Implications of the FESAC Fusion Development Path Study for FESAC Strategic Planning Panel Priority Criteria

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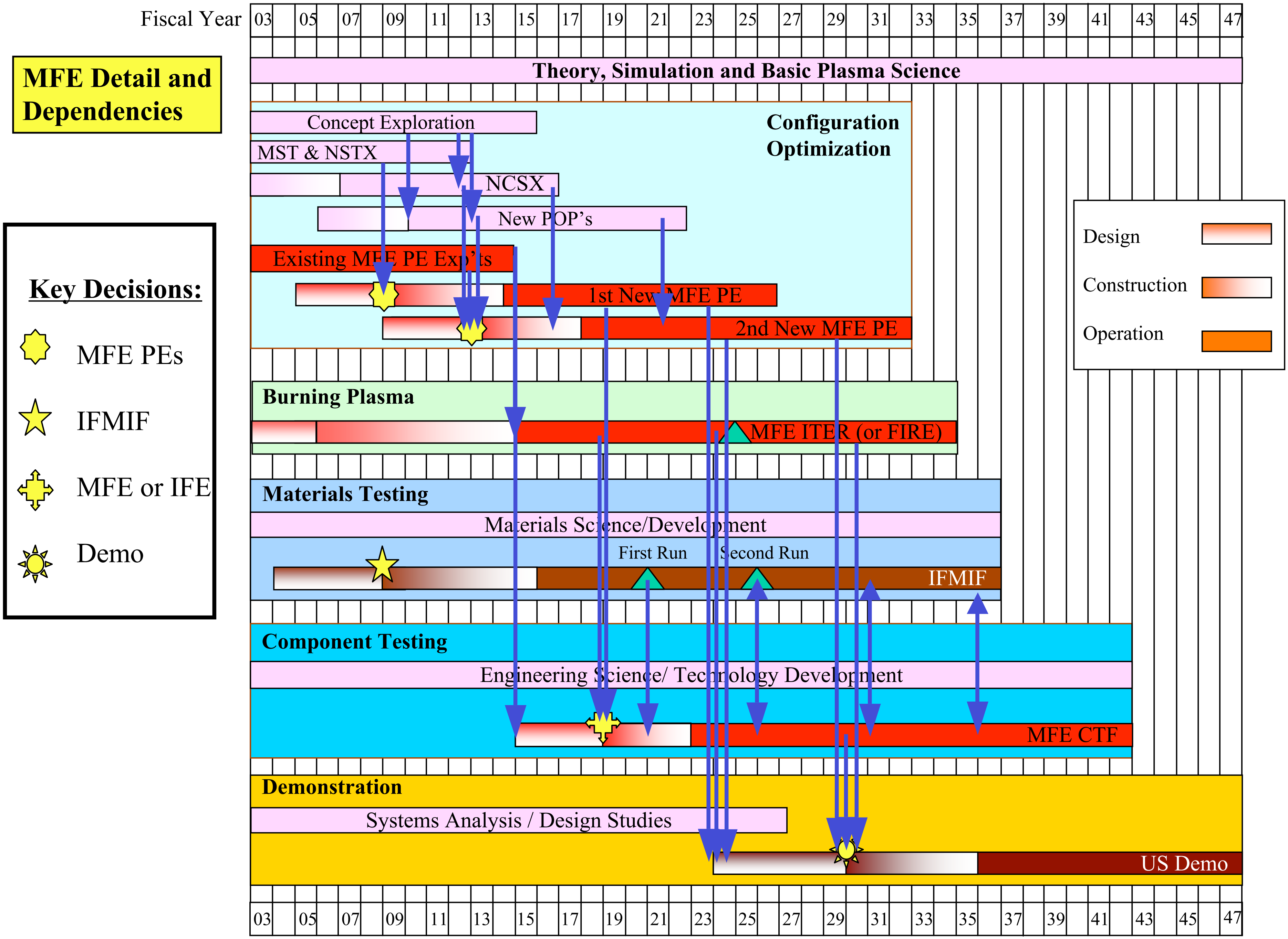
Key Guidelines & Conclusions of FESAC Fusion Development Path Study

The goal of the plan is operation of a US demonstration power plant (Demo), which will enable the commercialization of fusion energy. The target date is about 35 years. Early in its operation the Demo will show net electric power production, and ultimately it will demonstrate the commercial practicality of fusion power.

The plan recognizes that difficult scientific and technological questions remain for fusion development. A diversified research portfolio is required for both the science and technology of fusion, because this gives a robust path to the successful development of an economically competitive and environmentally attractive energy source.

The Plasma Configuration of the MFE Demo. The cost-basis scenario as articulated provides for the option that Demo can be configured differently from the advanced tokamak as it is presently understood. It should be anticipated, however, that the initial operation of Demo will require more learning in this case and the initial production of electricity would be somewhat delayed as a result.



MFE Detail and Dependencies
Fiscal Year
03 05 07 09 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47
Theory, Simulation and Basic Plasma Science
Configuration Optimization
Concept Exploration
MST & NSTX
NCSX
New POP's
Existing MFE PE Exp'ts
1st New MFE PE
2nd New MFE PE
Burning Plasma
MFE ITER (or FIRE)
Materials Testing
Materials Science/Development
First Run
Second Run
IFMIF
Component Testing
Engineering Science/ Technology Development
MFE CTF
Demonstration
Systems Analysis / Design Studies
US Demo
Key Decisions:
MFE PEs
IFMIF
MFE or IFE
Demo
Design
Construction
Operation

FESAC Strategic Planning Panel
Criteria for Prioritization

- **Importance:**
  - How central is the issue to the fusion mission and extrapolation required to DEMO?
- **Urgency:**
  - What is the impact on development plan schedule? When must significant work on this issue begin? Includes considerations of risk, dependencies and decision points.
- **Uncertainty:**
  - How much technical uncertainty does the issue present? To what extent are the programs in place likely to resolve the issue?
- **Generality:**
  - Are solutions to issue generic with respect to possible instantiations of DEMO?
- **Opportunity for U.S. leadership:**
  - How strong is the opportunity for US leadership on this issue? Includes areas where we currently have strength or leadership and/or where the international program leaves an opening.

Risks Drive Urgency in FESAC Plan

- **There are significant risks for any Demo configuration.**
  - **Stability and sustainment of the AT and ST.**
    - **Can disruption control be made adequate to allow tritium breeding?**
    - **Can ELMs be made compatible with required divertor lifetime?**
    - **Can recirculating power for current drive be made acceptable?**
  - **Magnets and maintenance of the CS and AT.**
    - **Can complex magnets be made cost effectively?**
    - **Can maintenance meet availability requirements?**
  - **High heat flux, tritium retention and nuclear components, for all concepts.**

- **Sustainment of a broad program is urgent to support Demo.**
  - **ITER may succeed, but point to the need for simpler magnets and/or maintenance, lower recirculating power and/or disruption immunity.**
  - **Closely allied configurations can allow the fusion program to benefit from ITER's success, but only if they are sufficiently developed.**

Dependencies Drive Urgency in FESAC Plan

Work Backwards to Analyze Dependencies

- The links back from Demo in the Development Path Plan are to CTF, to ITER and to the New MFE PE Experiments
  - CTF supports Demo nuclear components
  - ITER provides burning plasma and tokamak information
  - New MFE PE experiments provide breadth for risk reduction
- The links back from CTF are to IFMIF, ITER, the first new MFE PE Experiment and existing PE experiments
  - IFMIF provides information on materials for CTF.
  - ITER provides long pulse, high power operation in a nuclear environment and confirmation of MFE.
  - The 1st new MFE Performance Extension experiment should make critical technical contributions to CTF.
- This analysis points to near-term urgency for a new MFE PE experiment, both for Demo breadth and to support CTF.

Programs must Address Key Physics and Technology Uncertainties

- **The key advanced physics issue that may appear to be beyond planned long-pulse AT, ST and CS devices is high-gain nonlinearity at high performance.**
  - **Experiments could be performed, *e.g.* on JT-60SA, varying heating power profile proportional to $n^2<\sigma v>$.**
  - **Similar experiments could be performed, for a similar reason, on a PE-class low aspect ratio device for the ST line.**
  - **Also on NCSX for the CS line (to demonstrate calculated CS insensitivity to profiles). LHD and W7-X as well.**

- **Such experiments plus ITER can provide the basis for an AT, ST or CS Demo through a broadly focused FSP, avoiding the need for a high-gain long-pulse device between ITER and Demo.**
  - **Enabling ITER to be the "penultimate" step to Demo, as in the Development Path plan.**

- **Stable sustained non-nuclear high-performance operation with high heat flux and acceptable tritium retention is *not* covered.**

- **Reliable multi-week nuclear operation with tritium breeding is *not* covered.**

Facilities that Provide Critical & Generic Data Minimize Risk

- **An experimental program supporting a breadth of configurations provides the greatest risk reduction, while benefiting from ITER.**
  - Existing and planned facilities world-wide will contribute a great deal.
  - ITER will provide critical and generic burning plasma physics.
  - The issue of the compatibility of high heat flux and low tritium retention with stable continuous operation is critical and generic.
    - A relatively low aspect ratio, high power density device can address these issues and also provide the additional information needed for an ST Demo: Confinement scaling, stability, startup and sustainment.
  - Continuous nuclear operation and tritium breeding are critical and generic issues.
  - The attack on both issues requires collaboration with IFMIF
    - To assure that neutron effects on tritium retention are tested, and on high-heat-flux materials properties are taken into account.
    - To assure that blanket materials are optimized.
- **Test facilities, theory & modeling also minimize risk**
  - Facilities should be designed to cover a wide range of options.
  - Theory and modeling – FSP – should seek broad applicability.

Urgency, Uncertainty and Generality as Priority Drivers are Consistent with FESAC Dev Path

- The Development Path Plan shows the urgency to sustain a broad risk-reduction strategy, including a plan for a new MFE PE facility, as well a CTF, both running in parallel with ITER.

- Key uncertainties not covered in the world program include stable high performance operation with high heat flux and acceptable tritium retention; continuous nuclear operation and tritium breeding.

- Generality, inclusive of at least AT, ST and CS configurations, as well as a range of technological approaches, is necessary for credible risk reduction.

- FESAC Strategic Planning Panel has a good model for prioritization.