# Purpose of this meeting - #2

- To thank you – all chapters now have at least a draft
  - Some are draftier than others
- Provide chapter authors with some initial "high-level" comments and observations on the status of the chapters
- Highlight some specific positive/negative features from chapters that other chapter authors might want to incorporate/avoid
  - This is 2nd cut at cross-chapter consistency and optimization
- Will hear from chapter author version of perceived status and needs – compare to cross-chapter view
- Next 5 year plan update meeting will be in early January
  - Updated draft chapters will be due before next meeting
  - Stay tuned for Doodle

# Overview chapter status

- Intro and plan structure sections drafted
  - Need to add references
- Started "thrust" overview section ~ 1/3-1/2 complete
  - Several chapters to not have clear intro/overview sections with thrust summaries at/near the beginning of their chapter → **authors need to provide this ASAP**
    - BP and MP need the most work
    - Other chapters are in acceptable to good shape
- Need "Planned Research in Support of ITER" from Stan
- Need "Long-Range Plans for NSTX Upgrade" from JM
- Will likely add final/new section "Motivation and Prioritization of Proposed Near-term Facility Enhancements"
  - Put summary of rationale for cryo, ECH, NCC all in 1 place

# What is a “Thrust”

- Set of **actions** that will be performed to achieve a goal
  - Written like a milestone, but with longer time-frame
  - Roughly, 2 – 5 years
- In overview chapter, JM summarizing thrusts by providing:
  - Big-picture motivation (ITER, FNSF) ~ few sentences-1 paragraph
  - Unique contributions of NSTX-U ~ few sentences-1 paragraph
  - Paragraph of thrust description / action
  - See initial/draft overview chapter (+ next slide) for examples
- Your chapters need to put the intros, goals, and thrusts up front, then write research plan to explain and support, then finish by providing (brief) time-line of plan elements

# Examples of thrust summaries in Overview chapter

- **Thrust MS-2: Understand 3D field effects and provide the physics basis for optimizing stability through equilibrium profile control by 3D fields**
  - *The upgraded SPAs will be utilized to study non-resonant error field effects on resonant error field correction, and to develop the physics basis for control of toroidal rotation through magnetic braking while simultaneously applying RWM and dynamic error field correction. The effects of magnetic braking will be systematically studied as a function of plasma collisionality as density control tools are improved during the 5 year plan period. The toroidal rotation profile will also be more widely varied using the 2nd off-axis NBI system. The combination of the new NBI and the upgraded SPAs and proposed NCC coils will be utilized to vary and understand toroidal momentum transport for a range of magnetic field spectra and plasma collisionality conditions to develop the physics basis for rotation profile control to improve and optimize plasma performance.*
- **Thrust TT-1: Identify regime of validity for instabilities responsible for anomalous electron thermal, momentum, and particle/impurity transport in NSTX-U**
  - *NSTX researchers will identify isolated regimes for micro-instabilities using theories and reduced/first principle models, experiments for measuring turbulence and transport in these regimes and comparisons between measured transport levels and turbulence characteristics with theoretical and numerical predictions. Experimental parametric dependence will be used for further distinguishing different instabilities. For example, the dependence of microtearing and ETG modes on s/q and $Z_{eff}$ are opposite to each other, and this trend can be utilized to identify each mode. The enhanced capabilities of NSTX-U, in particular the increased range of collisionality, doubled heating power from the 2nd NBI, and active flow and current profile modification using the 2nd NBI and 3D coils, will provide a versatile set of experimental control tools for modifying transport and turbulence to achieve the goals of this thrust.*

# Macroscopic stability

- Overall structure improved
- NCC incorporated earlier, and spread throughout
- Thrusts in reasonable shape
- Research plan for Thrust 1 is organized by year rather than research carried out
  - Prefer structure of thrusts 2 and 3 where year-by-year is at end of section
  - Make Thrust 1 more like this
- Yes – move "Boundary stochastization and ELM control" using NCC coils to boundary physics chapter – this can be part of pedestal control thrust

# Transport & Turbulence

- Got Thrust 2 contribution from Walter – thanks
- Chapter is now very thorough (treatise) on NSTX transport results
- Extended momentum transport research section – good
- **Still no mention of NCC coils (need to fix this)**
  - This should at least show up in momentum transport studies for improved/varied perturbation control, and influence of rotation profile control generally
  - Read MS chapter on NCC, talk with JKP and JB about potential applications
- Initial sections still have plans subdivided into years 1-2 and 3-5 – review to make sure this is consistent with diagnostic/facility availability, etc.

# Boundary physics

- Still need intro section - unclear what the research thrusts are
- Now have divertor section - good – thanks
- Got LGI description – good, but still need EHO antenna text
- Edge/SOL physics now includes collisional/drift effects and scalings
- Initial section on divertor physics "Divertor transport, Heat flux width scaling, connection to SOL models, projections to ST-FNSF" described need for improved physics basis for perp. SOL heat flux
  - This appears to be redundant with earlier section in same chapter "Plasma transport and flows in the edge/SOL"
  - Need to consolidate this
- Cryo-pumping for particle control section extended – thanks – much better
- Need to incorporate NCC for ELM control from MS chapter
- Need to add discussion of Li evaporation for particle control – should this be in BP or MP chapter? (might vote for MP chapter)
  - Could include discussion of related surface studies, upward evaporator

# Materials and PFCs

- Organization improved
  - Added figures, graphs, and previous results - good
  - Intro improved, includes discussion of FNSF needs (and quantitatively)
- Shouldn't have "notional milestones" – need to convert to "thrusts"
  - The thrusts should identify the actions you will take to meet the goals
- Plan section is ~ 1 page bulletized list – **need actual text!**
  - Nearly all of the chapter is background, results (which are good, but…)
- Still insufficient detail on: "staged implementation of high-Z PFCs"
  - Need plan for which areas will be covered with TZM tiles, and why and when
  - Can't plan liquid metal divertor module w/o first addressing high-Z tile issue since LMD is ill-posed if completely surrounded by C tiles
  - **What is the plan?**

# Energetic Particles, Wave Heating and CD

- EP chapter – good enough for now

- RF Chapter – now mentions ion-cyclotron resonant absorption results – good
- RF figure issues:
  - Figures 7.2.1, 2, 3 need to be added
  - Figure 7.3.1 missing
  - Figure 7.3.2  shown twice ?
- Need to show/add result on EBW H&CD projections in NSTX-U H-mode scenario(s) – most likely for full NICD scenario

# Solenoid-Free Start-up

- Thrust/goal descriptions spend too much time on history and technology detail – need to state clearly (and briefly) what actions will be taken in the thrust(s) for the 5 year plan

- Need to include Figure showing 0.5MW or 1MW 28GHz heating efficiency of low-Te CHI-like target plasma – only have this in words right now

# Advanced Scenarios and Control

- Got input on “Advanced Boundary and Position Control” – good

# Facility chapter

- Good first draft – lotsa material and figures
  - Need to put figures into text
- As previously mentioned - need strategy on high-Z divertor & PFCs
  - Rajesh will present this plan at PAC and has initiated planning discussions
  - Need to reach closure by early January so plan is firm for all chapters and for dry-runs

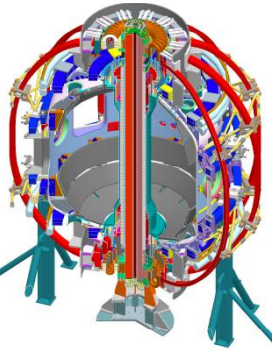
# Strawman/draft upgrades to be in place by 2018 assuming base budget

| 2014 | 2015 | 2016- 2018 | | | | | |
|---|---|---|---|---|---|---|---|

**Upgrade Outage** | **1.5 → 2 MA, 1s → 5s**

*Masa+Stefan+Bob+Brent need to ID which FY11-12 capabilities will be ready for 1st full year of NSTX-U ops*

New center-stack



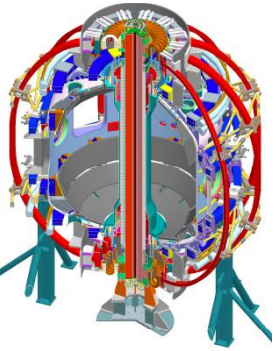
2nd NBI

| | | |
|---|---|---|
| Start-up and ramp-up | Upgraded CHI | ECH/EBW 1 MW |
| Boundary physics | | Divertor cryo-pump |
| Materials and PFCs | | U or L Mo divertor |
| Lithium | Li granule injector | Upward LiTER |
| MHD | MGI disruption mitigation tests | Enhanced RFA/RWM sensors |
| Transport & turbulence | High $k_\theta$ | Polarimetry and DBS |
| Waves and Energetic Particles | | HHFW limiter upgrade |
| Scenarios and control | | Control: rotation, snowflake, divertor radiation, $q_{min}$ |

# 5-8 year plan upgrades with ~10-15% increment

| 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|
| Upgrade Outage | 1.5 → 2 MA, 1s → 5s | | | | Advanced PFCs, 5s → 10-20s | | | | |

New center-stack



2nd NBI

| | | | | | |
|---|---|---|---|---|---|
| Start-up and ramp-up | 0.3-0.5 MA CHI | 0.5-1 MA CHI | 0.2-0.4 MA plasma gun | up to 1 MA plasma gun | Extend NBI duration or implement 2-4 MW off-axis EBW H&CD |
| | ECH/EBW | 1MW → 2 MW | | | |
| Boundary physics | Divertor cryo-pump | Divertor Thomson | Diagnostics for high-Z wall studies | | |
| Materials and PFCs | U or L Mo divertor | U + L Mo divertor | All High-Z PFCs | Hot High-Z FW PFCs | |
| Lithium | Li granule injector | Upward LiTER | Flowing Li divertor or limiter module | Full toroidal flowing Li divertor | |
| MHD | MGI disruption mitigation tests | Enhanced RFA/RWM sensors | NCC coils | NCC SPA upgrade | |
| Transport & turbulence | High $k_\theta$ | $\delta B$ polarimetry | DBS | PCI or other intermediate-k | |
| Waves and Energetic Particles | HHFW limiter upgrade | HHFW straps for EHO, *AE | Dedicated EHO or *AE antenna | | |
| Scenarios and control | Rotation control | Snowflake control | Divertor radiation control | $q_{min}$ control | Control integration |

U.S. FNSF conceptual design including aspect ratio and divertor optimization

# Draft PAC-33 agenda and speakers

## PAC dates: February 19-21, 2013

| | |
|---|---|
| • Program overview | Jon Menard |
| • Upgrade progress, facility and diagnostic prep, budget | Masa Ono |
| • Initial Operations Plan, Scenarios and Control | Stefan Gerhardt |
| • Macroscopic Stability | Jack Berkery |
| • Non-axisymmetric control coil (NCC) applications | Jong-Kyu Park |
| • Transport and Turbulence | Yang Ren (or WG) |
| | |
| • Energetic Particles | Mario Podesta |
| • HHFW and ECH / EBW | Gary Taylor |
| • Solenoid Free Start-up and Ramp-up | Roger Raman |
| • Long-term issues and strategy for boundary and PMI | Rajesh Maingi |
| • Pedestal, SOL, Divertor | Vlad Soukhanovskii |
| • Cryo-pumping and particle control | John Canik |
| • Materials and Flowing liquid Li module development | Mike Jaworski |

# Importance of the plan

- Plan must be:
  - Scientifically relevant and compelling for FNSF, ITER, Demo, toroidal plasma science
  - Innovative, but realizable
  - Strongly supportive of development of predictive capability
    - For this reason, I think explicit inclusion of theory/simulation capabilities to be utilized/developed is a net plus for each chapter, even if it is a bit of extra work (i.e. a good task for the theory TSG deputies)
- Requested facility and diagnostic upgrades must be well-founded and supported in the plan
  - Competition for resources will continue to be intense
- Must satisfy all of the above with:
  - Base budget and associated upgrades
  - Incremental budget (which is much easier)

# Comments on plans vs. ideas

- Avoid statements that say we “could” or “might” or “should” do something
  - Need to be concrete in the plans, even in face of budgetary and/or scientific uncertainty
    - Be definitive:  we will do “X”, or plan to do “Y”
  - Resources are finite, prioritizations have to be made
    - and of course plans may change after 5 year plan is completed + reviewed
  - Allowable hedges:
    - “(resources permitting)”
    - “(pending incremental funding)”
  - If a research element/plan is not in the base or incremental plan/budget, it effectively does not exist in the 5 year plan

- Make sure your timelines are consistent with text

# Comment on granularity of plan years

- Chapters have research plans split into 2 large chunks: years 1-2 and 3-5. This split is ok (as per previous guidance), but without some additional year-by-year detail, this can come across as a plan that is too vague or insufficiently thought-through
- Suggestions:
  - Wherever reasonable, try to give more a more detailed time-line
  - Year-by-year is best for the early years, especially since it's difficult to justify a lack of specificity in years 1-2
    - Example splits: Year 1, 2, Years 3-4, 4-5
    - As stated previously, uncertainty should be placed in the out-years
  - Also ok to have overlapping periods (e.g. years 1-3, 2-4, 4-5)
- Reminder: Assuming the research is still relevant, a significant amount of year 1 and 2 research should incorporate planned research for the FY2011-12 run that was not carried out
  - Can/should use FY11-12 run plan as a resource (and many chapters have)