Proposal for 2002-2005: Application of Model-Based Multivariable Control Design Methods to NSTX

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- **Derivation of NSTX axisymmetric system models:**
  - → NSTX vessel/conductors, PF coils;
  - → Power supplies;
  - → Plasma.
- **Validation of system models:**
  - → Vacuum response experiments;
  - → Power supply tests;
  - → Plasma response piggybacks (coil current perturbations).
- **Simulations:**
  - → Off-line (Simulink models);
  - → "Online": connected to PCS in closed loop.
- **Design of Plasma controllers:**
  - → Design for specific configurations/experiments;
  - → Maximize benefit from detailed dynamic control.
- **General goals:**
  - → Near term (2002-2003):
    - Development of models and simulations;
    - Proof of principle control of reference configuration(s);
  - → 2003+: operational use
  - → Long term (>2003):
    - Integrated plasma control (shape, profiles, performance?);
    - Facilitation of ongoing research goals of NSTX using integrated multivariable control;

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- Development of previously-unsuspected operations and experimental capabilities!

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Model-based MIMO Controller Design is a Key Enabling Technology for Tokamaks

- **Technical Advantages:**

  → Systematic design method for new plasma configurations;

  → Systematic method for designing/evaluating control requirements for next-step devices;

  → Explicit means for trading off conflicting control demands (e.g. relative accuracies of overall shape and X-point control);

  → Methods for dealing with hardware constraints (e.g. giving up control accuracy as coil currents approach limits);

- **Meets NSTX Needs:**

  → Ambitious research program with much unexplored territory:

  - Limited time for empirical optimization of control;
  - Model-based, modern techniques allow off-line design and verification.

  → Integrated controllers are required for highly-coupled systems:

  - Profile, shape, position, kinetic control are coupled;
  - Off-line model-based controller design using modern techniques is the only practical method.

- **Exploits Experience of DIII-D and Community:**

  → Model-based MIMO controllers have been implemented on DIII-D and are being further developed for routine operation;

  → Model-based MIMO controller design is a research topic with widespread interest and application throughout the fusion program:

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- Used extensively in design of ITER plasma controllers;
- Applied to COMPASS, TCV, …

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Products of NSTX Model-Based MIMO Control Effort

- **Detailed, *Accurate, Validated* Models of NSTX Systems:**
  - → Vessel, conductors;
  - → Power supplies.
- **Detailed, *Accurate, Validated* Models of NSTX Plasma Shape/Position Response:**
  - → Validated models demonstrate what physics must be included to accurately represent NSTX plasmas response.
- **Off-line simulations of NSTX Shape Control:**
  - → Plasma/tokamak open-loop response;
  - → Realtime EFIT;
  - → Closed-loop NSTX/controller simulations;
  - → Executables anyone can use!
- **Multivariable Shape Controllers:**
  - → Smooth, accurate shape control;
  - → Robustly high-performance control dynamics;
  - → Explicit tradeoffs between competing control constraints;
  - → Prevent current limiting.