ReNeW Workshop

Theme I: Burning Plasma Physics on ITER

Theme II: High-Performance Steady-State Burning-Plasmas

March 23-27, 2009, General Atomics

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Princeton, NJ
United States of America

ARIES Project Meeting
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University of Wisconsin, Madison WI

Theme I and II Joint Workshop

- Theme I and II Workshop agenda, white papers and presentations at:
  http://fusion.gat.com/global/Renewt12_agenda
- Five day workshop with ~ 140 attendees, 52 + 82 = 134 White Papers
- A total of about 9 potential research thrusts were identified, and are now being refined as people work on a draft Report.
- The final ReNeW workshop with all five themes will be held June 6 - 12, 2009 at Bethesda MD. Nominally, by invitation only. However, interested parties should contact the organizers.

Recent FESAC Reports Identified Fusion Science Themes, Issues, and Gaps

- Priorities, Opportunities and Gaps Panel (MG) identified three themes:

  A. Creating predictable high-performance steady-state burning-plasmas

  B. Taming the Plasma Material Interface

  C. Harnessing the Power of Fusion

- Toroidal Alternates Panel (DH) identified ITER-Era Goals and Issues for non-tokamak magnetic configurations

- The Renew Process has adopted a five theme approach based on the FESAC reports.

Theme II - Create Predicable High-Performance Steady-State Burning-Plasmas

- Greenwald FESAC Panel: Theme A - Creating predictable, high-performance, steady-state (burning)-plasmas: The state of knowledge must be sufficient for the construction, with high confidence, of a device that permits the creation of sustained plasmas that meet simultaneously, all the conditions required for practical production of fusion energy"

- The Greenwald Panel had ITER was part of Theme A, and assumed it would achieve baseline objectives. However, ReNeW does not assume ITER success and includes a separate Theme I to ensure ITER will achieve baseline objectives.

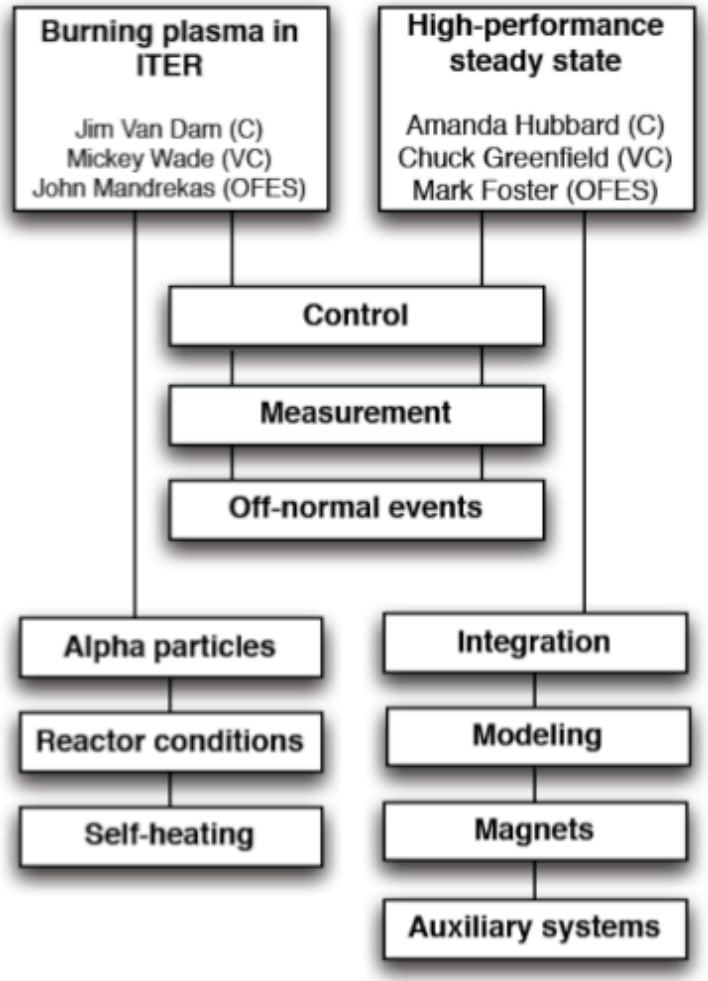
- Panels (Titles at Workshop), Theme II Chair - Amanda Hubbard, MIT
  1. Measurement - Jim Terry, MIT
  2. Integration of High-Performance Steady-State Burning Plasmas - Chuck Kessel, PPPL
  3. Validated Theory and Predictive Modeling, George Tynan, UCSD
  4. Plasma Control - Dave Humphreys, GA
  5. Off-normal Events - Richard Hawryluk, PPPL
  6. Plasma Modification by Auxiliary Systems - James Wilson, PPPL
  7. Advanced Magnets - Joe Minervini, MIT

Theme I - Achieving and Understanding the Burning Plasma State in ITER, Chair Jim VanDam, UTex

PANELS	LEADS
Understanding alpha particle effects	**Don Spong**
Extending confinement to reactor conditions	**Craig Petty**
Creating a self-heated plasma	**Ron Parker**
Controlling and sustaining a self-heated plasma (joint with Theme 2: "Control")	**Dave Humphreys** (lead-2) **John Ferron** (deputy-1)
Mitigating transient events in a self-heated plasma (joint with Theme 2: "Off normal plasma events")	**Rich Hawryluk** (lead-1) **Steve Knowlton** (deputy-2) **Jon Menard** (deputy-1)
Diagnosing a self-heated plasma (joint with Theme 2: "Measurement")	**Jim Terry** (lead-1) **Rejean Boivin** (deputy-2)

Theme I - Theme II Joint Panels

- The Greenwald Panel Report was driven by Issues not Facilities, and Theme A included both ReNeW Theme I and Theme II.



- **Jointness:**
  - 3 of the panels
    - 50% joint for Theme 1
  - 32 of the White Papers
    - 46 total for Theme 1 (hence 70% joint)
    - 77 total for Theme 2 (hence 42% joint)
  - Theme leaders
    - 3 (of 6) from USBPO
    - 1 on ITER Research Plan int'l working group
  - This week's workshop
    - 5 days of togetherness

Theme I - *Potential Thrusts for Achieving and Understanding the Burning Plasma State in ITER*

1.1. Provide physics basis and maximize physics output for ITER baseline operation
- 1.1.1 Mission Critical solutions - disruptions, ELMs, T retention
- 1.1.2 Specific Research Issues - hi Z PFCs, fast particles,transport,..
- 1.1.3 Essential Tools and capabilities - diagnostics, control, RF launcher PWI

1.2. Demonstrate ITER enhanced operation in preparation for DEMO
- 1.2.1 Steady state operation modes
- 1.2.2 Alpha particle control
- 1.2.3 Small-ELM and/or ELM-free operational regimes

Details at: http://burningplasma.org/web/ReNeW/ReNeW%20Thrusts%2007Apr09.pdf

Theme II - *Potential Thrusts for High Performance Steady-State Burning Plasmas*

2.1. Controlling and sustaining fusion plasmas - *How high performance a fusion plasma can be controlled and maintained for an unlimited period of time*?

2.2. Predictive capability - *Can the complex, multi-scale phenomena of fusion plasmas be understood and predicted, through advances in theory and simulation and comparison with detailed measurements?*

2.3. Measurements for burning plasmas - *Advance measurement capability for the harsh fusion environment to enable the success of ITER and control of steady state fusion plasmas.*

2.4. Advanced magnets for fusion - *Can high temperature superconductors and other magnet innovations be exploited to advance fusion research?*

Theme II - *Potential Thrusts for High Performance Steady-State Burning Plasmas*

2.5. Integrated dynamics of burning plasmas - *How will the complex, coupled dynamics of the core burning state evolve as the self- sustained limit is approached?*

2.6. Core-boundary integration - *How do sustained plasmas with high energy flow interact with their material interfaces? Using this understanding, what is the optimal solution for both sustainment and power handling?*

2.7. Steady-state, alpha-dominated plasmas - *Can the knowledge gained in each of the above Research Thrusts be integrated to demonstrate confidence in a steady-state, alpha-dominated plasma which is attractive for producing fusion energy)?*

High-Performance Steady-State Burning-Plasma Integration Issue Gaps (an example)

Integrate Fusion Gain, Sustainment and Exhaust Power Density

Table I. Individual Issue (Metric)	Today* ($>10\tau_E$)	ITER	ARIES-I	ARIES-AT	<Gap> IT to AR
Fusion Gain (Q)	**< 0.2**	**5**	**20**	**50**	**7**
Self-heating (%)	4	50	80	91	1.7
Sustainment (100% NI) (P_{cd}/P_α)**	**>25**	**1**	**0.25**	**0.1**	**6**
Current Drive fraction ($1-f_{bs}$) (%)	~30	~50	32	9	2.5
Neutron Wall Loading (MWm^{-2})	0.1	0.5	2.5	3.3	6
Plasma Pressure (atm)	1.6	2.5	10	10	4
Fusion Power density (MWm^{-3})	0.3	0.5	4	4.7	8
Plasma Control* (P_{cont}/P_α)	>25	1	0.25	0.1	6
Exhaust Power Density (P_{heat}/A_{ps} (MWm^{-2})	**0.85**	**0.2**	**1**	**1**	**5**
Self-Condition PFCs & FW f(t_{pulse}, T, ϕ,	No	?	Yes	Yes	?

* Not all simultaneous

** Current Drive Power + Plasma Control Power = 5 P_α/Q

Assumes ITER will be upgraded with addition of Lower Hybrid current drive for Scenario 4.

- The individual gaps are taken to be independent, therefore the Integration Gap is the product of individual gaps.
- **The Integration Gap for Fusion Gain, Sustainment and Exhaust Power density is ≈ 200**

Issues

- The Fusion ReNeW process started with an environment from the previous administration that is constraining the discussion and development of Bold Thrusts.

- The workshop was to start with issues, then develop thrusts independent of specific hardware proposals. However, ...

- The one week workshop for Theme I and II while tiring, was only long enough to have a blizzard of presentations with advocates of hardware flooding the system with white papers and presentations. This limited time left for discussion of the scientific issues, little time to digest new ideas and reflect. The workshops should have been two weeks long.

- Thrusts are now being refined off-line by small groups of the leaders.

Upcoming Tasks for Theme I and II

- **Theme I - ITER**
  - Most straight forward theme -
    What is the baseline? Are upgrades realistic?
- **Theme II -**
  - Working on quantifying issues/integration
  - Emphasis on specific hardware proposals is causing problems
- All this comes together at June 6-12, 2009 Workshop
- Report to DOE in July, Possible FESAC meeting in August
- Is the ReNeW process properly tuned for the new Administrations' energy emphasis?