Center for Simulation of Wave – Plasma Interactions

Response to PSACI Panel Questions

May 24, 2006

Original Goals and Near Term Priorities

- **Original Project Goals**
  - Develop an integrated wave simulation capability for the ion cyclotron, lower hybrid and electron cyclotron range of frequencies with self-consistent wave fields and plasma distributions (AORSA, TORIC, CQL3D, ORBIT-RF).
  - We will initiate the process of connecting to transport, MHD and micro-turbulence models, through SciDAC and FSP.
  - Support for ITER in the near term through scenario development and other contributions to the ITPA process, and through support of the RF system design.
  - Carry out studies of nonlinear power losses to RF sheaths on or near the RF antenna, investigate global power losses in the edge region, and address the proper calculation of the launched wave spectrum in full tokamak geometry.

- **Near Term Priorities**
  - Self-consistent LHCD with full-wave + Fokker Planck
  - Quantify fast ion tail physics (QL formulation and finite orbit effects).
  - Implement nonlinear BC’s for RF sheaths (PIC and full-wave).
  - Antenna – core modeling (TORIC + TOPICA).
  - Investigate driven MHD modes near Ω_{ci}
  - Continue ITER-ITPA and USBPO support of ICRH using full-wave & Fokker Planck codes.

Response to Bill Kruer's e-memo)

- **Project's Responsiveness to 2005 PSACI Recommendations**
  - "PAC recommends that a substantial effort be devoted to examining the origins of irreversibility and delineating the regimes of validity of the quasilinear calculations for evolving the distribution functions"
    - **We did this for the C-Mod benchmark case and will continue this type of analysis in the other cases we investigate (e.g. the HHFW – beam interaction experiments).**
  - "It is recommended that perhaps with increased funding support for CSET collaborations and reinstitution of support for the SAPP project, more rapid progress will be stimulated in using multi-scale adaptive spectral representations of the fields in advanced full-wave solvers."
    - **We have plans to investigate these techniques (Summer student will work on this and we plan to write a whitepaper).**
- **Increased scientific understanding achieved in the Project.**
  - First ever self-consistent ICRH simulations using AORSA and CQL3D.
  - New understanding of role of finite drift orbit effects in ICRH experiments on Alcator C-Mod and DIII-D:
    - Ascertained validity of QL theory and suggested experimental tests.
  - Demonstrated feasibility of algorithm for time domain solution for ICH.
  - Quantified level of parasitic losses due to fast alphas in ITER ICRH scenario and identified possible ICW mode conversion scenario for ITER.

Terascale days: Activities of the Project that are resulting in new understanding

- Self-consistent energetic ion tail calculations using AORSA and CQL3D:
  - 1000 – 10,000 processor hours (on CRAY XT3) to do ICRH in present day devices with a single toroidal mode:
- Full-wave LH field solutions have been obtained in a tokamak for the first time ever:
  - 5000 processor hours to simulate LH wave propagation in a present day size device for a single toroidal mode.
  - 50,000 processor hours to do LHCD with nonthermal electron distributions (combined full-wave – Fokker Planck calculation).
- Full-wave spectral solver (TORIC) provides enough resolution to resolve driven CAE mode in NSTX:
  - 1000 processor hours to resolve a single toroidal mode, at a minimum.
- **Breakdown of processor utilization:**
  - Have been using 100,000 – 150,000 processor hours per month (JAGUAR)
  - About 90% of processor hours at 256 or less doing debugging, development, model problems, bench marking.
  - About 10% @ 1000-4000 processors (this mix will be evolving with porting of TORIC to the CRAY XT3.

Petascale Nights: Dreams of the Project

- Self-consistent energetic ion tail calculations using AORSA and CQL3D:
  - 20,000 – 200,000 processor hours (on CRAY XT3) to do ICRH in present day devices **for a complete antenna spectrum.**
- Full-wave LH field solutions in ITER:
  - At least a peta-scale and more with a full antenna spectrum.
  - Increased time to do LH wave – fast alpha interaction.
- 3D ICRF heating and mode conversion studies:
  - At least peta-scale
- Antenna to core modeling with nonlinear plasma effects in the antenna region:
  - Quantitative antenna design and predictions of edge plasma evolution near antennas.
- Multi-scale physics applications coupling RF with MHD or transport will require petascale.