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Further Context for NAS Burning Plasma Study

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Introductory

- **Thank you to the NAS BP Panel members for serving on this study**
  - More than a decade since the 2004 NAS BP study led by Fonck and Ahearne
  - Huge task to analyze many reports, solicit and review extensive community input, assess the US and international fusion research program, evaluate ITER project, etc.

- **You invited me to speak about:**
  - The state and potential of magnetic confinement-based fusion research in the U.S.
  - Guidance on the preparation of the committee's final report in light of the interim report and of the committee's statement of task
    - » If desired, can be available later for comment on interim report when released
  - Views of any budget implications relevant to the long-term strategic guidance that will be presented in the final report
  - Views of (1) the potential impact on this plan if the U.S. is, or is not, a partner in the ITER project, and (2) DOE research program elements that might strengthen or accelerate U.S. research in burning plasma science given that economical fusion energy within the next several decades is a U.S. strategic interest

Austin community workshop

- **Appreciate that the community self-organized to provide input to the NAS BP study**
  - Extensive community input

- **Some observations**
  - Strong participation by the significant number of "early career" researchers at this workshop (and presumably also the Madison workshop)
    - Quote: "ITER has now become no longer 'my tokamak,' but the tokamak for the next generation."
  - All participants have "yearning for burning"
    - Quote: "I got into this field because of the beautiful physics, and subsequently embraced the fusion energy goal of this physics"
  - "Be bold" versus "be reasonable" (cost, schedule)
    - Cf. FY18 budget request data point

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Challenges for burning plasma/ITER

- **ITER challenges**
  - Cost to the U.S.: CD-2 cost estimate ($4.5-6.1B) compared to CD-1 preliminary estimate ($1.1B)
  - Credible schedule: New schedule has First Plasma at 2025 and D-T burning plasma operation at 2035
    - Last week ITER announced 50% completion of First Plasma construction
  - Shared governance framework; more central authority

- **Fusion challenges**
  - In the past: Over-optimistic/over-promised
  - In the present: Constrained budgets & higher priorities; hybrid nature of our field (science/energy)
  - In the future (economic): Timeline to get on the grid; competitive cost of electricity; technology issues (e.g., tritium production/handling)
    - » Should socio-economic energy studies for fusion be revived?

Energy for the future

- **Renewable energies**
  - Technology advancing swiftly
  - Intermittency
  - Advanced energy storage (batteries etc.)

- **Nuclear energy: Fission**
  - Can provide baseload energy; also load-following (modular)
  - Fuel supplies and waste management
  - Advanced modular/small reactors

- **Fusion energy**
  - Can provide baseload energy ("disruptive" technology); also load-following, high power density, minimize transmission
  - Advantages: safe, carbon-free, abundant fuel, short-term waste, etc.
  - Disadvantages: not small, not cheap, not simple, not yet
  - Intermediate milestones, earlier than full DT, with industry (to push high tech)?
  - Quote: "Fusion energy is inevitable--when and what form remains to be determined, depending on budgets and on political factors and other things."

Global context

- **US community has vital experience, skills, and technology for BP**
  - Examples: disruption mitigation (SPI on JET); plasma control; large-scale simulations; advanced diagnostics; central solenoid fabrication; ITPA; IO staff; etc.
- **Potential impacts are significant:**
  - If stay in ITER: budgetary
  - If leave ITER: program attractiveness; national reputation
- **Worldwide cooperation**
  - Feature of fusion research since 1958 Geneva Conference
  - Collaborative research (experimental, theory, technology, diagnostics) has been productive and cost-effective
  - Size/cost of next-step major facilities (e.g., ITER) requires partnering
  - LBNF (in US) has international partners and funding
  - Should US more thoroughly coordinate its strategic planning with world fusion research program?

International impetus

- **Paradigm has reversed**
  - Other countries used to watch what the U.S. did and follow the U.S. lead
  - Now?
- **Example: CFETR**
  - Workshop in Beijing two weeks ago to celebrate tenth anniversary of ITER project; also confirmed Chinese decision to proceed with CFETR next phase ("Beijing Declaration")
- **Example: EU roadmap**
  - Facilities assessment and planning
  - Being updated now to take into account the ITER delay and new phased schedule

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Integration of program elements

- **Fusion plasma physics**
  - Excellent research on core plasma dynamics; recent focus on edge plasma, SOL, divertor, plasma-wall interactions
- **Fusion materials, nuclear science, & technology**
  - Vital, yet under-resourced
  - Leverage mutual-benefit opportunities with other fields?
- **Theory & simulation**
  - Appropriate balance
  - Leverage government-wide priority on high-performance computing (e.g., WDM, SciDAC, ECP, machine learning, QIS)
- **Discovery plasma science**
  - DOE stewardship (cf. 2010 Decadal Study)
  - Broad scientific connectivity (e.g., space/solar/astro, low temp, HEDLP, antimatter)
  - Importance of university intellectual engagement; workforce development
  - Non-fusion experiments on major facilities (and vice versa)?

"Newness" factor

- **Worldwide fusion research activities (unclassified) since 1958**
  - Why not yet?
- **Technologies for accelerating progress**
  - Recent FESAC subcommittee on transformative enabling capabilities (to report out at the upcoming Feb 1-2, 2018, FESAC meeting – date conflict with NAS-BP Panel visit to ITER site)
- **Need for innovation and recognition**
  - Universities and early-career faculty are looking for new, high-impact research areas (to garner funding support, train students, gain recognition)
  - Federal and congressional stakeholders look for what's new/hot/visible/touted
  - Media exposure (Science & Nature & major news media, not just PRLs)
  - National/international awards
  - Citation index metrics (trends)
  - Broader scientific connectivity
  - High-risk, high reward research opportunities

Strategic planning

- **NAS BP charge**
  - "…provide guidance for a strategic plan if US is in and if US is out of ITER…."
  - Guidance might consist of recommendations concerning:
    - a planning process (e.g., involving the community & FESAC)
    - elements of a plan
    - a rough draft
  - Strategy involves: vision, mission, goals, objectives for the goals, measures for each objective, plans for implementing each objective, …
  - Intermediate goals? Several plans (near-, intermediate-, long-term)?

- **Resources**
  - Financial, human, facilities, infrastructure
  - Risky with constrained budgets (but taking no risk is also risky)

- **Inter-agency strategic planning**
  - NAS 2020 Decadal Survey to launch in 2018, for 24 months (plasma and fusion science): multiple federal sponsors (DOE-SC, DOE-NNSA, DOE-ARPA-E, NSF, AFOSR, ONR).

What next?

- **Anticipating:**
  - FESAC TEC report
  - Your NAS BP interim report, and later your full report
  - NAS Decadal Survey report
  - FY18 congressional budget allocation
- **How to involve:**
  - Community: third workshop?
  - FESAC
  - DPP
  - Other federal agencies that fund plasma research
  - AAAS?
- **Are we continuing into a P5-like process?**
- **Maintain/exploit appropriate roles and responsibilities**
  - Unique strengths; shared activities; federal prerogatives