FUSION SIMULATION PROGRAM (FSP):
UPDATES, SCHEDULES, &
KICKOFF MEETING GOALS

FSP KICKOFF MEETING

July 15 - 16, 2009

W. M. Tang

U.S. DEPARTMENT OF ENERGY | Office of Science

PRINCETON UNIVERSITY

PPPL PRINCETON PLASMA PHYSICS LABORATORY

FSP PLANNING UPDATES/SCHEDULES & GOALS FOR THIS MEETING

- Basic Goal for This Meeting: *In accordance with activities described in our successful FSP Program Definition/Planning Proposal, develop an appropriate time-line for delivering the "living roadmap" of scientific deliverables/milestones and associated time-lines for this planning process*
  - includes approach for estimating needed resources (manpower, computing resources, etc) and an effective overall FSP management structure
  - assessments of current capabilities with associated "gaps analysis"
  - plans for integration/coordination with FES SciDAC centers and Base Theory Program (including plasma-materials interface (PMI) area)
- The FSP team will carry out a detailed "planning study" during the next two years (beginning July of FY '09 & ending July of FY '11)
  - Equivalent to "Project Definition" phase in *Project Management* language, leading to *Critical Decision 1 (CD-1)*
  - Although the FSP does not fall under the provisions of DOE Project Mgt. Order 413.3 A, associated *"best practices" will be adopted to ensure its success*
- List of what is expected at the end of the 2-year planning period described in the original DOE announcement/RFP: http://www.sc.doe.gov/grants/FAPN09-04.html
- *Based on a favorable outcome of DOE-SC review and the availability of appropriated funds, the full FSP would be launched in the late FY 2011 or beginning of FY 2012*

FSP PLANNING UPDATES/SCHEDULES & GOALS FOR THIS MEETING (continued)

- **Our FSP Proposal was very favorably *peer-reviewed by 9 experts from U. S. and international community* and strongly recommended for acceptance**
  - ***Prioritization*: strong cautionary to avoid "lowest common denominator" approaches and being "all things to all people"**
  - ***Approach*: emphasis on strategic importance of delivering practical near-term software capabilities to the user community (based on specific user requirements)**
  - ***Validation*: need to demonstrate strong coupling to experimental observations/data**
  - ***Risk Mitigation*: nearer-term deliverables should be based on reasonably well-known software platforms, and new physics components should be benchmarked/tested vs. simpler models**
- **Current Funding is $4M over 24 months to support the formulation/articulation of the FSP Project Definition/Plan -- with *opportunity for an additional $2M in FY'10* to support possible *focused complementary R & D topical initiatives***
  - ***Focus of tomorrow (Thursday) morning's session***

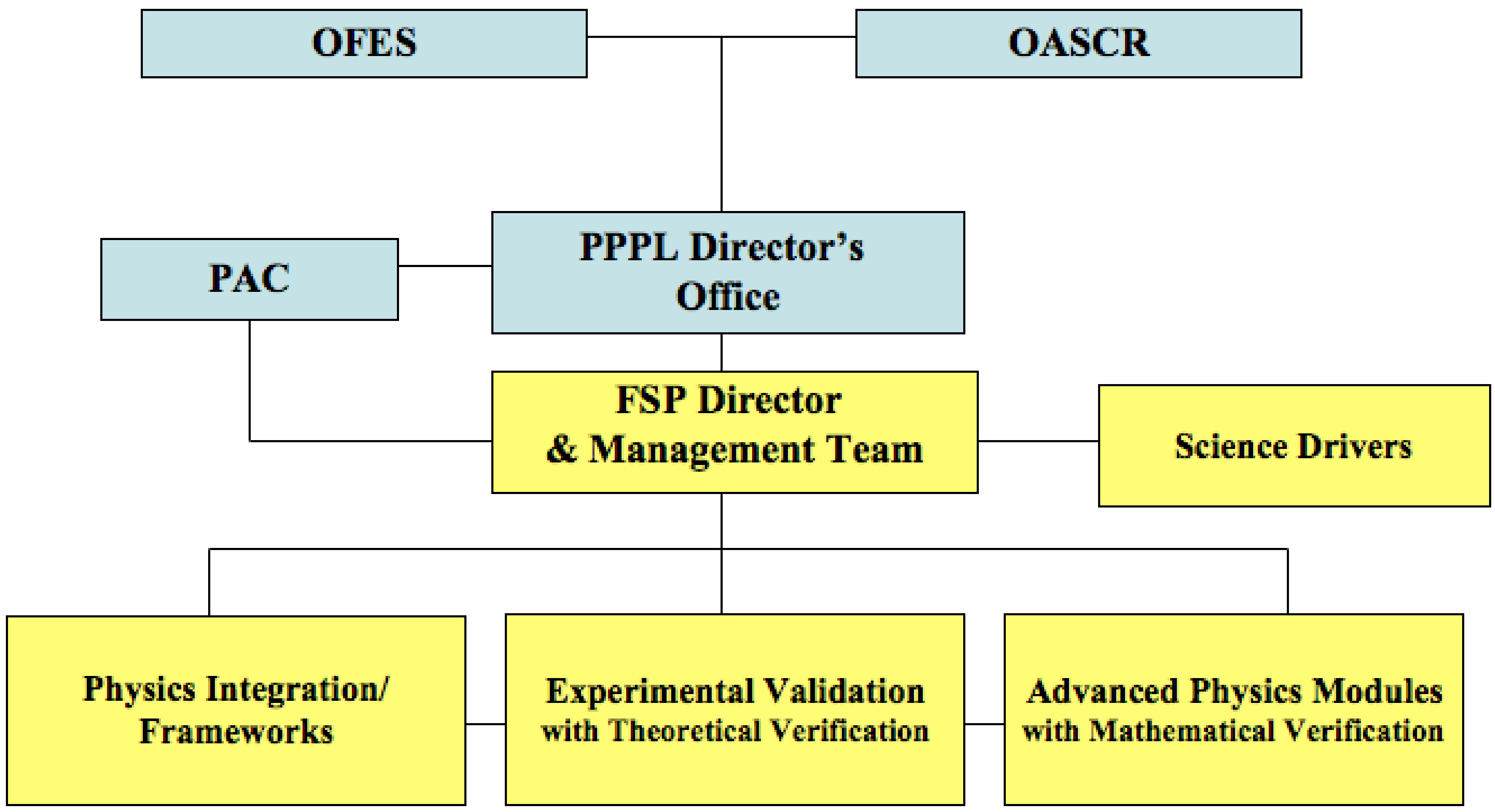
FSP PLANNING UPDATES/SCHEDULES & GOALS FOR THIS MEETING (continued)

- EXPECTED UPCOMING TIME-LINE*:

- Mid-September, 2009: FSP Program Advisory Committee (PAC) Meeting
- October 15, 2009: DOE quarterly progress review
- January 15, 2010: DOE quarterly progress review
- February 15, 2010: Possible FSP PAC Meeting (frequency TBD) on Progress
- April 15, 2010: DOE quarterly progress review
- July 15, 2010: DOE quarterly progress review
- Mid-September, 2010: FSP Program Advisory Committee (PAC) Meeting
- October 15, 2010: DOE quarterly progress review
- January 15, 2011: DOE quarterly progress review
- February 15-16, 2010: FSP PAC Meeting on Near-Final Project Definition/Plan
- April 15, 2010: DOE quarterly progress review
- July 15, 2010: Delivery of Final FSP Project Definition Plan to DOE

*Associated task assignments and team meetings (determined at this and following meetings/teleconferences) will necessarily track/complement this time-line

Management Structure for FSP Planning/Program Definition



FSP Program Advisory Committee

Raymond Fonck, *PAC Chairman*, Prof. of Physics, U. Wisconsin
Tony Taylor, DIII-D Program Director, General Atomics
Earl Marmar, C-MOD Program Director, MIT
Allen Boozer, Prof. of Physics, Columbia U.
James Van Dam, Director, Institute for Fusion Studies (IFS) and Director, US Burning Plasma Organization (BPO)
Gregory Hammett, Principal Research Physicist, PPPL
Wayne Houlberg, Fusion Science & Technology Dept., ITER Organization
Carl Sovinec, Prof. of Engineering, U. Wisconsin

*__Leslie Greengard__, Prof. of Mathematics and Director, Courant Institute of Mathematics, NYU
*__Rick Stevens__, Prof. of Computer Science, U. Chicago & Associate Director for Computating, Environment, & Life Sciences, Argonne National Laboratory
*__Brian Gross__, Deputy Director, Geophysical Fluid Dynamics Laboratory
* __Daniel Meiron__, Prof. of Applied & Computational Mathematics and Computer Science, Cal Tech
*__Michael Norman__, Prof. of Physics, UCSD and Chief Scientific Officer, San Diego Supercomputing Center, UCSD

* *Non-Plasma Science Members*

FSP PROGRAM DEFINITION/PLANNING MANAGEMENT TEAM*

- Director (*W. Tang, PPPL*), Deputy Director *(D. Kothe, ORNL)*

- Science Drivers *(Lead, A. Kritz, Lehigh U.)* with
  Supporting Team *(P. Diamond, UCSD, et al.)*

- Frameworks/Physics Integration *(Lead, J. Cary, Tech-X)* with
  Supporting Team *(A. Siegel, ANL, et al.)*

- Experimental Validation *(Lead, M. Greenwald, MIT)* and
  Theoretical Verification *(Lead, V. Chan, GA)* + Supporting Team

- Advanced Physics Modules *(Lead, X. Tang, LANL)* and
  Mathematical Verification *(L. Diachin, LLNL)* + Supporting Team

*W. Tang (PPPL/PU). D. Batchelor (ORNL), H. Berk (IFS), J. Brooks (Purdue U.), J. Cary (Tech-X/U. Colorado), V. Chan (GA), C.S. Chang (NYU), P. Colella (LBNL), L. Diachin (LLNL), P. Diamond (UCSD), M. Greenwald (MIT), D. Keyes (Columbia U.), D. Kothe (ORNL), A. Kritz (Lehigh U.), W. Nevins (LLNL), A. Siegel (ANL/U.Chicago), X. Tang (LANL), G. Tynan (UCSD)

EXAMPLES OF SCIENCE DRIVERS FOR THE FSP

(key issues for burning plasmas and ITER operation)

1. **Disruption Effects & Mitigation** - *Large-scale macroscopic events producing rapid termination of plasma discharges*
   - Need to avoid since ITER can sustain only a limited number of full-current disruptions
   - Need to predict the onset of a disruption and to mitigate/minimize associated damage if it occurs
2. **Pedestal (steep-spatial gradient) Formation and Transient Heat Loads on Plasma Periphery (divertor region)**
   - Need to predict onset and growth of pedestal since its height is observed to control confinement
   - Need to predict frequency and size of Edge Localized Modes (ELMs) crashes to mitigate damage to the divertor and to plasma facing components
3. **Tritium Migration and Impurity Transport**
   - Need to predict tritium recycling, diffusion, and trapping since tritium inventory must be controlled
   - Need to predict impurity influx and transport since they can dilute D-T fuel and degrade fusion power production

EXAMPLES OF SCIENCE DRIVERS FOR THE FSP

(key issues for burning plasmas and ITER operation)

4. Performance Optimization & Scenario Modeling

- Need to optimize performance (including sustaining maximum fusion power production) while planning experiments
  - *cost consciousness -- with each ITER discharge approaching $1M*
- Need to control plasma current and pressure in more challenging scenarios --moving from present experiments (*10's of seconds duration*) to ITER discharges dominated by alpha-self-heating and *lasting thousands of seconds*

5. Plasma Feedback Control - *Burning plasma regime is fundamentally new with stronger self-coupling and weaker external control*

- Need to design real-time feedback control to avoid disruptions and to optimize the performance of burning plasma experiments near operational limits
- Need to control edge localized modes (ELMs) since they can damage the divertor and impact the rapid erosion of plasma facing components

NOTE: *Items (1) thru (3) focus on improved scientific understanding of physical processes [demanding integration of a few "1st principles solvers" with high physics fidelity] while (4) and (5) focus on new tools for operational control [requiring integration of a large number of reduced dimensionality models]*

Verification & Validation Challenges

- **Establishing the physics fidelity of modern plasma science simulation tools demands proper Verification & Validation (V&V) -- *Reliable codes demand solid theoretical foundations and careful experimental validation***

  • **Verification assesses degree to which a code (*both in the advanced direct numerical simulation (DNS) and reduced models categories*) correctly implements the chosen physical model**

  --- more than "essentially a mathematical problem"

  e.g., accuracy of numerical approximations, mesh/space and temporal discretization, statistical sampling errors, etc.

--- Special emphasis should be placed on code verification via:

(1) comparisons with theoretical predictions

e.g. -- threshold/onset conditions for instabilities; weakly nonlinear evolution; nonlinear saturation estimates; etc.

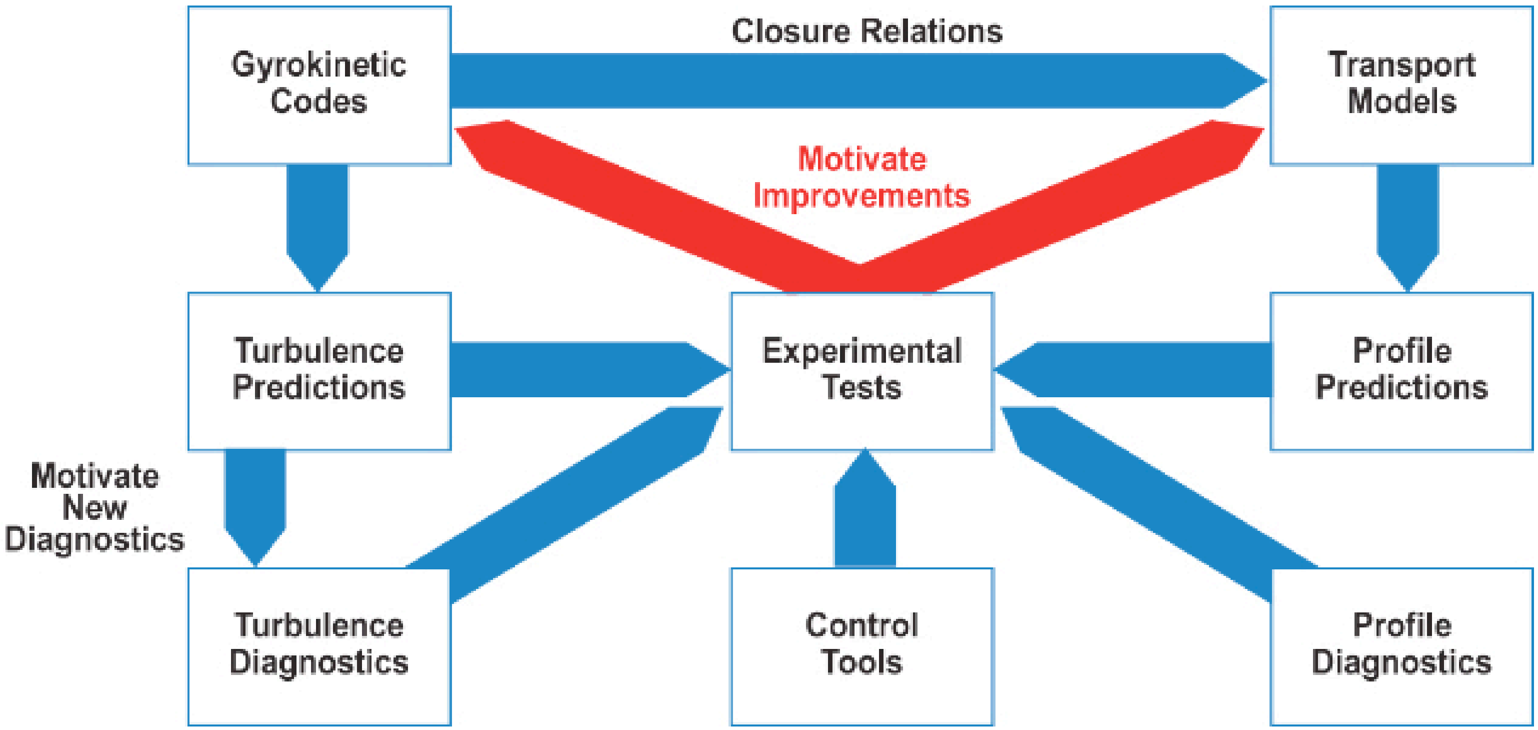
(2) cross-code benchmarking (codes based on different mathematical formulations/algorithms but targeting the same generic physics)

e.g. -- finite difference, finite elements, spectral methods, implicit schemes, etc.and/or models such as Particle-in-Cell, Vlasov/Continuum, Hybrid PIC-Fluid, etc.

Verification & Validation Challenges

- **Validation** assesses degree to which a code (within its domain of applicability) "describes the real world," e.g.

  Schematic: *Combined Efforts from Theory/Modeling/Experiment for Realistic Predictive Transport Capability in Plasma Core*



- *V & V in FES/Plasma Science can benefit from "lessons learned" from other prominent applications domains featuring large scale simulations -- e.g., climate modeling, combustion, ASCI, etc.*

Proposed Milestones in FY '09

(July '09 through September '09)

- **Perform a *"gaps analysis"* for simulations of fusion systems**
  - *Will utilize relevant current information gathered, for example, by the recent national ReNew process*

- **Develop *program and management plans to address the gaps*, and produce a *living-scientific-road-map that identifies viable deliverables***
  - *Cognizance of strategic importance of delivering some nearer-term software capabilities to the user community*

- **Develop plan for *inclusion of requisite expertise from the community needed to address the FSP goals with prioritization***
  - *Cognizance of cautionary (from referees' reports) to avoid "lowest common denominator" approaches and being "all things to all people"*

Proposed Milestones in FY '10 and '11

(October, '09 through July, '11)

- Produce a *program execution plan (PEP)*, including:
  - *conceptual design of the FSP*
  - *initial technical approaches*
  - *program milestones*
  - *MOU's for participating institutions (e.g., HEP example)*

- Estimate the *manpower, computing resources [both LCF ("capability") & Mid-range ("capacity")], and funding* requirements based on this technical plan

- Work with the scientific community, OFES, and OASCR to *secure the broad support needed* to launch this program after successful completion of FSP Program Definition/Planning phase

Original FSP Proposal: Science Drivers

Task	Year 1 (percentage)	Year 2 (percentage)
Establish criteria for prioritizing science drivers	10	
Establish prioritization of drivers	10	10
Presentations and fact finding at fusion facilities	30	20
Evaluation of component and framework plans in order to establish the sequencing of science goals	20	20
Develop a plan to continuously monitor progress in addressing science drivers	20	30
Document and disseminate science driver information	10	20
Total	**$200K**	**$200K**

Original FSP Proposal: Physics Integration/Frameworks

Task	Year 1 (percentage)	Year 2 (percentage)
Management, including coordination of framework design, user needs, software engineering and providing assistance with all tasks	20	20
Framework design, including assessment of previous efforts, determining technologies to adopt, setting standards for inclusion, designing the workflow	35	35
Assessing user needs, defining use cases, determining level of user support needed,	25	25
Software engineering including assessing and adopting systems for builds, tests, version control, release management.	20	20
Total	**$460K**	**$460K**

Original FSP Proposal: Advanced Physics Components/Modules

Task	Year 1 (percentage)	Year 2 (percentage)
Overall coordination	15	15
Science driver to component requirement	20	5
Assess present capabilities	20	5
Gaps and opportunities analysis	15	20
Prioritization and design initial approaches	5	15
Verification strategy	20	20
Roadmap + implementation plan + deliverables	5	20
Total	**$460K**	**$460K**

Original FSP Proposal: Experimental Validation

Task	Year 1 (percentage)	Year 2 (percentage)
Study and document lessons learned	10	
Perform gap analysis	20	
Develop validation strategy	20	40
Develop documentation strategy	10	10
Coordination with experimental and code groups	35	35
Estimate resource requirements for FSP validation	5	15
Total	**$360K**	**$360K**

Original FSP Proposal: Management Planning

Task	Year 1 (percentage)	Year 2 (percentage)
Overall leadership and coordination of program	10	10
Development of FSP management plan	10	10
Presentations and outreach activities	10	20
Monitor and assess progress on milestones and deliverables in all task areas and conduct quarterly reviews	20	10
Document and disseminate program plans	10	10
Contingency resources (*to be distributed*)	40	40
Total	**$520K**	**$520K**

FES community involvement with the FSP

- **The FSP planning team members are actively involved with:**
  - ***(i)*** ***the current national ReNeW process -- a major source of community input on key FSP topics as well as with ongoing TTF, BPO, ITPA activities***
  - ***(ii)*** ***the current development of a major DOE report on "FES Grand Challenges and Computing at the Extreme Scale," involving over 100 of the top scientists from the FES, Applied Math, and Computer Science communities***
- **Project definition deliverables will include plans for continuing interaction & coordination with:**
  - ***the FES analytic theory & modelling communities to help address: (1) key physics gaps in the models implemented in the FSP codes; & (2) effective process for incorporating improved theoretical models into the FSP simulation tools***
  - ***the FES experimental community to help address: (1) key physics gaps in the models implemented in the FSP codes; & (2) formulation of a successful and credible verification and validation plan***

****Also will engage international integrated modeling efforts -- coordination with EU, Japan, … in addressing needs of the international ITER Organization***

FUSION SIMULATION PROGRAM (FSP) KICKOFF MEETING AGENDA

WEDNESDAY, JULY 15, '09

9:00 AM -- 10 AM
Welcome from PPPL Director Stewart Prager
FSP Updates/Schedules & Goals for this Meeting (W. Tang)

10:00 AM -- 10:15 AM: Coffee Break

All presentations should allow at least half of the allotted time for discussions

10:15 AM -- 11:15 AM
Plans & Action Items for Science Drivers (A. Kritz)

11:15 AM -- 12:15 PM
Plans & Action Items for Physics Integration/Frameworks (J. Cary)

12:15 PM -- 1:15 PM LUNCH

1:15 PM -- 2:15 PM
Plans & Action Items for Advanced Components/Modules
with Mathematical Verification (X. Tang/L. Diachin)

2:15 PM -- 3:15 PM
Plans & Action Items for Experimental Validation
with Theoretical Verification (M. Greenwald/V. Chan)

3:15 PM -- 3:30 PM: Coffee Break

WEDNESDAY, JULY 15, ‘09

3:30 PM -- 4:30 PM
Plans & Action Items for FSP Management Plan (D. Kothe)

4:30 PM -- 6:10 PM
Preliminary Summary of Action Items -- 20 minutes for each area
(A. Kritz, J. Cary, X. Tang, M. Greenwald, D. Kothe)

6:10 PM
Adjourn for Day 1

THURSDAY, JULY 16, ‘09

9:00 AM -- 11:00 AM
Discussion of Possible Focused Complementary R&D Topical Initiatives
[informal presentations from (1) D. McCune/M.Zarnstorff; (2) R. Samtaney; (3) C. Holland;
(4) S. Kruger; (5) G. Bateman; (60) R. Cohen]

(no formal break, but coffee provided at 10 AM)

11:00 AM -- 12:30 PM
Final Summary of All Action Items & Associated Discussions

12:30 PM -- Lunch and Adjourn Meeting