1. **Overview of the NSTX Upgrade Research Plan for 2014-2018**

1. **Research Goals and Plans for Macroscopic Stability**
   1. Overview of goals and plans (Park)
      1. Establish predictive capability for the sustained stability of high performance FNSF, ST Pilot, and ITER plasmas
      2. Thrusts and goals by topical area
         1. Advance passive and active control to sustain macroscopic stability at high non-inductive current fraction
         2. Achieve predictive capability of 3D field effects to produce sustained stability and profile control
         3. Investigate and test stability physics for disruption avoidance, detection, and mitigation in high performance ST plasmas
   2. Research Plans
      1. **Thrust 1 – Advance passive and active control to sustain macroscopic stability at high non-inductive current fraction (Berkery, Sabbagh, Park)**
         1. Year 1 of NSTX-U operation
            1. Recover and explore NSTX MS control capabilities on stability
            2. Assess the β or q limit with new shaping control and off-axis NBCD
            3. Recover and test upgraded RWMmulti-component sensor and model-based state space control with independent actuator coils, including n>1 and multi-mode control
            4. Study and attempt initial control of internal MHD modes during current ramp-up (Gerhardt)
         2. Year 2 of NSTX-U operation
            1. Validate RWM physics at reduced ν\* and varied fast ion populations
            2. Utilize off-axis NBCD to vary Vϕ and q-profile and investigate RWM/TM stability
            3. Understand and control internal MHD mode physics for long pulse, high performance scenarios (Gerhardt)
         3. Year 3 of NSTX-U operation
            1. Utilize the rotation control to improve RWM/TM stability
            2. Explore the lowest ν\* regimes and test RWM/TM stability
            3. Assess and optimize tradeoffs between Vϕ, q-profile, β to improve RWM/TM/internal MHD mode stability
         4. Year 4 of NSTX-U operation (with NCC)
            1. Utilize the Vϕ-profile control to improve RWM/TM stability
            2. Investigate the combination of the Vϕ-profile, β-feedback, and active mode control to improve RWM/TM/internal MHD mode stability and to sustain high performance plasmas
            3. Investigate RWM mutli-mode control vs. various 3D coil combinations
            4. Provide FNSF/Pilot projection on macroscopic stability
      2. **Thrust 2 – Achieve predictive capability of 3D field effects to produce sustained stability and profile control (Park, Sabbagh, Berkery)**
         1. Year 1 of NSTX-U operation
            1. Identify n > 1 intrinsic error fields and optimize correction using independent actuator coils
            2. Explore upgraded 3D capabilities of active mode control and dynamic error field correction
            3. Initiate NTV physics investigation with enhanced 3D field spectra and NBI torque profile
         2. Year 2 of NSTX-U operation
            1. Optimize and combine dynamic error field correction with the intrinsic error field correction
            2. Investigate NTV physics at increased pulse lengths and behavior at reduced ν\* regime
            3. Investigate NTV physics vs. Vϕ and q-profile with new NBIs and independent actuator coils
         3. Year 3 of NSTX-U operation
            1. Initiate the investigation of non-resonant vs. resonant error field effects
            2. Study NTV physics in the lowest ν\* regimes
            3. Optimize Vϕ feedback control in regimes of high non-inductive fraction to improve RWM/TM stability
            4. Utilize 3D field to assess and optimize tradeoffs between Vϕ, q-profile, β to improve RWM/TM/internal MHD mode stability
         4. Year 4 of NSTX-U operation (with NCC)
            1. Understand non-resonant and resonant error field effects vs. Vϕ
            2. Optimize 3D effects in combined Vϕ-profile, β-feedback, and active mode control to maximize performance
            3. Examine FNSF/Pilot projections on 3D field physics understanding
      3. **Thrust 3 – Investigate and test stability physics for disruption avoidance, detection, and mitigation in high performance ST plasmas (Gerhardt, Raman, Park)**
         1. Year 1 of NSTX-U operation
            1. Examine halo current loading on center column, and heat loading on divertor in disruption
            2. Assess improved MHD spectroscopy and examine model-based observer for disruption detection and avoidance (Sabbagh)
            3. Install MGI and conduct initial tests (Raman)
            4. Study the feasibility of EPI and CT injector system (Raman)
         2. Year 2 of NSTX-U operation
            1. Expand shunt tile measurements of halo currents in divertor
            2. Utilize model-based mode observer and resonant field amplification for disruption detection and avoidance (Sabbagh)
            3. Identify disruption characteristics in various scenarios obtained by off-axis NBCD
            4. Conduct MGI tests by varying positions and actuators (Raman)
            5. Test EPI and CT injection system if installed (Raman)
         3. Year 3 of NSTX-U operation
            1. Investigate thermal loading during VDEs and major disruptions using fast IR cameras and fast TCs
            2. Investigate disruption precursors and study avoidance scenarios with various MHD origins
            3. Explore MGI triggering and other mitigation techniques for real-time actuation (Raman)
         4. Year 4 of NSTX-U operation
            1. Utilize disruption precursors and test avoidance scenarios
            2. Couple real-time mitigation techniques to other MHD sensors (Raman)
            3. Provide FNSF/Pilot projection on disruption physics understanding
      4. **Year 5 of NSTX-U operation (Park, Berkery)**
         1. Integrate MS control to avoid RWM/TM/ELM/internal MHD instability, disruption, with disruption mitigation protection
         2. Provide FNSF/Pilot projection on integrated control
         3. Validate integrated modeling on macroscopic stability
   3. Summary timeline for tool development to achieve research goals
      1. Theory and simulation capabilities (both existing capabilities to be utilized and new capabilities to be developed)
         1. EFIT (Sabbagh)
         2. DCON (Park)
         3. IPEC / GPEC (Park)
         4. MISK (Berkery)
         5. POCA (Kim)
         6. VALEN (Bialek)
         7. MARS-K (Menard)
         8. M3D-C1 (Jardin)
         9. DEGAS (Raman)
      2. Diagnostics (TBD)
         1. Magnetic sensors including BP and BR sensors will be refurbished and upgraded
         2. Real-Time Velocity measurement for successful implementation of rotation control, and disruption detection
         3. Toroidally displaced multi-energy SXR to study 3D physics including island dynamics, and RWM eigenfunctions
         4. Core X-ray imaging spectrometer to study rotation effects on error field and early MHD without NBIs
         5. Internal magnetic fluctuation measurement for island structures
         6. Real time MSE and MPTS for fast and precise kinetic equilibrium reconstruction
      3. Other facility capabilities including plasma control
         1. Non-axisymmetric Control Coil (NCC) (Park, Berkery, Sabbagh)  
            1. Motivation and design
            2. Summary of physics studies

RWM active control for significant multi-mode spectrum (Bialek)

Rotation control by NTV braking

Error field correction and tearing mode stabilization

RWM kinetic stabilization (Berkery)

ELM control and stabilization (Evans, Maingi)

Simultaneous control for rotation, error field, RWM, TM, ELM

Prediction for ITER 3D coil capabilities