Fusion Simulation Project

(Tokamak Whole Device Modeling)

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Fusion Simulation Project Background - 1

- **Fusion Simulation Project (FSP) to address questions outlined in charge letter to FESAC from Acting Director of OFS February 22, 2002**
  - **Develop 5-6 year initiative the goal of which is develop an improved capacity for Integrated Simulation and Optimization of Fusion Systems**
    - **What is the current status of integrated computational modeling and simulation?**
    - **What should be the vision for integrated simulation of toroidal confinement fusion systems?**
    - **What new theory and applied mathematics are required for simulation and optimization of fusion systems?**
    - **What computer science is required for simulation and optimization of fusion systems?**
    - **What are the computational infrastructure needs for integrated simulation of fusion systems?**
    - **How should integrated simulation codes be validated, and how can they best be used to enable new scientific insights?**
- **FESAC appointed committee to develop a roadmap**

FSP Background - 2

- **Final FESAC Report December 2002**
  - **http://www.isofs.info/FSP_Final_Report.pdf**
    http://www.isofs.info/FSP_Appendix.pdf
  - **Fusion Simulation Project (FSP) envisioned as a 15 year, $20M/year multi-institutional project**
    - **Develop a comprehensive simulation capability for magnetic fusion experiments with a focus on ITER**
- **OFES formed an FSP Steering Committee in 2003**
  - **Develop project vision, governance concept, and roadmap for the FSP**
  - **Recommends that the FSP consist of three elements:**
    - **Production component, a research and integration component, and a software infrastructure component**
  - **Final report in Journal of Fusion Energy, Vol. 23, No. 1, March 2004**
  - **Recommended an approach through Focused Integration Initiatives**
    - **Coupling pairs of components before moving to whole device modeling**

FSP 2007

- **OFES Goal to fund FSP in Target Budget beginning in FY2009**
  - **Funding to grow to $28M/year within a few years for 15 year project**
- **To start the FSP project, it is necessary to describe:**
  - **(1) What are the deliverables, particularly at the end of first five years**
    - **Need a detailed FSP road map for the first 5 years and a plausible road map if the project is to continue longer**
  - **(2) How the project is organized**
    - **OMB might prefer organization that is analogous to the ITER organization.**
  - **(3) How will we insure that the goals are met**
- **To obtain the information required, OFES and OASCR cooperated in the formation of an FSP committee to plan a workshop organized in terms of panels**
  - **10 to 12 members from OFES and OASCR communities on each of four panels**

Committee Membership

- Co-Chairs: David Keyes (Columbia Univ.)
  Arnold Kritz (Lehigh Univ.)
- Phil Colella (LBL)
- Martin Greenwald (MIT)
- Dan Meiron (Cal Tech)
- Scott Parker (Univ. Colorado)
- Cynthia Phillips (PPPL)
- Tom Rognlien (LLNL)
- Andrew Siegel (ANL)
- Xianzhu Tang (Los Alamos)
- Pat Worley (ORNL)

FSP Workshop

- **Workshop will be held during the week of May 14, 2007**
  - **Venue will be in the vicinity of Washington, DC**
  - **Workshop – 2 days with FSP Committee members and Scribes continuing on third day to complete draft of workshop report**
- **Workshop will be organized in terms of panels**
  - **Currently the FSP Committee envisions four panels**
  - **Approximately 45 scientists will participate as panel members**
    - **Includes physicists, applied mathematicians, and computer scientists**
  - **Workshop will include opportunity for comments by observers**
- **FSP Workshop will be patterned after DOE-BES Workshops**
  - **Examples of 17 reports that have been written by Basic Energy Sciences (BES) workshops are available on the Web at http://www.sc.doe.gov/BES/reports/list.html**

FSP Workshop Report

- The result of the workshop will be a report containing the conclusions and recommendations of each panel
- The intent is that the result of the work of the FSP panels will be reviewed by a FESAC appointed subcommittee
  - Subcommittee will then report to FESAC (Fusion Energy Scientific Advisory Committee)
  - The FESAC then advises and makes recommendations to the DOE Office of Science
- There may also be a report to ASCAC (Advanced Scientific Computing Advisory Committee)

Panel Structure

At present four panels are envisioned

- **Project Structure and Management**
  - **A. Kritz, D. Keyes, M. Greenwald**
- **Integration and Management of Code Components**
  - **A. Siegel, D. Meiron, T. Rognlien**
- **Status of Physics Components**
  - **S. Parker, C. Phillips, X. Tang**
- **Status of Required Computational and Applied Math Tools**
  - **P. Colella, P. Worley, D. Keyes**

Project Structure and Management

- General management structure
- Establishing project Gantt charts
  - Process if deadlines are not met
- Coordination and management of geographically distributed teams
- Interaction with other related national and international projects
- How to allow for alternative approaches

Integration and Management of Code Components

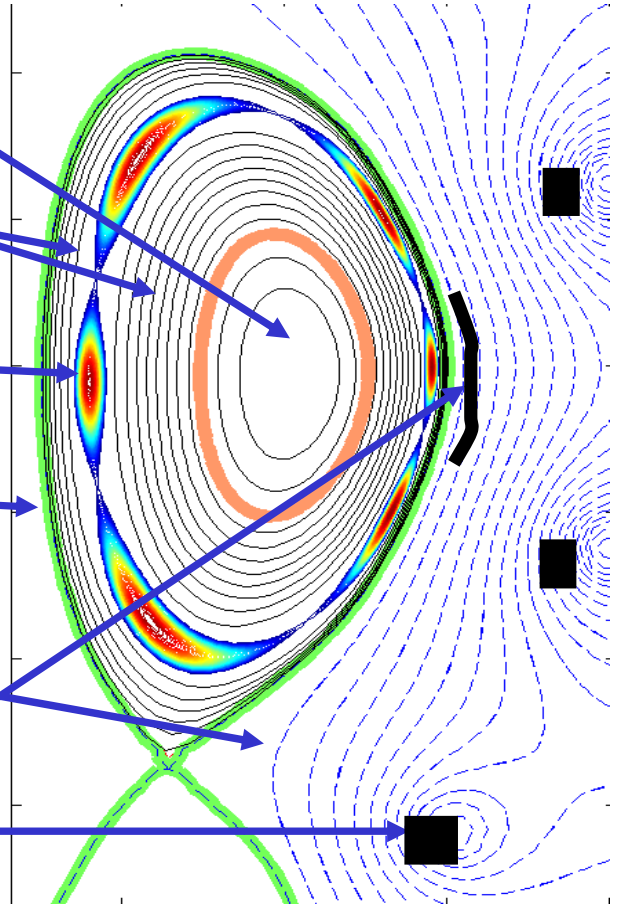
- Scope of the FSP (ITER requirements)
  - Discharge scenario planning
  - Real-time feedback control
  - Interpretation of diagnostics
- Component coupling – framework issues
- Project Phasing
  - Duration and sequencing of various phases
- Validation and Verification procedures
- Code version control and management
- Coding standards

Status of Physics Components

- Completeness and robustness of physics modules
  - NBI and RF and nuclear heating
  - Fueling
  - Current drive
  - Transport and turbulence
  - Large-scale instabilities
  - Plasma edge
  - Wall and atomic physics
  - Feedback control
- What can be achieved in various time frames

Elements of an Integrated Tokamak Modeling Code

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



Core Transport

Edge Transport

Plasma Turbulence

MHD Equilibrium

Heating Current Drive

Atomic Physics

Radiative Transport

Large Scale Instabilities

Plasma-Wall Interactions

Status of Required Computational and Applied Math Tools

- **Numerical algorithms**
  - **Discretization, adaptivity, solution, optimization**
- **Data handling**
- **Graphics and visualization**
- **Scalability to highest-end platforms**
- **Performance evaluation and performance engineering**

Questions for FSP Panels

- What are critical technical issues for the fusion program?
  - On what time scale is a resolution needed for each issue?
- How can high performance computer simulation contribute to the resolution of each critical technical issue?
  - What substantial contribution can computer simulation make that traditional theory or experiment, by themselves, cannot?
- What investments in fusion and computational science and infrastructure must be made to obtain the needed answers?
  - What contributions can be obtained from advancements in physics models, algorithms, software, and computer hardware?
- How do we organize and manage the Fusion Simulation Project to address these critical technical issues?

Current Status

- **FSP Committee in process of populating panels**
  - **Panels will begin to function when formed**
  - **In addition to panel Chair (or Co-chairs) each panel will have Scribe**
- **Procedures for obtaining broader community input regarding FSP will be established**
  - **There is a need to produce, in a timely way, advanced simulation capability that can provide exciting scientific deliverables which substantially impact realistic predictive capabilities**
  - **There is a need to make a clear distinction between new individual scientific discoveries driven by leadership class supercomputers and useful integrated models that are capable of delivering whole device simulations with significantly improved validation**