

SUMMARY OF THE
FORUM FOR MAJOR NEXT-STEP
FUSION EXPERIMENTS

Madison, 27 April - 1 May 1998

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Columbia University

Fusion Energy Sciences Advisory Committee
Gaithersburg, 26-27 May 1998

Goals of Forum

- Identify set of candidate “credible” strategy options for advancing fusion energy which have broad community support.
- Take a step towards a more effective method of building a community consensus and set stage for continuing this process
- Provide a sense of the US fusion community views on potential major next steps in fusion energy research as input into the ITER SWG discussions.

Forum for Major Next-Step Fusion Experiments

- Program arranged by Organizing Committee of ~40 drawn broadly from most institutions involved in fusion research.
- Organizing Committee met on February 26-27 at PPPL to plan Forum format and assign session organizational responsibility.
- Forum was held for 4.5 days in Madison and was well attended with about 165 people registered.

ORGANIZING COMMITTEE: FORUM FOR MAJOR NEXT-STEP FUSION EXPERIMENTS

Co-chairs: Drake – Navratil – Nevins

Columbia	Boozer, Navratil	[Mauel]
Cornell	Hammer	
Georgia Tech	Stacey	
NYU	Weitzner	
Swarthmore	Brown	
UC-Irvine	McWilliams	
UCLA	Abdou, Cowley	
UCSD	Najmabadi	
U. Colorado	Cary	
U. Maryland	Dorland, Drake	
U. Texas	Hazeltine*, Van Dam	
U. Washington	Jarboe	
U. Wisconsin	Callen*, Fonck, Prager	
ANL	Dale Smith	
GA	Luce, Taylor*	[Baldwin]
ITER	Tom James, Rutherford	[Baker]
LANL	Schoenberg	
LLNL	Nevins, John Perkins	[Thomassen]
MIT	Hutchinson, Montgomery*	[Porkolab]
ORNL	Lazarus, Peng	[Saltmarsh]
PPPL	F. Cheng, Hawryluk, Meade, Neilson, S. Zweben*	[Goldston]
Sandia	Ken Wilson	
Boeing	Davis	
Raytheon	Ellis	
Fusion Power Assoc.	Dean	
Jefferson Lab	Grunder	

* FESAC Member

[ex officio] head of sponsoring organization

Forum Agenda Structure

Monday

**Background Briefings:
Outside Views and Input
Breakout Group Assignment**

Tuesday

**Strategy Option Introduction and
Charge to Breakout Groups
Key Physics & Technology Issues**

**Tues.PM -
Wednesday**

**Review and Discussion of
Major Next Step Experiment Options**

**Wed. Evening
- Thursday**

**Discussion & Breakout Groups:
Formulation of a set of 'credible' strategy
options for advancing fusion energy**

Friday

**Summarize Progress and
Discuss Plans for Follow-on Activity
(Martha Krebs Participates in Discussion)**

Consensus Building in Science:

High Energy Physics, Nuclear Physics, & Astrophysics

- Scientific consensus on program direction and major experiments has been achieved and has led to larger/successful programs.
 - HEP and NP: Snowmass meetings sponsored by APS provide “internal education” of the community
 - Astrophysics: Decade Survey examines science issues and technical readiness as a “bottom-up” process
- All 3 sub-fields “invented” their own process over the past 20-30 years:
 - Common Feature: Very high fraction of the community was heavily involved and the process took up to 5 years. Process was very open and broad based.

Forum Process: Rules of Procedure

- **BREAKOUT GROUPS**

- + Every participant randomly assigned to one of 6 groups
- + Each group selects its own spokesman to report its finding and views in plenary session
- + Each group assigned a “Facilitator” who will assist spokesman and group in making progress on charge to the group.

Charge to Breakout Groups

- ① Formulate a set of credible strategies within your group, which your group supports, for the fusion energy science and technology leg of our program.
 - ② Identify the strengths and weaknesses of each strategy.
-

Your group should take into consideration primarily scientific and technical issues such as:

- Status of fusion energy science and technology today
- Relationship to and integration with the other elements of the fusion program in the U.S.

and, secondarily, other issues such as:

- Ability to muster support of the scientific, environmental, and energy policy communities
- ITER process & our partnership in the international effort
- FESAC/Grunder panel recommendations & options

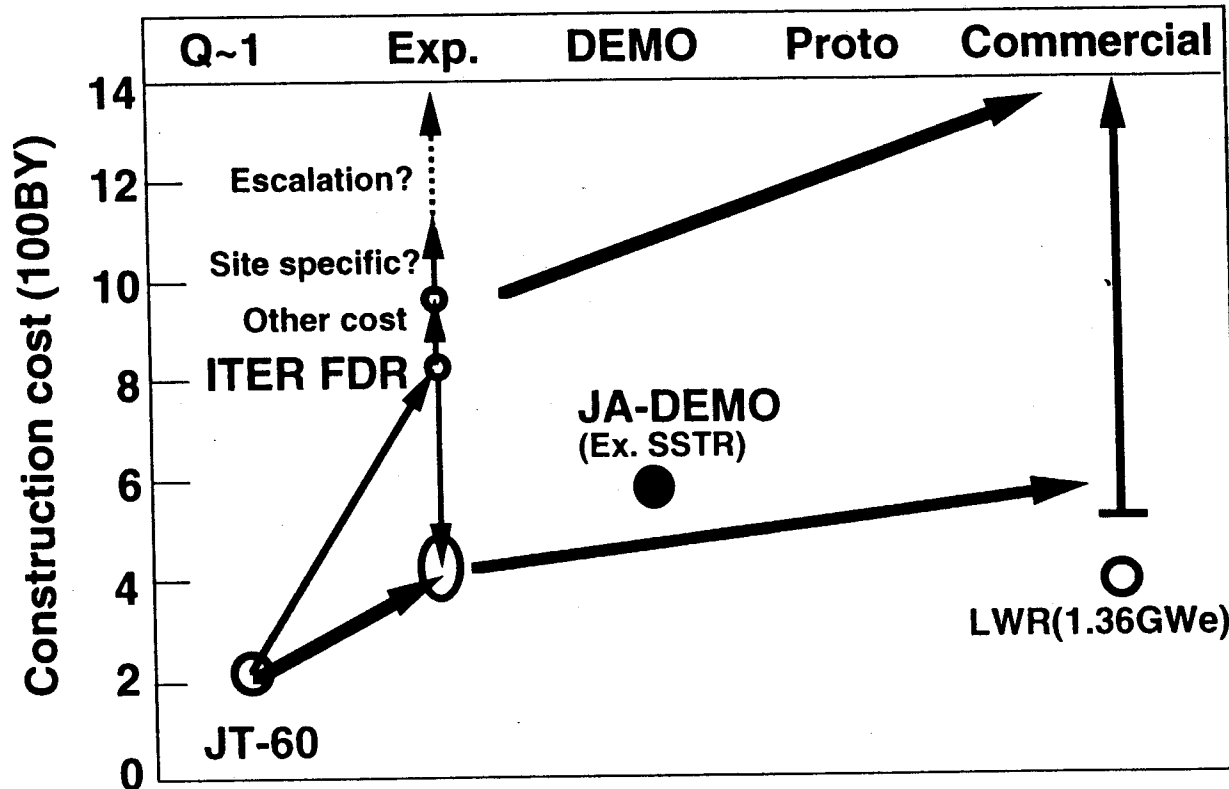
General Findings

- Need to reduce the cost of the individual development steps in our program to develop scientific and technical basis for a practical source of fusion energy:
 - “Cost of major steps characterizes the cost of the final product”.
- Attractiveness of a Next Step experiment is a primary concern: must emphasize innovation in our plan
- Exploration of a Burning Plasma was the primary priority for a strategy for a major next step experiment.

Approach toward DEMO and Fusion Power Reactor



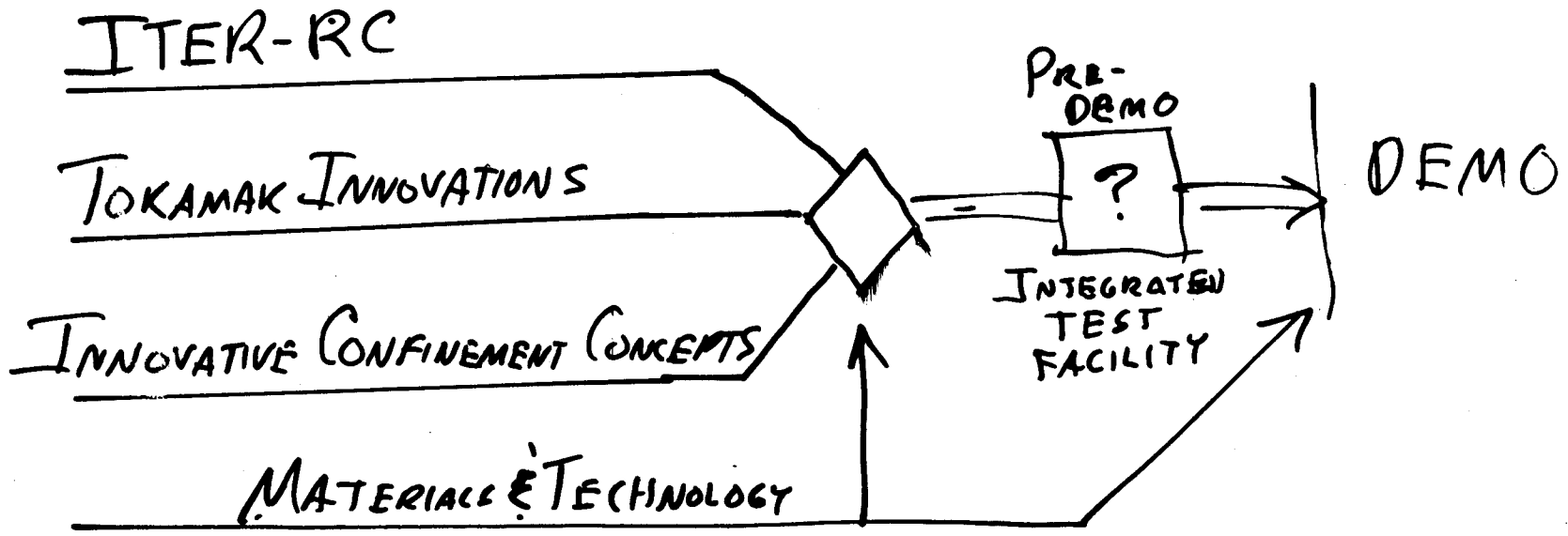
Fusion power development should be made so that people agree the cost as "rational expenditure" for the energy development.



Three Strategy Options

- **Single Machine:** take an integrated step forward now with the tokamak .
- **Multiple machine:** split mission elements and take a number of smaller parallel, phased, or sequential steps.
- **Defer major next step:** emphasize existing programs & innovative concept development

SINGLE MACHINE

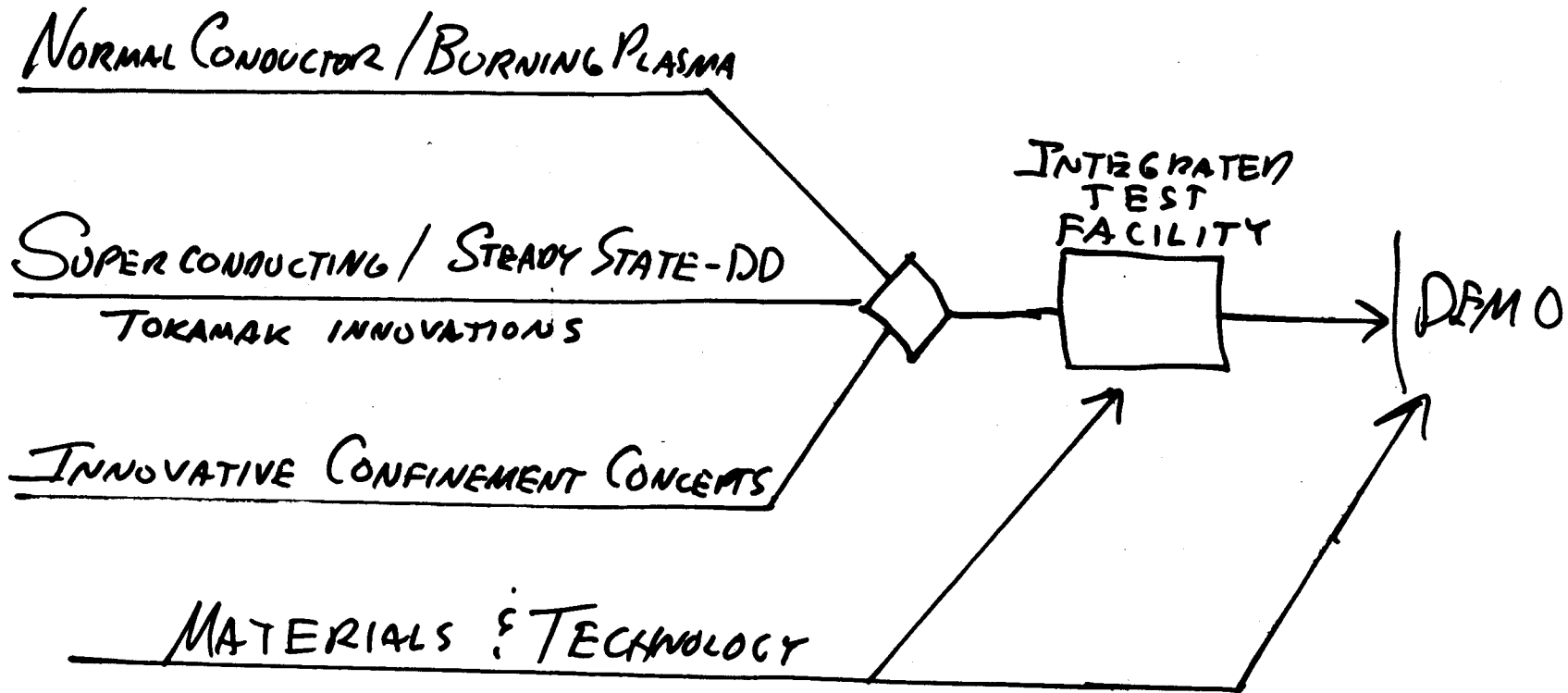


REDUCED COST ITER: MORE FLEXIBILITY AND AT CAPABILITY

PRO: EARLIEST PHYSICS/TECHNOLOGY INTEGRATION
BUILDS ON ESTABLISHED INTERNATIONAL STRUCTURE

CON: LESS FLEXIBILITY
COSTLY SINGLE STEP

MULTIPLE-MACHINE | INTERNATIONAL PROGRAM



PRO: GREATER FLEXIBILITY
LESS COSTLY ELEMENTS

CON: DELAYS INTEGRATION
NOT IN PRESENT INTERNATIONAL GAME PLAN

Example of Modular Strategy Element Costs

Range of normal conductor D-T burning plasma experiments:

- Italian Ignitor design ~<\$1B
- US BPX design ~\$1.7B
- US "PCAST" machine ~\$4B

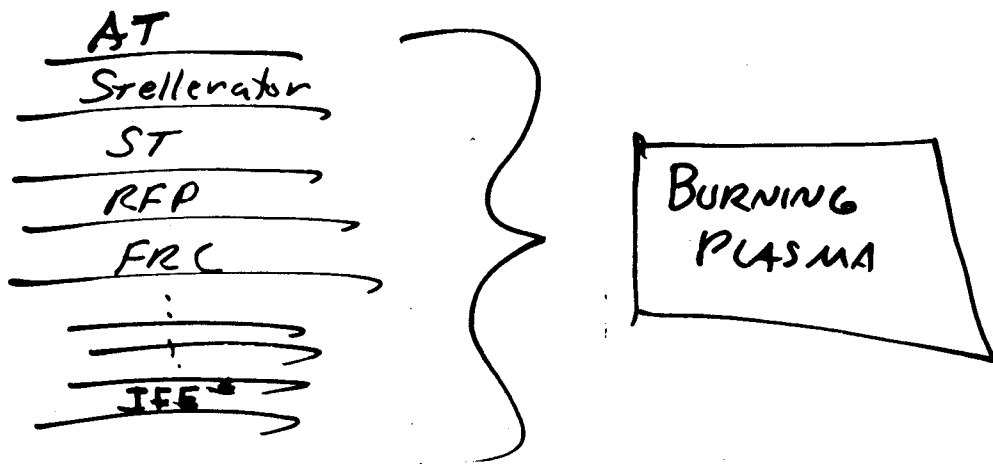
Range of steady-state D-D advanced tokamaks:

- Korean KSTAR ~\$0.4B
- US TPX ~\$0.7B
- Japanese JT-60SU design ~\$2.0B

The capital cost of the BPX plus TPX combination is about \$2.4B, or about 1/3 of the cost of the ITER EDA design.

VNS cost ~\$1B, therefore it seems reasonable to extrapolate that the full cost of these machines need not be significantly more than half the cost of the present ITER EDA design.

DEFER MAJOR NEXT STEP



PRO: MAY LEAD TO GREATLY IMPROVED APPROACH

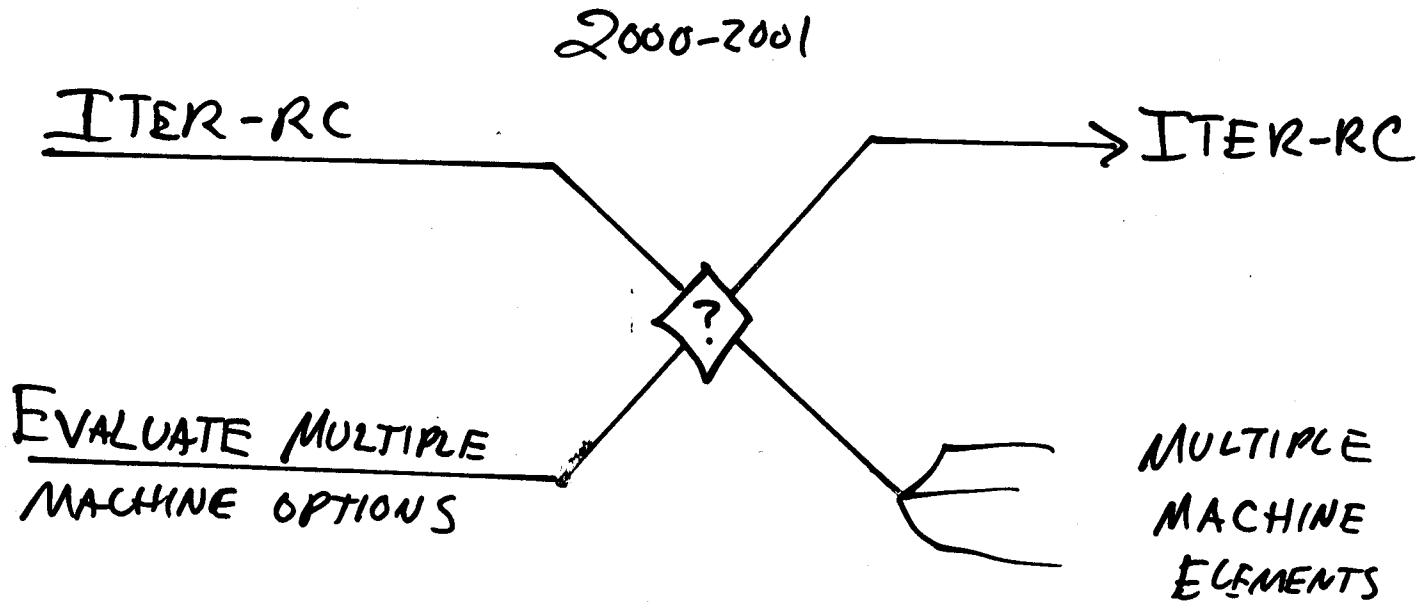
CON: NOT MOVING TOWARDS FUSION ENERGY

*IFE: not the appropriate forum

Views on the Strategies

- Both the Single-Machine and Multiple-Machine Strategies had substantial support.
- The Defer Strategy had no broad support and was opposed by several groups.
- Multiple-Machine strategy was preferred over the Single-Machine Strategy, and a minority was opposed to the Single-Machine Strategy.
- Consensus that we should not withdraw from the ITER process at this time: support for ITER contingent on improved flexibility to explore Advanced Tokamak physics in a reduced cost ITER.

COMBINED PARALLEL STRATEGY (NEAR-TERM)



Follow-on Activities

- Final Report preparation at meeting in San Diego June 18-20 organized by Charles Baker.
- Some additional work is needed/expected on elements of the Multi-machine or Modular Strategy over next 2 years.
- Fusion “Snowmass” meeting endorsed by American Physical Society Division of Plasma Physics is now being planned for 2 weeks in Summer of 1999.

Forum for Major Next-Step Fusion Experiments

27 April - 1 May 1998, Madison, WI

Monday, April 27 (9:00 am - 6:05 pm)

8:00	Continental Buffet Breakfast in Convention Center (breakfast each day is included in registration fee)		
9:00	Introduction & Fusion Program Status (Prager)		
	Format & Goals	Navratil (Columbia)	15 min
	Forum Process	Baker (UCSD)	10 min
	DOE View & Expectations	Davies (DOE)	10 min
	DISCUSSION		15 min
	Perspective on Fusion Energy Sciences Program	Grunder (Jeff. Lab)	15 min
	DISCUSSION		20 min
10:25	Break		15 min
10:40	Science, Economic & Environmental Issues (Drake)		
	Consensus Building & Planning in Astrophysics	Rosner (U. Chicago)	15 min
	Discussion		10 min
	Consensus Building & Planning in High Energy Physics	Reeder (U. Wisc.)	15 min
	Discussion		10 min
	Panel Discussion	Grunder, Reeder, Rosner	30 min
12:00	LUNCH		
1:30	Science, Economic & Environmental Issues (Drake)		
	Views of the Energy Community	Fetter (U. Md)	15 min
	Discussion		5 min
	Views of Environmental Community	Cochran(NRDC)	15 min
	Discussion		5 min
	Competitive Energy Market	Perkins (LLNL)	15 min
	Discussion		5 min
	Discussion with Speakers	all	40 min

3:10	Break		15 min
3:25	International Fusion Program (Weitzner)		
	Views on a Next-Step in the International Fusion Program	Baldwin (GA)	40 min
	DISCUSSION		40 min
4:45	ICF (Perkins)		
	NIF & IFE	Campbell (LLNL)	40 min
	DISCUSSION	Campbell, Bangerter	40 min
6:05	Adjourn		

Tuesday (8:30 am - 6:40 pm)

7:45	Continental Buffet Breakfast		
8:30	Preliminary Discussion of Strategies for Fusion & Charge to Breakout Groups		
	DISCUSSION	Mauel (Columbia)	25 min
			25 min
9:20	Physics Issues to be Addressed by Major Next-Step Expts	(VanDam/Zweben)	
	[Each talk 10 min + 2 min for questions]		
	Session Intro	Van Dam (U. Texas)	12 min
	Confinement	Dorland (U. Md.)	12 min
	MHD & Profile Control	Taylor (GA)	12 min
	Edge Physics Issues	Pitcher (MIT)	12 min
	DISCUSSION		22 min
10:30	Break		15 min
	Energetic Particle Physics	Cheng (PPPL)	12 min
	Self-Heating & Thermal Control	Perkins (ITER)	12 min
	Ignition Physics Requirements	Coppi (MIT)	12 min
	Long Pulse & Short Pulse Physics	Rosenbluth (UCSD)	12 min
	DISCUSSION		20 min
	GENERAL DISCUSSION		37 min
12:30	LUNCH		

2:00	Technology Issues to be Addressed by (Smith)		
	Major Next-Step Experiments		
-	Magnet Systems	Montgomery (MIT)	10 min
	Plasma Facing Components	Ulrichson (Sandia)	10 min
	Heating and Fueling Systems	Berry (ORNL)	10 min
	Materials	Mattas (ANL)	10 min
	Tritium Systems	Willms (LANL)	10 min
	Energy Extraction Systems	Abdou (UCLA)	10 min
	DISCUSSION		30 min
	Reactor Integration: ARIES	Najmabadi (UCSD)	15 min
	Innovative Reactor Design	Moir (LLNL)	10 min
	DISCUSSION		30 min
4:25	Break		15 min
4:40	ITER & ITER with Technical Modifications (Stacey)		
	ITER Introduction	Baker (UCSD)	10 min
	ITER Physics	Sauthoff (PPPL)	25 min
	Advanced Physics Database for Reduced Cost ITER	Simonen (GA)	15 min
	Reduced Cost ITER Design Space	Stacey (GA Tech.)	15 min
	DISCUSSION		55 min
7:30-9:00	Buffet Dinner		

Wednesday (8:30 am - 6:15 pm & 8:00 pm - 10:00 pm)

7:45	Continental Buffet Breakfast		
8:30	Superconducting Burning Plasma (Montgomery)		
	Next-Step Elements		
	JAERI Views on Reduced-Cost ITER	Kikuchi (JAERI)	20 min
	SUPERCODE Studies of Reduced Cost ITER Options	Uckan (ORNL)	15 min
	Advanced Physics & Engineering: Cost Reductions for Next-Step	Porkolab/Schultz	20 min
	DISCUSSION		55 min
10:20	Break		15 min

10:35	Other Major Next-Step Elements (Dorland)		
	JT60-SU	Kikuchi (JAERI)	15 min
	TPX/KSTAR	Neilson (PPPL)	15 min
	DISCUSSION		15 min
	Point neutron sources	Saltmarsh (ORNL)	15 min
	ST, Tokamak and GDT		
	Options for VNS	Peng (ORNL)	15 min
	DISCUSSION		25 min
12:15	LUNCH		
1:30	Normal Conductor Burning Plasma (Nevins)		
	Next-Step Elements		
	Why Compact Ignition?	Meade (PPPL)	5 min
	A Proposal for a Modest-sized Ignited Plasma	Luce (GA)	20 min
	Impact of Recent Discoveries on the Feasibility of a CIT	Hutchinson (MIT)	15 min
	DISCUSSION		30 min
2:40	Break		15 min
	Ignitor	Coppi (MIT)	20 min
	PCAST-scale Ignition	Lazarus (GA)	20 min
	Optimizing Normal Conductor Tokamaks	Wooley (PPPL)	5 min
	BPX-scale Ignition and Survey	Meade (PPPL)	15 min
	DISCUSSION		60 min
4:55	Advance Physics Base Using Smaller Facilities (Cowley)		
	Time to Pause before Next-Step	Siemon (LANL)	15 min
	Synergy Between Innovative Concepts and a Burning Plasma Next-Step	Fonck (U. Wisc.)	15 min
	DISCUSSION		35 min
6:00 pm	Review of Charge to Breakout Groups (TBD)		15 min
6:15 pm	Break for Dinner		
8:00 pm	6 Parallel Breakout Groups Meet:Session #1		120 minutes
10:00	Adjourn		

Thursday (8:30 am - 6:30 pm)

7:45	Continental Buffet Breakfast		
8:30	Strategies for Fusion Development/Discussion (Prager)		
	Summary of Issues & Elements	Prager	30 min
	Report from Each Breakout Group		60 min
	DISCUSSION/Discussion Leader: Prager		30 min
10:30	Break		15 min
	Individual Strategy Views (≤ 10 min each)		
	Goldston		
	Politzer		
	Stambaugh		
	Meade		
	Kotchenreuther		
	others TBD		
	DISCUSSION/Discussion Leader Mael		
12:00	LUNCH		
1:30	6 Parallel Breakout Groups Meet:Session #2		120 minutes
3:30	Break		
3:45	Strategies for Fusion Development/Discussion (Nevins)		
	Report from Each Breakout Group		60 min
	Discussion/Discussion Leader: Nevins		105 min
6:30	Adjourn		

Friday (8:00 am - 11:30 am)

7:15	Continental Buffet Breakfast		
8:00	Strategies for Fusion Development/Discussion		
	Progress in Identification of Credible Strategy Options	Navratil	20 min
	Comments by Dr.Krebs & Discussion: Primary Conclusions of Forum		130 min

10:30	Break		15 min
10:45	Follow-on Meeting Plans	Baker/Mauel	20 min
	Discussion		25 min
11:30	ADJOURN		