Excerpt from PAC report, T&T recommendations

However, the PAC is concerned that in FY15-16 insufficient emphasis is given to experimental studies of particle transport, and related validation of models. As previously emphasized in the PAC-33 report, particle transport plays a critical role towards the development of stationary scenarios for long-pulse operation, in particular at low density, with direct impact on the bootstrap current fraction and on the behavior of high-Z impurities. For this reason, the PAC recommends that higher priority be given to main plasma (electron) particle transport studies in combination with the already planned studies dedicated to other transport channels. In particular, perturbative experiments on particle transport could be considered, assessing the feasibility and extending the collaboration with CCFE for comparative analyses between NSTX-U and MAST-U in this topical area. In addition, in the framework of multi-channel transport investigations, which is of particular importance in assessing the role of the different instabilities in producing transport, main plasma (electron) particle transport should be included as an essential element, given that its specific properties help in discriminating among different transport mechanisms. Development and application of reduced transport models should include the simulation of the plasma density, in combination with the planned validation activity dedicated to the modeling of the ion and electron temperature profiles. In particular, initial studies could be dedicated to assess if a neoclassical particle transport model can reproduce the experimental density profiles in the core (considering the particle source produced by NBI), and in the pedestal, where, however, the role of the source is more difficult to establish. On a longer term (FY16 and beyond) the increased understanding of particle transport could be also considered to investigate the possibility of developing control schemes for the density profile shape, in addition to density control, certainly useful for long pulse operation (e.g. to be applied in experimental campaigns starting from 2018).

"Measuring, modeling and controlling particle transport should be higher priority" -- OK

- The problem identified by PAC: no reason to assume n_e profile set by neoclassical
  - Although impurity transport often well described by neoclassical, $|\Gamma_{e,nc}|$~1/60$|\Gamma_{i,nc}|$ much smaller
  - In the presence of an impurity, $\Gamma_{d,nc}+6\Gamma_{c,nc}+Z_i\Gamma_{Zi,nc}$ can satisfy quasineutrality independent of $\Gamma_e \rightarrow n_e$ profile could be determined from anomalous effects

Possible tasks:

1) More systematic experimental characterization and comparison to neoclassical theory over a range of discharge conditions could be useful, e.g.
   - Compare Γ_e with neoclassical theory in core (while also tabulating Γ/Γ_{nc} vs. Q/Q_{NC} vs. Π/Π_{NC}) using TRANSP/NUBEAM for source, NCLASS, NEO (centrifugal effects), GTC-neo, XGC0 (ρ_{ban}/L)
     - Caveat: even if magnitude similar, could still be anomalous with pinch – see #2 (below)
   - Characterize time-dependent behavior (e.g. τ_P vs. τ_E vs. discharge length, dN_e/dt vs. S_{nbi}) & n_e peaking vs. I_p, B_T, nu*, … to estimate what might happen in NSTX-U
2) Assess possibility of doing perturbative studies
   - Assess sensitivity of TS at 60 Hz (Diallo laser N/A – 50 pulses @ 1 or 10 kHz)
     - Simulate perturbative experiment with prescribed D and V to assess the error and optimal condition of using 60 Hz TS
     - If 60 Hz is not fast enough, consider conditional averaging by changing TS pulse timing relative to modulation cycle and assuming reproducible plasmas
   - ORNL antenna + UCLA profile reflectometry? (Unfunded)
     - Space, money, …
   - Interpretation with ME-SXR?
     - Very challenging, maybe with dn/n>1%?
   - Fuelling efficiency (gas puff, SGI)?
     - To be determined
3) Investigate theoretical global effects (for example, global microtearing) on particle transport
   - How to treat E_{r0}?
   - Can *AE influence particle electron particle transport?

"Are you happy with available turbulence measurements, especially toward pedestal?" (Rognlien)

- Have used high-k, BES, reflectometry in pedestal in the past (Ren, Canik, Smith, Kubota, …)
- DBS could be awesome (e.g. MAST, DIII-D), both flow and density
  - No money for this (UCLA priority is polarimetry?)
- CPS (incremental beyond DBS) would provide localized magnetic measurement
  - Maybe after polarimetry results, move to CPS/DBS

- **For us to consider**
- Re-evaluate priority of polarimeter vs. CPS/DBS?
- Is DBS/CPS possible with fixed reflectometer system? (Crocker, Kubota, Peebles, …)
- Revisit PCI as a possibility?
  - Localization from strong shear in local magnetic field pitch angle
- High-k localization in pedestal??? (Ren)

“What about confinement scaling with aspect ratio?” (Whyte)

- Yes, this will be investigated
- NSTX (A=1.3-1.6) → NSTX-U (A=1.6-1.9, maybe 2) → DIII-D similarity (A=3)

PAC DEBRIEF COMMENTS ON TRANSPORT & TURBULENCE

Turbulence and Transport, General Comments

- The PAC congratulates the NSTX Upgrade Team for the recent important results
  - Turbulence measurements across the L-H transition and comparison with lin. GK
  - Test of reduced models for μT turbulence
  - Development of increasingly realistic descriptions of GAE and CAE electron heat transport
  - Extensions in the physics description of momentum transport (including the application of global codes)

- The PAC applauds the strong links which are being built between experimental and theoretical research in this topical area, and acknowledges the specific consideration which has been given to the suggestions included in the last PAC report (in particular emphasis to GAE/CAE transport and application of global models).

- The PAC is pleased to learn that a strong link between exp. and theoretical investigations is already envisaged in the planning of FY15-16 research activities (including major theory upgrades, e.g. e.m. extension of global codes)

Turbulence and Transport, assessment of operational plan and research priorities for FY15 and 16

- The PAC acknowledges that the research plans are well aligned with the 5 –year thrusts and leverage the increased scientific possibilities offered by the upgrade

- The PAC agrees with the hierarchy of investigations towards lower collisionality and higher beta plasma regimes which range from the empirical characterization of global confinement properties to local investigations of multiple transport channels with the aid of multi-scale multi-field (from FY16) fluctuation diagnostics

- However, the PAC is concerned that in FY15-16 insufficient emphasis is given to experimental studies of particle transport, and related validation of models

- As already underlined in the PAC33 report, particle transport plays a critical role towards the development of stationary scenarios for long-pulse opearation (e.g. BS fraction and high-Z impurity control)

Turbulence and Transport, specific suggestions

- Higher priority should be given to particle transport perturbative experiments (assessment of feasibility, continue collaboration with CCFE for comparative analyses between NSTX-U and MAST)

- Main plasma (electron) particle transport be considered as essential element for multi-channel transport investigations

- Emphasis given to prediction of temperature profiles be extended to prediction of density profiles, e.g., does a neoclassical particle transport model really reproduce the experimental observations, in which regimes, in the core, in the pedestal?

- (FY16) Increased understanding of particle transport be considered also to investigate the possibility of developing control schemes for the density profile shape for FY17+ operation.