Summary for Integrated Scenario Breakout Group – Burning Plasma Organization Workshop, December 7-9, 2005

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The plenary presentation for the Integrated Scenarios Group was given by T. Luce (luce@fusion.gat.com), and noted that this group is concerned with self-consistency of the core plasma profiles and sources, compatibility of the plasma core with the boundary scrape-off-layer and divertor, and control of the plasma operating point and access to that operating point. The three main operating scenarios identified for ITER were briefly outlined by distinguishing their safety factor profiles; the ELMy H-mode, Hybrid mode, and Steady State mode. Progress on the ELMy H-mode since Snowmass 2002 included development of ELM mitigation methods, NTM suppression, demonstration of density peaking, and burn control and alpha-simulation experiments with ICRH. Progress of modeling included integration of pedestal models and dynamic ELM models into 1.5D simulations. Experimental progress on the Steady State scenarios since Snowmass included demonstration of > 90% non-inductive plasma for a resistive current relaxation time, optimization of performance through variation of the q-profile and boundary shape , fully non-inductive high bootstrap current discharges (at low Ip or high q_{95}). In modeling the progress included new algorithms for solutions with stiff transport models, scenario optimization through feedback, and self-consistent ITER scenarios. In addition, the hybrid type discharges have been developed since Snowmass 2002 on several tokamaks worldwide, including large parameter variations and stationary discharges for multiple resistive current relaxation times. In modeling the hybrid, ITER simulations are starting to examine the viability of this configuration. Some remaining issues for both experiment and modeling were outlined for the various scenarios, and it was noted that the existing ITPA Steady State Operation group has a similar mission to the Integrated Scenarios Group of the BPO, though with more of a restriction to advanced scenarios.

The Integrated Scenarios Group focused on cross-cutting issues in both experiments and simulations by having presentations in the six topical areas; ITER operating scenarios, Heating/CD/Momentum/Particle sources, Core transport, Pedestal and divertor compatibility, Scenario modeling capabilities and issues, and a joint session with the Plasma Control group. From the discussions it was noted that additional items had been established since the Snowmass 2002 meeting including broad radius ITBs with $\beta_N \approx 4$, the beginning of high performance integrated scenarios on STs, advancement of RF physics models via SciDAC initiatives, and community recognition of the need for comprehensive modeling efforts for burning plasmas (Fusion Simulation Project launched). The discussions also showed that the Integrated Scenarios Group generally was concerned about many of the same issues that were identified under other topical groups, and that we needed to focus on those that involved integration or were otherwise not covered elsewhere.

The Heating/CD/Momentum/Particle source area was treated in the Integrated Scenario Group's breakout meeting. The dominant theme that emerged was the need for a "critical" review of the heating/CD sources, raising the questions; are the day-1 source parameters sufficient?, will these sources actually deliver what is expected?, is lower hybrid current drive required for ITER, and if so, what are its parameters?, are the sources sufficiently flexible to deal with unknowns at least to some degree?. In addition, it was recognized that integrated modeling (and our physics understanding) of particle fueling and transport in the plasma core and connection to the SOL and divertor were rather weak. Since the operation and control of ITER would require fairly precise control of particles, and the fueling regime will be very different than in present experiments, this area needs a significant boost in effort.

The specific issues identified for Integrated Scenarios that were common to all the scenario types included:

1) the pedestal parameters/ELM regime and their compatibility with the core confinement and divertor power loading,
2) the significant differences between ITER regimes and those on present experiments (low torque/rotaton, $T_i \approx T_e$, higher n/n_{Gr}, and low neutrals penetration)
3) the need for increased attention on fueling and particle transport for particle and impurity control,
4) development of integrated simulation tools for prediction and control.

The first issue should be highlighted due to its simultaneous importance to ITER's burning performance and divertor survivability.

Additional specific issues identified for Advanced Scenarios (which includes the hybrid and steady state modes) were

1) limitations posed by ITER startup and current ramp evolution (outboard limiterstartup and long L-mode phase) which might too severely constrain the formation phase of these discharges, which is found to be important on present tokamaks. This area was considered time critical in case design modifications were necessary.
2) Reaching the full long pulse/fluence potential of the advanced scenarios will require upgrades (relative to the day-1 ITER design) to external systems, in particular, the heat rejection system (blanket module cooling) and cryoplant (TF and PF coil cooling). The point was raised at the summary session that the material lifetime limit for the blanket modules in terms of dpa (described as displacements per atom from nuclear damage) may also limits the increase in fluence over the reference ELMy H-mode operation.
3) A particular concern for the Hybrid scenario was the lack of understanding of the physics behind the confinement improvement and non-ideal MHD effects, which can make direct projections to ITER based on existing experimental results difficult. =
4) For the Steady State scenario, the concern is obtaining desirable pressure and non-inductive current profiles in high β regimes, with the added complexity of self-heating and the corresponding energy and particle transport response.
5) In addition, the divertor heat load issue becomes worse when large powers are injected at lower densities to drive current.

It was considered important to continue experimental demonstrations of advanced plasmas with progressively greater integration, such as, an AT scenario with a radiating mantle or divertor, with NTM control, and control of the safety factor simultaneously. These demonstrations provide some confidence that it can be achieved in a burning plasma, even if they are not ITER like in plasma parameter space. Integrated scenarios should also be demonstrated over a range of devices under conditions which are more ITER-like.

There was a consensus to establish an Integrated Scenarios topical group, which did not exist in the strawman BP organization. Since this type of work associated with integrated simulations is typically long term, a standing group was considered necessary. While the work is cross-cutting, it involves crucial compatibility issues which typically “fall between the cracks” of traditional topical areas. This would allow coordination with the ITPA Steady State Operation, Confinement Database and Modeling, and Transport groups, as well as integrated modeling efforts in the US such as PTRANSP and the Fusion Simulation Project. It would also, crucially, be the only group likely to identify, and establish BPO working groups to address, critically needed near-term tasks such as those listed below.

There was a consensus that there should also be a separate Wave-Particle topical group in the BPO (which was consistent with the strawman organization) which should include RF and neutral beams, and would address the heating/CD source issues in coordination with the Integrated Scenarios group. This group can coordinate with the ITPA Steady State Operation group (which is where wave-particle issues are covered in the ITPA), and existing RF groups (SciDAC, RF Topical conference).

Some specific near-term efforts were identified from the discussions which could form the basis of BPO task groups:

1) Critical assessment of the heating and current drive mix on ITER (ICRF, NNBI, EC, and LH) and impact on achievable scenarios.
2) Assessment of limitations to startup flexibility for advanced scenarios and their impact on establishing desired plasma profiles/regimes. Like Task 1, this could lead to recommendations for changes to ITER hardware and is thus time-critical.
3) Integrated modeling of ITER fueling (pellets and gas) and particle transport to assess density profiles and their controllability.