

Prospectus for Subgroup B, Fusion Development Path

Some of the major objectives and organizing principles of this subgroups discussion are:

1. The discussions in this subgroup fall in the intermediate ground between today's fusion status and experiments and the ultimate vision of a fusion reactor. We focus on the problems of fusion energy development that might be taken up in the next 20 years.
2. The discussions should provide an educational opportunity for the attendees to look longer term at what has to be done to actually move to fusion energy. The tasks that must be undertaken tend to evolve from today's largely scientific investigations to eventually nuclear technology issues.
3. The meetings are organized so that everyone gets to hear every presentation and to discuss all the same questions.
4. The meetings are organized so that MFE and IFE people must discuss matters together and educate each other.
5. The focus of the first two days is on overall forward looking roadmaps and the general issues of fusion development that lie ahead, in order to provide framework material for the second two days.
6. The second two days are devoted to discussions of specific machine proposals, examining them for what contributions they can make to fusion development and what research is needed to move them forward.

Reading List

A separate reduced version of this prospectus is available via the link below. It gives Web links to papers we recommend the participants read prior to Snowmass for background to the various discussion issues

<http://fusion.gat.com/snowmass/energy/subgroup-b/reading-list-b.html>

The four afternoons Tuesday July 13 through Friday July 16 will be divided into 8 half sessions separated by a coffee break and time for people to walk from plenary meeting rooms to breakout meeting rooms. The timing and content of the half day sessions are as follows:

	Tuesday July 13	Wednesday July 14	Thursday July 15	Friday July 16
First Half Session (starts 1:30 PM)	<u>Plenary</u> Roadmaps, Generic Development Issues Framed 90 attendees expected	<u>Breakouts</u> Discuss generic development issues 4 rooms, 25 attendees per room.	<u>Plenary</u> Specific Device Presentations 6 presentations 90 attendees	<u>Plenary</u> Specific Device Presentations 5 presentations 90 attendees
Break	3:20 – 3:35 PM	3:20 – 3:35	3:20 – 3:35	3:20 – 3:35
Second Half Session (ends 5:30 PM)	<u>Breakouts</u> Discuss generic development issues 4 rooms, 25 attendees per room	<u>Plenary</u> Discuss generic development path issues and roadmaps 90 attendees	<u>Breakouts</u> Discuss above presentations 4 rooms, 25 attendees per room	<u>Breakouts</u> Discuss above presentations 4 rooms, 25 attendees per room

Tuesday Early Session (Half Session 1, Plenary)

Roadmaps and Plans (60 minutes)

Three distinct roadmaps will be presented in three talks without questions to set some 20 year framework for the week's discussions. Those roadmaps and presentations are:

IFE roadmap by J. Lindl

Tokamak based MFE roadmap by J. Navratil

Spherical Torus based roadmap by R. Stambaugh

The output of this session will be the written submissions of the speakers and/or reference to existing roadmap documents (see overall Snowmass rules on written submissions).

Issues of Fusion Development (40 minutes)

The session convenors will present an introduction to the main issues of fusion development which are to be discussed in the subsequent breakout sessions. Those issues are framed below. We are asking attendees who come to these sessions to come prepared to discuss these issues and to educate your colleagues. Cross-cutting education can be one of our most important outcomes.

Q1) Burning Plasmas: Ignition and/or High Gain.

What is the importance of ignition/burn/high gain scientifically? What do we need to learn from a burning plasma experiment? What is the importance of achieving ignition or burn in a larger sense? Must we demonstrate ignition to move fusion forward or should we look further ahead to the challenges of high time averaged power and neutron fluence?

Participants in this discussion should be prepared to address these questions and to help hone the issue list below so we can well articulate the "yearn to burn." MFE and IFE

colleagues should be prepared to educate each other on the somewhat different burning plasma issues and objectives of their approaches.

MFE Burning Plasma Issues and Questions

To what extent must the issues below be answered in each separate kind of magnetic confinement device? How generic would results from a tokamak be?

Properties of DT plasmas (confinement, stability, n_e limits, L-H thresholds, etc.)

Confinement of alphas

Alpha heating

Alpha driven instabilities

Profile control in alpha heating dominated plasmas

Alpha heating effects on self-driven currents

Particle and power exhaust in alpha dominated plasmas (esp. He exhaust)

High gain burn control

IFE Burning Plasma Issues and Questions

To what extent must the issues below be answered for each different driver and target type in IFE? How generic are the results from NIF?

Drive requirements (energy, pulse shape, uniformity)

Central ignition

Propagating burn

Fractional burnup

Gain, and its relation to driver efficiency and type

Q2) The Challenge of Steady-state and High Time Average Power.

What are the non-nuclear issues connected with steady-state and high time average power?

How are we going to approach them and when? Are these issues more important than burning plasma issues?

MFE High Time Average Power Issues

Non-inductive current drive and profile control in devices with current

Is a pulsed magnetic system acceptable?

Stellarators

The problems of fluence, erosion and codeposition

Problems of operational boundaries (e.g. disruptions)

Problems of heat exhaust (both MFE and IFE)

IFE High Time Average Power Issues

First wall and optics protection

Chamber clearing between shots

High rep-rate drivers (KrF, DPSSL, HIB)

Low cost target production and high rep-rate target insertion

Problems of heat removal

Q3) Nuclear Technology Development

These questions are largely common to MFE and IFE and can be profitably discussed together.

What is our plan to develop blanket technology?

What are the limits on MW/m² of neutrons or heat at the first wall? What underlies those limits? What do such limits imply about the minimum size (or maximum power density) of fusion systems?

How are we going to survive neutron damage? We will endeavor to have experts at the meeting inform us as to the reasons why typical fusion systems project the need to change the blanket components every two-four years.

Do we need both a point neutron source and a volume neutron source? Should we plan to learn by doing, e.g build and deploy blankets on a suitable source?

How important are low activation materials and how are we going to introduce them? What are the viewpoints in MFE and IFE?

What do the MFE and IFE roadmaps envision for Tritium usage in the various stages of development? When must fusion energy make the transition from external Tritium supply to self-sufficiency?

How are we going to get an overall system TBR>1. What are the Tritium inventory centers in MFE and IFE systems? What research can we do to address the challenges?

In view of the above costly aspects of the DT fuel cycle, should we skip DT and aim for advanced fuel systems? What are the prospects for MFE and IFE?

Tuesday Later Session and Wednesday Early Session (Half days 2 and 3)

Breakout discussions on the issues of fusion development.

These sessions will be led by a facilitator and will have a recorder. The output of each breakout session should be a refinement of the above development issues and a record of discussion on the importance and technical aspects of the issues. The facilitator and recorder will be responsible to prepare the summary output. The Energy Subgroup B convenors, working with the breakout facilitators and recorders, will combine the breakout groups summaries into one summary.

To facilitate discussion, participants will be allowed to support points they wish to make with one viewgraph and are asked to provide the recorder with an electronic copy of that viewgraph and a one paragraph (electronic, less than half page) written description of their remarks. Participants in the discussion session who wish to present a prepared viewgraph should make their intent known to the discussion facilitator at the beginning of the breakout session or in advance on sign-up sheets on the Energy Group poster board

Wednesday Later Session (Half Day 4, Plenary)

Plenary discussion period on the issues of fusion development and the roadmaps presented in the first half day session. This discussion can draw upon the preceding breakout discussions of the general development path issues. This session should enable MFE/IFE development path cross-comparisons.

What are the key technical steps we need to make along various fusion development paths? What are the scientific and technological challenges that should be resolved? What are the decision criteria (scientific, technological, financial, and political) to move forward after completion of each step? How can we ensure that fusion technologies necessary for each step are developed?

This session will have its own facilitator and recorder. The output of this discussion should be a collection of critique type comments from the participants on how the different roadmaps address the general fusion development needs and a general summary discussion of the breakout groups discussions preceding. This overall summary will be prepared by the subgroup B convenors and breakout discussion facilitators and recorders.

To facilitate discussion, participants will be allowed to support points they wish to make with one viewgraph and are asked to provide the recorder with an electronic copy of that viewgraph and a one paragraph (electronic, less than half page) written description of their remarks. Participants in the discussion session who wish to present a prepared viewgraph should make their intent known to the discussion facilitator at the beginning of the breakout session or in advance on sign-up sheets on the Energy Group poster board

Next Step Options

**Thursday both half-sessions and Friday both half-sessions
(The first half session will be plenary and consist of presentations without questions. The second half session will be in breakouts to allow discussion of the presented devices.)**

A number of next step fusion devices have been proposed or are under construction: tokamaks (large integration, short-pulse ignition, and steady-state advanced tokamak), spherical tokamaks, stellarators, NIF, IRE, etc. In this Energy sub-group we will examine and discuss many of these proposed next step fusion devices from the point of view of their role in the development of fusion energy. The group should discuss these proposals in regard to their matchup to the list of Issues of Fusion Development given above.

The scientific issues related to most of the devices scheduled for presentation in our Thursday, July 15, and Friday, July 16, plenary sessions will be discussed in the morning MFE and IFE session and all participants are encouraged to attend these sessions as part of the preparation for our cross-cutting discussion in this Energy sub-group.

For each of the next-step opportunities, speakers in the plenary sessions are requested to address their presentations to answering the following questions::

- 1) What technical issues will the proposed step address? What critical fusion energy science and technology issues will this step not address?
- 2) What is the degree of technical risk does the proposed next step entail and is the schedule achievable? Does it depend on critical parallel or previous work as a prerequisite?
- 3) What opportunities are offered by the proposed step to reduce fusion development costs (either in the near term or integrated over time) and to achieve attractive economic and environmental features?
- 4) What are the prospects for significant international participation in the proposed step and what role might this step play in the international fusion program?
- 5) What position will the results, if as expected, put us in to move fusion forward to the next step beyond this proposed step?

On each day, following the plenary sessions, this Energy sub-group will divide into four equal sized breakout sessions, where each of the next step devices described will be

discussed in turn. The order of the discussion will be cyclically permuted between breakout groups to allow the plenary speaker to be present at every breakout session where the device they presented is discussed.

Participants in the discussion session who wish to present a prepared viewgraph (1 viewgraph limit!) on a point related to the devices under discussion should make their intent known to the discussion facilitator at the beginning of the breakout session or in advance on sign-up sheets on the Energy Group poster board and to provide the recorder with an electronic copy of that viewgraph and a one paragraph (electronic, less than half page) written description of their remarks.

The output of these sessions will be the speaker's written submission (see overall Snowmass rules on written submissions) and the record of discussion of each presentation from the breakouts. The breakout sessions will be led by a facilitator and will have a recorder. The facilitator and recorder will be responsible to prepare the summary of the breakout session. The Energy Subgroup B convenors, working with the breakout facilitators and recorders, will combine the breakout groups summaries into one summary.

Thursday, July 15, First Half Session (Plenary)

<u>Device</u>	<u>Speaker</u>	<u>Time</u>
FIRE	D. Meade	20
JET Upgrades	C. Gormezano	15
ST in a Fusion Development Facility	R. Stambaugh	20
IRE (Introduction and HIB driver)	R. Bangerter	15
IRE (KrF driver)	J. Sethian	10
IRE (DPSSL driver)	H. Powell	10
IFE Engineering Test Facility	W. Meier	20

Thursday, July 15, Second Half Session

Breakout discussions of the above presentations

Friday, July 16, First Half Session (Plenary)

<u>Device</u>	<u>Speaker</u>	<u>Time</u>
ITER-RC	R. Parker	25
Steady-state tokamak (e.g. TPX, JT60-SU, KSTAR)	K. Thomassen	20
Stellarator	N. Ohyabu	15
NIF and LMJ and Japan's ICF Program	W. Hogan	15
IGNITOR	L. Sugiyama	20
Discussion		15

Friday, July 16, Second Half Session

Breakout discussions of the above presentations