A Skeptical Assessment of Fission-Fusion Hybrids. V1a†

The Skeptics Panel

B. Afeyan, I. Hutchinson, D. Meade, D. Petti, J. Sheffield, D. Steiner, C. Baker, R. Hanrahan, M. Mauel, K McCarthy, P. Colestock

† These are, with small corrections, as presented at the workshop for discussion, but don't represent any final findings or position.

Skeptics aren't (just) Grinches

Our job is

(politely)

to ask hard questions

articulate the challenges

and downsides.

Picture of grinch (no copyright permssions).

John Sheffield in December?

We are not skeptics about fission or fusion,
or about the importance of benefitting from each other's expertise and research.
Opportunities for synergistic research in technology are many.

An assessment of Attractiveness

or ‘usefulness’ is essential.

We can’t just say: here’s something neat we could do. Still technical assessment.

Consider the Advantages of (pure) Fusion (Nuclear) Energy:

1. Practically inexhaustible **fuel resource** (D or Li). [C.f. some thousands years of fission.]

2. **Wastes** much easier managed. Fusion’s activation much less problematic than actinides and long-lived fission products.

3. **Safety**. Fusion has no criticality risks. Contains minimal (100-1000g) fuel or radioactive inventory at any instant. Negligible after heat. Risks far less.

4. **Proliferation**. Major fission proliferation threats are fuel-cycle (front or back). Fusion has no fissile fuel cycle, and no business having any actinides there, hence inspections are technically easy. Breakout threat minimized by zero inventory.

Fusion's disadvantages also real

and constitute its biggest challenges.

Net energy production is **very difficult**. Not yet demonstrated.
[C.f. relatively straightforward for fission: Chicago Pile.]

Challenge in materials and components that arise from **surface/volume fusion issues** (first wall, heat, neutron damage, ...).

Specific challenges associated with the **very large scale** of fusion devices.
No small-scale energy-producing prototypes.

Complex engineering challenge.

Hybrids may partially alleviate these challenges

But, which of fusion's 4 main advantages do hybrids retain?

NONE

NONE

of fusion's key attractions remain in hybrids

1. We are back to fission **fuel resource** limitation.

2. We are dealing with fission **wastes** not the minimal fusion activation.

3. All of fissions **safety** concerns, and more, are in play.

4. **Proliferation** risks are as bad as fission, or worse.

Fission-fusion hybrids combine most of the bad features of both (Holdren 1981):

fission: resource limitations, wastes, safety, proliferation

and

fusion: complexity, scale, difficulty, uncertainty, materials, ...

Advocates propose as motivations for hybrids:

- to support fission energy (through breeding or burning)
- to accelerate deployment of fusion energy

Critique of Proposed Hybrid Advantages c.f. Pure Fission

Burning Actinides. Does it transform the fission-fusion hybrid opportunities?
Breeding, burning, and energy production are all intertwined.
Thus the recent burn emphasis introduces nuances, more than totally new issues.

Subcriticality. Said by hybrid advocates to be a big deal for deep burning, & TRU fuels. Said by most fission colleagues to be a little deal.
Much the same burning can be obtained if desired by pure fission/recycle.
Criticality control, while important, does not dominate fission reactor safety.

How attractive is the burning TRU mission? Answers are equivocal.
Depends on nuclear energy scenario. Closeout? Sustained?

In a sustained nuclear energy economy, waste burning is not the issue,
integrated fuel breeding and management is.

Advocates say breeding is a longer term issue.
Many would say so is long-term disposal.

Fuel is a small part of current nuclear costs

Including the cost of ultimate disposal

Amount of nuclear fuel and waste is small (contra rhetoric).

There is a range of technically-acceptable ultimate disposal approaches.

Inherent costs of disposal are small fraction of electricity value.

- Actinide burning is laudable but not inherently very valuable.

Costs, and hence value can be greatly inflated relative to their inherent levels, by political action and by the opinions of society. But for the very long term there will be a strong tendency towards intrinsic cost-effectiveness.

The immediate "need" for hybrids for actinide burning appears mostly not to be pull, coming from the fission community but push, driven by hybrid advocacy (and the ADS community before it).

Hybrid Challenges c.f. Pure Fission

- driver development
- fission-fusion interface (complexity, transient loads, new risks, ...)
- fuel cycle, blanket (need to be developed)
- safety and licensing
- costs
- timescale

Critique of proposed Hybrid Advantages c.f. Pure Fusion

Timescale. It is said the hybrid offers a nearer-term application of fusion. Many dispute this because.

- Fusion technology and materials development is likely the pacing item. Hybrid technology is not qualitatively easier than pure fusion.
- Technology specific to hybrids must also be proven.
- Need for hybrids for burning/breeding is long-term, not short term.

Reduced requirements on fusion performance.

- Reduced Q. Reduced confinement, pressure... Reduced wall load. T-Breeding.

These are real reductions in fusion's difficulty. (But gains are constrained).

If we knew that pure fusion would not work, but hybrids would, maybe that would be a strong enough incentive. But few think that's the case.

Hybrid Issues c.f. Pure Fusion

- How much overlap is there between the R&D required for hybrids and that for pure fusion and/or pure fission?

- How significant are the actual advantages in neutron wall loading and materials feasibility, once fission neutrons and other constraints are also accounted for?

- How attractive are fusion hybrids relative to other neutron options like accelerators?

- How valuable is the fact that hybrids might be able to accept a lower availability?

These are open questions in our mind.

Fusion Energy: a Scientific and Technical Grand Challenge

- Intellectually and technically extremely difficult.
- But with transformational benefits if successful.

Fission-fusion hybrids may be equally challenging, but they can't transform the prospects and characteristics of nuclear energy.

That's why hybrids are not a 'Grand Challenge' like (pure) fusion.

- Hybrids might improve fission's ability to burn actinides (but maybe not)
- Burning actinides might be useful (but maybe not).

The cost is loss of all fusion's major attractiveness,

and addition of (almost) all its complexity and uncertainty.

Fusion technology R&D need for hybrids is little different from that for pure fusion, and requires additional breakthrough R&D in fission technology.

Science and technology priorities ought to be directed to the Grand Challenge. Hybrids are not thereby ruled out, but they don't drive near-term priorities.