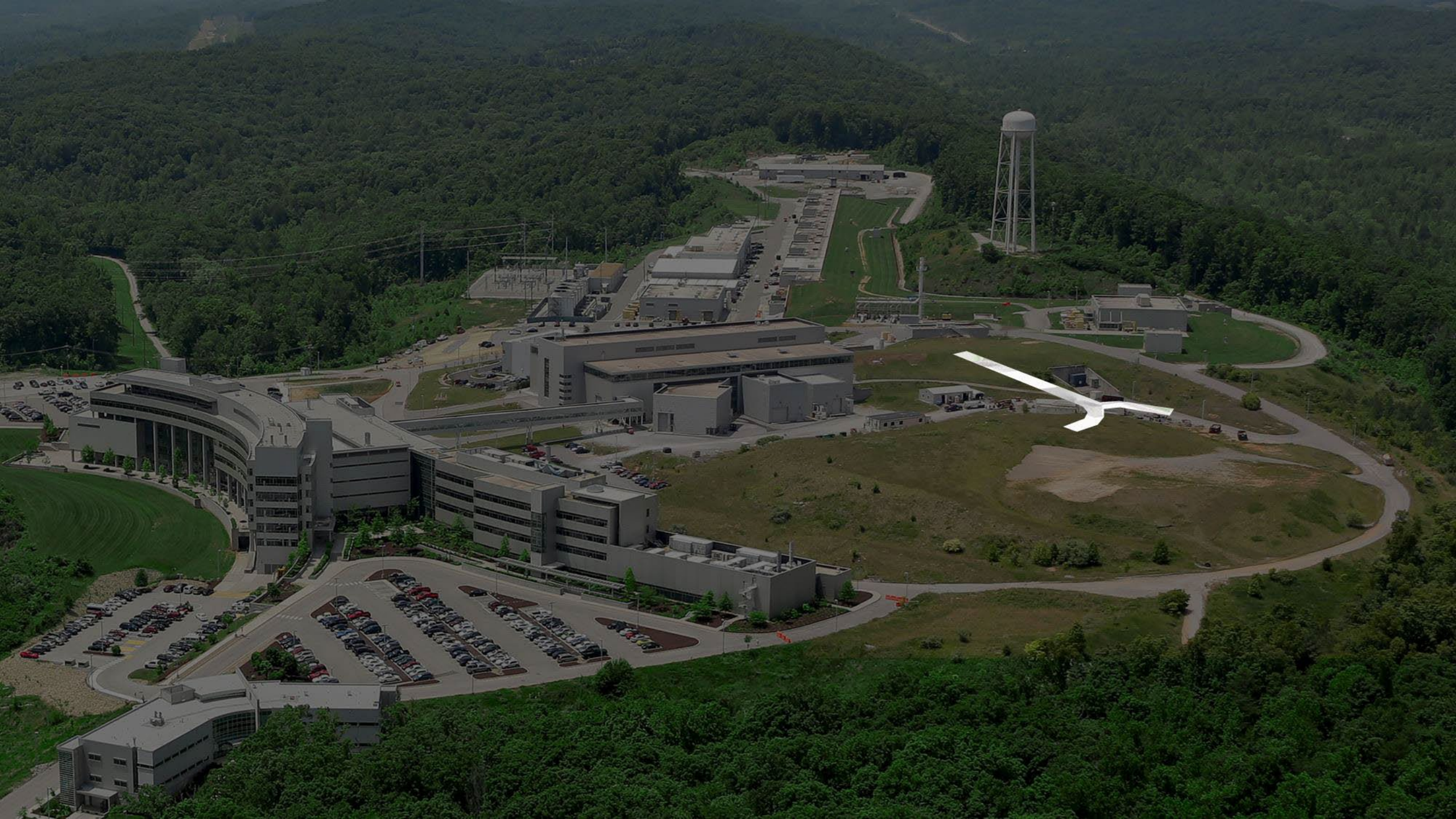
STS instruments see 4x more and 100x faster than today's similar instruments

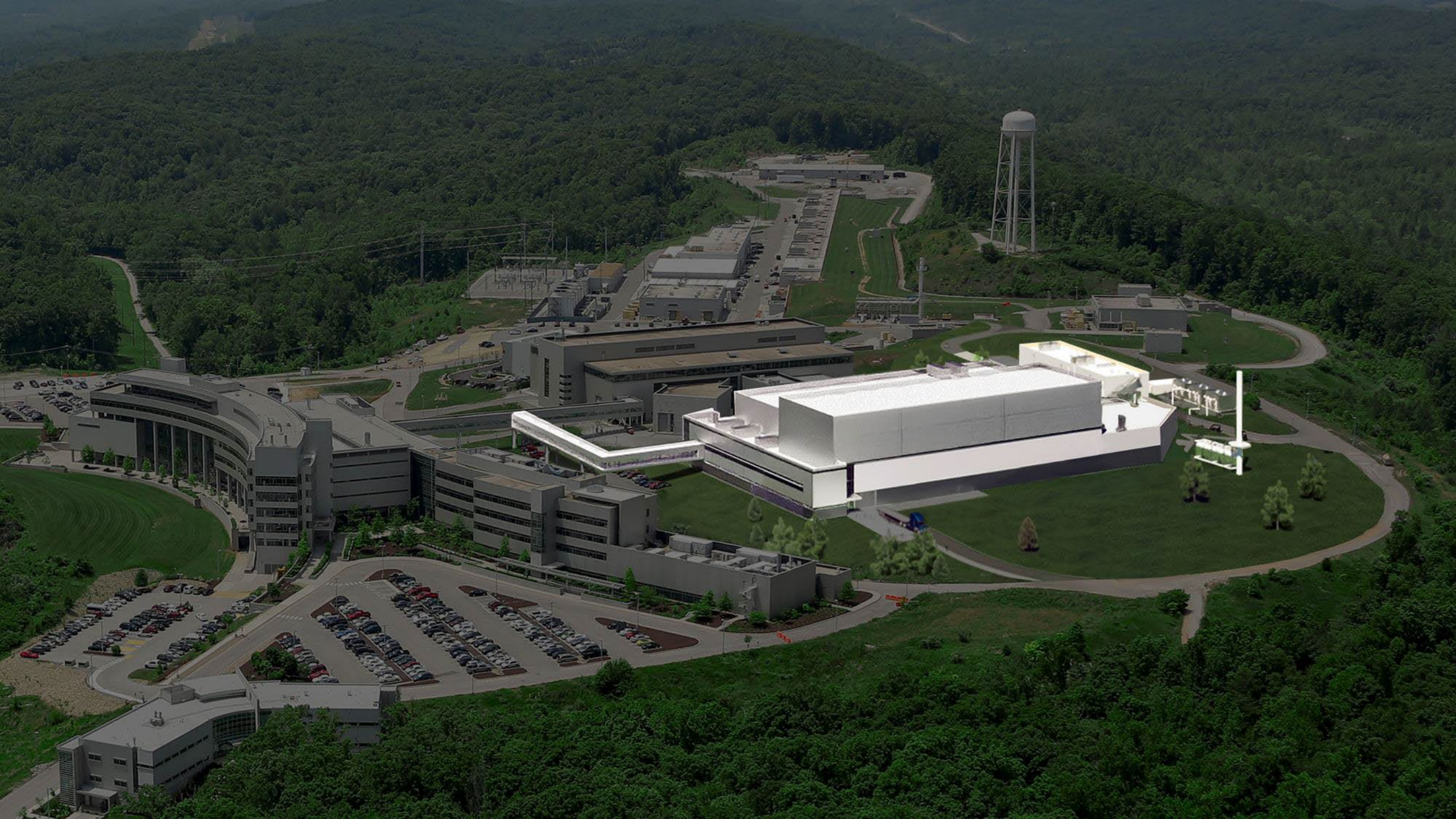
STS will make optimal use of the PPU-upgraded SNS accelerator capability



- 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





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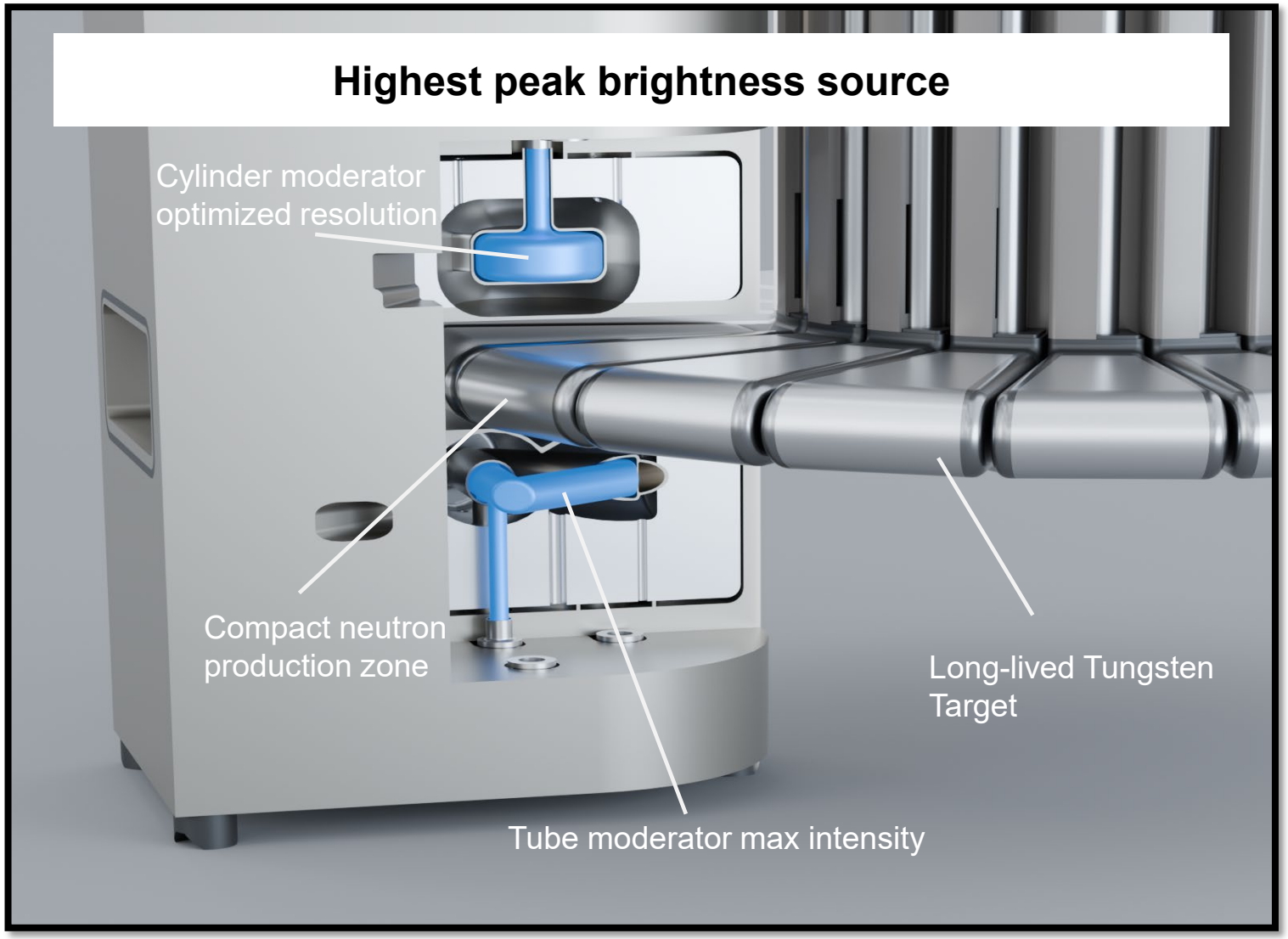

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Office of Research Education: Moody Altamimi
Partnerships: Shaun Gleason
UT-Oak Ridge Innovation Institute: David Sholl

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US ITER Project
Kathy McCarthy, Project Director

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Andrew Petzold, Director (Interim)
Stacy Boggs, Operations Director

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- **Research Computing Support Division** Brett Ellis

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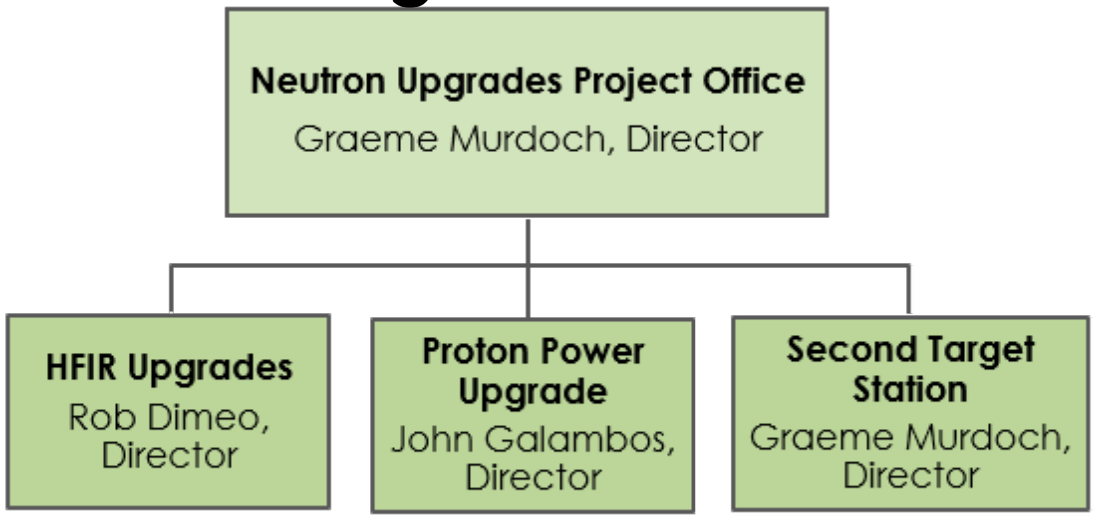
Neutron Upgrades Project Office (NUPO) established to consolidate major upgrades under one organization

- Reports through the ORNL Laboratory Director, and coordinates/ collaborates closely with the Neutron Sciences Directorate (NScD)
  - Share resources where appropriate
    - Accelerator physics support, target engineering, instrument scientist support, instrumentation & controls staff, survey & alignment, etc.



- Share lessons learned across NUPO projects
- Share engineering and business best practice across projects within NUPO and NScD
  - Engineering protocol, product lifecycle management (PLM)
  - Power BI tools for finance and project controls
  - ESH&Q, Facility Safety

STS Project organization chart

Project Advisory Board
Thom Mason, Chair

Oak Ridge National Laboratory
Stephen Streiffer, Laboratory Director

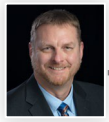
Program Office
Bindu Nair, AD, BES
Andy Schwartz, Deputy AD, BES
Ed Stevens, Program Manager

ORNL Site Office
Trey Wheeler, OSO Manager
Wendy Cain, Federal Project Director

External Committee
Technical Advisory Committee
Carl Strawbridge, Chair

Second Target Station Project

Graeme Murdoch, Project Director



Duke Hughes, Project Manager

Ken Herwig, Technical Director

Executive Assistant, Suzanne Reichert

S.01

Project Support

Business Manager, Justin Ferrell

Communications Coordinator, Amy Keller

ESH&Q Manager, Steve Trotter

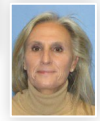
Human Resources Manager, Michelle Mazerolle

Procurement Manager, Landon Hill

Project Controls Manager, Ben Fox

System Eng. & Integration Lead, David Anderson




Accelerator Systems
Michael Allitt

S.02

Target Systems
Peter Rosenblad

S.03

Instrument Systems
Leighton Coates

S.04

Conventional Facilities
Gary Bloom

S.05

Integrated Control Systems
Steven Hartman

S.06

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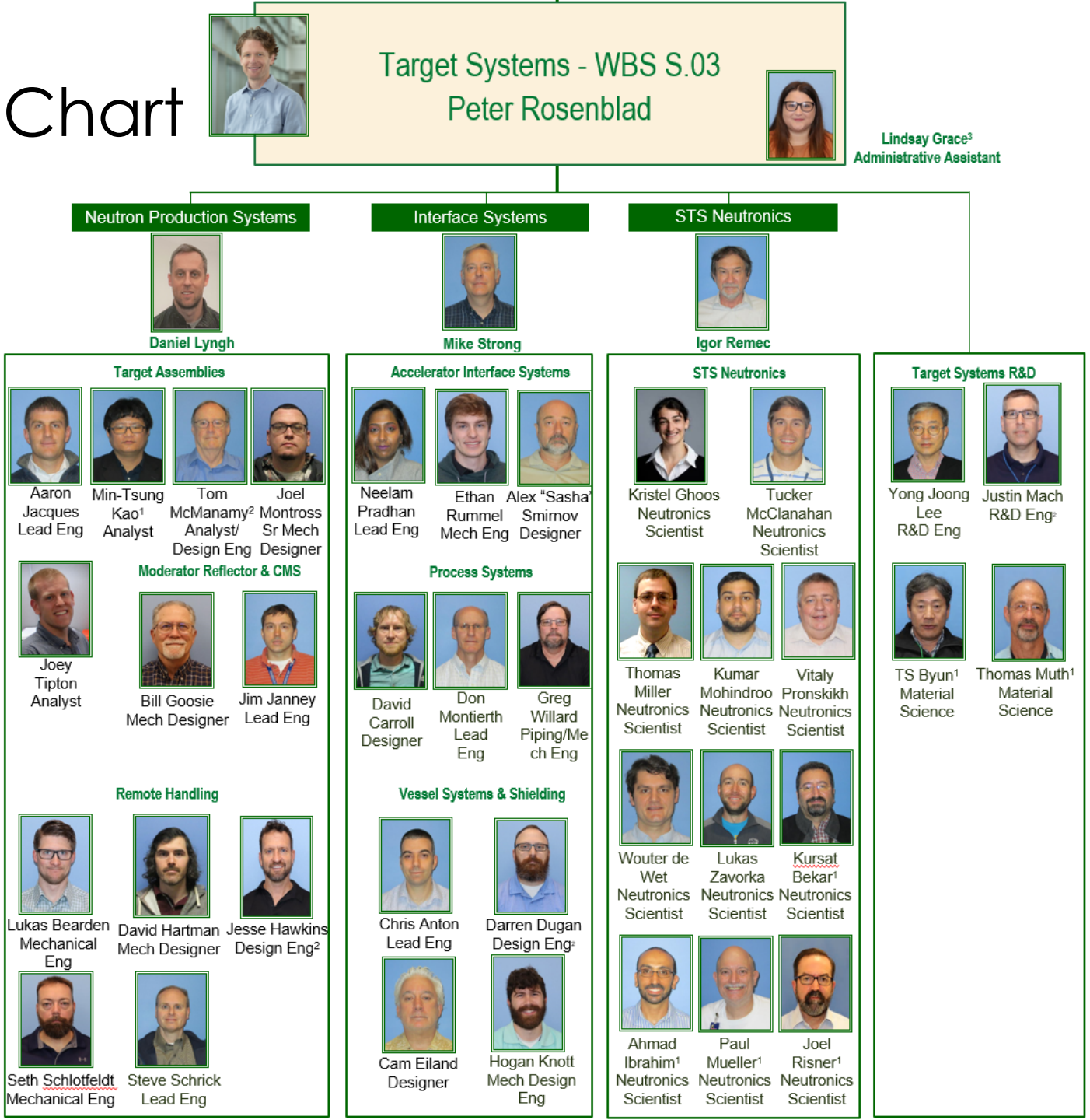
Target Systems Org Chart



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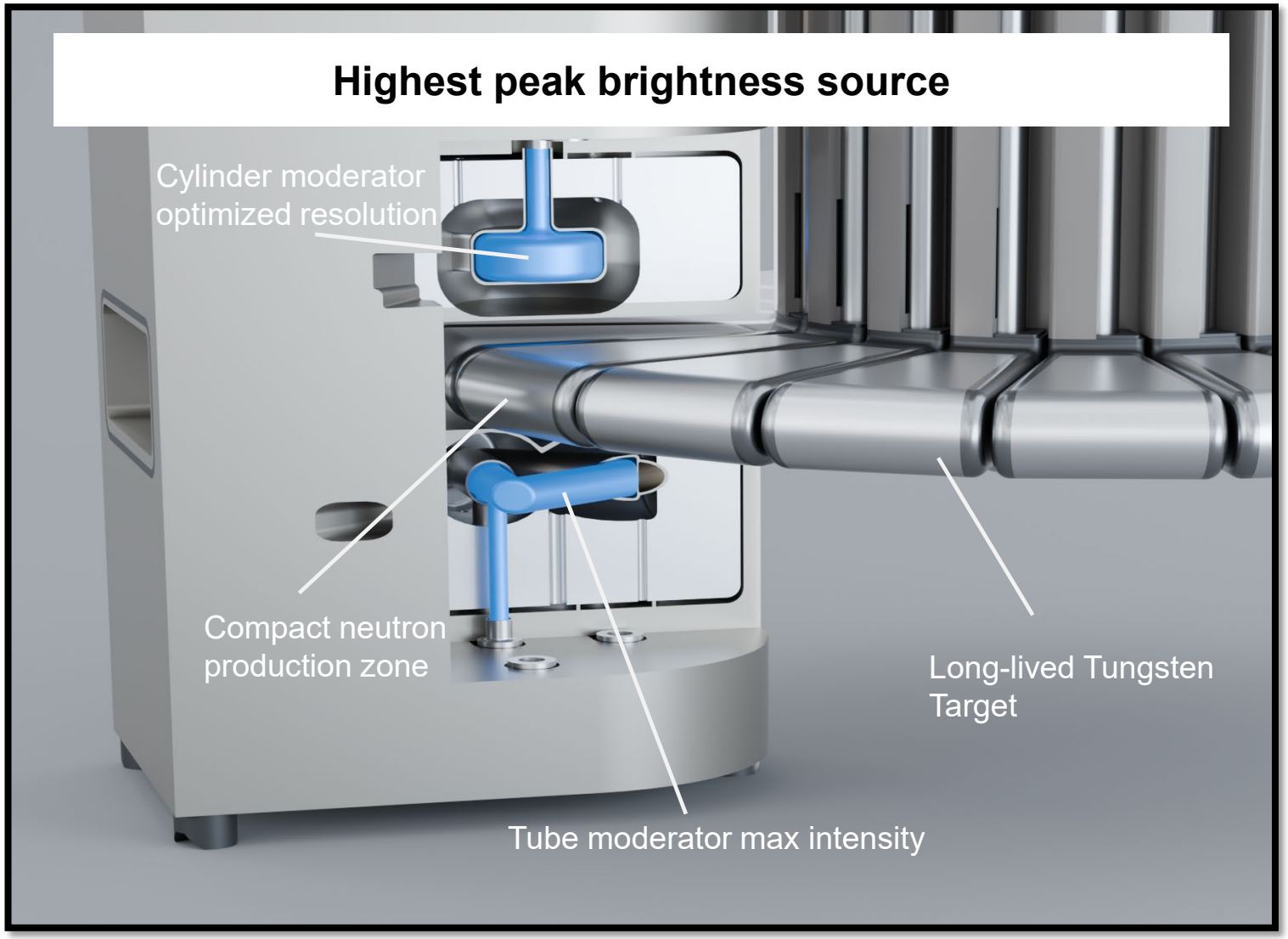
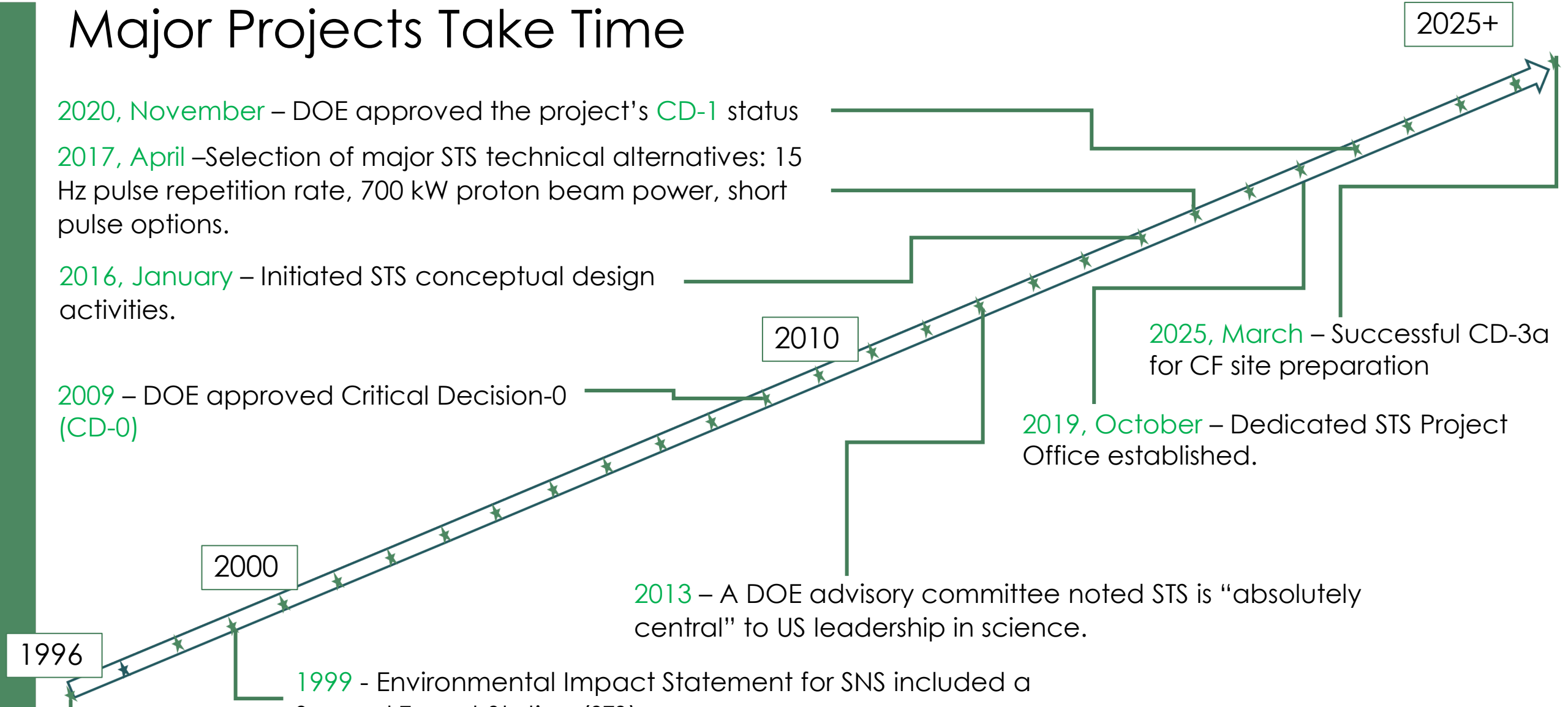
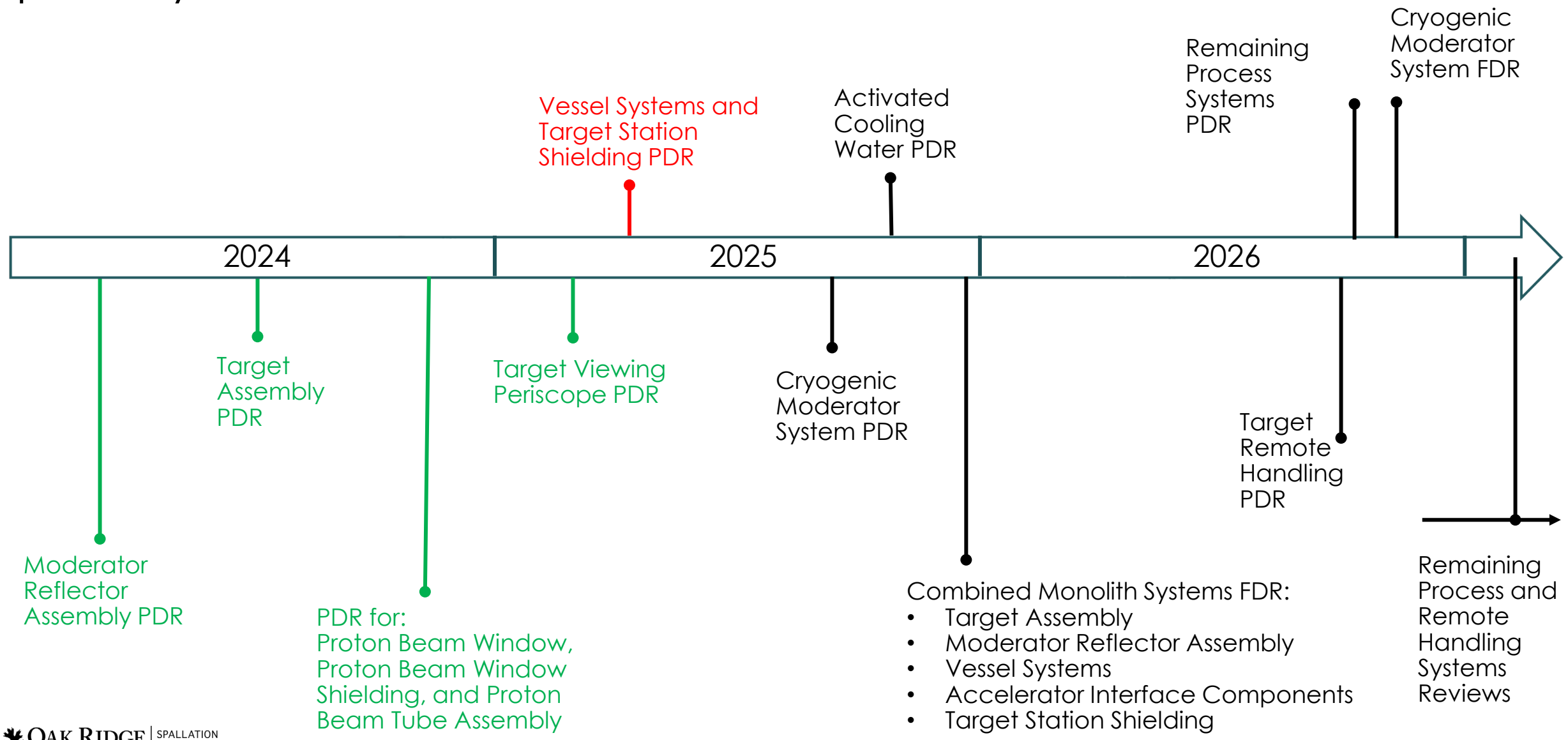


Major Projects Take Time



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



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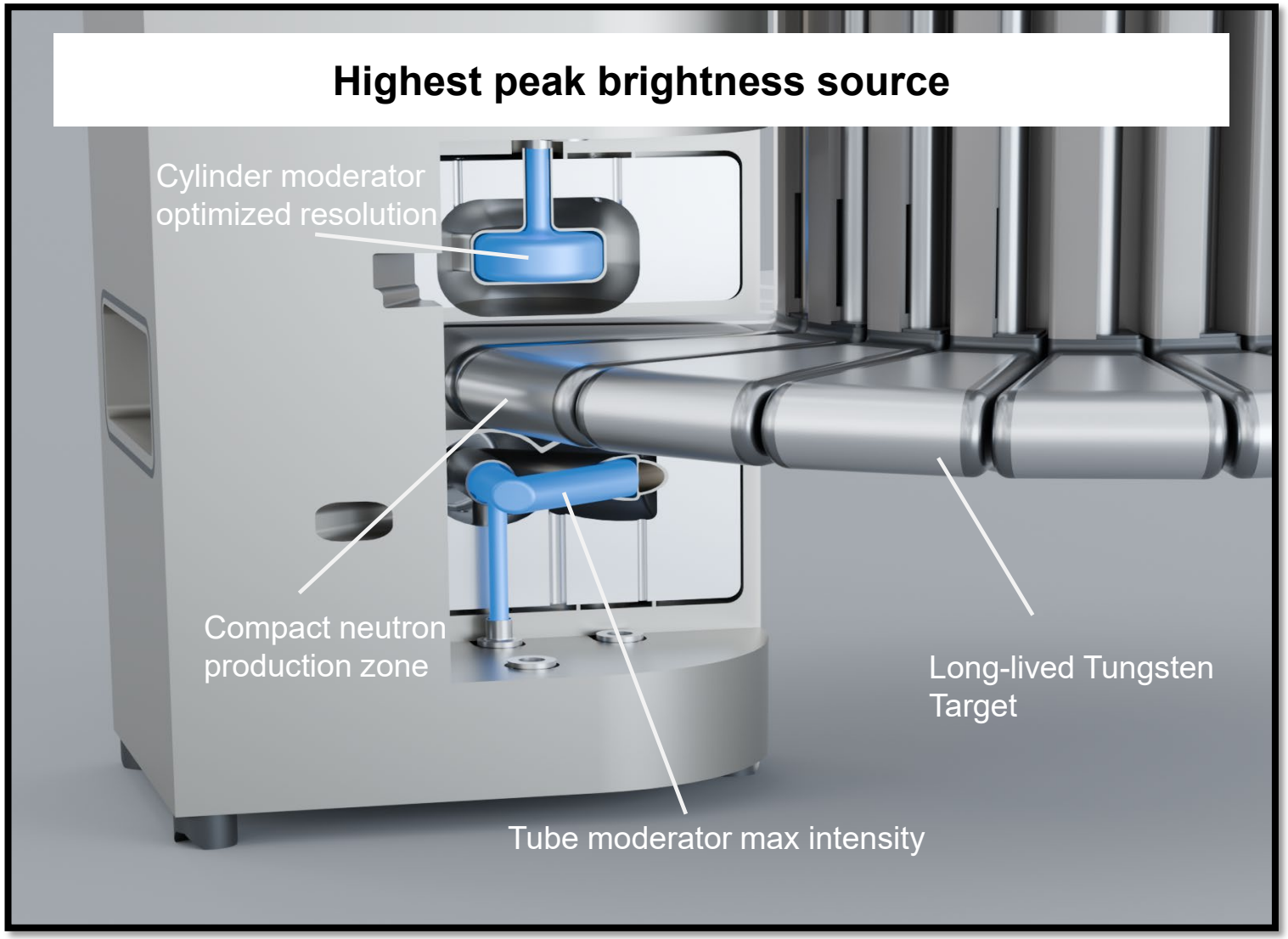
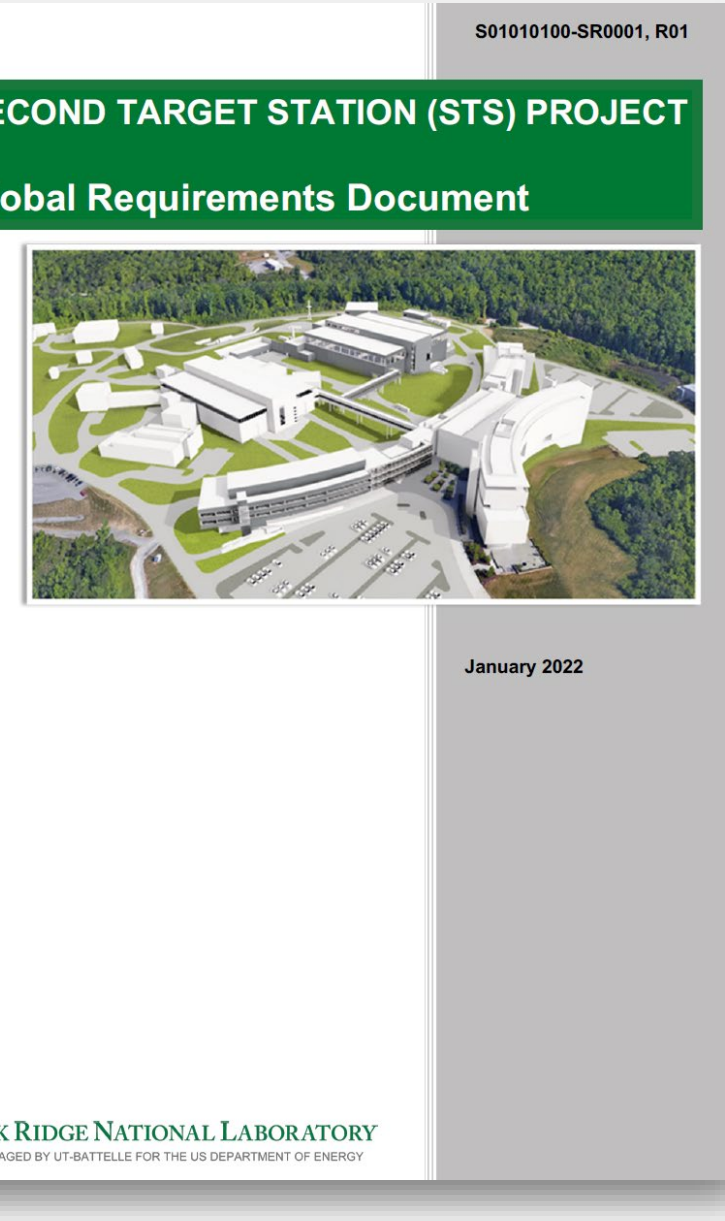


Preliminary Key Performance Parameters (PKPP) provide highest level of requirements

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



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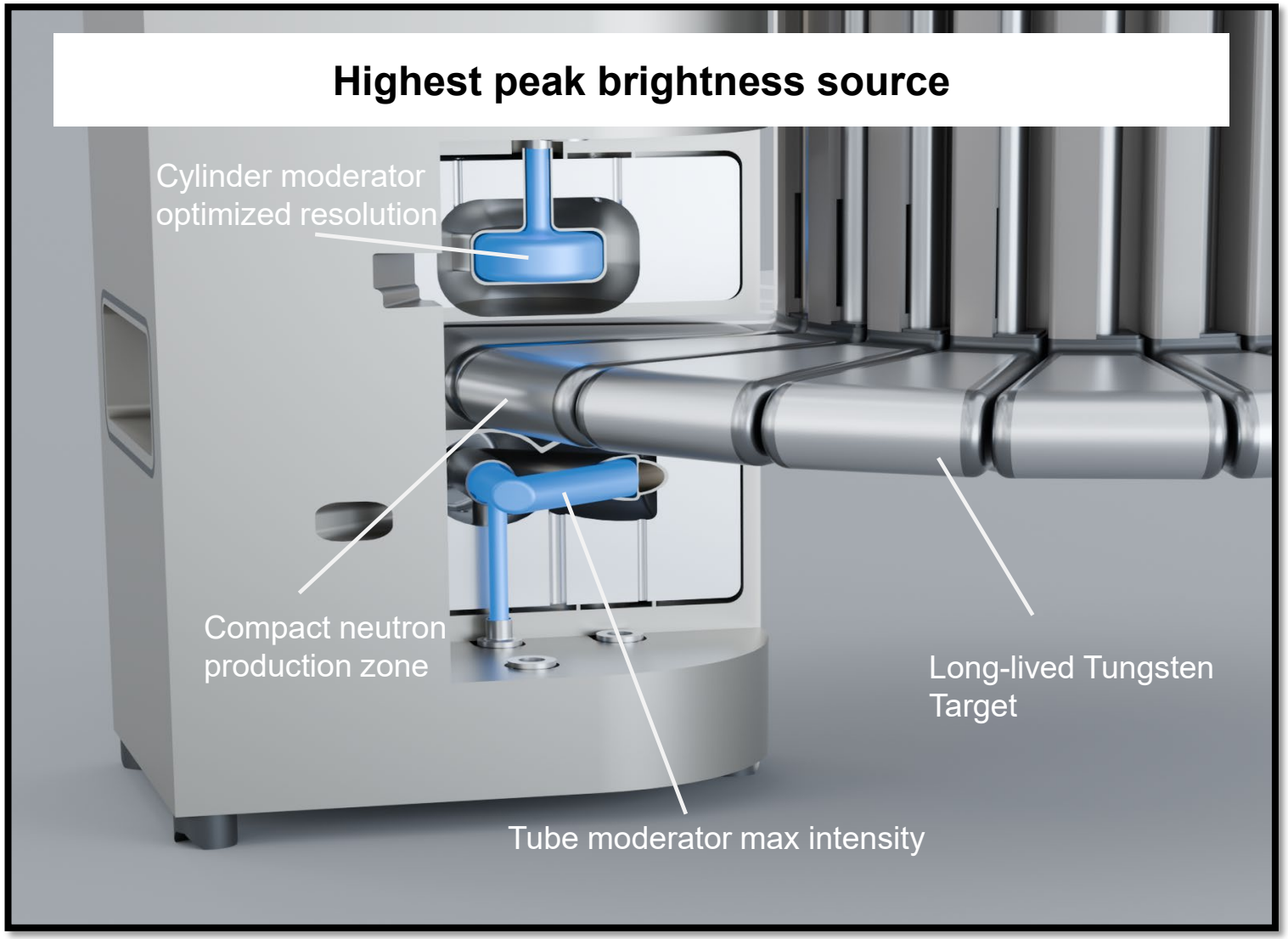


Preliminary design scope supports case for achieving world-leading capability

Accelerator

- Transport protons to STS operating at 15Hz
- Independent operation of First Target Station (FTS) and STS

Target

- Solid rotating water cooled tungsten target
- 2 high brightness, supercritical H_2 moderators

Instruments

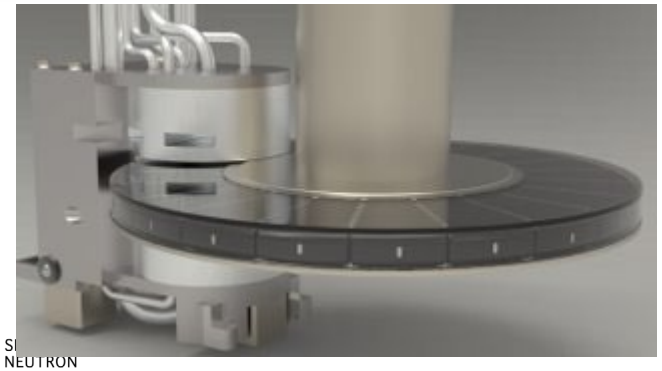
- Provide capability for ~20 instrument end stations
- 8 beamline instruments included in STS scope

Conventional Facilities

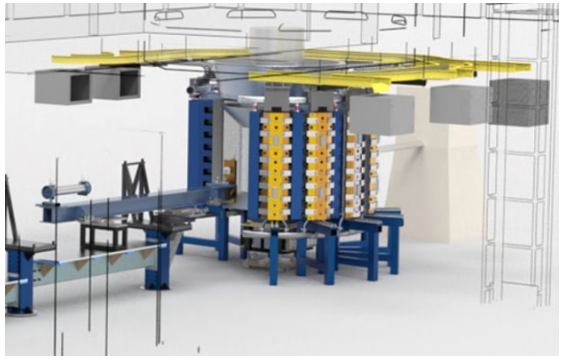
- ~220k square feet of new infrastructure

Integrated Controls

- 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

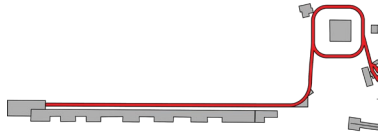
STS uniquely combines advanced technologies to deliver new science capabilities needed to understand more complex materials, processes, and devices

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

+

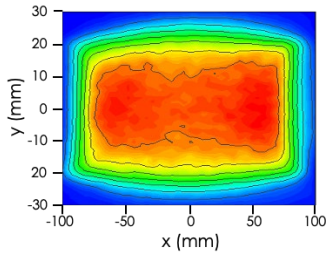
Use the accumulator ring to compress the proton pulse



1 msec linac production compressed to < 1 μsec

+

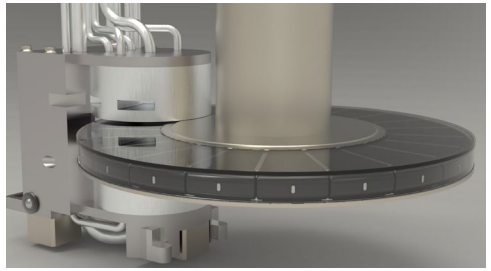
Add optics & transport to produce uniform proton spot size on the target



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

+

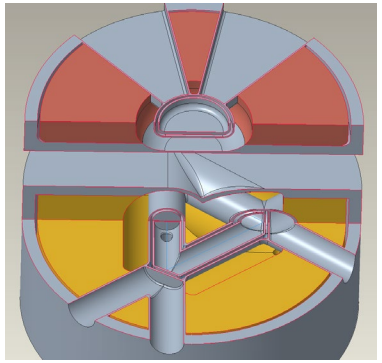
Add rotating, segmented solid-tungsten target



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)

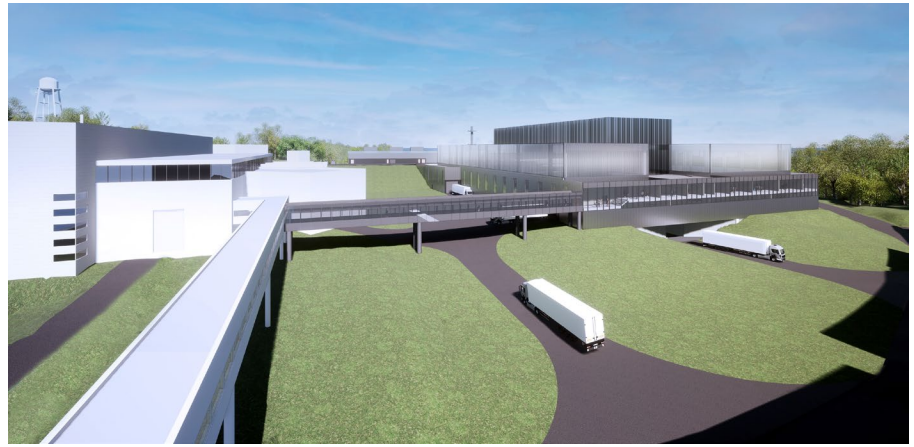
+

Add science-driven, optimized instrument designs

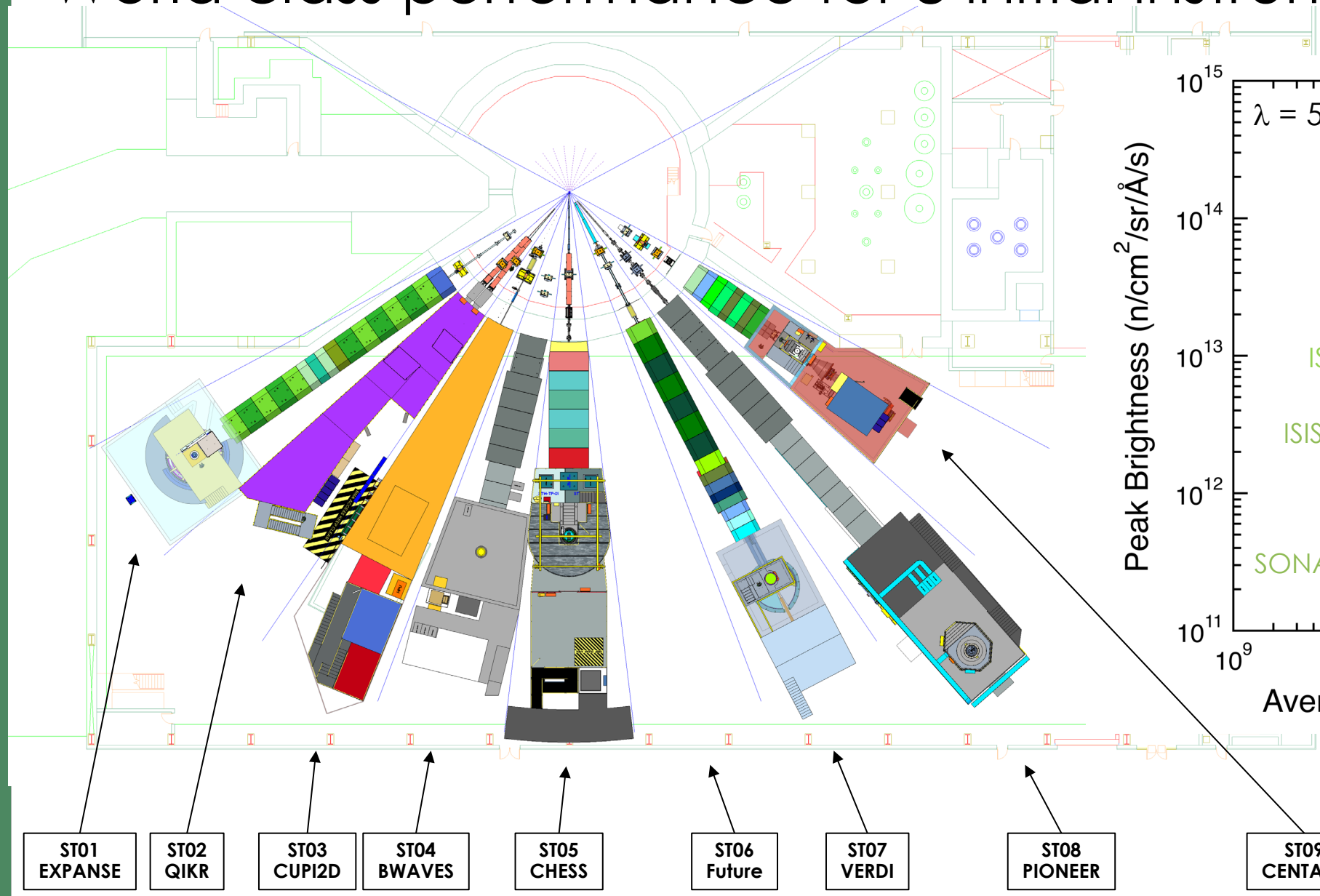
8 initial STS instrument, latest technologies, integrated controls, scientific software, proposed by and selected with the user community

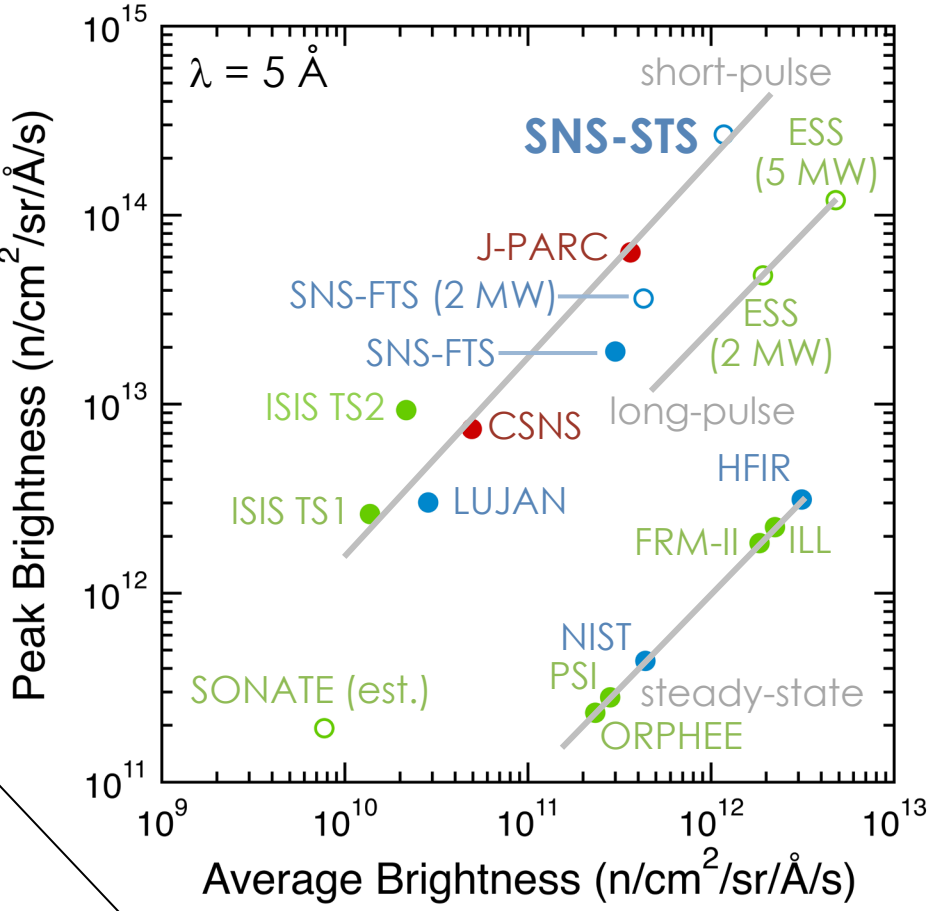
=

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



World class performance for 8 initial instruments





USA
Asia
Europe

○ Planned
● Existing

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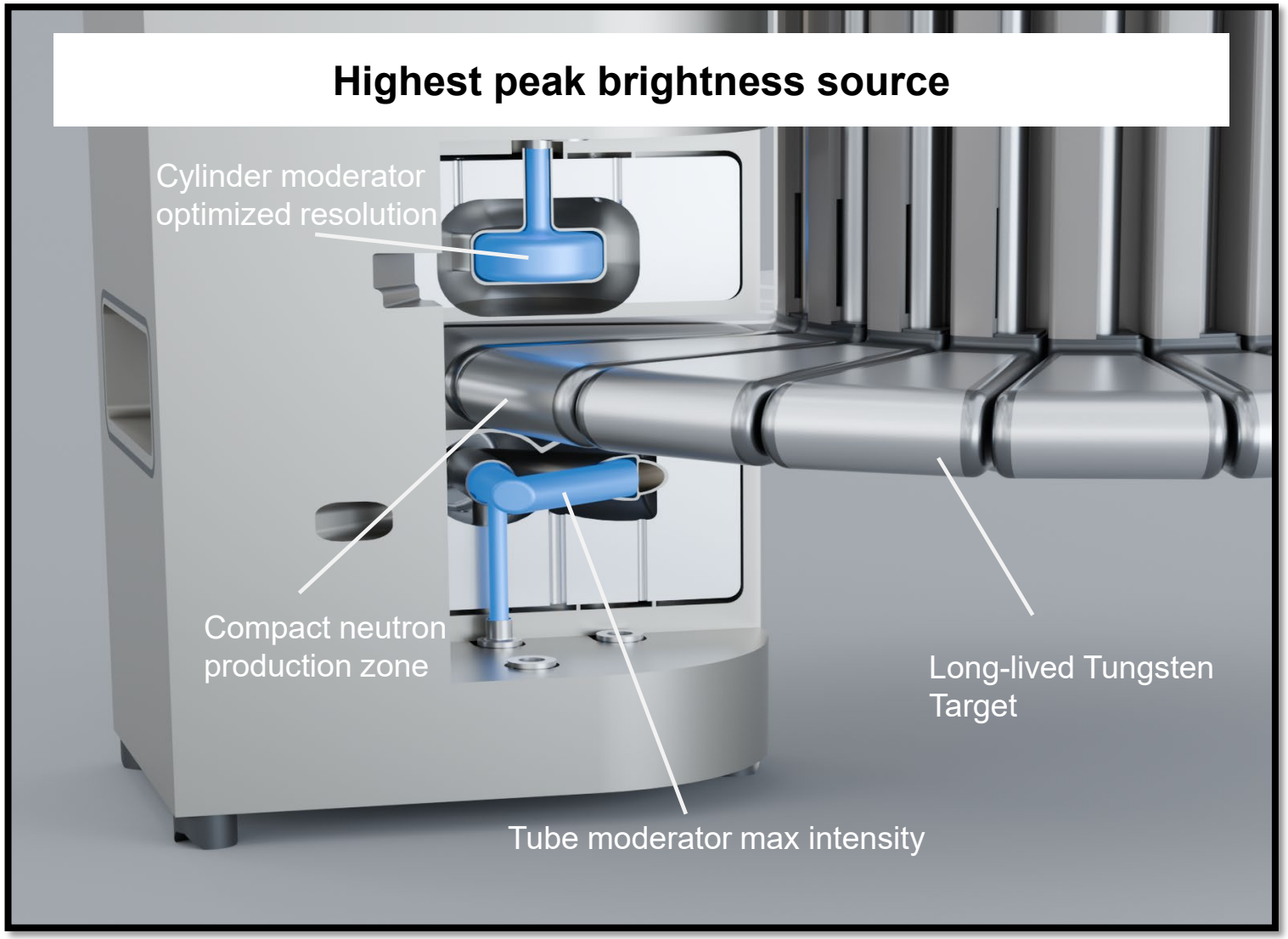
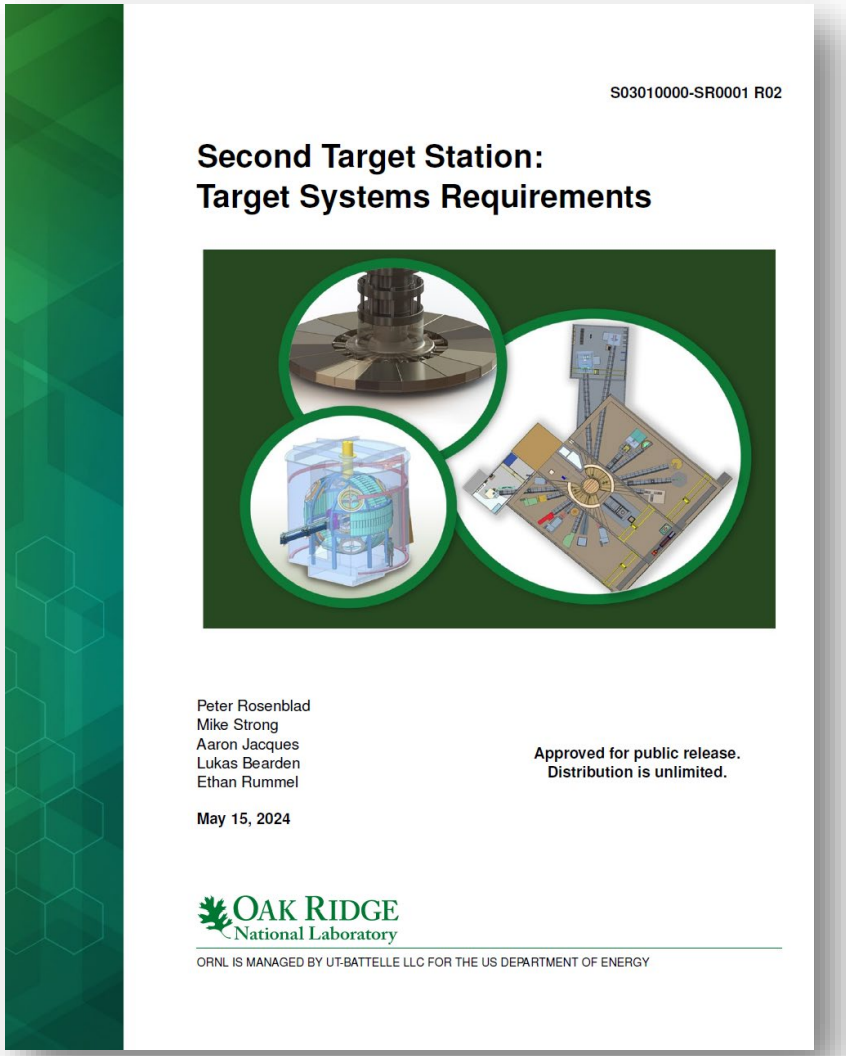


Target Systems (Level 2) requirements are established

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
- Allow safe operation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Second Target Station:
Target Systems Requirements

Peter Rosenblad
Mike Strong
Aaron Jacques
Lukas Bearden
Ethan Rummel

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May 15, 2024

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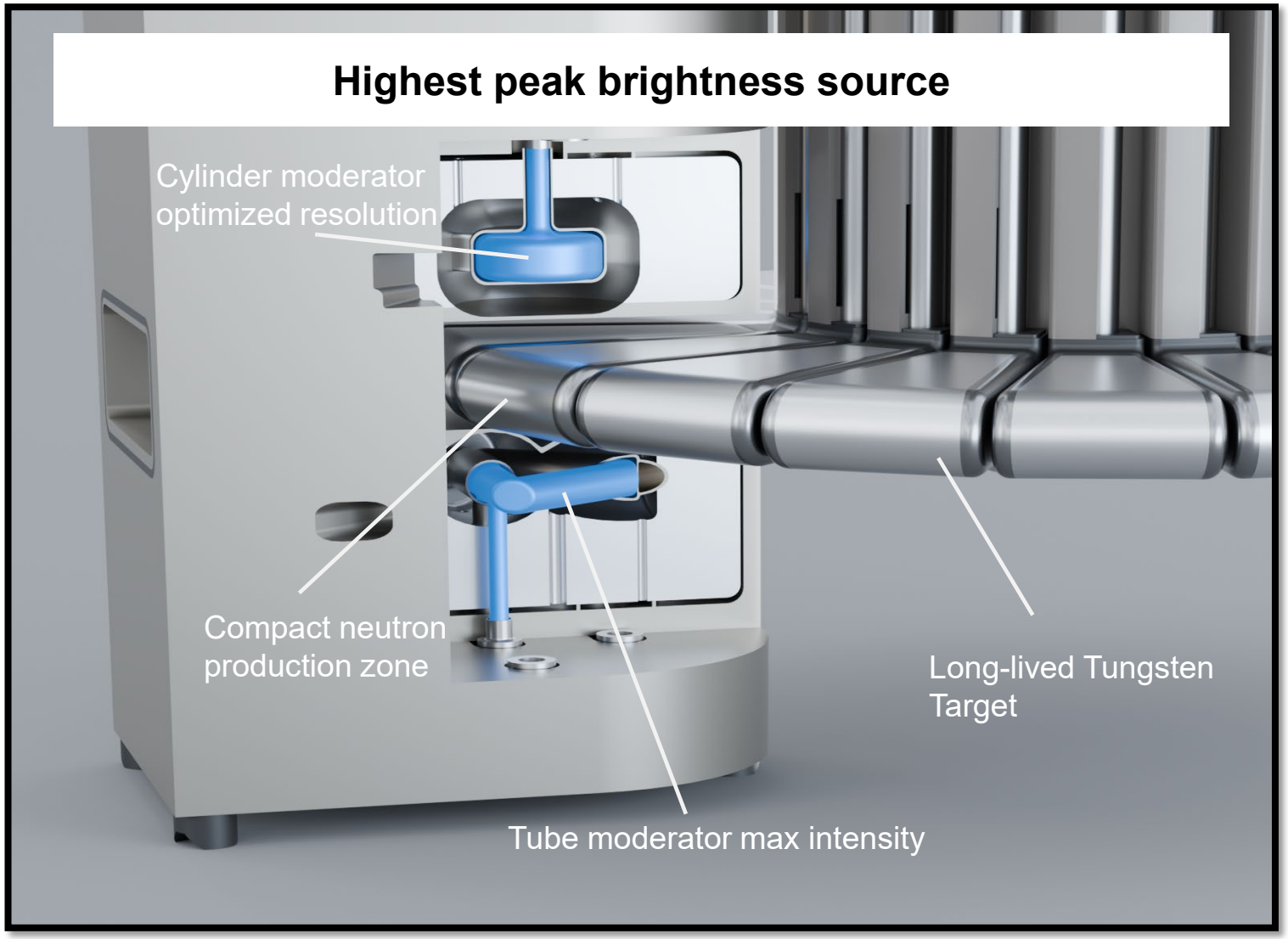
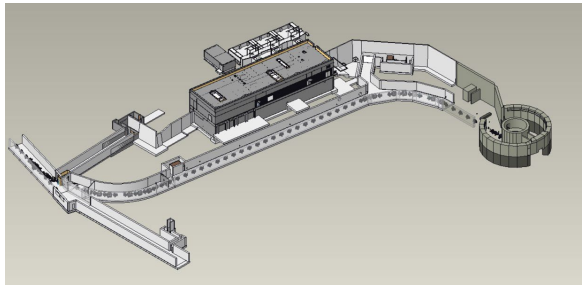
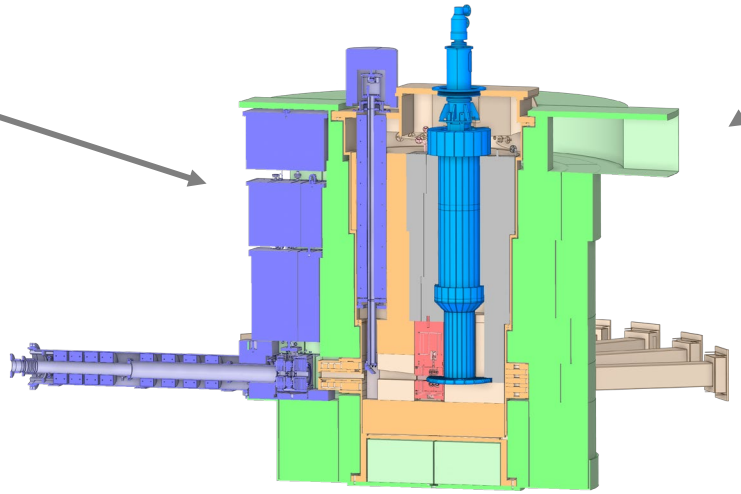


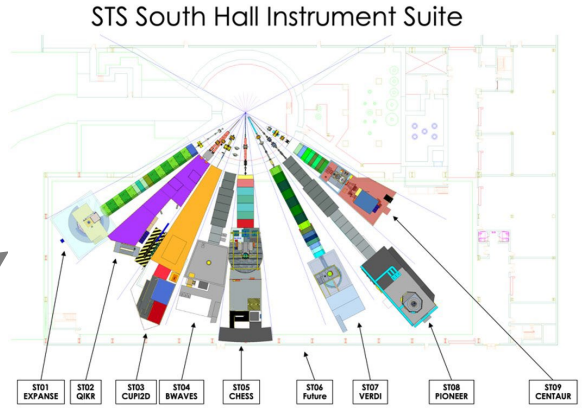
Scope is established to match requirements

- 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

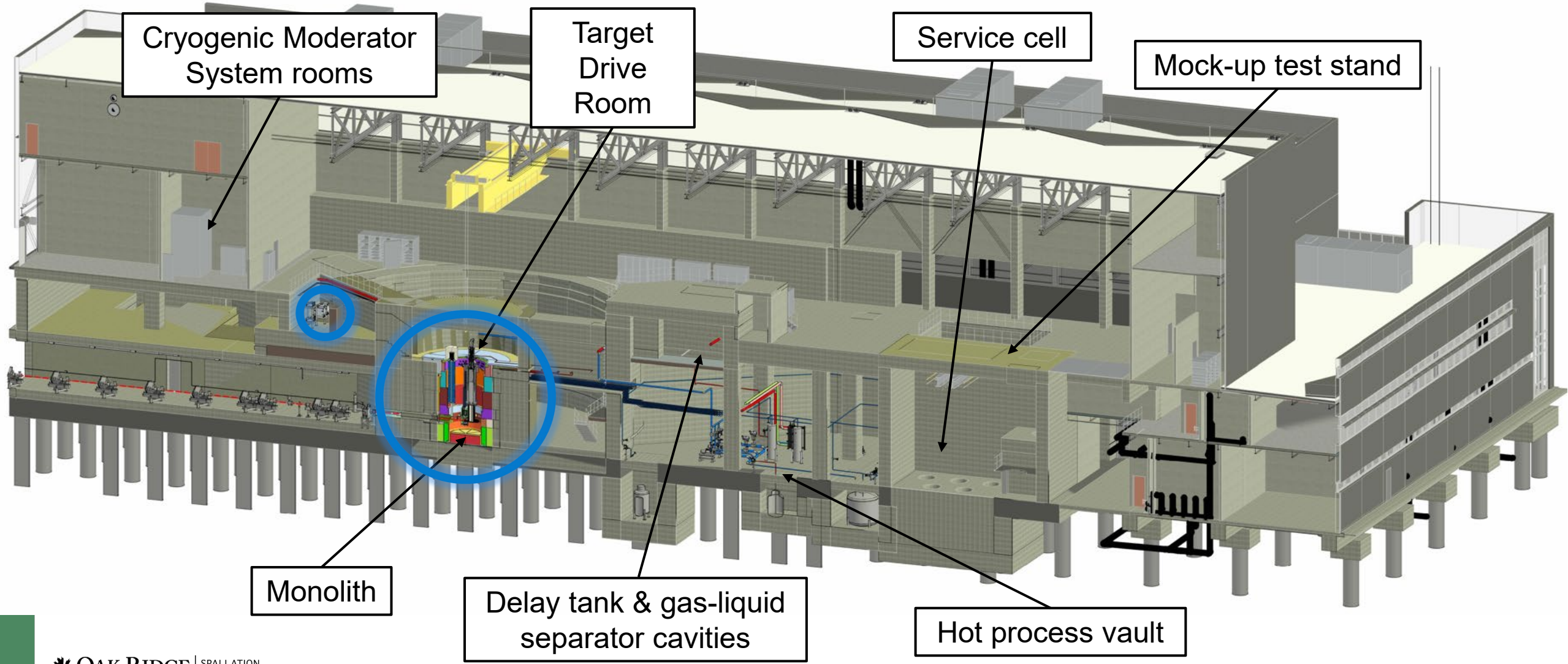
Key interfaces are established and actively updated



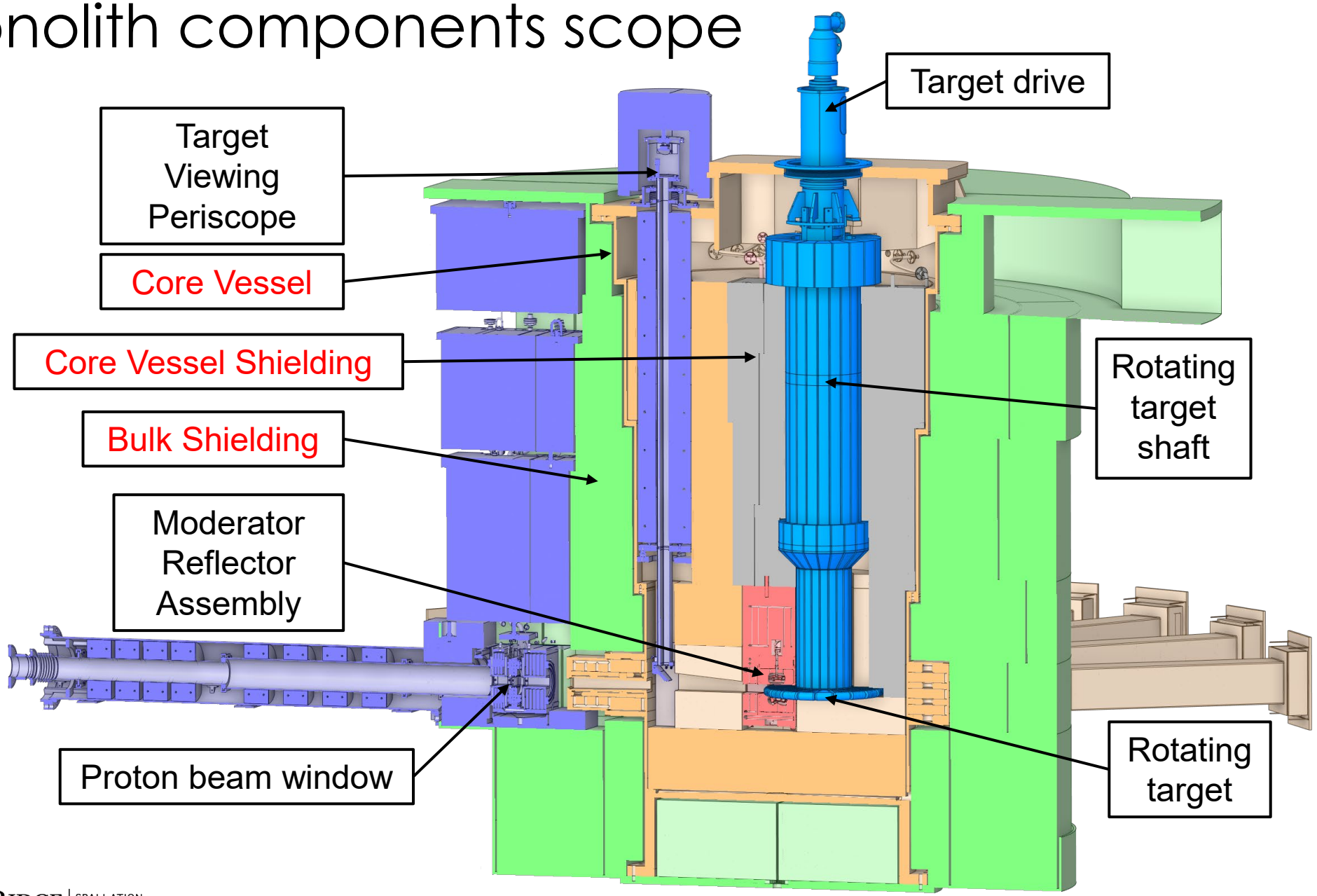




Target Systems scope

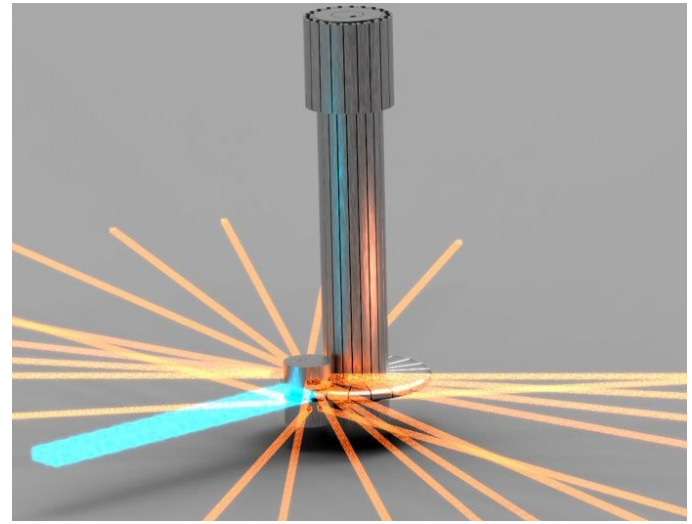


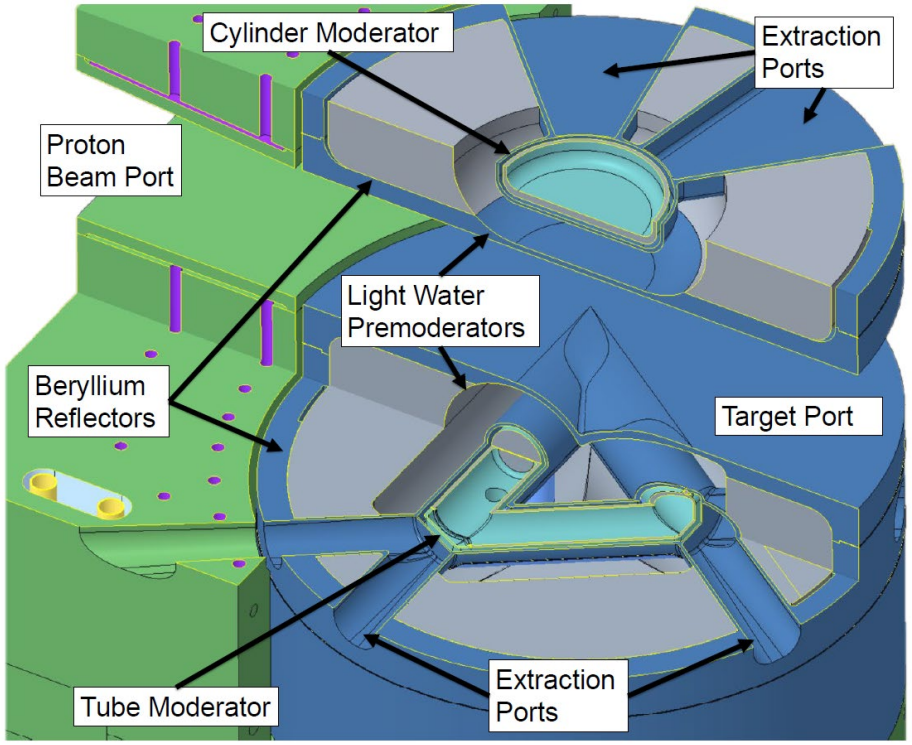
Monolith components scope



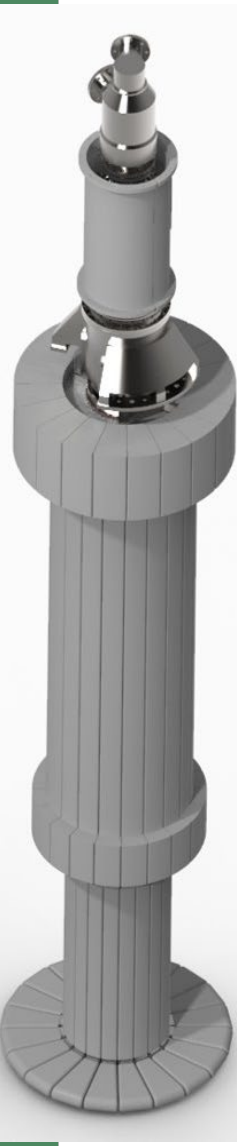
STS Target Systems key parameters / features

- 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

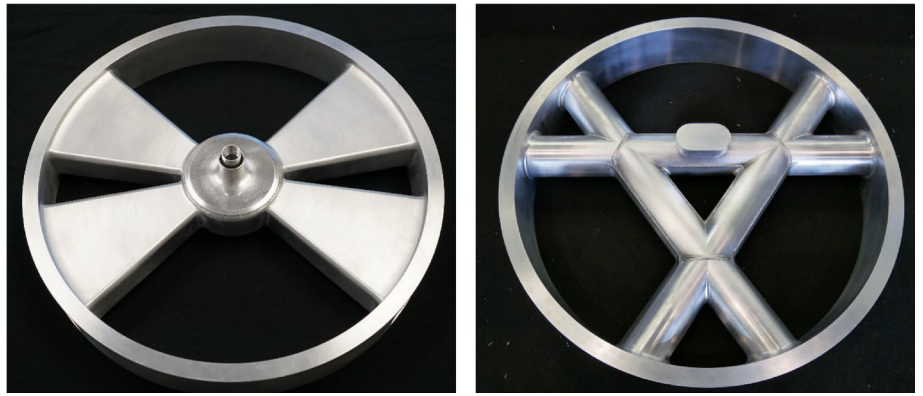


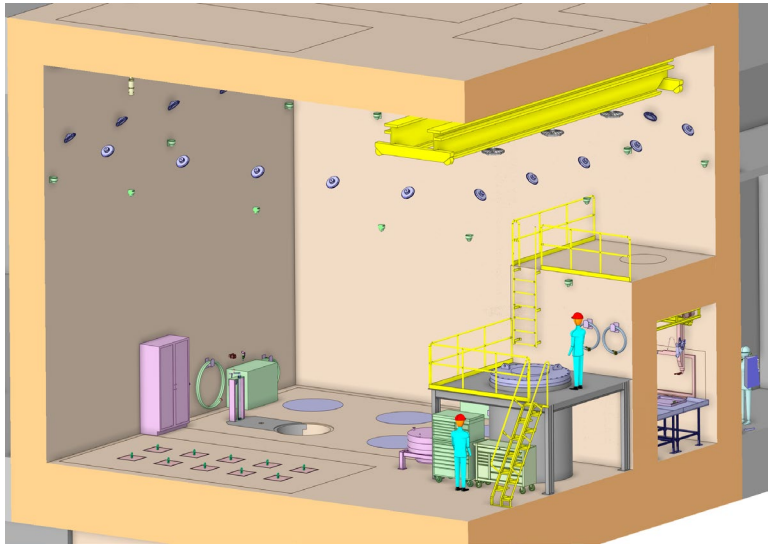


Key Target Systems decisions



- Rotating Target – afterheat protection, efficiency
- Vertical only access to monolith
- Segmented Target – maintenance, availability, and flexibility
- Brightness optimization – small proton beam, small target, close moderators
- Single hydrogen loop for both moderators – facility simplification and cost savings
- Target Viewing Periscope included
- Service Cell configuration
- Cost effective future PIE capability included
- 2nd harp near PBW is included





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
- Vessel Systems and Target Station Shielding preliminary design supports Target Systems and STS requirements.