The Fusion Program at PPPL
(in the context of the US program)

Stewart Prager
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ReNeW opportunities and the U.S. program

• Burning plasmas
• Steady-state, high performance
• Optimizing the magnetic configuration
• Taming the plasma-material interface
• Harnessing fusion power
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Materials and fusion nuclear science,
It is now time for the U.S. to move into fusion materials research,
Re-establish core competencies
ReNeW opportunities and the U.S. program

Plasma confinement science,
Opportunities to resolve remaining crucial issues,
Benefit from U.S. cutting edge expertise (and maintain that expertise)

- Burning plasmas
- Steady-state, high performance
- Optimizing the magnetic configuration
- Taming the plasma-material interface
- Harnessing fusion power

Materials and fusion nuclear science,
It is now time for the U.S. to move into fusion materials research,
Re-establish core competencies
Pathways towards integrated DT experiments

mission elements

plasma-materials interaction
neutron effects on materials
fusion nuclear science (component testing)
net electricity production (pilot plant)
Consider aiming toward a pilot plant

• $Q_{\text{eng}} > 1$, integrates missions in one facility

• Can start with demonstration of electricity production at low availability, then proceed with neutron fluence tests

• Pilot plant can be a driver for the fusion program and convey fusion’s potential to the public
Spreadsheet Pilot Plants parameters

\(Q_{\text{eng}} > 1\)

- **Tokamak**
  - \(R/a = 4\text{m}/1\text{m}, B_0 = 6\text{T}, I_p = 8\text{MA}\)
  - \(H_H = 1.5, P_{\text{fus}} = 500\text{MW}\)

- **Stellarator**
  - \(R/<a> = 4.6\text{m}/1\text{m}, B_0 = 5\text{T}\)
  - \(H_{\text{ISS04}} = 2, P_{\text{fus}} = 200\text{MW}\)

- **ST**
  - \(R/a = 1.5\text{m}/0.9\text{m}, B_0 = 2.2\text{T}, I_p = 15 \text{ MA}\)
  - \(H_H = 1.7, P_{\text{fus}} = 500\text{MW}\)
Can combine missions into facilities in various ways

- plasma-materials interaction
- neutron effects on materials
- fusion nuclear science
- net electricity production
very aggressive, possibly high risk

plasma-materials interaction
neutron effects on materials
fusion nuclear science
net electricity production

Pilot Plant
slightly less aggressive,

plasma-materials interaction
neutron effects on materials
fusion nuclear science
net electricity production

Fus Nucl Science Facility
Pilot Plant or Demo
less aggressive

plasma-materials interaction
neutron effects on materials
fusion nuclear science
net electricity production

See Goldston talk
A design/strategic study is required to assess risks, readiness, required R&D, costs, timeline of various paths
PPPL activities and plans span many ReNeW themes
NSTX

Spherical tokamak = relatively compact, high beta configuration
NSTX upgrade

Increase current 2x, increase pulse length 5x (2 MA for 5 sec)

second neutral beam

new center stack
Reasons for Upgrade

• PMI/first wall materials research
  high exhaust heat flux (≥ ITER)
  novel first wall boundary (liquid Lithium)
  scoping hot walls, advanced magnetic divertor

• Develop ST for fusion next steps
  Fusion nuclear science facility, toroidal PMI facility

• Explore new fusion parameter regimes
  confinement at low collisionality and low R/a

Cost effective: majority of funds provided by reduced NSTX operations
Evolving a program in PMI/first wall materials

**Experimental elements**

- Developing liquid metal boundaries
  NSTX-U, LTX (Lithium Tokamak experiment) test stands

- Testing materials and PMI at high heat flux
  NSTX-U (heat flux ≥ that of ITER) test stand

- Investigating hot walls and advanced magnetic divertors
  NSTX-U
Stellarator research

- Stellarators are increasingly critical to fusion steady-state, disruption-free, reduced control requirements, confinement physics of quasi-symmetry

- U.S. can play leadership role in world program through quasi-symmetry, building on tokamak understanding

- Collaborations with W7-X and LHD are expanding

- The National Stellarator Coordinating Committee is assessing opportunities for U.S. experiments scoping optimized designs for best step for US
Optimizing aspect ratio/coil complexity

Relaxing theoretical MHD stability constraints (based on experiments)
Optimizing aspect ratio/coil complexity

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Wisest experimental path will emerge from scoping studies
PPPL Tokamak program

• Collaboration program on off-site experiments (DIII-D, C-Mod, EAST, KSTAR, JET)

• Builds on other PPPL elements (NSTX, engineering, theory)

• Prepares for ITER (and other future tokamaks)
ITER design and fabrication

• Ongoing responsibility for diagnostics, steady-state electric power

• Leading the conceptual design of ITER in-vessel coils
  (construction decisions pending at international and national level)
Fusion Simulation Program

• Program definition phase launched in August (national effort, two years, PPPL has oversight responsibility)

• FSP Goal: 

   enable discovery and understanding of new plasma phenomena that emerge only upon integration.
The role of PPPL in FSP

• Responsible for facilitating success of FSP,

• Will oversee issues such as management, community outreach.....

• PPPL responsibility for national FSP is distinct from its scientific participation in FSP
Summary

• U.S. should move toward DT physics and engineering (encompassing ReNeW themes 1,4)

A national design/strategic study could assess DT pathways aiming toward a pilot plant

• U.S. should seize opportunities in first wall materials and plasma control (themes 1, 2, 3, 5)

• Opportunities and need for U.S. leadership across all themes, and to accelerate the availability of fusion energy

PPPL is collaboratively developing plans across several themes