Perspectives on fusion energy research: towards credibility

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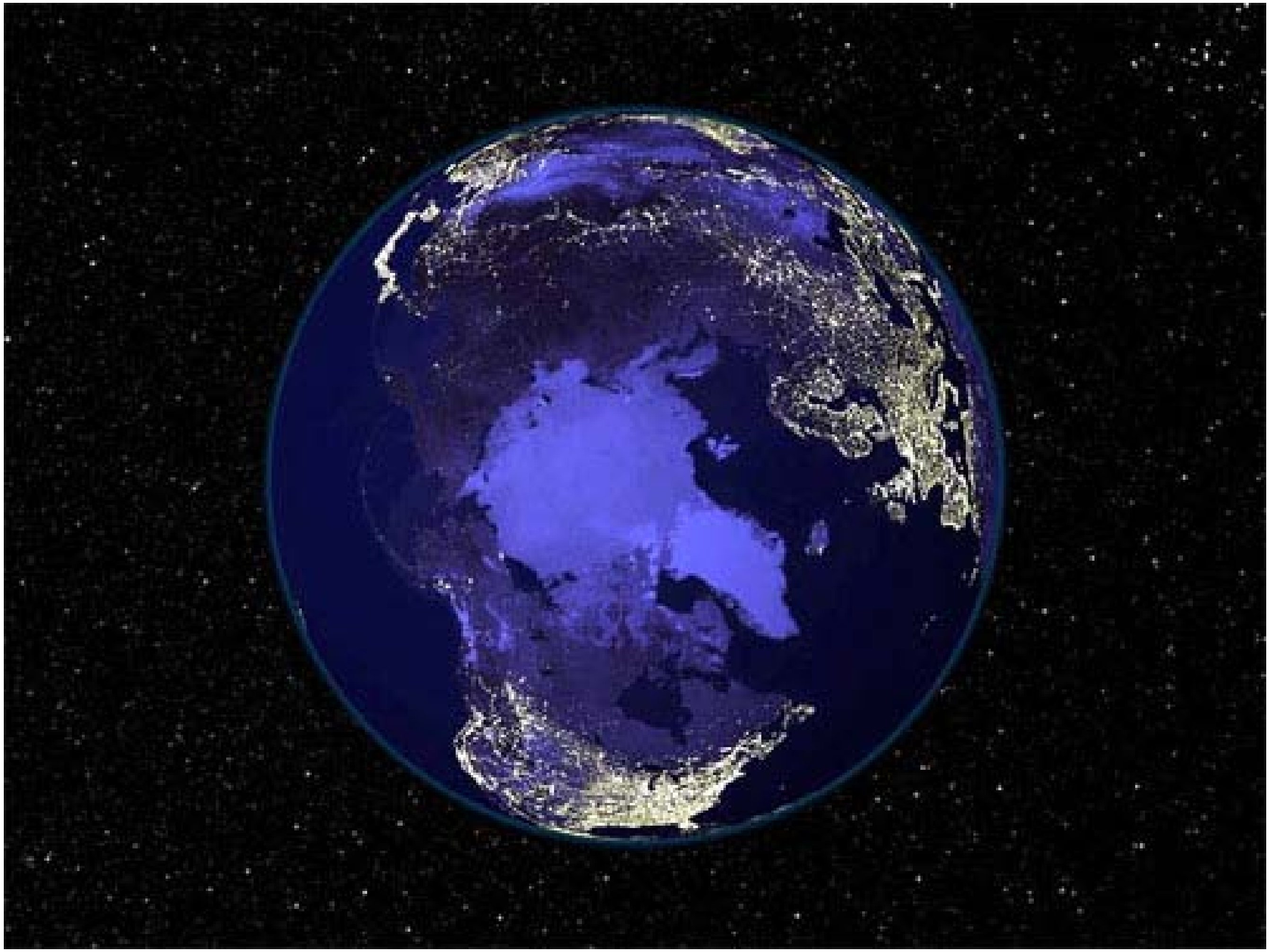
The ambition for fusion research has to be no less than powering the planet



We need to *focus and lever* our efforts in the U.S. to make fusion energy a credible option

- The leading challenge: establish scientific credibility
- The community has identified gaps in the world program that need to be filled. This can enable the U.S. to assert world leadership and establish credibility for the fusion enterprise
- The community has identified research approaches needed to fill those gaps

Perspective: we need to break out of scientific and political isolation

- *Scientifically: Our challenges are too deep, and the stakes are too high, to not use resources outside of our immediate sphere that could help advance the fusion cause and bridge the credibility gap.*
  - *Applies inter-institutionally and internationally*

- *Politically: No one will help you fight for research dollars and defend you if they don't have a shared interest in your program, especially in tight times*

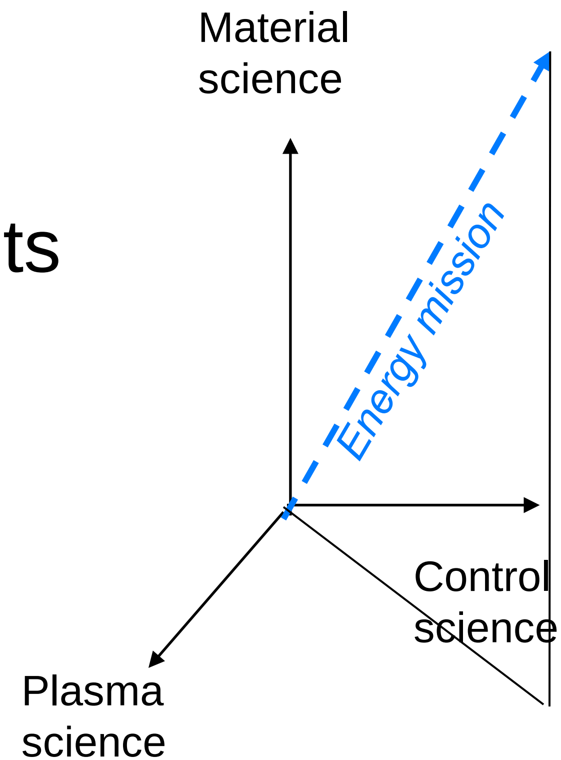
- *Scientific and political isolation are risky attributes that FES is living with, but smart leverage through partnerships can change this*

The science of fusion is rich and deep, and we can cast our research needs in the language of fusion science

Energy or science? Nearly moot right now: what we need to do to establish credibility towards an energy goal is deeply scientific in character.

The energy and basic science pursuits elevate each other

This basis set can be drawn for both MFE and IFE



Establishing credibility is our challenge

- There are at least three major scientific needs for establishing credibility for fusion energy:

  (1) We must generate, study, optimize, and learn to predict the properties of the burning plasma state

  (2) We must develop the scientific basis for robust control strategies for the burning plasma state

  (3) We must develop the understanding of the material/plasma interface, and the fusion nuclear science needed to endure the fusion environment and to harness fusion power

For the record: from Congressional testimony, 10/29/09

Oral Statement of Dr. Edmund Synakowski
Associate Director for Fusion Energy Sciences
Office of Science
U.S. Department of Energy Before the
Subcommittee on Energy and Environment
Committee on Science and Technology
U.S. House of Representatives
October 29, 2009

"…Strategic planning is underway aimed at filling gaps in the world program so as to assert U.S. leadership where it best advances fusion as a whole while maximizing U.S. scientific return. For magnetic fusion, the scientific challenges can be broadly stated as follows.

– (1) Understanding and optimizing the burning plasma state. Experiments, theory, and simulation have significantly advanced our understanding of what to expect from a burning plasma, and will continue to do so. But ITER provides the only platform planned to directly test and expand our understanding of this complex physics.
– (2) Understanding the requirements for extending the burning plasma state to long times – days, weeks, and longer. Many aspects of this are pursued in the U.S., and the second ten years of ITER's operation will put our understanding to crucial tests. However, overseas fusion programs are set to assert leadership in part through new billion dollar class research facilities in Europe, Japan, South Korea, and China. We are exploring growing our collaborations to increase their impact and the knowledge returned. And finally,
– (3) Advancing the materials science for enduring the harsh fusion plasma environment, for extracting energy, and for generating fusion fuel *in situ*. We will be exploring what is required to develop a materials and fusion nuclear science program, one that addresses the necessary fundamental scientific issues while weaving the results and advances into our best concepts of future fusion systems."

Establishing credibility is our challenge: *burning plasmas*

- There are at least three major scientific needs for establishing credibility for fusion energy:

  (1) We must generate, study, optimize, and learn to predict the properties of the burning plasma state

  (2) We must develop the scientific basis for robust control strategies for the burning plasma state: in MFE, this includes developing the scientific understanding to enable long plasma pulses

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Establishing credibility is our challenge: *burning plasmas*

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  ➔Our participation in ITER, ensuring its success through present-day research, and developing a validated predictive capability for going beyond it has to be our highest priority

Validated predictive capability is about risk mitigation as well as scientific discovery

- The steps required to optimize the reactor vision may be unattractive to an investor, despite the success of any fusion demonstration or development effort

➔ *places an enormous demand on taking a qualitative step forward – or two – in validated simulation.*

Seeking leverage:

- can we lever experience and computational resources of the ASC community?

- are we doing the best experiments and measurements to enable us burrow down on some of the critical basic physics questions for validation?

Establishing credibility is our challenge: *steady-state*

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Establishing credibility is our challenge: *steady-state*

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  (2) We must develop the scientific basis for robust control strategies for the burning plasma state: in MFE, this includes developing the scientific understanding to enable long plasma pulses.

  ➔ We need to understand far better than we do what our opportunities are in international collaboration, given the investments made overseas in long-pulse tokamaks and stellarators

For steady-state research, our programmatic challenges are many

- What do the most effective collaborative efforts look like? Can we learn from the other sciences?

- What do the overseas programs need from us?

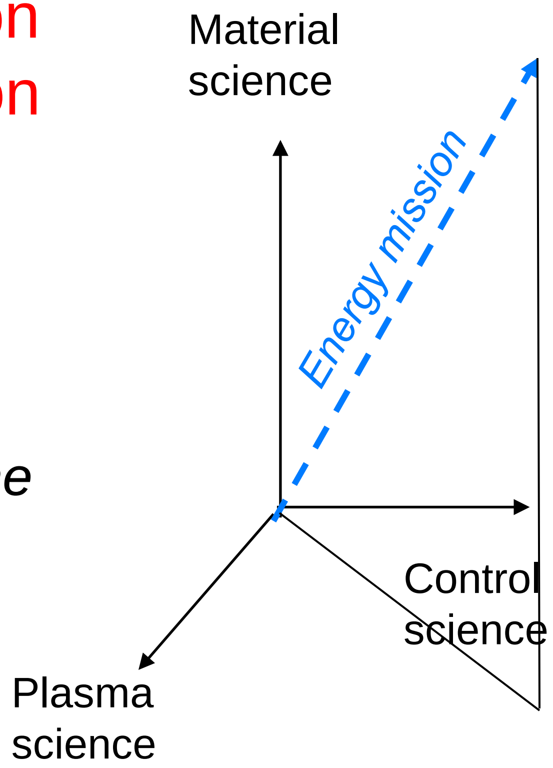
- Again, what are the requirements for a truly deep understanding that will enable us to reduce risk in next-steps? For example,
  - the wave physics at DEMO conditions
  - we see benefits of 3-D fields in tokamaks (10^{-3}) and stellarators (10's of %). Will our predictive capability enable us to bridge the gap and find an optimal configuration, given the few data points we will ever obtain in this operating space?

Establishing credibility is our challenge: *materials*

- There are at least three major scientific needs for establishing credibility for fusion energy:

(3) We must develop the understanding of the material/plasma interface, and the fusion nuclear science needed to endure the fusion environment and to harness fusion power

At present, fusion materials and nuclear science is our smallest projection on our needed basis set, but it may be where the most opportunity for leverage resides



The materials challenge is enormous, both non-nuclear and nuclear, and the program needs to be carefully thought out

We need to construct a sensible program: deeply scientific as well as sharply directed

➔ What does a sensible program look like that advances materials science efficiently and effectively, towards a facility to investigate volume neutron effects on structures and materials and for harnessing fusion power?

Fundamental materials science Computation, facilities, improved diagnostics	⟺	What facilities are at the center of a fusion nuclear science mission? What does the progression of research to a major facility look like? What does any major facility look like?

A tightening spiral of research and concept definition

There are opportunities for leverage in the materials arena

- Critical to explore leverage because
  - Resources: they are tight
  - Ideas: we need to share expertise. Stakes are too high to do otherwise

  End result of successful leverage: advance the science, and gain much-needed support

- Other disciplines and offices have research needs in materials as well, e.g. advanced fission (NE), NNSA. Within Office of Science, there is BES, NP. Perhaps NSF. ASCR and NNSA leverage and partnership for computing (materials by design)
- IFE needs in materials are strongly related to MFE needs.
- With a green light from SC leadership, I am exploring developing a broad, cross-office move on "Materials for Energy"

On IFE and HEDLP: we need to be prepared

- Fusion is hard, and the stakes are high. IFE has very different technical risks. We can work with NNSA and lever the nation's investments in ICF to develop this option to broaden fusion's portfolio and reduce risk.

- The science of HEDLP is rich; lab astro, for example, can answer many fundamental questions
  - Missing x-ray emission from black hole accretion disks
  - Scale of the universe: Radiative transfer of "standard candles"
  - Earth's magnetic field generation: melt point of iron
  - More…

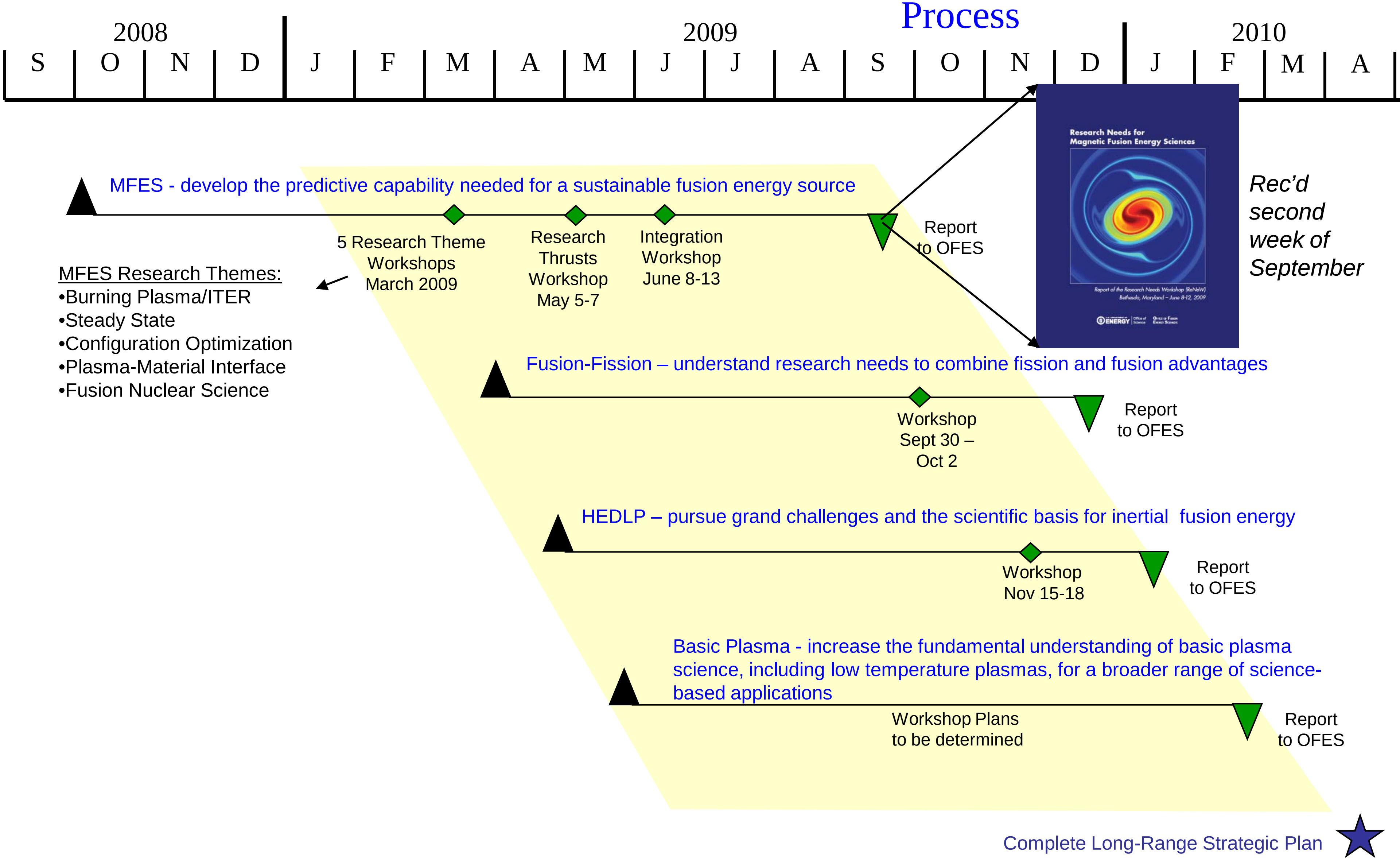
- Science of IFE-related science is deep
  - e.g. Multiscale physics of advanced ignition scenarios

MFE and IFE have many common needs regarding materials science

- Either approach would benefit from a 14 MeV neutron source, point or volume
- NIF success is going to bring even further attention to the area of materials science and fusion nuclear science
- This provides a further reason to look for levering opportunities

MFE’s and IFE’s successes need to be applauded as successes for fusion and thus for all

Fusion Energy Sciences Program
Research Needs Workshops and Strategic Planning Process



On process…

- MFE ReNeW report received in our office early September. There are also recent and further workshops (fusion-fission, HEDLP). Many arrows in the quiver, at the ready
- FES's role: establish the rights of way for the railroad, especially since emergent priorities include elements that have not been supported in the past ➔ *aligning leadership above FES, and engaging OMB*
- We are beginning to ask some of you to the Office in Germantown to further educate us, discuss and clarify ReNeW initiative suggestions and reflect off of you an emerging vision, given opportunities and limits that we see.

If my tenure in this Office is successful…

- Fusion will move to the front page: the path to credibility will be clear

- We will be speaking with a clear, coherent voice, and touting a vision that is sharp, focused, relevant, and scientifically rich

- The plasma and fusion energy-related sciences will naturally broaden and deepen, as their relevance and power is increasingly demonstrated

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