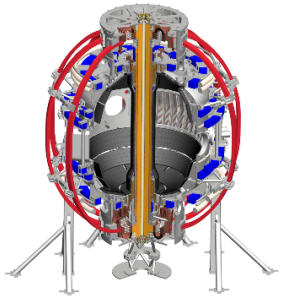
NSTX-U is sponsored by the
U.S. Department of Energy Office of Science
Fusion Energy Sciences

NSTX-U Five-Year Research Progam (2021-2025)

- Background and Governance -

S.M. Kaye, Research Program Director

NSTX-U/Magnetic Fusion Meeting
8 February 2021



Background

The Mission of NSTX-U is defined by the 2009 NSTX-U Mission Needs Statement

- “Establish the physics basis for next-step ST facilities”
- “Broaden the scientific understanding of plasma confinement for ITER”
- “Maintain U.S. world leadership in ST research capabilities”

Five-Year Research Plan (2021-2025) based on Mission approved by external review panel in June 2020

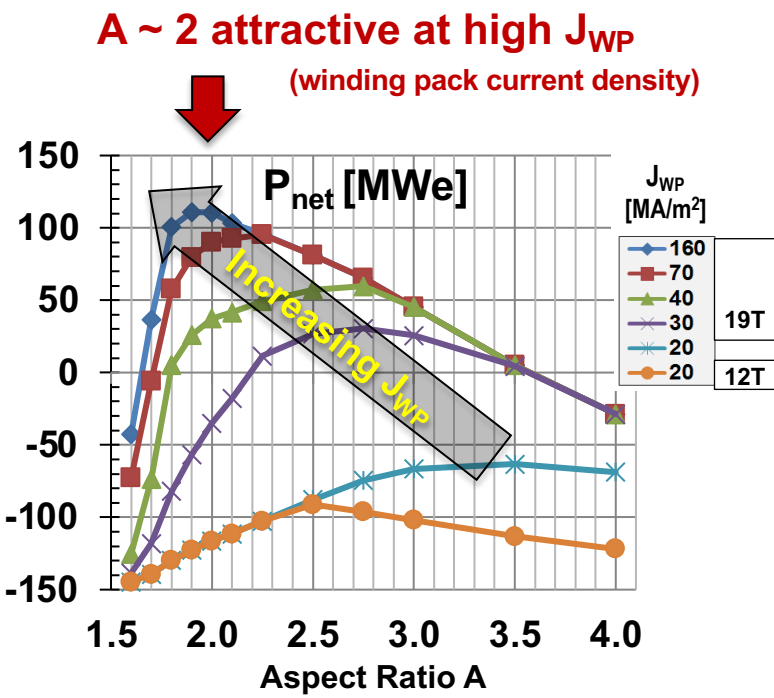
- Plan "refreshed" from 2014-2018 Plan
  - Progress in 2016, but curtailment of ops prevented addressing most of Plan
- Defined high-level goals and detailed research elements for refreshed Plan through a series of community-wide videoconferences
  - Reflects NSTX-U as a FES User Facility
- Plan focuses on **three** high-level Objectives to achieve Mission
  - W. Guttenfelder, D. Battaglia, R. Maingi synthesized community input for Objective writeups (see following talks)
  - Small revisions to plan based on Review Panel & FES input (see ff. VG)
- Collaborative funding based on 5YP elements
  - Collaborations for full five years

NSTX-U Research Plan is mission-driven, and it is based on three high-level research objectives

- **Objective 1:** Extend confinement and stability physics basis at low-A and high beta to lower collisionality relevant to burning plasma regimes
- **Objective 2:** Develop operation at large bootstrap fraction and advance the physics basis required for non-inductive and low-disruptivity operation of steady-state compact fusion device
- **Objective 3:** Develop and evaluate conventional and innovative power and particle handling techniques to optimize plasma exhaust in high performance scenarios

Objectives of NSTX-U Research Plan support directly the recommendations of the NAS / FESAC TEC / CPP/FESAC panels

- NSTX-U will play a major role in determining the aspect ratio and geometry of a more cost-effective Fusion Pilot Plant (FPP) / STEP (UK)
  - Enhanced confinement necessary for FPP; does good ST confinement extend to low ν^*?
    - Superconducting ST-based next-step
  - Optimized geometry (e.g., aspect ratio, κ, δ,) for FPP
- Possible liquid lithium divertor in 2026-2030
  - Prototypes proposed for 2021-2025
- NSTX-U Science mission will address crucial issues (EP & SOL) for ITER



Comments on/revisions to 5YP (from Review Panel and/or FES)

- "Central mission of NSTX-U": *Integrate physics basis developed at low aspect ratio with that developed at conventional aspect ratio to enable scenario and configuration optimization of possible future tokamak concepts*
- Thrust 1-2 is "Highest priority thrust of entire 5YP": *Identify transport and stability mechanisms that determine core and pedestal profiles and overall performance*
- Stressed importance of wall conditioning comparison (B vs Li) for study at low R/a and for comparison to conventional R/a using similar wall conditioning
- Objective 2 deliverable modified to "*Access* fully and partially non-inductive scenarios for good energy confinement, low disruptivity and suitable heat flux mitigation:
  - "*Optimization*" to wait for next 5YP

Comments on/revisions to 5YP (cont'd)

- Upward LITER moved from third to second physics campaign
- Powder dropper moved from first to third physics campaign (if needed for particle control)
- MAPP not supported
- I-mode not supported as specific research deliverable
- For next 5YP
  - A Mission Needs Statement for LM research needs to be written and approved before LM can be considered a Mission
  - Cryopump can be considered
  - *Optimization* of non-inductive scenarios

Research Participation

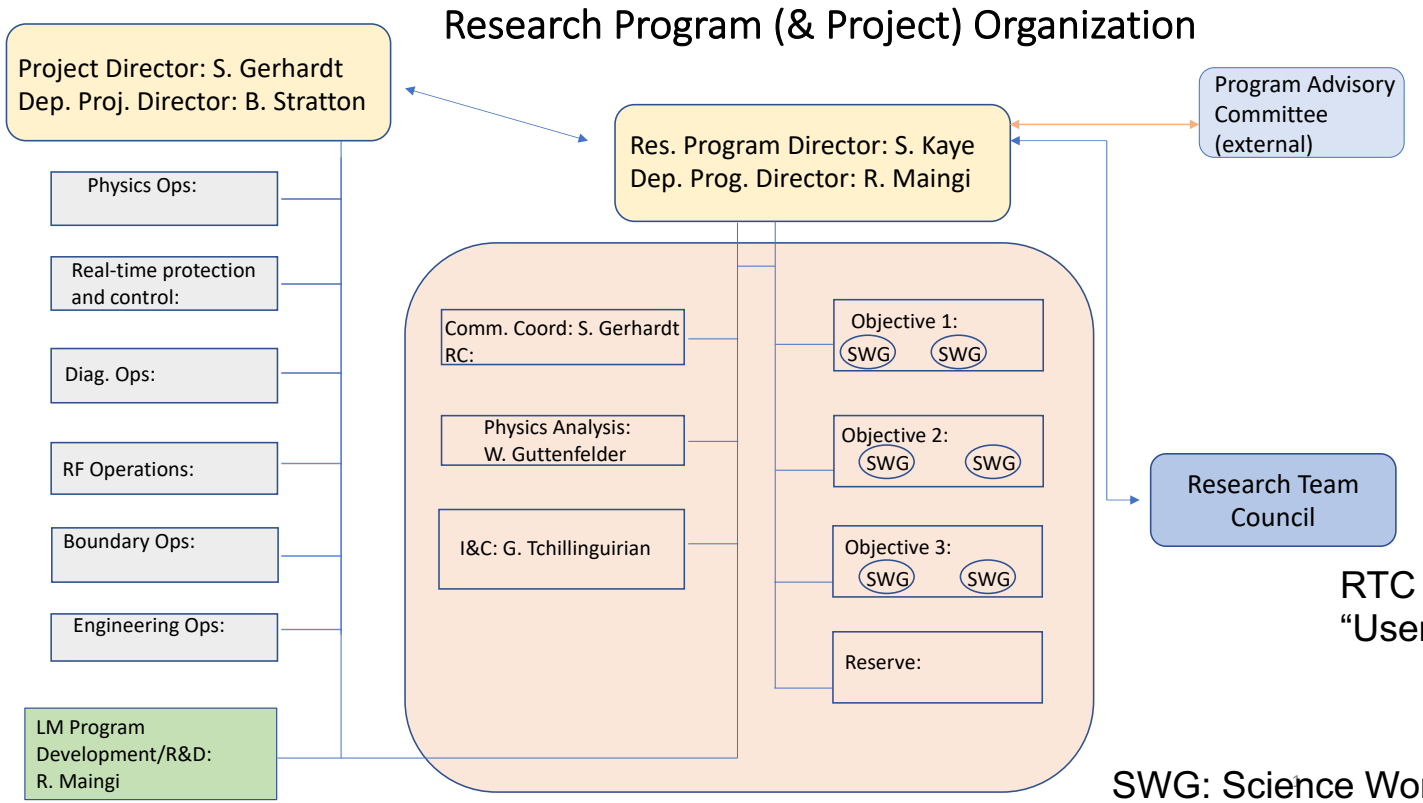
- Core/Pedestal Transport and Turbulence
  - Theory and Modeling: W. Guttenfelder, C.S. Chang et al., W. Wang, J. Dominski, C. Clauser (Lehigh U): G-K sims, T. Rafiq (Lehigh U): transport model development
  - Profile diagnostics: R. Bell: CHERS, B. LeBlanc, A. Diallo/M. Lampert: MPTS/PBLS, L. Delgado-Aparicio, E. Gilson: Bolometry, F. Levinton et al (Nova Photonics): MSE
  - Turbulence diagnostics: D. Smith et al. (U. Wisc.): BES, N. Luhmann et al. (UC Davis)/Y. Ren: High-k, FireTip, MIR, D. Brower (UCLA): Internal B, B-twid, T. Rhodes et al. (UCLA): Internal B-twid, Intermediate to High-k n-twid & Flows
- Core/Pedestal Stability
  - Analysis/theory/modeling: R. Maingi, Z. Sun and R. Lunsford, N. Ferraro et al.: M3D-C1, S. Jardin
  - 3D physics: J.K. Park/Z. Wang, R. Fitzpatrick/S. Mordijk (UTexas/W&M)
  - Disruption Prediction and Avoidance: S. Sabbagh/J. Berkery et al. (Columbia U)
  - Core MHD: S. Munaretto: Magnetics, K. Tritz et al., (JHU): SXR
- Energetic Particle physics
  - M. Podesta, J. Yang, E. Fredrickson
  - W. Heidbrink/L. Stagner et al. (UC Irvine/GA): FIDA
  - Theory/Modeling: C. Liu: M3D-C1K, E. Belova: HYM, N. Crocker/Z. Lin (UCLA/UC Irvine), N. Gorelenkov, V. Duarte, R. White
  - Neutronics: E. Gilson (from D. Liu)

Research Participation (cont'd)

- Scenario Development and Control
  - D. Battaglia: Physics Ops, R. Raman (U. Wash.): Ramp-up scenario development/physics ops, D. Boyer, E. Kolemen: real-time TS, M. Podesta: real-time CHERs, E. Schuster et al. (Lehigh U): Physics-based modeling and model-based Control, K. Thome et al. (GA): Predict-First development of non-inductive scenarios
- HHFW Physics
  - Modeling and operations: M. Ono, S. Shiraiwa, N. Bertelli
  - S. Baek (MIT): RF probes to study HHFW interaction with SOL
- Boundary and divertor physics
  - R. Maingi, R. Lunsford, Z. Sun: Wall conditioning techniques, effects
  - T. Gray/Z. Unterberg (ORNL): PFC heat load characterization, high core radiation performance
  - B. Wirth/K. Gan/T. Looby (UT-K): Thermography and Spectroscopic Diagnostics Evaluation of PFCs
  - V. Soukhanovskii et al. (LLNL): Divertor diagnostics and advanced divertor physics and PSI
  - J.P. Allain/B. Koel/K. Woller (PSU/PU/MIT): Liquid Metal surface properties and plasma material interactions for plasma-facing component development

Governance

Proposed governance of research program: can and will evolve as necessary



Science Working Groups form the basis for experimental proposals/analysis within each Objective

- Support the research thrusts in each campaign
  - Develop and execute XMPs, XPs for experimental campaign
- Support pre-ops Research Milestones
- Each SWG will have a leader
- Each Objective will have a leader/coordinator
- See following vgs for some ideas for SWGs

- *Intent is to identify leaders and form these asap to support **ongoing** Research Milestones, theory/modeling efforts*

SWGs for Objective 1 – First physics campaign thrusts

1. Transport & pedestal structure
   - R(21-1): ST pedestal transport modeling using gyrokinetics
   - Effect of low collisionality
   - Effect of wall conditioning
2. Energetic particles
   - R(21-3): Optimization of NBI mix for AE-mitigated scenarios
   - Characterization of NB EP distribution
   - Validate NB deposition and current drive models
3. HHFW coupling physics
   - SOL loss physics

SWGs for Objective 2

1. Macrostability: *Demonstrate high-β, low-li discharges at low disruptivity*
   - R(21-2): Prepare tools for commissioning
   - Error field assessment/mitigation; TM/NTMs
   - Kinetic stabilization of RWM at low collisionality: real-time control
2. Scenarios and real-time control*: Establish and optimize high non-inductive fraction operation; Particle control and heat flux mitigation necessary for stationary discharges*
   - R(21-2): Prepare tools for commissioning
   - Start-up/Ramp-up scenarios
   - Particle control

SWGs for Objective 3

1. Power exhaust*: Assess performance and lifetime of new NSTX-U PFCs, and establish the physics and engineering basis to enable future PFC/divertor upgrade; Develop and evaluate power exhaust techniques for mitigating high projected NSTX-U heat fluxes*
   - Power exhaust and control:
   - SOL heat flux width
2. Particle control and PMI: *Investigate the sustainability of particle exhaust and PMI control via lithium pumping for density and impurity control consistent with integrated scenarios*
   - Particle control (Overlap with 2.2)
3. ELM stability and control*: Develop and understand techniques to mitigate/eliminate edge transients and the associated enhancement of PMI*
   - R(21-4): ST pedestal stability modeling and determination of stability thresholds associated with ELMs
   - ELM-free and mitigated regimes

Research Team Council represents NSTX-U Users

- The RTC will provide a formal and organized framework for interaction between NSTX-U researchers and NSTX-U management. The broad concern of the RTC is to represent researchers to enhance and optimize the NSTX-U user experience within the framework of the 5Y Research Plan.
- Membership (tbd – would like feedback on this from group)
  - One rep from each funded collaboration (18) + 4 PPPL (?)
  - ~Six reps from funded collaborations + ~2 PPPL (elected by entire Research Team?)
  - NSTX-U management ex-officio
- Meet annually or more often if needed
- Provide written recommendations to NSTX-U management on concerns to users at large, issues raised by management
  - Recommendations resolved by mutual agreement between RTC and management
  - Specific issues concerning individual researchers or institutes are out of scope of RTC
- Charter being drafted