Fusion Simulation Program (FSP)

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EU-US WORKSHOP ON SOFTWARE TECHNOLOGIES FOR INTEGRATED MODELLING IN FUSION

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Presented by C. S. Chang
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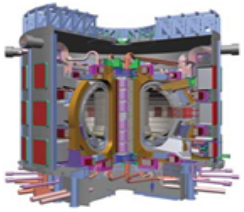
FSP -- A Strategic *Opportunity* to Accelerate Scientific Progress in FES

- **Need for reliable predictive simulation capability for *BP/ITER* *(especially in the US)***
- **Powerful ("Leadership Class") Computational Facilities moving rapidly toward petascale & beyond**
- **Interdisciplinary *collaborative experience*, knowledge, & software assembled over the course of nearly a decade under SciDAC plus OFES and OASCR base research programs in the US**



U.S. Simulation Needs for ITER

FSP

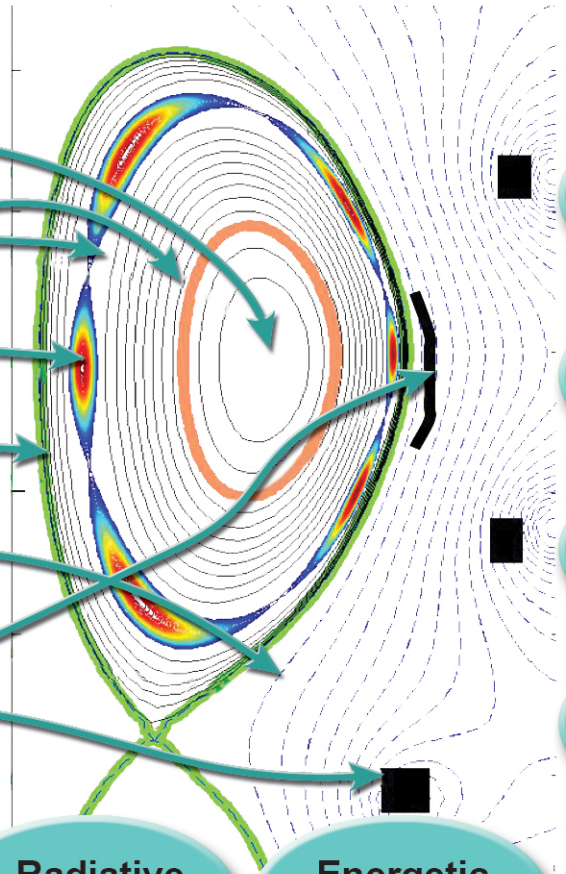
Petascale Computing Capability

Knowledge and Software Base

OFES Theory Program	OFES Experimental Program	OFES SciDAC	OASCR SciDAC	OASCR Math Program	OASCR CS Program

Elements of an FSP Integrated Model

- Sawtooth Region (q < 1)
- Core confinement Region
- Magnetic Islands
- Edge Pedestal Region
- Scrape-off Layer
- Vacuum/Wall/ Conducctors/Antenna



Core & Edge Transport

Plasma Turbulence

Large Scale Instabilities

MHD Equilibrium

Heating & Current Drive

Energetic Particles

Radiative Transport

Atomic Physics

Plasma-Wall Interactions

FSP Products Address Critical Science Drivers

- **Science drivers: Compelling scientific problems chosen to focus FSP's design and implementation**
  - Important and urgent for the fusion program
  - Clear need for multi-scale, multi-physics integration
- **The FSP will build *Integrated Science Applications* targeting these problems**
  - Modeling tools for the whole fusion community

- **Science Drivers:**
  - **Plasma Boundary Physics**
  - **Pedestal**
  - **Core Profiles**
  - **Wave-Particle Interactions (EP & RF)**
  - **Disruption Avoidance & Mitigation**
  - **Whole Device Model**

FSP Collaborations with FES Theory & SciDAC Programs

- **Basic Theory Role**: *provide scientific foundation and rigorous formulation of the physics models and identify limitations to approaches*

- **Computational Models from US Theory Program & FSP**: *complementary (not duplicative) approaches for reduced models & fundamental simulations with goal of "open source" versions meeting FSP metrics*

  -- FSP will involve Theory Program in independent physics verification of code components & in exploration of alternate strategies

  -- FSP will collaborate with SciDAC centers in developing physics components and integration techniques (e.g., identifying tools needed to address "gaps" inhibiting progress on Science Drivers)

- **International Modelling & FSP**: *information exchange targeting potential areas of fruitful collaborative research with integrated modelling programs outside the US, such as:*

  -- US-Japan Workshop on Integrated Modeling at MIT – P. Bonoli (US), A. Fukuyama (Japan), co-chairs with P. Strand (EU), M. Greenwald, A. Kritz, J. Cary, C. S. Chang, et al. (Feb, 2010)

  -- Bilateral workshops such as the current EU-US workshop

FSP Collaborations with FES Experimental Programs

- **Basic Experimental Role**: *provides validation foundations for physics fidelity of theoretical and simulation models*

- **Experimental Validation in US & FSP**: *good progress on discussions with the major facilities (DIII-D, C-MOD, NSTX) to define:*

  -- General *principles for intellectual property (IP) sharing*
  -- *Roles & Responsibilities* for the FSP and for experimental teams in their collaboration
  -- *Cross-membership* in planning groups
  -- *Lessons learned* from experimental facilities useful in planning FSP R&D program
  -- e.g., *open annual community research forums*

- **International Experimental Validation & FSP:** *Discussions have also been initiated with non-US facilities that have capabilities unavailable in US [e.g., JET (EU), EAST (China), KSTAR (Korea), …]*

- **University Collaborations in Theory & Experiments**: *University community participation welcome in expected Open Annual FSP Research Forum for impacting future planning of FSP R& D Program (during "Execution Phase")*

FSP Prioritization Metrics (basic considerations)

1. **A clear need for multi-scale, multi-physics integration**:
   - proposed topic should be outside focus area of current modeling programs
   - solving/significant advances on problem would demonstrate FSP "is more than the sum of its parts"

2. **Importance and urgency**:
   - solve problems integral to creation of knowledge base needed for Fusion Energy Sciences (FES) mission leading to "an economically and environmentally attractive fusion energy source"
   - urgency is related to schedules, dependencies and critical paths for program elements that FSP would support.

3. **Readiness and Tractability:**
   - The underlying physics base (with applied math, CS, and computing platforms), should be sufficient to begin work at outset of FSP
   - Need for FSP to impact ongoing research at an early date
   - Need for clear "living roadmap" for substantive progress on this research topic

4. **Opportunity for New Lines of Research:**
   - Associated R&D offer opportunities for delivering new insights or potential breakthroughs, particularly those not accessible by other means.

FSP Prioritization Metrics (additional considerations)

(1) Avoid "Stove-piping:"

- Each Integrated Science Application (ISA) program plan should reflect ***clear cognizance/ linkage to the others*** – especially the Whole Device Modelling ISA

(2) Ensure "Buy-in" from "Customer-base" for FSP products:

- The ISA documents should explain/highlight ***what user communities are interested in the FSP software capabilities proposed for development and with what level of urgency***
- Needs to reflect realistic level of ***"market analysis"***
- Appropriate ***user-advisory panel*** should be part of our FSP plan
- Sources of input include BPO and ITPA – since associated listed priorities exist & should be reflected in ISA documents
- Cross-references to the U.S. RENEW document, priorities of the Fusion Facilities Coordination Committee (FFCC), and areas of focus for international experimental facilities & modelling efforts

(3) Roles and Responsibilities of the ISA leaders/managers:

- The ISA documents will define the associated roles & responsibilities of each ISA leader/ managers
- ISA leaders must collaborate with each other as well as those leading the development of physics components, frameworks, etc.

Associated Tasks for FSP Prioritization

(1) **Identify calculations or modeling campaigns** ***required to help target the key physics mechanisms for each ISA, including assessments of:***

-- readiness of current modeling tools
-- current state of validation

(2) **Identify experiments** ***needed to be performed to help focus on the key physics mechanisms for each ISA***

-- specify/propose measurements (diagnostic capabilities) needed to understand key phenomena associated with each ISA

Summary Comments

- **FSP will establish credible base of *component capabilities and framework approaches* to produce *integrated software tools within the next 5 years* to enable significant progress on each of the integrated science applications (SD's)**
  - **-- Address needs identified by *"gaps analysis" of science & simulation tools required to improve fidelity***
  - **-- Implement strong Verification, Uncertainty Quantification, and Experimental Validation campaign enabled by *effective partnership with experimental facilities/ community***
  - **-- Identify limitations and adopt associated *risk mitigation plans***

- **FSP scope will focus on *common components/integration R&D approaches* to address Integrated Science Applications (ISA's)**

- **FSP's *whole device modeling (WDM) ISA will unify R&D thrusts across other ISA areas* – i.e., physics integration areas on converging paths toward WDM**

FSP Upcoming Events

- **Major Community FSP Planning Workshop –** ***week of February 7, 2011 at General Atomics, San Diego, CA***
- **FSP Information Presentations planned for upcoming TTF and Sherwood Meetings to discuss Draft of FSP Plan:** ***Spring 2011 (to be announced)***
- **Delivery of final FSP Plan (with resource loaded documentation) – mid-July 2011**

A DOE-Office of Science assessment expected at the end of the 2-year planning study (shortly after July of 2011)

More Information: FSP planning team* has posted on its national web-site ***[http://www.pppl.gov/fsp/] with "Frequently Asked Questions (FAQ) & Answers section***

-- welcomes input, comments and suggestions from the FES and ASCR communities.

****Team of 6 national labs (PPPL, ORNL, LANL, LBNL, LLNL, ANL), 2 companies (GA, Tech-X), and 9 universities (MIT, Princeton, Columbia, NYU, UCSD, Chicago, Lehigh, Purdue, Texas)***

VERY POSITIVE ENCOURAGEMENT FOR FSP

U. S. Energy Undersecretary Steven Koonin:

3 November 2009 – American Physical Society Meeting, Atlanta,Georgia

"Validated predictive simulation capability is key to advancing fusion science towards energy"

"Our confidence in validated simulation [close integration of theory, modeling, simulations, and experiments] has to take a major step up

- *moving from description to prediction*
- *use simulation to explore regimes beyond current experimental capabilities*
- *Fusion Simulation Program (FSP) is a start along this path."*

U.S. Energy Secretary Steven Chu:

27 September 2010 – "All Hands Meeting" at the Princeton Plasma Physics Laboratory, Princeton, NJ

"The world's energy challenge requires a strong continued commitment to plasma and fusion science."

"Progress in fusion has to be grounded in validated predictive understanding: the DoE is clearly interested in your planning and progress for a strong Fusion Simulation Program (FSP)."