Appendix A - Table I. NSTX Measurement Capabilities – August 2008

(black – routine operation, blue – under active development)

Physics Measurement	Typical range and coverage	Spatial; Temporal Resolution	Typical Precision	Available Diagnostic Techniques	Comment	Contact
Coil currents		follow pulse shape.	0.5%	Rogowski coil on buswork	For EFIT equilibrium reconstruction	S. Gerhardt – PPPL
Plasma current, I_p,		0.1 ms	1.0%	2 Rogowski coils around plasma outside vacuum vessel	For EFIT reconstruction	S. Gerhardt – PPPL
Plasma position		10 mm absolute 1 ms	3 mm with RTEFIT	2D and 3D solenoids inside vv, flux loops inside and outside vv	For EFIT reconstruction	S. Gerhardt – PPPL
Plasma kinetic energy	> 10 kJ	1 ms	1 kJ	diamagnetic loop	EFIT constraint, uses TF coil	M. Bell - PPPL
Electron density line integrals	>2x10^{11} cm^{-2}	500 kHz	2x10^{11} cm^{-2}	tangential interferometry, polarimetry (FIReTIP)	FIR laser with retro-reflectors in 4 tangential chords (2 additional under dev)	K. C. Lee – UC Davis
		500 kHz		1 mm radial interferometer	1 mm reflected from center stack	S. Kubota - UCLA
Electron density profile	5x10^{11} - 5x10^{14} cm^{-3}	3.0 cm core, 0.9 cm edge, 2 30 Hz lasers	>3%	Thomson scattering	60 Hz Nd:YAG, laser nearly radial on horizontal midplane, 30 of 48 channels implemented	B. LeBlanc - PPPL
	2x10^{12}– 3x10^{13} cm^{-3}	Up to 100 kHz, 9273 sweeps	~ 1 cm	reflectometry FM/CW	13 – 50 GHz swept; radial correlation lengths (can be used simultaneously with correlation reflectometry	S. Kubota - UCLA
	.02-1.6x10^{13} cm^{-3}	1 kHz		reflectometry (SOL)	6 - 36 Ghz swept system, 1 kHz sweep rate	J. Wilgen - ORNL
	0.1-1.6x10^{13} cm^{-3}	1.5 mm, 2 ms per point, 60 ms per profile		fast scanning midplane probe	18 cm below midplane, τ_{insert}<100 ms, τ_{dwell} =2-50 ms, 10 tips	J. Boedo - UCSD
Electron temperature profile	0.003 – 5 keV	3.0 cm core, 0.9 cm edge, 2 30 Hz lasers	>3%	Thomson Scattering	2 - 30 Hz Nd:YAG lasers nearly radial on horizontal midplane, 30 of 48 possible spatial channels implemented	LeBlanc - PPPL
				fast scanning midplane probe	see above	J. Boedo - UCSD
	0.1-5 keV	4 cm, < 100 kHz	5% (rel)	tangential multi-color sxr arrays	3 color/ 16 spatial channels, CsI:Tl phosphor and PM arrays	L. Delgado - JHU

				imaging horizontal x-ray crystal spectrometer	vertical profile ±30 cm, requires Ar injection, spherical crystal, being upgraded to PILATUS II solid state detectors	M. Bitter - PPPL
Ion temperature profile	0.02 – 5.0 keV	3.0 cm core, 0.5 cm edge, 10 ms	≥ 2%	toroidal CHERS	51 channels system using C VI with heating beam, dedicated background view	R. Bell - PPPL
		3.0 cm edge only, 10 ms	≥ 2%	edge Doppler spectroscopy	7 channels from tangential view and 6 channels from vertical view of outer midplane edge. Uses intrinsic C III and He II.	R. Bell - PPPL
	0.2 – 5.0 keV	2.5 cm, 5 ms	≥ 5%	scanning neutral particle analysis	horizontal and vertical scan, profile requires vertical scan, L-mode beam heated discharges only	S. Medley - PPPL
		5 cm, 20 ms		imaging horizontal x-ray crystal spectrometer	see above	M. Bitter, K. Hill - PPPL
Plasma rotation profile	-100 km/s to +300 km/s	3.0 cm core, 0.5 cm edge, 10 ms	≥ 2%	toroidal CHERS	see above	R. Bell - PPPL
		~ 3.0 cm edge only, 10 ms	≥ 2%	edge Doppler spectroscopy	see above	R. Bell - PPPL
		1.6 cm core, 0.6 cm edge, 10 ms		poloidal CHERS	up and down views of heating beam and dedicated background views, 75 active channels using C VI with heating beam.	R. Bell - PPPL
		~ 3.0 cm, 10 ms		edge Doppler spectroscopy	see above	R. Bell - PPPL
	1.1-2.0 x10^{13}cm^{-3}	variable		correlation reflectometry	30-40 Ghz (core access for peaked low density profiles). Radial or poloidal correlation	S. Kubota - UCLA
B field pitch (for determination of q(R) using LRDFIT or EFIT)		3 cm core, 2 cm edge, 10 ms (target 5 ms)	≥ 0.2°	motional Stark effect based on collisionally-induced-fluorescence (MSE/CIF)	16 of 19 channels implemented, presently applies correction for toroidal rotation, requires heating beam source A.	F. Levinton, H. Yuh - NOVA
		target - 3 cm core, 2 cm edge, 10 ms	target ≥ 0.2°	motional Stark effect based on laser-induced-fluorescence (MSE/LIF) using DNB	requires compact, radial DNB	F. Levinton, J. Foley - NOVA
Profile of the radial Electric field		5 cm core, 2 cm edge, 10 ms		MSE/CIF and MSE/LIF	see above; requires heating source A and DNB	F. Levinton, H. Yuh, J. Foley - NOVA

		3.0 cm core, 0.5 cm edge, 10 ms		toroidal and poloidal CHERS	see above; requires heating beam	R. Bell - PPPL
		3.0 cm, 10 ms		edge Doppler spectroscopy	may need helium	R. Bell - PPPL
	10V–30kV/m	1.5 mm, 1 μs		fast scanning midplane probe	see above, edge only	J. Boedo - UDSD
Radiation profile		8 cm, 0.2 ms		toroidal bolometer array	tangential view, 16 channel AXUV diode array	S. Paul - PPPL
		8 cm, 5 ms		divertor bolometers	20 gold foil bolometers: 8 viewing divertor radially from outside, 8 viewing divertor from top, and 4 viewing down from midplane	S. Paul - PPPL
Z_{eff}		line integral	10% abs.	visible continuum sensor	single filterscope chord, R_{TAN}~60 cm, λ=	C. Skinner - PPPL
		3.0 cm core, 0.5 cm edge, 10 ms	≥ 5% in (Z_{eff}-1)	toroidal CHERS	see above, assumes C only impurity	R. Bell - PPPL
Impurity concentrations	C^{+5} conc.	3.0 cm core, 1.0 cm edge, 10 ms	20% abs.	toroidal CHERS	see above	R. Bell - PPPL
	H/D ratio, detachment signature, line emission	Integral; 10 ms	5% (rel)	Visible (VIPS) survey spectrometer	several sightlines coupled via fiber to 0.5 M Czerny-Turner; 3500-11000Å, CCD detector	C. Skinner, S. Paul - PPPL
	O/C ratio, impurity influx	Integral; 15 ms	5% (rel)	VUV (SPRED) survey spectroscopy	100 – 1100Å with 2 gratings, radial midplane view, microchannel plate with CCD readout	C. Skinner, S. Paul - PPPL
	Z≥6 ions (C, O, Cu, Ne, Ar, Kr)	5 cm; 5 ms for impurities	15% abs	filtered poloidal soft x-ray arrays	1 vertical array (16 ch); 2 horizontal arrays (32 ch); discrete AXUV diode arrays	K. Tritz - JHU
		r/a~0.08, 100 ms	15% abs	TGI spectrometer	12 chord transmission grating imaging spectrometer; 10Å – 300Å CMOS detector	D. Stutman - JHU
		Integral; 90 ms	5% (rel)	EUV spectrometer (XUES)	Flat field grazing incidence spectrometer covering 10-60 Å	P. Beiersdorfer-LLNL
		Integral; 90 ms	5% (rel)	EUV spectrometer (LoWEUS)	Flat field grazing incidence spectrometer covering 60-220 Å	P. Beiersdorfer-LLNL

Low (m,n) MHD modes, sawteeth, locked modes, and disruption precursors	$\Delta B/B = 10^{-4} - 10^{-1}$, (0,0)<(m,n) < (5,10)	poloidal DC – 250 kHz toroidal DC – 2 MHz		low frequency Mirnov coils outside plasma	12 toroidal, 24 poloidal	E. Fredrickson - PPPL
		5 cm; < 300kHz bw		filtered poloidal sxr arrays	1 vertical array (16 ch); 2 horizontal arrays (32 ch); discrete AXUV diode arrays	K. Tritz - JHU
				fast tangential soft x-ray pinhole camera	uses various foils and apertures, phosphor and demagnifying image tube with PSIV camera (5×10^5 frames/sec for 300 frames)	B. Stratton - PPPL
		4 MHz		quadrature reflectometer	30, 42, 49 GHz	S. Kubota - UCLA
		500 kHz		Neutron scintillator array	plastic scintillators with PM tubes 1-ZnS; 3 BC400	L. Roquemore - PPPL
				dynamo probe on fast scanning midplane probe		J. Boedo - UCSD
High frequency instabilities (MHD, fast ion modes)	$\Delta B/B \leq 10^{-2}$, $\Delta n/n \leq 10^{-2}$, n = 10 – 50, $\Delta\phi \leq 10^{-2}$	5 MHz		Mirnov coils outside plasma	B_T and B_P	E. Fredrickson – PPPL
		5 cm; < 300kHz bw		filtered poloidal sxr arrays	1 vertical array (16 ch); 2 horizontal arrays (32 ch); discrete AXUV diode arrays	K. Tritz - JHU
	1.1, 1.5, 2.2, 2.5. 3.1 $\times 10^{13} cm^{-3}$	4 MHz		quadrature reflectometer	30, 35, 42, 44.5, 50 GHz	S. Kubota - UCLA
	$>2 \times 10^{11}$ cm^{-2}	500 kHz	2×10^{11} cm^{-2}	tangential interferometry, polarimetry (FIReTIP)	FIR laser with retroreflectors in 4 tangential chords (2 additional)	K. C. Lee – UC Davis
	$>2 \times 10^{11}$ cm^{-2}	500 kHz	2×10^{11} cm^{-2}	1 mm radial interferometer	1 mm reflected from center stack	S. Kubota - UCLA
Core turbulence	1.1-2.0 $\times 10^{13} cm^{-3}$	variable		correlation reflectometry	30-40 Ghz (core access for peaked low density profiles). Radial or poloidal correlation	S. Kubota - UCLA
	2×10^{12}– 3×10^{13} cm^{-3}	Up to 100 kHz, 9273 sweeps	~ 1 cm	reflectometry FM/CW	13 – 50 GHz swept; radial correlation lengths (can be used simultaneously with correlation reflectometry	S. Kubota - UCLA
	$-20\ cm^{-1} < k_r < 20\ cm^{-1}$, $\Delta R \sim 5$ cm		$\Delta n/n$ >0.1%	high-k scattering	tangential microwave scattering at λ= 1 mm, 5 detector channels viewing r/a ~ 0.3-0.8	E. Mazzucato - PPPL

	$k_\perp \rho_I < 1$	ΔR ~2 cm; 120 cm < R< 150 cm	$\Delta n/n$ >0.1%	Beam Emission Spectroscopy	2 arrays viewing heating beams with 2-D (radial and poloidal) array of 32 detector channels	G. McKee-UW, B. Stratton-PPPL
Edge turbulence	10% -100% Δn_e, $\Delta\phi$	1.5 mm, 1 μs		fast scanning midplane probe	see above	J. Boedo - UCSD
	ΔT_e	1.5 mm, 1 μs		fast scanning midplane probe	see above	J. Boedo - UCSD
		~ 1 cm for r/a> 0.8, <500 kHz		gas puff imaging	Supported by gas puff manifold. Various fast cameras used	S. Zweben – PPPL, R. Maqueda - NOVA
	B, ΔB .01 – 100G	1 mm, 2 μs		dynamo probe tip on fast scanning probe	all components	J. Boedo - UCSD
	$k_\perp \rho_I < 1$	ΔR ~2 cm; 120 cm < R< 150 cm	$\Delta n/n$ >0.1%	Beam Emission Spectroscopy	see above	G. McKee-UW, B. Stratton-PPPL
Edge recycling and impurity influx		2 kHz		filterscopes	5 upper divertor, 5 lower divertor, 12 midplane CS. filters include $H_{\alpha,\beta,\gamma}$, CII, CIII, LiI, BII	V. Soukhanovskii – LLNL, R. Maingi – ORNL, C. Skinner - PPPL
		0.2 ms/frame		1D CCD cameras	2 lower divertor, 1 midplane CS, 1 radial horizontal view of lower divertor	V. Soukhanovskii – LLNL
		1.5 cm sightline separation		high resolution divertor fiber view	32 channels viewing inner and outer divertor from top, channel separation at divertor 1 – 3 cm. Used with filterscopes and visible spectrometers	V. Soukhanovskii - LLNL
Edge and SOL flows	Mach .1-2	1.5 mm, 1 μs		fast scanning midplane probe	see above	J. Boedo - UDSD
		1 mm, 2 kHz		Shifted-Wavelength Interference Filter Technique (SWIFT)	uses fiber views of gas puff manifold , requires helium injection	S. Paul - PPPL
Dust monitoring		1 kHz	sens. 1μg/cm^2	electrostatic grid detector	biased fine pitch PC grid, pulse counting electronics, Bay C bottom	C. Skinner - PPPL
First wall deposition		2 sec continuous		quartz microbalances	four QMBs (Bay H top, Bay H bottom, Bay I midplane, Bay B midplane), 3 shuttered, Inficon XTM/2	C. Skinner - PPPL
Spectroscopic n_e , T_e in divertor		1.5 cm sightline separation		visible filterscopes viewing lower divertor	see above	V. Soukhanovskii - LLNL
n_e , T_e at target	3 - 50 eV			Langmuir probes	flush-mount probes embedded in carbon tiles (3 inner div, 4 outer div.- upper and lower, 8 on CS)	C. Bush - ORNL

Neutron source profile				neutron collimator	one-channel prototype being tested	L. Roquemore - PPPL
Neutron flux monitors		1 ms	5% rel. 25% abs.	fission chambers	2 U^{235} detectors with x26 sensitivity ratio	L. Roquemore - PPPL
		0.2 µs	<5% rel.	scintillator detectors	plastic scintillators with PM tubes 1-ZnS; 3 BC400	L. Roquemore - PPPL
RF driven surface waves				high-frequency Langmuir probe	located between antenna segments,	R. Wilson – PPPL, J. Wilgen - ORNL
Mode conversion efficiency of EBW emission				EBW radiometer	2 obliquely-viewing antennas ; 2 radiometers covering 8-18 GHz and 18-36 GHz	G. Taylor- PPPL J. Kaughman. J. Wilgen - ORNL
Gas pressure at several locations				Penning gauges	1 in lower divertor, 1 in upper divertor, 1 in pumping duct with spectroscopy, 1 below lower divertor with spectroscopy	R. Raman – U. Wash
				micro-ion gauges	Bays E and C-midplane, Bay L-pumping duct, Bay C-top	R. Raman – U. Wash
Gas composition in vacuum vessel	typ A = 1-50/100, ΔA=1	Approx. 1 min./1 sec. mass sweep	10^{-11}/10^{-9} torr typical sens.	2 Residual gas analyzers (continuous monitoring/after discharge measurements)	In Bay L pumping duct, differentially pumped system	W. Blanchard - PPPL
Runaway electrons		10 ms	30%	hard X-ray detector	at start-up and thermal quench	L. Roquemore, K. Hill - PPPL
First wall filtered visible images	Phantom MIRO2	>256x256	10 bit	5.5 kHz at 32x16	cameras share various views: • top view of lower divertor • tangential view of lower divertor • fish eye radial view of entire plasma • 3 tangential midplane views including one view near pellet port • view of gas puff manifold along B field	L. Roquemore - PPPL
	Phantom 7.3-2048	>32x32	14 bit	190 kHz at 32x32		L. Roquemore - PPPL
	PSI V	64x64	12 bit	300 frames at 250 kHz		S. Zweben - PPPL
	Photron	>64x64	8 bit	<40 kHz		N. Nishino – U. Hiroshima
	Phantom	>64x64	12 bit	120 kHz continuous		R. Maqueda - NOVA

First wall temperature	20-1200°C	30 Hz, 1 kHz; 15° FOV	5°C abs <1°C rel	IR Cameras	2 FLIR Omega and 1 FLIR Alpha compact μbolometer cameras (30 Hz) and one fast IR camera(1 kHz) with views of lower divertor, CS, and beam armor	R. Maingi - ORNL
Vacuum Vessel Illumination				3 in-vessel tungsten filaments, ~ 25x5 mm helical	Provide lighting of the first-wall surfaces, Bays G and K near midplane, Bay K/L above midplane	H. Kugel - PPPL
Fast Lost Ions				FLIP	radial array of Faraday cups	D. Darrow - PPPL
		1 kHz		SFLIP	scintillator probe with energy and pitch angle resolution	D. Darrow - PPPL
Fast ion dynamics	$n < 5x10^{13}$ cm^{-3}	10ms, 5cm, 10keV		Spectrometer	Vertical views from bay A/B. Based on active charge-exchange spectroscopy: requires NB injection; MPTS and CHERS data needed for analysis	M.Podestà, UCI
		20us, R=100, 120,140cm		Energy-integrated signal		M.Podestà, UCI
Fast ion distribution	1-100 keV	2 msec	rel 5% abs. x2	scanning NPA	horizontal and vertical spatial distribution	S. Medley - PPPL
	35 – 100 keV	1 msec counting window		solid state NPA	4 chords R_{TAN}= 60, 90, 100, 120 cm, Si-diodes with 0.15μ Al foils and apertures, pulse height analysis	D. Liu, W. Heidbrink – UC Irvine

Appendix A - Table II. Systems Capable of Supporting Active Diagnostics - August 2008 (black – routine operation, blue – under active development, red – EXAMPLES of potential future diagnostics)				
System	Purpose of system	Characteristics	Used in diagnostic:	Contact
Heating Neutral Beam	Provide neutral population to produce beam emission for various diagnostics	D, 90 - 100 keV, ~50cm V x 20cm H, ~ 150mA/cm^2 neutrals entering plasma	CHERS, MSE, MSE/LIF, BES (D)	T. Stevenson - PPPL
Diagnostic Neutral Beam	Provide excited neutral atoms for intensity and polarimetry measurement	H, 40 keV, 1 - 2 cm dia., 30 mA neutrals entering plasma	MSE/LIF	F. Levinton, J. Foley NOVA
Impurity Pellet Injector	Provide impurity population to enhance signals	solid pellets or dust, .5 – 10 mg per sabot, < 200 m/s, ≤ 8/pulse	pellet plume detector	H. Kugel - PPPL
Supersonic Gas Injector	Provides low divergence, high pressure gas jet	Laval nozzle, on midplane probe	thermal atomic beam spectroscopy	V. Soukhanovskii - LLNL
Gas Puff Manifold	Provides neutral atoms to highlight edge density turbulence	linear manifold ⊥ to edge B field, multiple 1 mm dia holes, D, He or Ar.	gas puff imaging SWIFT	S. Zweben - PPPL