Comments on FESAC charge #2

(perspective on a flat MFE budget for 10 years

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PPPL PRINCETON PLASMA PHYSICS LABORATORY

DEI SVB NVMINE VIGET

An MFE domestic program at flat-funding
(~ $260M, excluding GPS, HEDP)

Criteria:

- World-leading research on important topics

  Focus on original, important, selected, exciting activities where the US can lead or be at the world forefront

- Linked/preparatory to ITER and a fusion roadmap to DEMO

  Maintain ability to contribute to ITER and breakout into fusion energy development program

Therefore,

- Choose work with breakthrough potential

- Do not choose development work that is incremental or secondary to similar but larger efforts elsewhere
  (except in some cases to maintain core capability needed for breakout to fusion development program)

- Choose activities over full range of three topic categories
  - Confinement (high performance, steady-state, burning)
  - Plasma-material interface
  - Harnessing fusion power

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

1. Plasma confinement

   (high performance, steady-state, burning plasmas)

   Fusion simulation program

Examples of research activities for US leadership in 10 yrs
(~ $15M to ~ $50M blocks)
(listed in unprioritized order)

1. Plasma confinement

   (high performance, steady-state, burning plasmas)

   - Fusion simulation program
   - Magnet development
     - High field, high Tc superconductors
     - potentially significant implications for tokamak, stellarator
     - e.g., reduction in size

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

1. Plasma confinement

   (high performance, steady-state, burning plasmas)

   - Fusion simulation program
   - Magnet development
   - Tokamak facility (AT or ST)
     - investigating novel features (e.g, new divertors, new PFCs)
     - preparing for ITER, FNSF
     - maintaining tokamak operational expertise

Examples of research activities for US leadership in 10 yrs
(~ $15M to ~ $50M blocks)
(listed in unprioritized order)

1. Plasma confinement

   (high performance, steady-state, burning plasmas)

   - Fusion simulation program
   - Magnet development
   - Tokamak facility (AT or ST)
   - Stellarator program
     - steady-state, disruption-free, good confinement
     - novel designs for US research
     - new confinement science
     - preparing for FNSF

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

1. Plasma confinement

   (high performance, steady-state, burning plasmas)

   Fusion simulation program

   Magnet development

   Tokamak facility (AT or ST)

   Stellarator program

   Perhaps support ≤ 2 confinement facilities by end of decade (AT, ST, stellarator)

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

1. Plasma confinement

   (high performance, steady-state, burning plasmas)

   Fusion simulation program

   Magnet development

   Tokamak facility (AT or ST)

   Stellarator program

   International collaboration on SC facilities

   ~ maintain scientific balance of trade

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

1. Plasma confinement

   (high performance, steady-state, burning plasmas)

   - Fusion simulation program
   - Magnet development
   - Tokamak facility (AT or ST)
   - Stellarator program
   - International collaboration on SC facilities (quid pro quo)
   - Exploratory fusion concepts
     - re-evaluate opportunities

Examples of research activities for US leadership in 10 yrs
(~ $15M to ~ $50M blocks)
(listed in unprioritized order)

2. Plasma-material interface

New divertor geometries

(e.g, snowflake, super-X)

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

2. Plasma-material interface

- New divertor geometries
- Liquid metals
  - unique advantages as first wall
  - US at forefront, can lead
  - some synergies with blanket liquid metal issues

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

2. Plasma-material interface

New divertor geometries

Liquid metals

Tungsten development

- studies in plasma test stands and confinement facilities
- high temperature
- developing new tungsten alloys
- (not obvious can be at world forefront)

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

2. Plasma-material interface

    New divertor geometries
    Liquid metals
    Tungsten development

3. Harnessing fusion power

    Modified US accelerator neutron source
        e.g, ORNL, LANL for fusion relevant neutrons,
            joining IFMIF

Examples of research activities for US leadership in 10 yrs (~ $15M to ~ $50M blocks) (listed in unprioritized order)

2. Plasma-material interface

   New divertor geometries
   Plasma test stands
   Liquid metals
   Tungsten development

3. Harnessing fusion power

   Modified US accelerator neutron source
   Blanket studies
      possible niche is DCLL
      some synergy with liquid lithium PFC
      (not obvious can be at world forefront)
      possibly needed capability for breakout potential

Examples of research activities for US leadership in 10 yrs
(~ $15M to ~ $50M blocks)
(listed in unprioritized order)

4. Scoping studies for activities after 2020

Scoping/conceptual design studies

- Fusion Nuclear Science Facility (FNSF)
- Toroidal facility for plasma-materials interface
- Stellarators

Roadmapping and socioeconomic studies

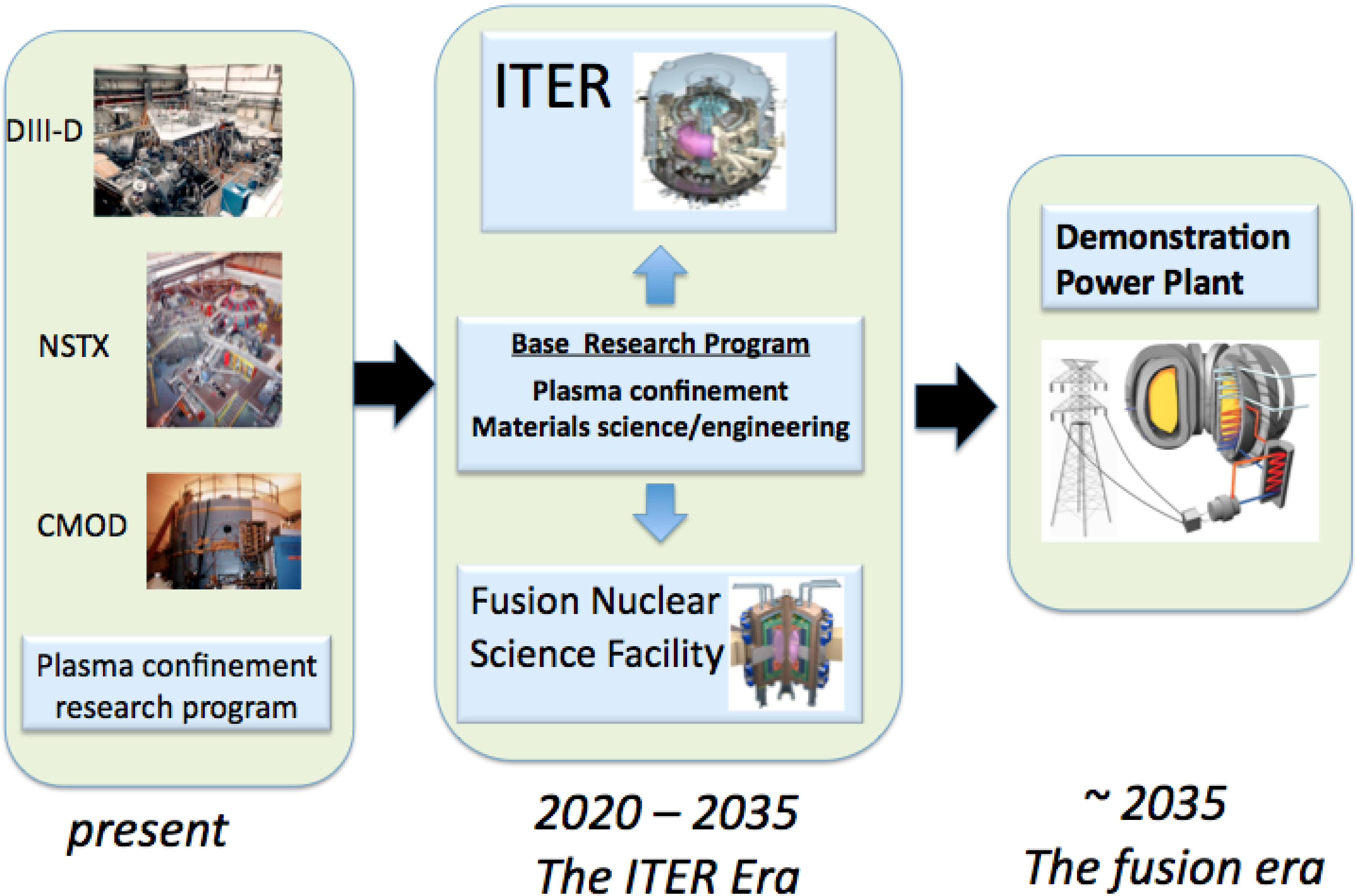
- Considering the international context,
  possible international collaboration on FNSF/DEMO

Some strategic issues

- Workforce
  - key to maintain and evolve workforce, nondisruptively
  - what core capabilities to emphasize?
    (among plasma, material science, technology?)
  - influenced by potential areas of world leadership
  - an answer:
    maintain plasma science workforce at world forefront,
    build materials/technology workforce in selected areas

- Impact on fusion roadmap

How will this charge affect the "standard" roadmap discussed in the US



Impact on roadmap

One scenario:

- Engineering design of FNSF not affordable in next ten years(~ $50M per year in second five-year period?)
- Delays FNSF start to ~ 2032 (10 year design/construction), DEMO to ~ 2047 if place FNSF and DEMO in series
- Therefore, consider option to proceed straight to DEMO, with FNSF mission as phase I

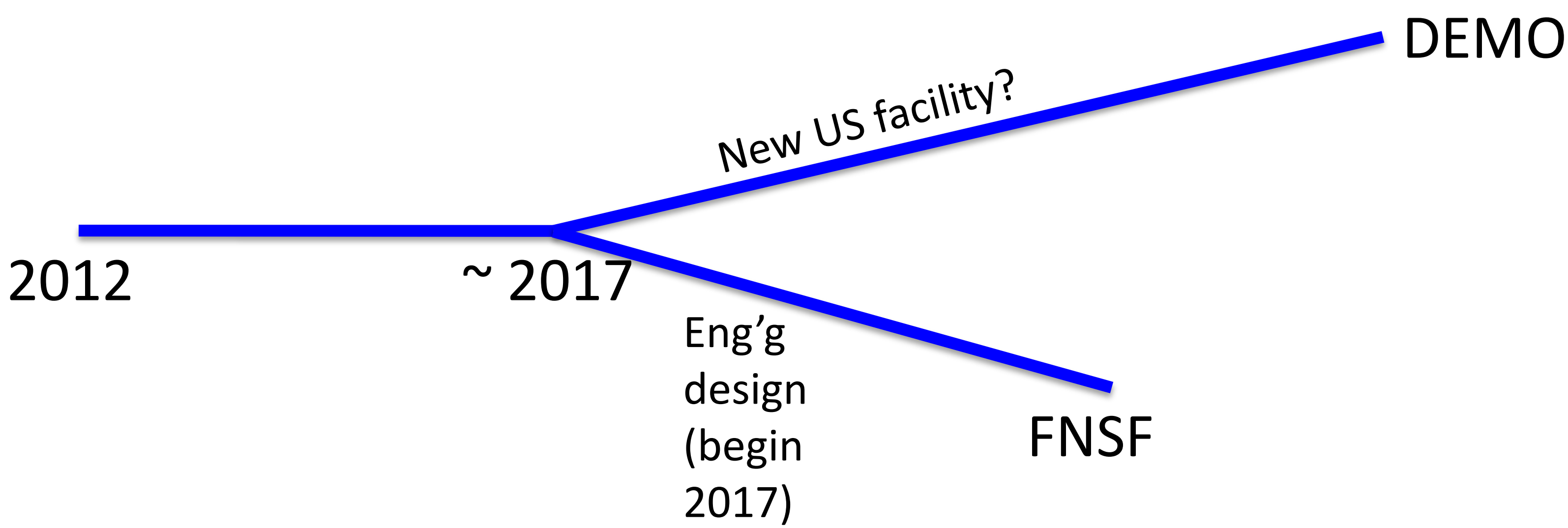
  (similar to plans of other ITER parties)
- Orient research program to solving long-range issues for fusion, emphasizing innovative solutions

Possible path

- Proceed for 5 years along path to either FNSF or DEMO

- Develop physics basis (AT, ST, stellarator) and materials basis to FNSF or DEMO

- In ~ 5 years, proceed toward FNSF (possibly with international collaboration) if US funding situation changes dramatically or proceed straight to DEMO



A sample "new" lean OFES program in ~ 8 years

Plasma confinement $170M

magnet developmnt (hi Tc SC, hi B)

~ 2 confinement facilities (AT, ST, stellarator)

int'l collab on SC facilities (quid pro quo)

exploratory fusion concepts

FSP/theory

Plasma-material interface $40M

new divertor geometries

plasma test stands

liquid metals

Harnessing fusion power $30M

Modified accelerator neutron source

Blanket studies (DCLL)

Scoping studies $15M

scoping/design for next-step facilities

roadmapping/socioeconomic

TOTAL $275M (incl. $20M "other")

- Even without any “competitive-scale” facility, minimal set of opportunities barely fits within a flat budget

- At $40M - $50M less:

  eliminate whole research areas
  (PMI or confinement facility or FNS),
  huge negative impact on workforce and US core capabilities,
  impede ability for breakout to fusion development program
  (an assessment of core capabilities might be useful)

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