NSTX

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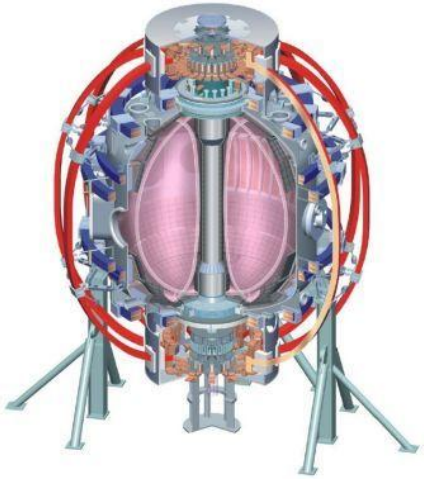
Update on NSTX Program

J. Menard

for the NSTX Research Team

NSTX Team Meeting
LSB B318 PPPL
June 21, 2011



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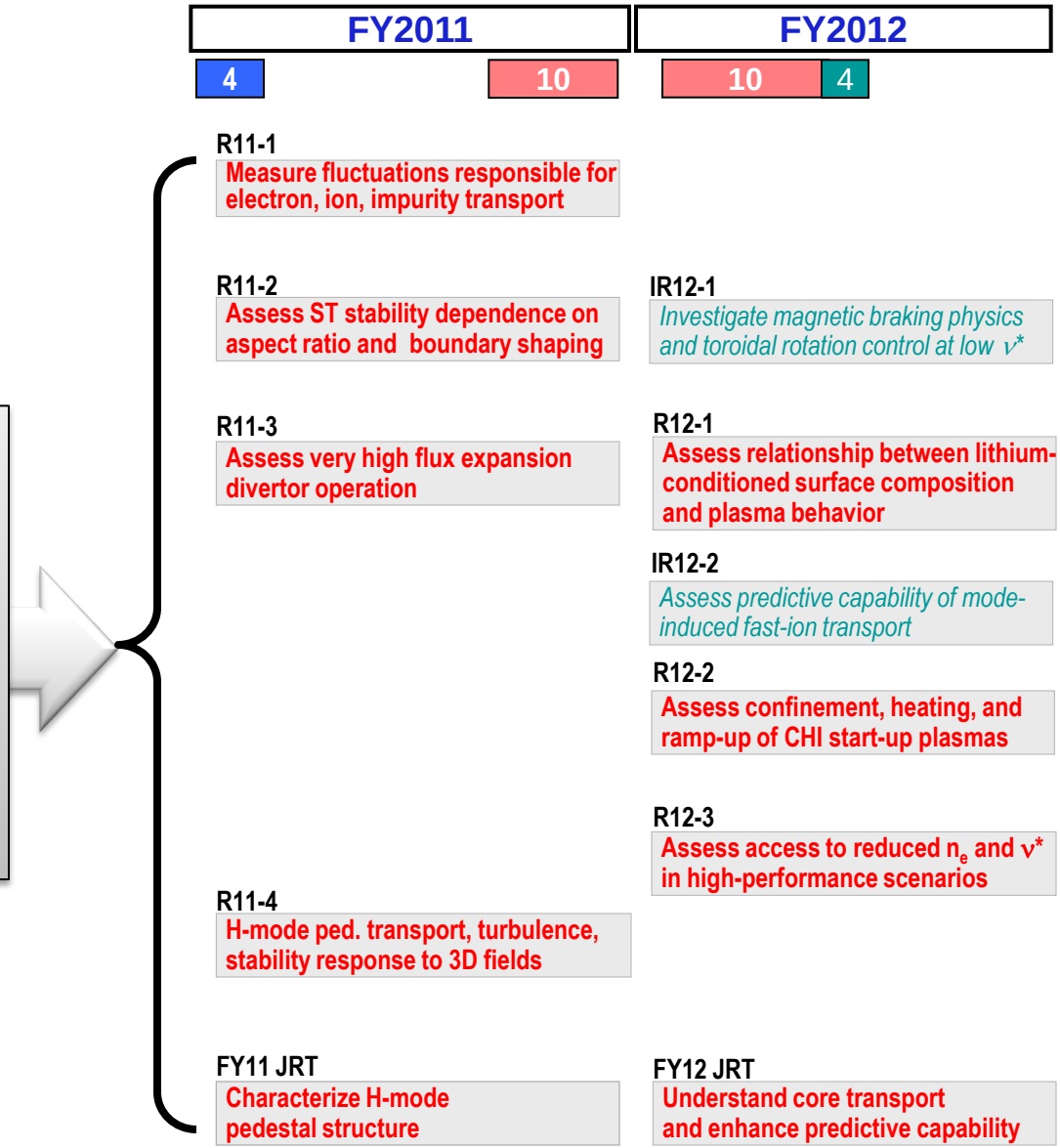
Outline

- Reminder on XP review
- Mid-term review
- Diagnostic collaboration solicitation
  - Considerations
  - Draft 5 year plan → diagnostic idea form
- International ST Workshop

TSG leaders: please continue to get high priority experimental proposals (XPs) reviewed, approved

Highest priority is to get FY2011 milestone XPs ready to run



NSTX 5 year Plan Mid-term Review

- Held at OFES – June 6-7, 2011
  - NSTX, C-Mod, DIII-D
- 3 charge questions:
  - Progress and merit of research and facility improvements
  - Adaptation to technical or programmatic changes
  - Areas of future improvements and their priorities
- 9 member review panel
  - International/universities (i.e. unaffiliated with 3 major programs)
- Presentations to review panel (times include discussion):
  - J. Menard - Research Program Progress and Plans – 2hrs
  - M. Ono - Facility Status and Plans (+ NSTX Upgrade) – 1hr
- Providing final responses to panel questions this week…
- URL: http://nstx.pppl.gov/fiveyearplan_mid.html

Considerations for upcoming FES Collaboration Solicitation for NSTX-U Diagnostics

- NSTX program letter will be issued ~ Aug. 1, 2011
- Diagnostics should target usage for, and needs of, NSTX Upgrade.
- FES/Eckstrand has indicated next diagnostic collaboration solicitation will be for 4 years instead of the usual 3 so that collaborators will have 1 year of (new) data during grant period on which to base progress and future proposals → next diagnostic collaboration: FY2012, 13, 14, 15
- FES also anticipates other next collaboration cycles (University and Industry, National Labs) would be extended 1 year to synchronize

- Will gather ideas through ~July 1, then have brainstorming meeting(s) during early July 2011 to get ideas on the table – discuss as a team
  - Goal is to have TSGs prioritize diagnostic ideas for each topical science area
- New/upgraded diagnostics should take into account:
  - Research goals of NSTX Upgrade program – especially the early/initial years (FY15-16)
  - 2x higher TF, 2x higher plasma current and poloidal field, 2x higher heating power
  - Up to 5x longer pulse = 5-10s versus present 1-2s
  - 2nd NBI will displace several diagnostics – how will capabilities be replaced?

Some example ideas for diagnostics that could be provided by NSTX collaborators - by topical area:

- Start-up and Ramp-up
  - Improved diagnostics for formation phase, impurities, temperature, density of helicity injection start-up
  - Fast ion diagnostics suitable for monitoring AE event driven by 2nd NBI during ramp-up plasma target
- Sustainment:
  - Real-time MSE diagnostics for real-time J(r) reconstruction → feedback control using 1st + 2nd NBI
  - Any clever ideas for fixing lack of background sight-lines/signals for CHERs?
- Boundary:
  - Heat flux, impurities, plasma temperature and density (divertor MPTS?) during snow-flake operation.
  - May need real-time measurements to control real-time heat-flux and/or divertor temperature
  - Improved Li diagnostics
  - Additional GPI views in divertor to correlate midplane and divertor turbulence.
- MHD
  - Improved magnetic sensors, or SXR-based mode-ID? Imaging?
- Turbulence and transport:
  - Improved BES? Improved high-k scattering measuring both k-r and k-theta?
  - Ideas on how to measure micro-tearing?
- Energetic particles:
  - Array of SSNPAs, neutron camera, or other
  - Energy dependence of distribution function w/o NPA?
- HHFW:
  - Improved surface wave detection? Array of toroidally distributed high-f (i.e. RF) Mirnov coils?

Please use draft plan for 2011-2018 as guide, send diagnostic ideas to Brent Stratton by July 1

	Operation 2011	Operation 2012	Upgrade Outage 2013	Upgrade Outage 2014	Operation 2015	Operation 2016	Operation 2017	Operation 2018
Start-up and Ramp-up	Increase CHI closed-flux current to 200-250kA	Couple CHI start-up to low-Ip OH; test with HHFW; maximize non-inductive fraction	Prep CHI for Upgrade - equilibrium calcs with new PF coils	Prepare plasma guns for Upgrade - power supplies, gas systems, time-dependent modelling	Utilize CHI and/or plasma guns to form 0.5MA closed-flux plasma	Utilize CHI and/or plasma guns to form 0.5 MA closed-flux plasma	Utilize CHI and/or plasma guns to form 0.5-1MA closed-flux plasma	Optimize start-up for 100% non-inductive sustainment and high beta & confinement
	Assess HHFW as tool to heat CHI plasma, increase/extend plasma current	Validate time-dependent modeling of CHI start-up with NIMROD; TSC using 2011 data	Perform updated TSC/NIMROD simulations for projecting CHI start-up to Upgrade and FNSF/Pilot	Update time-dependent modeling of NBI ramp-up using projections of anomalous fast-ion diffusion	Ramp up 0.6-0.8MA plasma to 0.8MA with 2nd NBI	Ramp up 0.6-0.8MA plasma to 0.8MA with 2nd NBI, perform assessment of implications for FNSF/Pilot	Ramp up 0.6-0.8MA plasma to 0.8-1.0MA	Optimize ramp-up for 100% non-inductive sustainment and high beta & confinement
Sustainment	Initial tests of sustainment of low-Ip plasma with HHFW and/or NBI CD and heating	Sustain low-Ip plasma with HHFW and/or NBI	Model/benchmark low-Ip sustainment results	Model sustainment - update projections for Upgrade and FNSF/Pilot	Access 100% non-inductive for several tau-E using 2nd NBI	Access 100% non-inductive for 3 tau-CR - perform assessment of sustainable scenario for FNSF/Pilot	Extend 100% non-inductive to relaxed q-profile (2-5 tau-CR)	Integrate non-inductive start-up, ramp-up, and sustainment, project performance to FNSF/Pilot
Scenario Development and Control	Implement and assess improved vertical control at higher A and kappa for Upgrade, FNSF/Pilot	Assess and optimize scenario performance at reduced density and collisionality	Update time-dependent modeling of NBI current-drive sustainment using projections of anomalous fast-ion diffusion	Perform initial design of real-time MSE and CMERS (for Er correction), design control algorithms for current profile control	Demonstrate q/rot-profile variation with NBI mix/on-axis using 2nd NBI	Utilize 1st + 2nd NBI mix/on-axis to optimize stability and transport	Develop/optimize real-time control of current profile for high non-inductive fraction plasmas (~1MA)	Utilize current profile control to maintain high-confinement and stability - project to requirements for FNSF/Pilot
	Utilize ECHs, 3D fields, and other scenario variations to reduce impurities in D-pumped scenarios	Implement real-time edge rotation measurement and initial control algorithms	Project reduced density operating results to pumping and divertor heat flux mitigation requirements for Upgrade	Implement density feedback control for current-ramp-up phase, extend to flat-top if feasible.	Extend 1MA plasmas from 3s to 5-6s, increase flat-top current to 1.5MA for 1-3s	Extend 1MA plasmas to 5s, extend 1.5MA flat-top to 2-4s, increase flat-top current to 2MA plasmas for 2s - perform assessment of scenario performance for FNSF/Pilot	Extend 0.7-1MA plasmas to beyond 5s, extend 1.5MA flat-top to 5s, extend 2MA plasmas to 2-4s flat-top	Extend 2MA plasmas to 5s and/or highest power to enable high P/R and P/S PMI studies for FNSF/Pilot
Transport and Turbulence	Measure low-k and high-k turbulence, prepare for PPCS MT	Compare low-k and high-k turbulence to measured diffusivity trends, contribute NSTX data to PPCS MT	Pre-conceptual design of new high-k scattering to improve k-space coverage	Finalize preparation for installation of new high-k scattering system	Implement new high-k system, measure low-k turbulence requested to reduced ne* at higher-Ip and BT in Upgrade	Measure high-k turbulence at reduced ne* at higher Ip and BT to determine modes responsible for e- transport, utilize global confinement trends to project size and power requirements for FNSF/Pilot	Compare low-k and high-k turbulence to measured diffusivity trends to determine dominant instabilities for e- transport and i-transport	Utilize turbulence understanding and ST confinement trends to finalize FNSF/Pilot size, power requirements
MHD Stability, Stability Control	Implement and assess improved RWM control at higher A and kappa for Upgrade, FNSF/Pilot	Assess RWM kinetic stability, RWM control, and error-field physics at reduced density/collisionality	Physics design of new 3D in-vessel coils for RWM/RWP/EF/MI/NTV/TM.	Implement rotation control algorithms and research field amplification (RFA) identification and control algorithms. Design rotation and RFA control algorithms.	Utilize rotation control using 3D fields and 2 NBI system to optimize rotation profile for global and edge stability	Utilize real-time EFA measurements + beta feedback control for real-time prediction and avoidance of stability limits. Rapid in-vessel 3D field coils if installed/available.	Combine rotation + RFA/beta control to improve scenario stability and sustainment - project is sustainable beta achievable in FNSF/Pilot	Incorporate real-time/q profile information into rotation and beta control and optimization to improve scenario stability and sustainment
Boundary Physics	Improve understanding of pedestal structure - PPPL MT	Assess controllability of LLD, snowflake divertor in preparation for Upgrade	Specify and implement snowflake specific control algorithms into shape controller in prep for Upgrade	Assess/incorporate snowflake divertor into FNSF/Pilot design concepts	Assess pedestal structure (especially Te height) and SOL heat-flux width at higher field and current up to 1.0MA	Assess pedestal and SOL at up to 2.0MA, project size, power, heat flux mitigation requirements for FNSF/Pilot. Design real-time control of divertor gas/impurity puffing for heat flux mitigation.	Utilize divertor radiation and new 3D field coils to modify/optimize pedestal transport, divertor detachment and performance. Implement divertor real-time gas/impurity puff control.	Real-time control of snowflake + radiation + 3D fields to control and mitigate divertor heat flux
	Assess heat flux mitigation and power accountability with snowflake divertor, assess performance of Mo tiles - high-Z impurities and radiation	Model and conceptual design of cryopump(s) for Upgrade for snowflake divertor configurations including conventional flux expansion and high flux expansion (snowflake)	Finalize conceptual design of cryopump(s) for Upgrade. Based on performance of Mo tiles in PY2011-12, decide on whether entire/select Upgrade PFCs will be Li or Mo.	Implement divertor cryo-pumping system(s) in Upgrade.	Assess impact of modified pedestal and SOL at higher Ip+2MA on snowflake divertor performance, and assess cryo-pumping performance with snowflake divertor	Assess impact of modified pedestal and SOL at highest Ip+2MA on snowflake divertor performance, and assess cryo-pumping performance with snowflake divertor	Assess synergies of snowflake divertor, radiative impurities, and 3D fields for particle and power exhaust at very high normalized heat flux - project to FNSF/Pilot	
Lithium Research	Assess inboard divertor Mo tiles as improved substrate for evaporated Li	Assess Li D pumping vs. surface conditions using MAPP probe	Assess applicability of Li coatings for pumping Upgrade plasmas, enhance evaporator systems as needed. Design solid high-Z PFCs for outboard walls	Design/develop methods for increased Li coating coverage of walls (evaporation in bi-metal gas, Li paint sprayer, upward pointing evaporator). Fabricate high-Z PFCs for outboard wall.	Assess impact of full wall coverage of solid Li on particle pumping, plasma performance. Install high-Z PFCs on outboard walls.	Assess impact of full coverage high-Z PFCs + Li on particle pumping, plasma performance. Assess/design hot wall (using baffled rail) capability.	Utilize hot first-wall capability with Li on high-Z PFCs, assess impact on particle pumping, plasma performance.	Incorporate Li-wall results into other facilities (EAST collaboration), and into designs of FNSF/Pilot and other next-step facilities.
	Test molybdene Li granule injector as Li delivery system and for ELM triggering/pacing	Test thicker and/or more rapidly deposited Li layers for enhanced Li pumping and refurbishment modifications	Design of next-generation liquid lithium systems focusing on continuously refreshed Li for Z-pinch, and/or flowing Li for divertor heat flux mitigation. Begin design of removable divertor module (RDM).	Fabrication of prototype next-generation liquid lithium divertor system. Complete design of removable divertor module (RDM) for Upgrade, begin fabrication.	Test next-gen LLD prototype(s) on PMI test stand (at PPPL or other, as available), iterate as needed on design. Implement RDM on Upgrade.	Test next-gen LLD on RDM in NSTX Upgrade. Utilize high-heat-flux plasma to characterize lithium performance and LLD power handling capabilities. Iterate design. Perform preliminary projection of next-gen LLD to FNSF/Pilot.	Complete design, begin fabrication of complete toroidal coverage next-generation LLD for NSTX Upgrade.	Implement and test full toroidal coverage next-gen LLD for pumping and power handling capabilities - project performance to FNSF/Pilot
Energetic Particles	Measure fast-ion redistribution and tangential NBI, *AE eigenfunctions with BES. Design prototype *AE antenna.	Use tangential + perpendicular FIDA to characterize distribution function modifications induced by *AE modes. Implement prototype *AE antenna.	Use data obtained in FY12 to compare to NOVA-K + DEBS, MISK, HYM simulations of fast-ion transport in early phase of avalanche evolution. Begin design of upgraded *AE antenna.	Extend simulations of fast ion transport to later in avalanche evolution, develop reduced model of fast-ion transport valid during avalanche burst, and impact on fast ion profiles. Finalize design of upgraded *AE antenna.	Measure *AE activity observed to be driven by more tangential 2nd NBI - compare to existing more perp NBI. Implement upgraded *AE antenna.	Simulate *AE activity observed to be driven by more tangential NBI, compare simulations to new data. Extend simulations of avalanches to FNSF/Pilot sustainment phase	Utilize *AE predictive capability to optimize/minimize *AE activity during non-inductive current ramp-up with 2nd NBI. Compare simulations to experimental results.	Extend simulations of *AE avalanches to FNSF/Pilot current ramp-up phase, assess implications for FNSF/Pilot design, in particular NBI injection geometry, expected current drive.
RF - HHFW	Heat low-Ip plasma, achieve high non-inductive current fraction, improve coupling to NBI-heated H-mode plasmas	Heat CHI start-up plasma coupled to inductive, outside low-Ip plasma 100% non-inductively, improve coupling to NBI-heated H-mode plasmas	Assess/model expected fast-ion loss orbs HHFW antenna for Upgrade plasmas and ITER-FNSF and Upgrade NBI heating powers. Develop physics basis for EHO excitation.	Modify HHFW antenna limiter as needed for Upgrade operations. Model achievable performance and Upgrade NBI heating powers. Develop physics basis for particle transport induced by EHO excitation.	Assess HHFW performance at higher magnetic field and higher plasma density, especially with reduced number of antenna straps. Develop physics basis for compatibility with high-power NBI operations. Design EHO antenna using HHFW straps, or same location in NSTX-U	Utilize HHFW to assist start-up plasma formation - compare to start-up by ECH. Also assess impact of HHFW on heating + non-inductive current ramp-up. Simulate/model up performance using reduced number of straps. Implement EHO antenna compatible with HHFW requirements.	Modify actual HHFW antenna system to have reduced number of straps. Test EHO antenna for impact on density/particle control.	Utilize modified HHFW system heating and CD to optimize plasma start-up, ramp-up, and NBI sustainment.
RF - ECH			Assess upgraded ECH system requirements for plasma start-up support (e.g. pre-ionization, heating of CHI/gun plasmas, ERW current drive, expected current for subsequent NBI ramp-up)	Update design of ECH system plasma start-up support	Implement short-pulse, high-power ECH system for plasma start-up support (assess impact on closed-flux current achieved, pulse-length extension, non-inductive fraction)	Test short-pulse, high-power ECH systems for plasma start-up support (assess impact on closed-flux current achieved, pulse-length extension, non-inductive fraction)	Upgrade ECH system power and pulse-length for ERW heating studies (1MW, 0.2-0.5s)	Pending successful ERW heating results, further upgrade ECH system power and pulse-length for ERW heating studies (2-4MW, 1-5s), project ERW CD performance to FNSF/ITER
ITER support	Assess pedestal transport and stability response to 3D fields for ITER ELM/ mat physics basis. Contribute PY11 JRT data on pedestal structure for ITER projections.	Compare divertor gas injection to molybdene gas injection for disruption mitigation - assess density assimilation, thermal and current quench evolution and. Assess dis-gas puff for ITER if NSTX results favorable.	Utilize 3D coil design and NSTX physics basis to assist in projections to ITER error identification and correction, RWM control, and RWP ELM control in ITER.	Assess/apply RWM state-space controller to ITER advanced scenarios. Assess RFA real-time measurement and control for ITER advanced scenarios.	Apply *AE avalanche predictive capability to ITER burning plasmas - baseline scenario, hybrid scenario, and advanced scenario. Apply HHFW performance expectations at higher field and current to ITER antenna design and performance projections.	Apply measured pedestal and SOL transport, fast-ion loss projections for ITER pedestal and divertor performance.	Apply Upgrade divertor radiation control experience to proposed ITER, partially-detached divertor and associated control requirements	Apply 100% non-inductive integrated scenario and control experience to preparation for ITER advanced scenarios.
ST-based FNSF/Pilot Physics Basis and Design Concepts	Publish NF paper on pilot plants including ST pilot	(CRD to optimize ST FNSF/Pilot size(s) and configuration(s) based on proposed mission(s). Additional collaboration with Culham on staffing mission and device configurations.	(CRD to optimize and finalize ST FNSF/Pilot configurations, explore divertor, first-wall, and blanket maintenance and impact/benefits of same change-out capability.	Use NSTX team to update and enhance FNSF/Pilot physics design using CRD effort as starting point - focus on impact of testing different divertor configurations in FNSF/Pilot	Update physics basis and design point to incorporate preliminary results on start-up, ramp-up, and sustainment, and snowflake	Update physics basis and design point to incorporate results on start-up, ramp-up, and sustainment at higher plasma current, and first results from next-generation lithium divertor	Update design point to incorporate results on achievable plasma beta and confinement in fully non-inductive scenarios. Compare NSTX-U snowflake/super-x divertor to preliminary MAST-U Super-X performance.	Update design point to incorporate results on fully integrated NSTX-U upgrade scenarios (start-up + ramp-up + sustainment + divertor), assess impact of Li-wall experiments.

Please send this completed form to Brent Stratton by July 1, 2011 (bstratton@pppl.gov)

Diagnostic idea/title:

Proposer and affiliation:

- What new physics would be obtained with this diagnostic capability? or, what critical existing capability will this diagnostic maintain?

...

- Is this a new diagnostic, or an upgrade of an existing diagnostic? If an upgrade or an enhancement, please provide some details of the enhancement (spatial/time resolution, etc).

...

- How does this diagnostic support NSTX Upgrade research plans? (see XL spreadsheet)

...

- Does this capability address a critical issue for ST-FNSF physics, ITER, or both?

...

- Is the scope of this diagnostic well-suited to university/industry collaboration? If not, why not?

...

- Are there any diagnostics that are not applicable or productive for the Upgrade that could be removed to save resources and/or free up ports?

...

- Are there any other important considerations/issues not addressed in the above?

...

Your ideas will also inform longer-term planning: i.e. next collaboration solicitation, 5 yr plan for 2014-18

International Workshop on Spherical Torus (ISTW2011) 27-30 September 2011 in Toki, Japan

- Planned attendees: Ono, Menard, Tritz, Raman, Gates (via NIFS)
  - There will also be poster session – we can cover several posters each
- July 1, 2011 - Submission of abstract to:
  - istw2011@nifs.ac.jp, and abstract and IAEA participating forms to proper authorities of country (or EU)
- July 11, 2011 – Request invitation letter for VISA application to enter Japan
- July 15, 2011 - Decision on paper acceptance
- July 22, 2011 - Application for IAEA travel grants
- August 29, 2011 - Hotel registration
- September 27-30, 2011 - Joint ST meeting
- September 30, 2011 - PDF file of presentation or poster
- September 30, 2011 - Submission of manuscript
- Meeting website: http://istw2011.nifs.ac.jp
- For additional info, contact. Y-K M. Peng, pengym@ornl.gov