NCSX Requirements

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Requirement-related information is documented on the NCSX Engineering Web

- Requirements
  - Currently defined…
    - General requirements
    - WBS 1 (Stellarator core)
    - WBS 2 (Plasma heating, vacuum pumping, fueling)
  - Need to complete for other WBS elements
  - Eventually, system level requirements will flow down to the procurement specifications
- Also available on the Web…
  - Technical data for the current reference design
  - Conventions
  - Design criteria

The CDR milestone

- The CDR is a key milestone for requirements
  - All system level requirements should be finalized
  - A plausible design concept should be in place that fully meets the system requirements and can be implemented within specified cost and schedule constraints
- Following the CDR, more detailed subsystem level requirements will be developed requiring comprehensive and stable system (top level) requirements!

Intermediate milestones

- Preliminary requirements review
  - Review system (top) level requirements
  - Review how we plan to show that the requirement is met
  - Identify required technical data
  - Make sure plans are in place to provide missing requirements and technical data
  - Schedule
    - ***General requirements – today!***
    - WBS 1-7 – next project meetings
- Final requirements review (early December)
  - Make sure all requirements and necessary technical data is in place to complete Conceptual Design by mid-February

General requirements

- Cost & schedule objectives
- Design constraints
- Plasma parameters
- Operational requirements
- Magnetic field polarity
- Reference scenarios
- Flexibility requirements
- Field error requirements
- Disruption requirements
- Bakeout requirements

Cost & schedule objectives

- NCSX is a “design to cost” project with a $55M (FY99) cost objective
- Change control procedures will be implemented that will track incremental costs
- Changes with positive cost increments will be packaged with changes with negative cost increments where necessary to prevent cost growth above the $55M cost objective
- The first plasma date is used to calculate time-dependent costs (such a project management), not as an immutable constraint itself

TPC scope

- Philosophy is to be able to support “initial experimental objectives and accommodate required upgrades”
- Initial experimental objectives will provide basis for initial diagnostic and heating complement
- The need to improve the link between experimental objectives and critical diagnostics is recognized (ref. PVR recommendation II-5 and project response)
- Finalizing the initial diagnostic and heating complement will follow – add to work plan [GHN]

Design constraints

- Combined PLT/PBX test cell identified as site for stellarator core
- Derived constraints to be documented [WR]
  - module size (entry to test cell)
  - footprint of stellarator core and ancillary equipment (test cell size)
  - maximum required lift (crane capacity)
  - floor loading
- Other design constraints and external interfaces should be identified where appropriate [WR]

No significant issues in next few sections

- Reference plasma configuration, size, and field identified - provides quantitative basis for developing reference scenarios
- Operating cycles (daily, yearly, total)
- Repetition rates
- Fuel species
- Biological shielding requirements
- Magnetic field polarity

Reference scenarios

- Two reference scenarios defined
  - High field scenario (1.7T, 3 MA/s)
  - Day One scenario (1.7T, 2 MA/s)
- High field scenario set up as the “long pole in the tent” to drive the coil and ultimate power system design
- Day One scenario invented to avoid accommodating very high ramp rates in TPC
  - Day One scenario only affects initial power system design
- Low field (1.2T) scenario dropped because it did not appear to drive anything

Reference scenario issues

- The definition of the reference scenarios not reconciled with simulations by Lazarus
  - State definitions
    - Ramp to full current prior to any heating?
    - Controlled rampdown required?
  - Ramp rates
  - Volt-second requirements
- Not explicitly addressed in current work plan [MZ]

Reference scenario issues (2)

- Equilibria need to be developed and validated that provide the necessary shaping fields and inductive current drive while satisfying engineering constraints
  - Coil constraints to be developed and communicated to Physics [BN/WR]
  - Equilibria for each state to be developed [NP]
- Already addressed in work plans following development of new coil design

Flexibility

- Coils designed to provide flexibility, power system must be upgradeable
- 3 types of flexibility identified in requirements
  - External iota flexibility
    - 0.44-0.85 at fixed global shear, Ip, Bt
  - Internal iota flexibility
    - Vary Ip at fixed Bt
    - External iota fixed? What range in Ip?
  - Shear flexibility
    - Vary edge iota from 0.44-0.85 at fixed central iota (0.43), Ip, and Bt

Flexibility issues

- Parameter ranges lifted from Pomphrey's parameter scan at full field and identified as TBR (to be revised)
  - Preliminary coil constraints to be provided to Pomphrey prior to developing static equilibria at extrema in flexibility space
  - More detailed assessment of design and cost impacts to follow
  - Plan is to finalize flexibility requirements by early December
- Beta not specified, just Ip, Bt, and iota
- Range of plasma current operation not specified for internal iota flexibility
- Requirements for PFCs and ancillary systems not specified

Field errors

- "*Field errors from all sources shall not result in islands that significantly increase transport*."
- Approach
  - Design coils that produce adequate surface quality in the reference high beta equilibrium
  - Add trim coils to restore adequate surface quality in other equilibria
- Auditability
  - Engineering will develop tolerance requirements that if met, will not compromise surface quality due to construction errors
  - Engineering will incorporate trim coils of specified geometry and current (presently, n/m=3/5,3/6)
- Current work plans include tasks to validate the trim coil design, derive tolerance requirements, and assess impacts from known sources of field errors

Disruption requirements

- "*The device shall be designed to withstand electromagnetic forces due to major disruptions characterized by the disappearance of the plasma at any time in the high field scenario*."
- Flexibility in internal iota may result in plasma currents (and disruption loads) that are higher than in the high field scenario
  - A maximum plasma current should be specified
  - A significant effort is required (and planned) to modify SPARK handle stellarator symmetry, thereby allowing a tractable number of elements

Bakeout requirements

- *"The carbon plasma facing components shall be bakeable at 350C. The metallic and high-Z plasma facing components shall be bakeable at 150C."*
- No issues seen in implementing these requirements
  - Vessel will be baked to 150C
  - Carbon-based liner will be separately baked to 350C

Summary

1. Requirements need to be defined for WBS 3-7
2. Requirements for WBS 1-2 will be reviewed at the August project meeting, WBS 3-7 at the following project meeting
3. Requirements must be finalized by early December, well in advance of the CDR
4. NCSX is a “design to cost” project with a $55M (FY99) cost objective
5. The initial diagnostic complement will be finalized after improving the link between experimental objectives and critical diagnostics

Summary (2)

6. Two reference scenarios now specified
   - High field and Day One scenarios
7. Review of scenario specifications in order
   - Reconcile with Lazarus simulations
   - Controlled rampdown, volt-second requirements, etc.
8. Coil constraints to be developed to guide development of equilibria for reference scenarios and flexibility
9. Three types of flexibility specified (external iota, internal iota, and shear)
10. Assessment of design and cost impacts at flexibility extrema planned prior to finalizing requirements

Summary (3)

11. Flexibility requirements for PFCs and ancillary systems need to be determined
12. A maximum plasma current should be specified (for flexibility and disruption requirements)
13. Engineering will address field error requirements through derived requirements on coil tolerances and by incorporating trim coils of specified geometry and current
14. Good progress has been made since the last project meeting on coordinating Physics and Engineering tasks and incorporating requirements-related tasks into work plans