Renew Workshop on Fusion-Fission Hybrids

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Fusion Power Associates
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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
- $3.7 \times 10^{10}$ 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
One of six 1st Wall modules that contain fusion and multiply and thermalize the 3-5 MW/m² of 14.1 MeV neutrons

One of ~ 50 DPSSL beams that provide 1 - 2 MJ @ 15 Hz

ICF Targets @ 15 Hz
(Not to scale)

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
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!