NCSX Diagnostic Planning Status Report

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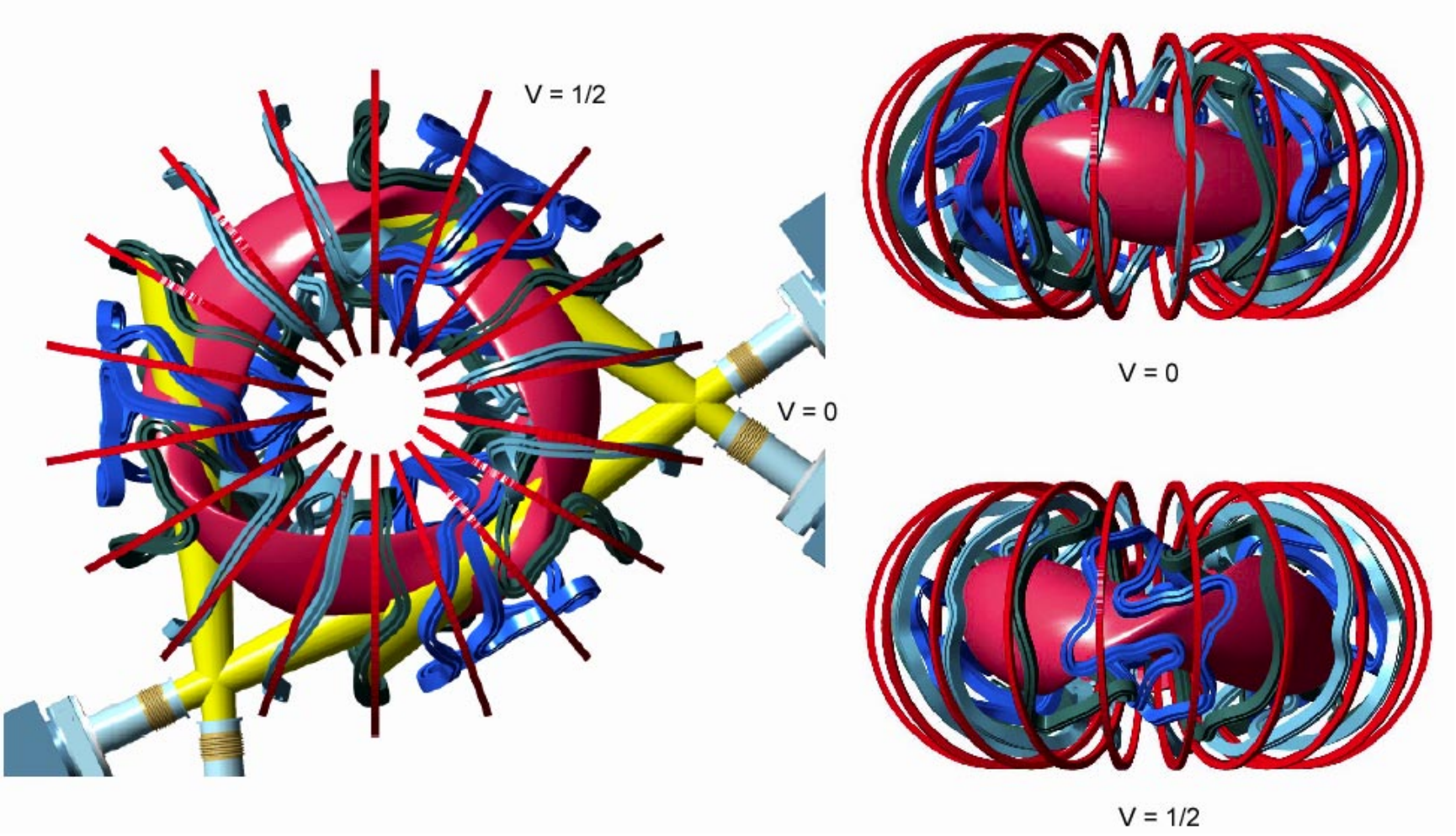
Status of NCSX Diagnostic Planning

- Goals of planning effort are to insure that device design will accommodate adequate diagnostic capability, and to estimate cost/schedule of diagnostic implementation.
- Diagnostic issues identified at PVR are influencing the direction of the design effort.
- Top-down approach to integration will be illustrated.
  - Physics research topics ➡ measurement requirements ➡ diagnostics
    - Considering advancing implementation of Thomson scattering to permit earlier investigation of n_e, T_e profiles.
    - Considering plan for optimization of magnetics sensor type and location to provide for efficient control of discharge evolution and for accurate equilibrium reconstruction.
- List of proposed diagnostics to satisfy these requirements
  - Will lead to definition of space requirements and port allocations (when 3-D engineering model available at end of November) ➡ possible iteration on fine points of design
  - Basis for revised diagnostic cost/schedule estimates for CDR.

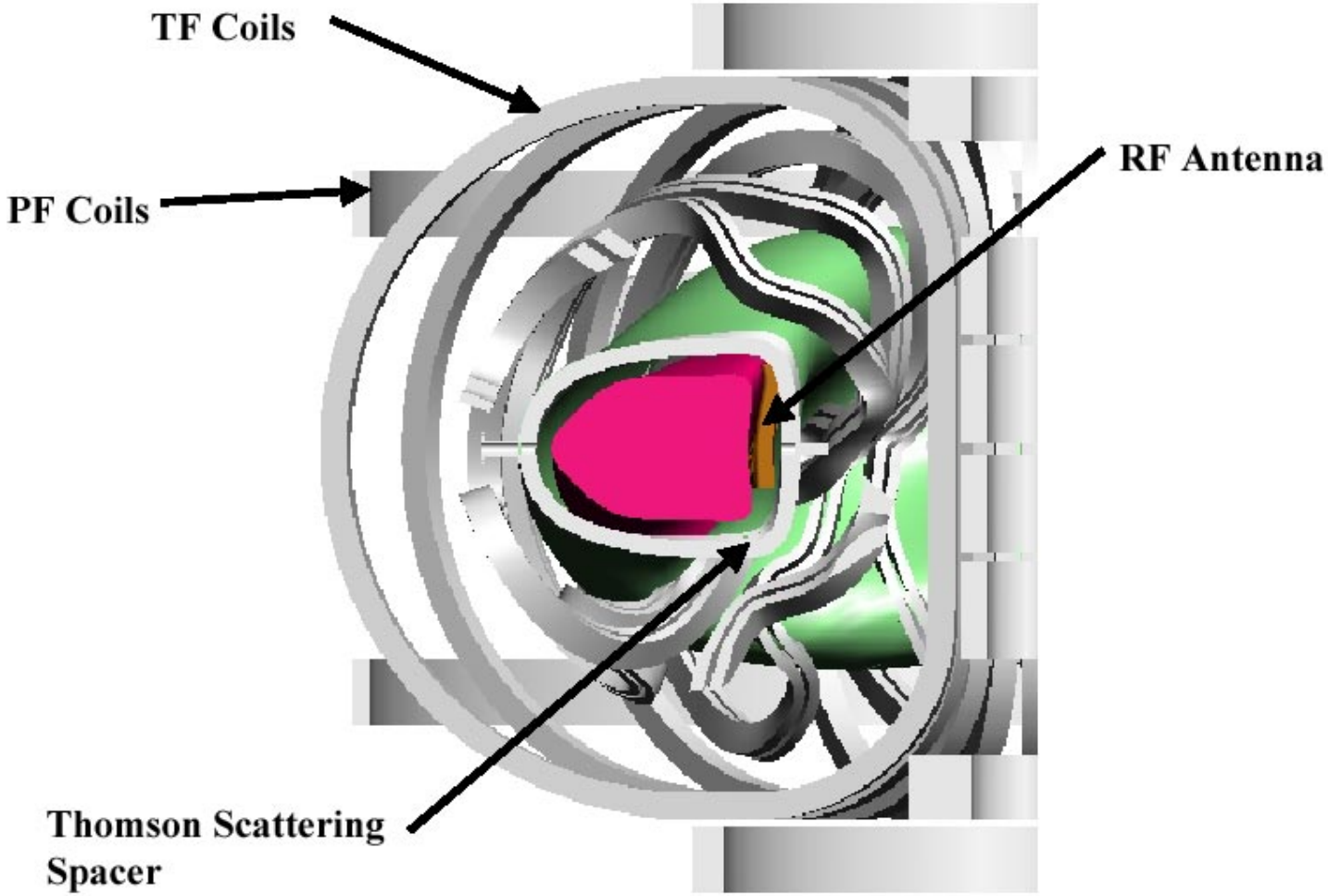
Progress Since PAC-4 on Diagnostics

- Based on PVR machine design, rough assessment, based on the number of ports available, indicated that diagnostic access was adequate, but problematic in several areas:
  - In PVR 21 coil design, placement of TF coils between modular coils made diagnostic access difficult. Fewer coils in the new 18 coil design features TF coils roughly in line with modular coils ➡ more space available for diagnostics.
  - No diagnostic access was available at symmetry planes. New design provides for diagnostic access at symmetry planes.
  - Personnel access for diagnostic maintenance and calibration was marginal in PVR design. New, larger vessel design has improved personnel access.
  - 3-D engineering model of new design will be available shortly, permitting sightline definition and tentative port allocation for diagnostics.
  - At the PVR, sightline investigation for active spectroscopy measurements indicated that these diagnostics would not have adequate spatial resolution, because of the geometry of the heating beam and the plasma. Need to consider diagnostic neutral beam for active spectroscopy.
- Urgently need to continue these sightline definition efforts for new machine design. These efforts can start in December.

New Coil Design Improves Access



Thomson Scattering Access to Bullet Symmetry Plane



Integration of Measurement Needs with Research Topics

Phase	Topic	Aux Power	Essential Measurements
1. Initial Operation			plasma current
	initiate plasma	OH	conductivity
	control plasma evolution		plasma position
			plasma/wall imaging
			total stored energy
			line integrated density
			total radiated power
			central electron temperature
			impurity species Z<30
2. Field Line Mapping			
	map flux surfaces	no plasma	vacuum flux surfaces
	verify iota and QA		
3. Initial Ohmic			
	Improved plasma control, plasma evolution control	OH	electron temperature profiles
	global confinement & scaling, effect of 3D shaping		electron density profiles
	density limit & mechanisms		radiated power profiles
	study of Te and ne profiles.		low (m,n) MHD (<50kHz)
	vertical stability		flux surface topology
	current-driven kink stability		Zeff
	effect of low-order rational surfaces on flux-surface topology		hydrogen recycling
	initial study of effect of trim coils, both signs		
	effect of contact location on plasma edge & recycling		
	initial attempts to control plasma contact location		

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Integration of Measurement Needs with Research Topics

Phase	Topic	Aux Power	Essential Measurements
4. Initial Aux. Heating			
	Plasma control with NB heating and CD	3MW NBI	ion temperature profile
	confinement scaling w/ iota, B, …		toroidal rotation profile
	local transport measurements		poloidal rotation profile
	test of quasi-symmetry on confinement and transport		Shafranov shift
	perturbative transport measurements		iota profile
	density limits with heating		fast ion loss
	density control with aux. Heating		ion energy distribution
	test of kink & balooning stability at moderate beta		neutron flux
	effect of shaping on MHD stability		IR imaging
	pressure effects on surface quality		high frequency MHD(<5Mhz)
	controlled study of neoclassical tearing using trim coils		
	use of trim coils to minimize rotation damping		
	initial study of Alfvenic modes w/ NB ions		
	blip measurements of fast ion confinement and slowing down		
	wall coatings with aux. Heating		
	effect of contact location on plasma edge & recycling		
	initial attempts to control plasma contact location		
	initial attempts to obtain enhance confinement regimes		
	wall biasing effects on confinement		

Measurements Specifications for Initial OH Research (Phases 1-3)

MEASUREMENT	RANGE	RESOLUTION		ACCURACY	DIAGNOSTIC TECHNIQUE
plasma current	1-200 kA	1 ms	integral	1% + 0.1KA	Roqowski coils
conductivity		1 ms	integral	1%	loop voltage
plasma position		1 ms		0.3 cm	magnetics/EFIT SXR arrays
plasma/wall imaging	several views	1, 20 ms	0.2 cm		CCD cameras
total stored energy	20 kJ - 500 kJ	1 ms	integral	10 kJ	diamagnetic loop
line integrated density	10^{18} -5x10^{20} m^{-2}	1 ms	integral	5-10%	interferometer
total radiated power	0.05-10 MW	1 ms	integral	15%	wide angle bolometer
central electron temperature	0.1-5 keV	1 ms		10%	filtered SX diodes Thomson scattering
impurity concentration species Z<30	10^{-1} - 10^{-4}	1 ms	integral	50%	SPRED, visible spectrometer
vacuum flux surfaces	bullet cross section		0.2 cm	0.2 cm	e-beam, fluorescent rod/screen
electron temperature profile	0.05-5.0 keV	10 ms	2 cm	5%	Thomson scattering
electron density profile	5x10^{18}-5x10^{20} m^{-3}	10 ms	2 cm	5%	Thomson scattering
radiated power profile		10 ms	2 cm	5%	foil bolometer array AXUV diode array
low (m,n) MHD modes, sawteeth, disruptions		50 kHz		10%	Mirnov coils SXR arrays
flux surface topology		50 kHz		10%	SXR arrays + tomography
Zeff	1-10	5 ms	integral	20%	VB array with 1-D CCD
hydrogen recycling		20 ms		10%	H_α filterscopes, filtered CCD camera

Additional Measurements Specifications for Initial NBI Research (Phase 4)

MEASUREMENT	RANGE	RESOLUTION		ACCURACY	DIAGNOSTIC TECHNIQUE
ion temperature profile	0.05-5.0 keV	10 ms	2 cm	5%	CHERS with DNB
toroidal rotation profile	10-500 km/sec	10 ms	2 cm	5%	CHERS with DNB
poloidal rotation profile	10-500 km/sec	10 ms	2 cm	5%	CHERS with DNB
iota profile		10 ms	2 cm	5%	MSE with DNB
fast ion loss		20 ms		10%	scintillator loss probe
ion energy distribution	0.1-100 keV	5 ms	integral	10%	NPA
neutron flux		1 ms	integral	20%	epithermal neutron detector
IR imaging	several views	20 ms			IR camera
high frequency MHD(<5Mhz)		5 MHz		10%	high frequency Mirnovs

Diagnostics Proposed for Phases 1-4

DIAGNOSTIC TECHNIQUE	DESCRIPTION	PHASE	SENSOR TYPE	FIELD OF VIEW	PORT
MAGNETICS					
Roqowski coils	2 plasma current Rogowski's	1		TBD	TBD
flux loops	~20 loops at inner vessel, ~ 20 loops at outer vessel, ~20 loops at inside of modular coils	1		TBD	TBD
B probes	~ 20 in pol. array, ~ 20 in tor. array	1	TBD	TBD	TBD
diamagnetic loop	2 identical loops	1	TBD	TBD	TBD
flux loops	additional as needed	3		TBD	TBD
B probes	additional as needed	3	TBD	TBD	TBD
high freqency Mirnov	4 outer, 2 inner	3	TBD	TBD	TBD
X-RAY					
filtered SX diodes	3 diodes with different filters	1	AXUV diodes	TBD	TBD
SXR arrays	4 compact arrays	1	TBD	bullet x-section	TBD
SXR arrays	12 compact arrays	3	TBD	bullet x-section	TBD
CAMERAS					
visible cameras	standard video rate visible camera	1	standard CCD, 8 bits	TBD	TBD
fast visible camera	fast camera (<20 kHz full frame)	1	fast CCD, 8 bits	TBD	TBD
IR camera		3	TBD	TBD	TBD
visible cameras	high dynamic range camera	3	fast CCD, 12 bits	TBD	TBD
MICROWAVE					
interferometer	1 mm quasi-optical reflecting off inner wall	1	TBD	TBD	TBD
BOLOMETRY					
wide angle bolometer	core calibrated single channel	1	foil with bridge circuit	TBD	TBD
foil bolometer array		3	foil array with bridge circuit	TBD	TBD
AXUV diode array	compact array for improved time response	4	AXUV diode array	TBD	TBD

Diagnostics Proposed for Phases 1-4 cont'd

DIAGNOSTIC TECHNIQUE	DESCRIPTION	PHASE	SENSOR TYPE	FIELD OF VIEW	PORT
SPECTROSCOPY					
Ha filterscopes	~6 fibers/telescopeswith filters	1	APDs	TBD	TBD
filtered CCD camera	filtered 2-D CCD with camera lens	3	2-D CCD	TBD	TBD
visible spectroscopy	Czerny-Turner with multiple gratings	1	cooled 14-bit CCD	TBD	TBD
UV spectroscopy	SPRED UV survey spectrometer	1	cooled 14-bit CCD	TBD	TBD
VB array	filtered 1-D CCD with camera lens	3	1-D CCD	TBD	TBD
ACTIVE SPECTROSCOPY					
diagnostic neutral beam	TBD	4	TBD	TBD	TBD
CHERS with DNB	spectrometers/detectors	4	fast, cooled 14 bit CCDs	TBD	TBD
MSE with DNB	TBD	4	TBD	TBD	TBD
THOMSON SCATTERING					
Thomson scattering	100 Hz Nd:YAG laser, ~ 50 spatial positions	3	polychromator/APD arrays	bullet midplane	TBD
NON-THERMAL PARTICLES					
scintillator loss probe	energy/pitch angle resolving	4	intensified CCD	TBD	TBD
epithermal neutron detector		4		TBD	TBD
neutral particle analyser	TBD	4	TBD	TBD	TBD
FIELD MAPPING					
e-beam	TBD	2		TBD	TBD
fluorescent rod	TBD	2	cooled 14-bit CCD	TBD	TBD
fluorescent screen	TBD	2	cooled 14-bit CCD	TBD	TBD

Plan to Optimize Magnetic Sensors for Control and Equilibrium Reconstruction

- Ed Lazarus has proposed a multi-year plan to develop a 3-D equilibrium code that can be used to optimize the types, numbers and locations of the magnetic sensors, in order to provide adequate convergence for the full range of anticipated equilibria.
- We currently guess that the initial complement will be ~ 100 sensors.
  - Need to examine the point in the detailed design when the optimum set needs to be defined, in order to link to Ed's development schedule.
  - Need to reserve space at various locations (inner vessel wall, outer vessel wall, inside surface of modular coils) for sensors.
  - Need to reserve vacuum feedthrus for sensors.
  - Need to carefully consider assembly logic, including these sensors.

Summary

- A top-down approach to diagnostic planning is well underway, which is driven by the needs of the research program. This plan will be used to define the requirements for diagnostics and to assign priority to their implementation.
- With the 18 coil design, significant progress has been made to improve diagnostic access, including access to symmetry planes, and more space for personnel inside vessel.
- In December, the 3-D engineering model of the new device design will be adequate for insertion of diagnostic ports and diagnostic-specific port allocations will begin.
- A plan to use a 3-D equilibrium solver to optimize the number and location of magnetic sensors has been proposed.