Renew Workshop on Fusion-Fission Hybrids

Jeff Freidberg (MIT) Chair
Phillip Finck (INL) Co-Chair

Fusion Power Associates
December 2, 2009

Goals

- Are hybrids sufficiently promising to motivate DOE to initiate an R&D program?
- What are the research needs to move the hybrid concept forward?

Process

- Activity took place over 5 months
- Committee and subcommittees formed
- Multiple conference phone calls
- 3.7×10^{10} e-mails
- A 3 day workshop

  Sept. 30 - Oct. 2, 2009

  Gaithersburg, Maryland
- Preparation of Final Report

The Workshop

- Sponsored by OFES, NE, NNSA
- About 100 attendees
- From fusion and fission
- From universities, labs, government and industry

The Workshop (cont)

- **First morning plenary talks**

Welcome and workshop goals	Jeff Freidberg (MIT) and Phillip Finck (INL)
The potential role of hybrids	Massimo Salvatores (CEA)
DOE OFES perspective	Ed Synakowski (DOE)
DOE NE perspective	Buzz Savage (DOE)
DOE NNSA perspective	Kirk Levedahl (DOE)
Nuclear industry perspective	Adrian Heymer (NEI)
Proliferation and reprocessing	Bob Bari (BNL)

- **Panel discussion** — Andy Kadak (MIT) Moderator

Structure of the Report

Chapter 1	F & F	Introduction
Chapter 2	F & F	The hybrid primer
Chapter 3	Bob Hill (ANL)	Fuel cycles
Chapter 4	Harold Weitzner (NYU)	Fusion concepts
Chapter 5	Neil Morely (UCLA)	Blankets
Chapter 6	Albert Machiels (EPRI)	Non-hybrid alternates
Chapter 7	Walter Sadowski (U Md)	International program
Chapter 8	John Sheffield (U. Tenn)	Skeptics
Chapter 9	All contributed	High level findings
Chapter 10	All contributed	Technical findings

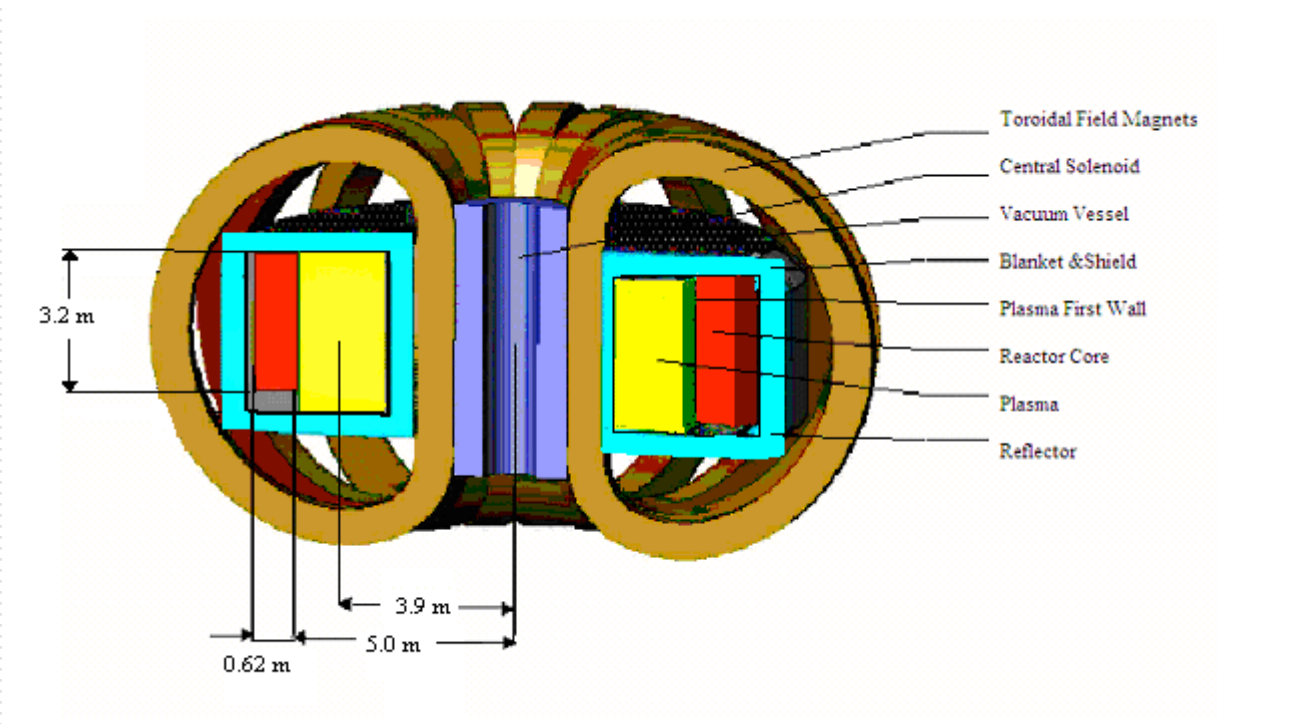
Status of Nuclear Power
Fission View

- Components of nuclear power
  - Fuel supply (from mining)
  - Electricity (from LWRs)
  - Waste management (on site storage)
- Natural uranium: 50 -100 yrs
- On site storage: 50 years
- Biggest industry problem now: economics
- Fission solutions for sustainability
  - Fast burners – waste management
  - Fast breeders – fuel supply

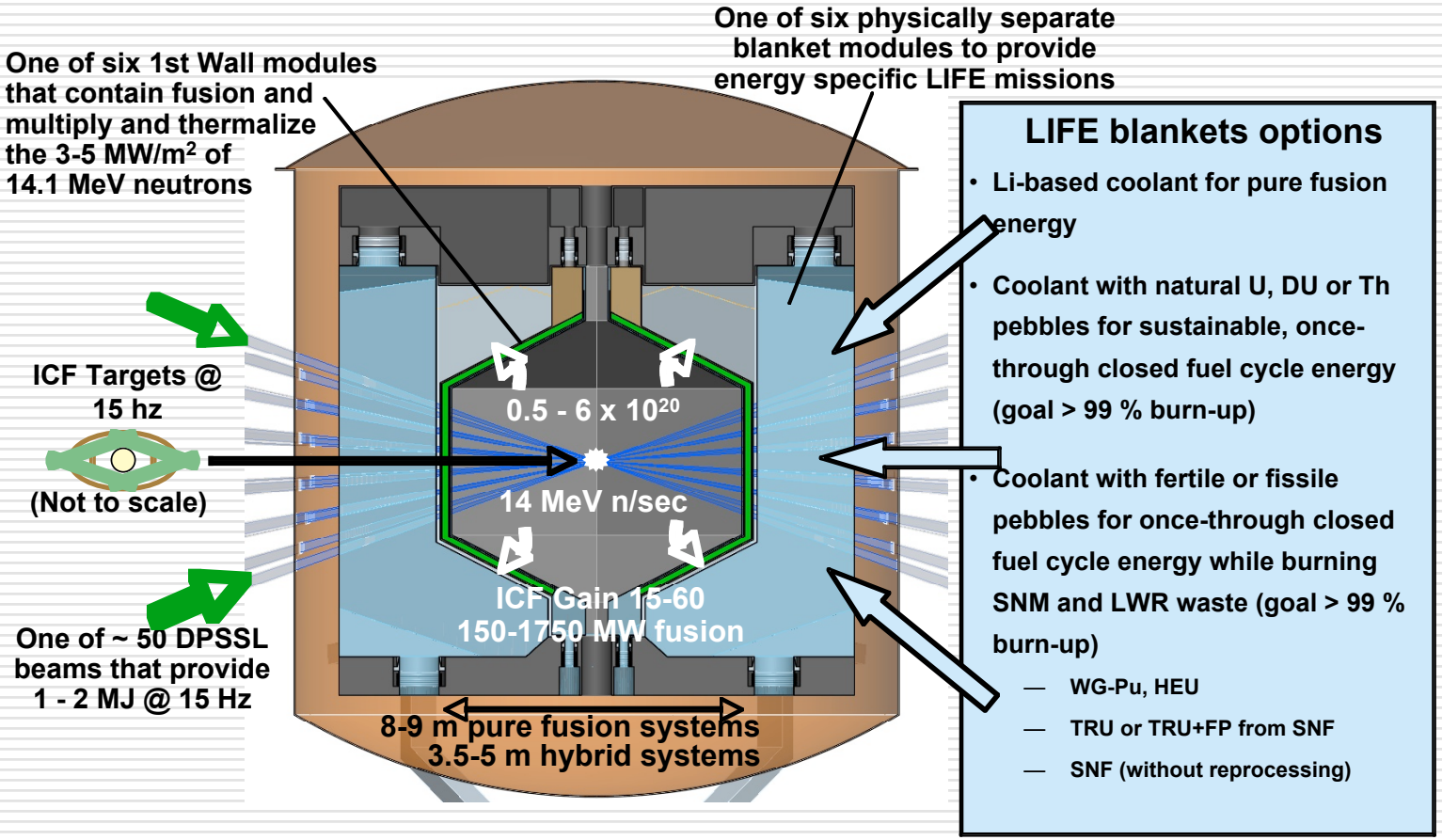
High Level Findings

- Potential roles of hybrids:
  - Fuel supply
  - Electricity production
  - Waste management
- Fusion-fission hybrid concepts:
  - Tokamak with minimum advanced technology (SABR)
  - ST with removable fusion core (U Texas)
  - IFE burn and bury electricity (LIFE)
  - Hybrid fuel producer (LLNL mirror)
  - All require various levels of advanced technology

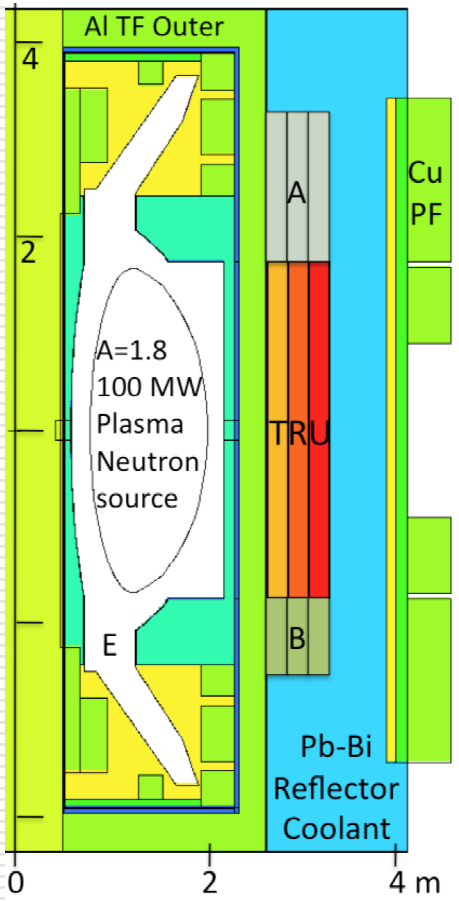
SABR


Toroidal Field Magnets
Central Solenoid
Vacuum Vessel
Blanket &Shield
Plasma First Wall
Reactor Core
Plasma
Reflector
3.2 m
3.9 m
5.0 m
0.62 m

LIFE


One of six 1st Wall modules that contain fusion and multiply and thermalize the 3-5 MW/m^2 of 14.1 MeV neutrons
One of six physically separate blanket modules to provide energy specific LIFE missions
ICF Targets @ 15 hz
(Not to scale)
One of ~ 50 DPSSL beams that provide 1 - 2 MJ @ 15 Hz
0.5 - 6 x 10^{20}
14 MeV n/sec
ICF Gain 15-60
150-1750 MW fusion
8-9 m pure fusion systems
3.5-5 m hybrid systems
LIFE blankets options
• Li-based coolant for pure fusion energy
• Coolant with natural U, DU or Th pebbles for sustainable, once-through closed fuel cycle energy (goal > 99 % burn-up)
• Coolant with fertile or fissile pebbles for once-through closed fuel cycle energy while burning SNM and LWR waste (goal > 99 % burn-up)
— WG-Pu, HEU
— TRU or TRU+FP from SNF
— SNF (without reprocessing)

U. Texas


Al TF Outer
4
2
A=1.8
100 MW
Plasma
Neutron
source
E
A
TRU
B
Cu
PF
Pb-Bi
Reflector
Coolant
0
2
4 m

High Level Findings (cont)

- Repositories:
  - Both pure fission or hybrids require repositories
  - Fission byproducts, not actinides may be most dangerous
  - Least expensive technical solution
  - Very difficult politically (e.g. Yucca Mt.)

High Level Findings (cont)

- Technical comparison of pure fission vs. fusion-fission hybrids
  - Hybrids compare favorably to pure fission solutions (e.g. breeders and burners)
  - **Not a fair comparison!**
  - Hybrids assume advances in technology: materials and new fuel forms
  - Pure fission assumes existing technology
  - Comparing apples and oranges
- A quantitative comparison can not be made at this point in time

High Level Findings (cont)

- Economic comparison of pure fission and fusion-fission hybrids
  - General consensus for a single reactor is that

$$\$LWR < \$Fast\ reactor < \$Hybrid$$

  - Fair comparison requires overall systems analysis
  - Which costs more?
  - Large number of LWRs + a few hybrids
  - Small number of LWRs + a large number of breeders

High Level Findings (cont)

- Are hybrids an intermediate step to pure fusion?
- Advocates say "yes"
  - Reduced plasma physics requirements (e.g Q = 2)
  - Reduced first wall problems (lower heat flux and neutron flux)
- Skeptics say "probably no"
  - Fusion-fission interface more complicated
  - Blanket has fission + fusion roles
  - Technology, not plasma physics, will determine the time scale
  - Overall time scale comparable for both

High Level Findings (cont)

- What about our international colleagues?
- They are leaving us in the dust
- Active programs in
  - Russia
  - South Korea
  - China
  - India
- Collaborations are possible
- What do they know that we don't?

High Level Findings (cont)

- Proliferation
  - Hybrids have significant quantities of fissile materials
  - Proliferation risk much greater than for a pure fusion reactor
  - Proliferation risk comparable to a pure fission reactor
  - Substantial variation depending on design and fuel cycle

High Level Research Needs

- Comparison of pure fission with hybrids
  - The most important near term problem
  - Compare, at a basic systems level, various hybrid concepts with comparable fission solutions
  - This must done in a fair way
  - Comparable assumptions for both
  - Hybrids using fission assumptions
  - Fission using hybrid assumptions

High Level Research Needs (cont)

- Fusion technology
  - US fusion technology program has been decimated
  - We will not be able to make hybrids or pure fusion in 50 years unless we restart technology
  - Of particular importance is materials research
- If we maintain our present strategy
  - Our international colleagues will be leaders in fusion and hybrid energy applications
  - We will be followers

The Bottom Line

- Do we need hybrids? A razor sharp "Maybe"
- Do we need them very soon? Probably not
- Is this a problem? Probably not – we need R&D time
- Are they more attractive than pure fission solutions? Don't know yet
- What should we (OFES, NE, NNSA) do?
  - Carry out a fair comparison study
  - Restart fusion technology program

It’s Here!