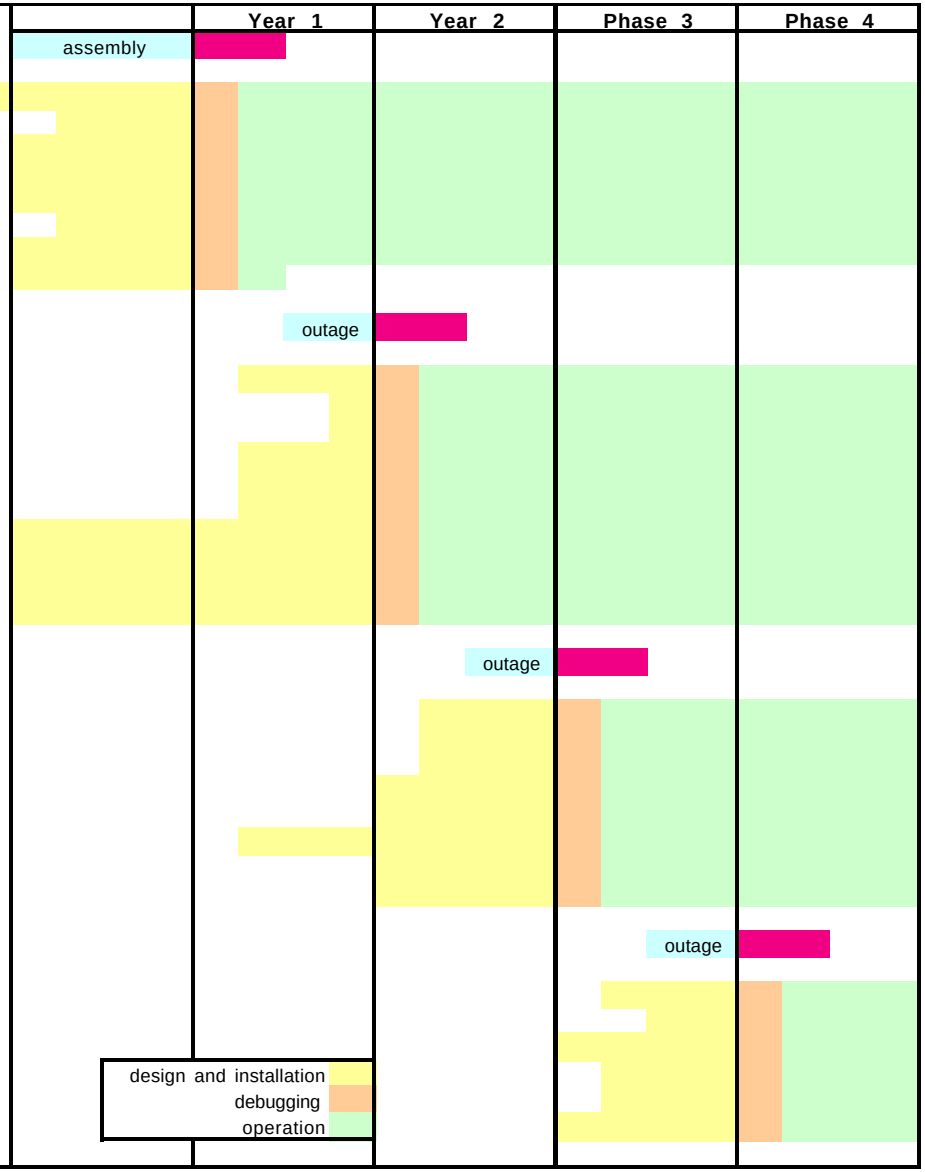
Pre-CDR Diagnostics Work Plan

NCSX Diagnostic Task (PVR Recommendations addressed)	Co-Workers	FY01	FY02
Continue to develop the logic linking diagnostics to physics program and priorities as indicated in the diagnostic implementation plan. Develop matrix relating physics issues to plasma parameters measured to diagnostic requirements. Include in the matrix a summary of geometrical access requirements for diagnostics in the plan. Provide more detail on plans for measurements of flow and turbulence. (II-5, IV-8, IV-11)	D. Johnson M. Zarnstorff Trip to W7-AS	5	5
Integrate diagnostic access requirements with the VV and coil design for particular diagnostic systems included in the diagnostic implementation plan with initial assessments of sightlines and fields of view obtainable, and identification of critical issues. In particular, consider whether diagnostic access to symmetry planes be obtained. Also give particular attention to diagnosing 3-D nature of the plasma. (IV-8, IV-12)	D. Johnson M. Cole	5	16
Complete conceptual design of magnetic diagnostics required for plasma control, equilibrium reconstruction and MHD analysis. This design should be integrated with the engineering design of the vacuum vessel, the PFC system, and the diagnostic access ports. Begin optimization of sensor number and location in conjunction with development of 3-D EFIT. Consider strategy for installation and maintenance of in-vessel senors.(IV-10)	E. Lazarus D. Johnson M. Cole	2	5
Develop concepts for implementation of adequate beam-based diagnostics	D. Johnson		4
Complete conceptual design of E-beam mapping system and plan for operation. Assess feasibility of a retractable system deployable without serious impact on plasma operations. (IV-9)	D. Johnson Trip to HSX		5
Prepare for CDR presentation			5
	Total DWJ days	12	40

Diagnostic Implementation Plan

		ports
1st Plasma, Field Mapping, and OH Studies		
Magnetics 1	100 channels	12
Visible Cameras 1	3 views, 1 fast, 2 slow	3
Interferometer	single chord, 1mm	1
UV Spectroscopy	single sightline	1
Visible Spectroscopy	direct+several fibers	1
Visible Filterscopes 1	3 views, 10 sightlines	3
SXR Arrays 1	1 compact array	1
e-Beam Field Mapping	probe, mesh, CCD	2
Initial Plasma Heating and Transport		
Magnetics 2	50 additional channels	6
Visible Cameras 2	2 add. fast cameras	
SXR Arrays 2	2 additional arrays	2
Bolometer Arrays 1	2 arrays	2
Fixed Langmuir Probes	20 probes	5
IR Camera	1 camera, multi. wind.	3
Thomson Scattering 1	100 Hz, 15 pos.	4
CHERS	50 ch system, 5 msec.	2
MSE 1	1 view, 10 channels	1
Diagnostic Neutral Beam	???	1
Optimize Confinement and Beta		
Magnetics 3	50 additional channels	
SXR Arrays 3	3 add. arrays,	3
Bolometer Arrays 2	2 add. arrays	2
Reflectometry	multiple scanning	1
Thomson Scattering 2	200 Hz, 30 chns.	
MSE 2	2nd view, 10 chns.	2
Fast Ion Loss Probe	fixed probe	1
Fast Scanning Edge Probe	1 pos.	1
Sustainment at High Beta		
Magnetics 4	additional channels	
IR Camera 2	additional camera	
Fluctuation Imaging	2-D imaging system	1
Divertor Bolometer	2 high res. Arrays	2
Divertor UV Spectrometer	scannable instrument	1
Fluctuation Diagnostic	undetermined	1
	total	65



Integration of Research Topics with Measurements

Phase	Topic	Aux Power	Essential Measurements
1. Initial Operation			conductivity
	initiate plasma	OH	plasma position
	control plasma evolution		plasma current
			visible image of plasma/wall
			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		stellarator symmetry
3. Initial Ohmic			
	Improved plasma control, plasma evolution control	OH	core electron temperature profiles
	global confinement & scaling, effect of 3D shaping		core electron density profiles
	density limit & mechanisms		more extensive visible imaging
	study of Te and ne profiles.		core radiated power profiles
	vertical stability		MHD (<100kHz)
	current-driven kink stability		average Zeff
	effect of low-order rational surfaces on flux-surface topology		hydrogen recycling
	initial study of effect of trim coils, both signs		presence of runaway electrons
	effect of contact location on plasma edge & recycling		
	initial attempts to control plasma contact location		

Integration of Research Topics with Measurements

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		

Table of Measurements - W7-X Example

QUANTITY	PARAMETER RANGE	ACCURACY TIME/SPACE RESOLUTION	CANDIDATE DIAGNOSTIC
GENERAL/CONTROL			
in-vessel viewing		20 ms/3 cm-	video cameras
vacuum flux surfaces		1-2 mm	rod/screen
line integrated density	10^{18} -5x10^{20} m^{-2}	5-10%	Cotton-Mouton
total stored energy	1-5 MJ	10 kJ	diamagnetic loop
total radiated power	0.1-10 MW	15%	bolometer
plasma current, total	1-200 kA	100A	Rogowski coil
Zeff, mean	1-10	10ms, 20%	visible bremsstrahlung
electron temperature central	0.1-10 keV	10%	SX ECE Thomson scattering
plasma position		10 ms/ 1 cm	video camera reflectometer Li-beam SX-camera
impurity ions with Z<30	10^{-3} - 10^{-4}	1 ms/factor2	SPRED, Double SPRED, Compact Flat field Grazing Incidence, CO-Monitor
	>10^{-4}	1ms, 30% absoute, <5% relative	Multi Channel Bragg Spectrometer, HiRes X-ray Imaging Crystal Spectrometer
conductivity			loop voltage plasma current

Table of Measurements - W7-X Example

	BULK			
	electron temperature profile	0.1-10 keV	< 2-3 cm 10%	Thomson scattering ECE
	electron density profile	$5x10^{18}$-$5x10^{20}$ m^{-3}	2 cm, 10%	Thomson scattering multichannel interferometer reflectometer
	ion temperature profile	0.1-10 keV	3 cm 15%	CX-NPA, CXRS (n-spectrometer), HiRes Imaging Crystal Spectrometer
	electron energy distribution	0.1-100 keV		ECE Thomson Scattering SX
	ion energy distribution	0.1-100 keV		CX-NPA
	β-profile	0.1-15%	2-3 cm	kinetic profiles
	Shafranov-shift	0. 5-10 cm	1 cm	SX tomography ECE
	impurity profiles light He, B, C	< 1% ne	15%	CXRS VUV SX
	impurity convection velocity		factor 1.5-2	
	Zeff profile	1-10	20%,100ms, 3-10mm	visible neutrons SX Thomson detection (red)
	iota profile (current density profile)	0.1-1	20%	computed, checked vs. low order rationals
	total radiation profile		2cm, 100ms	bolometer array

NCSX Diagnostic Tables

Table of Experimental Studies

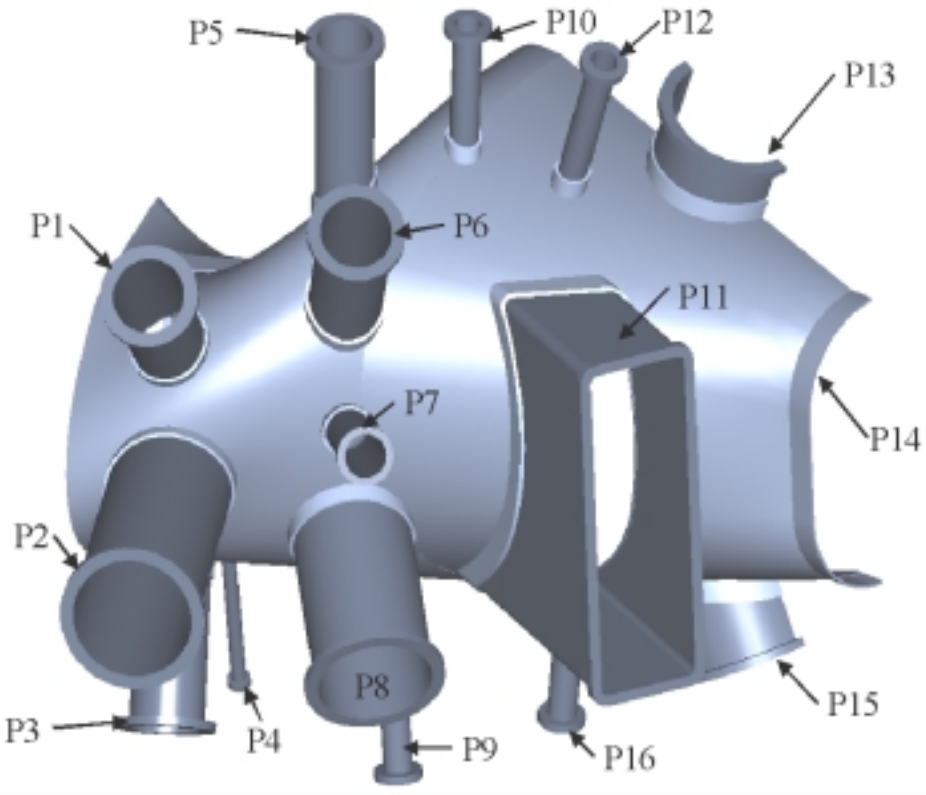
Experimental Objective	Phase within Program	Essential Measurements	Comments
transport analysis of ohmic plasmas	2	plasma boundary location conductivity electron temperature profile ion temperature profile radiated power profile Z_{eff} profile	?

Table of Measured Quantities

Quantity Measured	Parameter Range	Plasma Region	Accuracy (space/time res.olution)
Radiated power profile	.05 – 5 watt/cm^3	core	10%, 2 cm, 10msec 30%, 2 cm, 1 msec
Diagnostic Techniques	**Phase of Initial Implementation**	**Comments**	**?**
foil bolometer array AXUV diode array	2 1	For high accuracy For high time response	??

Table of Diagnostic Techniques

Diagnostic Technique	Primary Reason for Measurement	Plasma Region	Type of View, # channels
bolometer array	radiated power profile for power balance	core	2 poloidal arrays, 16 channels each
Phase of Implementation	**Port Allocation**	**Comments**	**Expert Group**
2	??	??	??

Adequacy of Diagnostic Access

- Planned diagnostics need ~ 65 ports. Current vessel design has 87 ports for all systems.
- A concept has been developed for Thomson scattering which looks feasible with some port modifications.
- Access concepts for all of the diagnostics listed will be developed as a priority in the conceptual design.
- Diagnostic integration is an explicit part of the project plan.
- At this point, diagnostic access appears adequate for measurement needs, if available space is used optimally for specific views.