NCSX
Physics Design Strategy & Plan

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Outline

- Review of PAC and FESAC Comments
- Status of design
- Overview of Task Plan
- Plan Elements

PAC Comments (June 1999)

Acceptable point-design has been demonstrated (c82)

1) Critical next task for PVR is to develop & determine device flexibility

2) Need to clarify achievable physics program and required capabilities (pulse length, field strength, heating power)

In addition:

- Confinement enhancement methods need to be explored and designed. Current indication is that 6MW is marginal to achieve β=4%
- Start development of a strategy to obtain good flux surfaces
- The design β=4% is marginal. Explore ideas for configurations with higher stability limits.
- Plasma access requirements should get some attention

FESAC PoP Evaluation (August 1999)

Significant issue that must be resolved before PoP program can begin, to be addressed as part of CDR:

> The design "must exhibit robustness of the equilibrium configuration throughout the plasma evolution."

⇒ Need to develop startup scenario & strategy for good flux surfaces

Additional Developments

- Problems with VMEC equilibrium calculation, force balance.
- Varying currents in saddle coils is not sufficient to heal islands
- Neoclassical transport in c82 appears ~ sub-marginal
  Re-analysis at APS indicates need 6.9 MW of NBI for β=4%
  (2.3xISS'95, B=1.5 T). Only have ~5.5 MW.
  (α-particle confinement is inadequate for reactor)
- Transport is not well correlated with quasi-symmetry measure used in optimizer.
- Need to further reduce saddle coil current densities to get desired B=2T capability

Physics Task Plan

- Tasks needed for PVR
- Emphasis on developments needed before *scheduling* PVR.

- Target identified major issues

- Plan represents our current understanding.
  It will change as our understanding changes.

- Phases:
  1. Improve tools to incorporate new understanding, fix problems, attack new aspects.
  2. Apply improved tools to design new configurations & coils, decide between alternative approaches
  3. Evaluate and confirm final design, prepare for PVR

Plan: 3D Equilibrium & Surface Quality

- Develop new VMEC differencing to accurately calculate force balance, improve convergence
- Improve PIES convergence, physics treatment of islands, bootstrap current, speed-up.
- Adapt M3D for calculating stellarator equilibria & stability
- Benchmark all available equilibrium codes, and against experimental data
- Develop optimizer criteria to encourage good surface quality.
- Develop methods to design coils to give good surfaces.

Plan: Flexibility & Startup

- Define flexibility requirements
  - Profile variations: p, j
  - Simple
  - Experimental program flexibility needs - SFGs

- Model startup scenarios
  - New tool to model current evolution in stellarators

- Develop tools to assess flexibility of coil-configurations
  - Free-boundary optimizer
  - Phase II of Control-Matrix project

Plan: Improved Plasma Configurations

- Improve optimizer
  - Better transport evaluator
  - Surface-quality
  - Cobra ballooning code (for speed)
  - Incorporate new VMEC

- Improve optimizer searching
  - Control-Matrix characterization of neighborhood
  - Global search algorithms

- Explore for higher-β, better confinement configurations

- Design for reactor configurations

Plan: Improved Coils

- Use Onset & Coilopt to 3D optimize present designs

- Extend GA method to odd-number of contours, modular coils and PF-coil currents, address access

- Extend tools to handle alternate coil topologies, and alternate background coils

- Evaluate "Quality Matrix" approach to relax constraints on coils by ignoring components of B_{norm} that do not matter to the plasma physics

- Design flexible coils
  - Modify GA to fit to multiple equilibria
  - Ideas being discussed on ways to analyze multiple equilibria to derive the coil-sets needed for flexibility, using SVD or GA *Not yet in plan.*

Plan: Adequate Confinement

- Develop transport evaluator for optimizer
  - DKES
  - J contour alignment with flux surfaces
  - Nemov/Kernbichler $1/\nu$ transport calculation
  - Monte-Carlo particle following - for fast ions

- Develop strategies and requirements for enhanced confinement, to ensure access to high-β
  - H-modes, pellets, driven rotation effects, hot-ion regimes
  - Requirement on flow-damping

- Review and continue development of confinement evaluation for configurations
  - Self-consistent profile modeling w/ neoclassical transport

Plan: Physics Requirements and Program

- Access requirements – NBI, RF, Diagnostics, Pumping
- RF heating scenario and requirements
- Power and Particle Exhaust
- Required physics program, program context
- Update physics requirements on device design

Summary

- We have a lot to do before the PVR !
  - Flexibility
  - Good surface quality throughout evolution
  - Improved configurations and coils
  - Enhanced confinement

  In many cases, we are researching new areas ⇒ results will be exciting and uncertain.

- We need to focus on our main issues, to ensure completion

- The plan will change as we learn more, as we have more good ideas