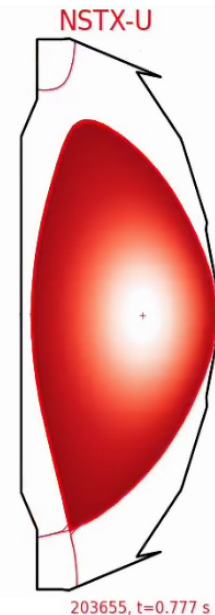


# Predict-First Modeling and Experimental Demonstration of a Fully Noninductive Scenario in NSTX-U

**Kathreen Thome with  
Andrea Garofalo, Orso Meneghini, Joey McClenaghan,  
Craig Petty, Bob Pinsker, Sterling Smith, Bart Van  
Compernelle, Will Wehner, Anders Welander, and more  
to come**

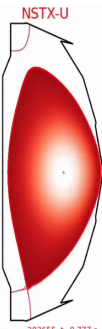
Virtually presented at the  
**NSTX-U/Magnetic Fusion Science Meeting**  
San Diego, CA  
February 15<sup>th</sup>, 2021

Feel free to contact me at:  
[thomek@fusion.gat.com](mailto:thomek@fusion.gat.com)



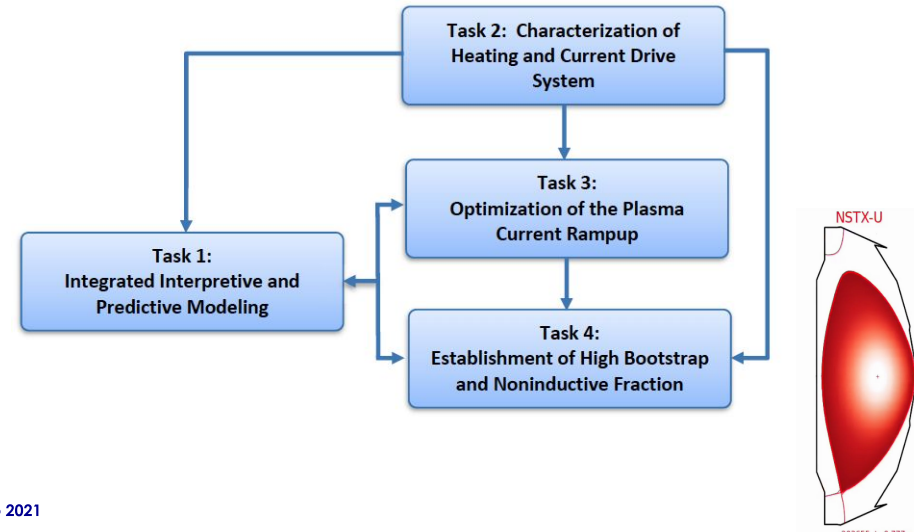
# Primary Goal of this Research is to Work with NSTX-U Team to Create a Stationary, Noninductive Scenario with high $\beta_T$ and $f_{BS}$

- Will utilize higher field and new/improved heating and current drive tools
- Primarily will address Objective 2 in NSTX-U 5 Year Plan, “Develop operation at large bootstrap fraction and advance the physics basis required for non-inductive and low-disruptivity operation of steady-state compact fusion devices”
  - Particularly Thrust 2-3, “Establish and optimize high non-inductive fraction operation”
  - Somewhat Thrust 2-2, “Demonstrate high- $\beta$ , low- $I_p$  discharges at low disruptivity”
- Also will participate in Objective 1 in NSTX-U 5 Year Plan, “Extend confinement and stability physics basis at low-A and high beta to lower collisionality relevant to burning plasma regimes”
  - A bit of all three Thrusts when relevant to primary goal
  - Will contribute to “Streamlined workflow and support to enable robust, routine equilibrium, transport and EP analysis”



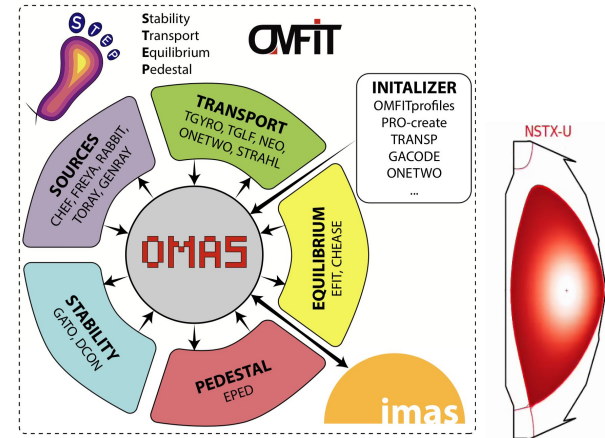
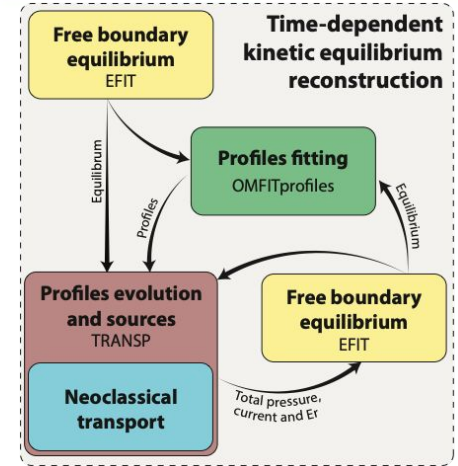
# Research is Composed of Four Interrelated Tasks that Reinforce Each Other to Achieve the Overall Goal

- **Current work is focused on:**
  - Task 1: Adapt integrative modeling framework used on DIII-D to NSTX-U
  - Task 3: Adapt and improve the DIII-D control flight simulator to work with the NSTX-U plasma control system (PCS) to assist in the optimization of the plasma rampup
- **As NSTX-U is returned to operation Year 2-3**
  - Task 2: Begin work on experimentally characterizing the H&CD systems
  - Task 3: Continue optimizing  $I_p$  rampup to minimize the  $I_i$  and maximize  $\kappa$
  - Task 1: Info from Task 2 and 3 will be used to improve predictive modeling
- **Year 3-4 Begin development of scenario with high  $f_{BS}$  and noninductive fraction**



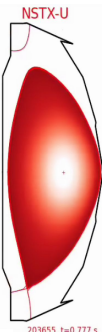
# Task 1: Integrated Predictive Modeling Plans

- **People:** Thome, Smith, McClenaghan, Meneghini, onsite postdoc and others
- **Year 1:** Implement capability to perform interpretive and predictive simulations for NSTX and NSTX-U
  - Will use both [STEP](#) (single time point OMFIT module) and predictive TRANSP (for time-evolving)
- **Year 2 and 3:** Perform predictions for upcoming NSTX-U campaigns
- **Year 4:** Implement improved predictive and H&CD models based on experimental data and perform predictions for upcoming NSTX-U campaigns
- **Year 5:** Implement new TGLF version optimized for low aspect ratio and validate in high beta plasmas



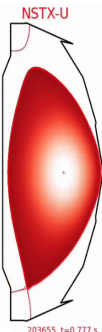
# Task 2: Characterization of Heating and Current Drive Systems Plans

- **People:** Van Compernelle, Pinsker, others
- **Year 2:** Perform scoping studies using GENRAY for HHFW
- **Year 3:**
  - NBI systems commissioning/characterization
  - HHFW commissioning/characterization for stationary low  $T_e$ , low  $I_p$ , low  $n_e$  plasmas
  - Comparisons of experimental data with GENRAY & PETRA-M/TORIC modeling
- **Year 4:**
  - Use HHFW to tailor current profile during  $I_p$  rampup
  - HHFW commissioning/characterization for noninductive scenarios specific for task 4
  - Comparison of experimental data with GENRAY & PETRA-M/TORIC modeling
- **Year 5:** Enable tasks 3 and 4 by use of NBI and HHFW systems



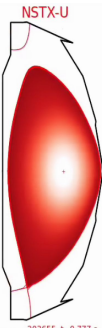
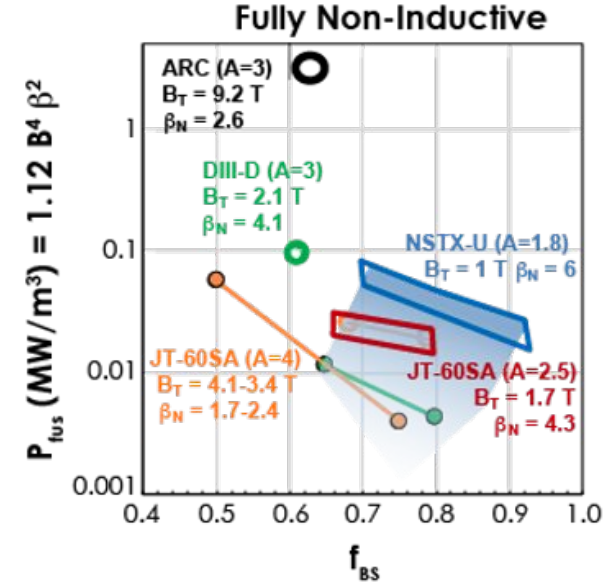
# Task 3: Optimization of the Plasma Current Rampup Plans

- **People:** Thome, Garofalo, Wehner, Petty, Welander, onsite postdoc 2 and others
- **Year 1:** Restore and update NSTX-U simserver functionality
- **Year 2:** Investigate nominal scenarios and algorithms in simulation for optimizing rampup control
- **Year 3:** Optimize startup waveforms to minimize internal inductance and maximize elongation at 0.85 T
- **Year 4:**
  - Optimize startup waveforms to minimize internal inductance and maximize elongation at 1 T
  - Optimize startup waveforms to minimize inductive voltage consumption
- **Year 5:** Investigate current overdrive to reduce inductive voltage consumption



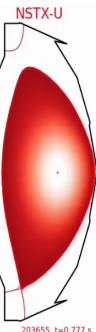
# Task 4: Establishment of High Bootstrap and Noninductive Fraction Plans

- **People:** Thome, Petty, Garofalo, onsite postdoc 2 and others
- **Year 3:** Create database of bootstrap fraction over range of operational space
- **Year 4:** Extend database of bootstrap fraction to higher field to identify promising noninductive regions
- **Year 5:**
  - Align bootstrap current and external current drive to optimal current profile
  - Extend noninductive scenarios to longer duration



# Work Ongoing on Integrated Modeling (Task 1) and PCS (Task 3)

- **Task 1:**
  - [OMFIT installation and environments are up to date and working on CENTOS7](#)
  - [Kinetic equilibrium reconstruction workflow working for NSTX](#)
  - [Initial mapping of NSTX data to IMAS](#)
  - Initial work to port latest version of EFIT to NSTX(-U) which enables equilibrium modification in predictive simulations
- **Task 3: GSevolve simserver (PCS in-the-loop simulation) for control development**
  - GSevolve: free-boundary simulation w/ piece-wise linear evolution of Grad-Shafranov equilibrium, connects with PCS for plasma control
  - NSTX-U instance (from 2018) updated for compatibility with latest GSevolve functions and latest NSTX-U PCS input/output structure
  - On going: power supply models updated
    - Vessel elements updated for better estimates of passive plate resistance
    - Incorporation of current profile evolution to simulation





# List of Key Needs and Requirements

- **GA Participants:** Kathreen Thome, Andrea Garofalo, Orso Meneghini, Joey McClenaghan, Craig Petty, Bob Pinsker, Sterling Smith, Bart Van Compernelle, Will Wehner, Anders Welander, two onsite postdocs (ideally one this summer and another closer to NSTX-U operations) and others
  - Portal, MDS+ (new version on server would be nice), TRANSP, PCS access
  - Diagnostics for kineticEFITs key, turbulence diagnostics helpful
- **Primary PPPL/NSTX-U contacts**
  - Overall: Devon Battaglia
  - Task 1: Devon Battaglia, Brian Grierson, Walter Guttenfelder, Francesca Poli
  - Task 2: Devon Battaglia, Masa Ono, Nicola Bertelli, Syun'ichi Shiraiwa
  - Task 3: Devon Battaglia, Dan Boyer
  - Task 4: Devon Battaglia

# GA is Excited to Participate in NSTX-U Research!

- We know the tools, we know how to make scenarios on DIII-D, but we need your experience and help to make our work a success for NSTX-U. Please reach out and contact me at [thomek@fusion.gat.com](mailto:thomek@fusion.gat.com) for questions or suggestions about our project.
- Please contact Sterling Smith ([smithsp@fusion.gat.com](mailto:smithsp@fusion.gat.com)) if you are interested in using our OMFIT workflows for your NSTX-U research, adding to OMFIT, or adding to the omas -> IMAS mappings of experimental data
- Please contact Will Wehner ([wehnerw@fusion.gat.com](mailto:wehnerw@fusion.gat.com)) if you are interested in using the PCS simserver/GSevolve tools