TO: A. vonHalle
FROM: S. Ramakrishnan

SUBJECT: Electrical Power System – WBS4

Date:09/26/08

Scope

The Electrical Power Systems WBS Element covers the supply and delivery of all AC and DC electrical power to all equipment associated with the NCSX experiment. The NCSX Project includes all Electrical Power System capabilities required for initial operation as defined in the GRD.
Included in the NCSX Project are design, component fabrication, assembly, and installation activities, system level commissioning, and testing. Electrical Power Systems (WBS 4) includes the power delivery work up to the bus stubs in the floor.

Electrical Power Systems (WBS 4) includes the following elements:

- AC Power Systems (WBS 41);
- DC Systems (WBS 43);
- Control and Protection Systems (WBS 44);
- Power System Design and Integration (WBS 45)

Status
AC Power Systems: AC distribution at the ground level within the NCSX Test Cell has been designed and installed. Work at the Mezzanine level has been designed but not installed.
DC Systems: Robicon Rectifiers that will be used for NCSX have been tested with Dummy Load. Design of the power loop has been partly completed and drawings generated but would need revision. No installation work has been performed.
Control & Protection System: A peer review of Protection has been completed. A preliminary control design with PLC was under development.

Power System Design & Integration: Discussions were held with other WBS to develop the power loop. A PDR was planned but not executed.

Interfaces
Interface Requirements with other WBS elements:
1. The responsibility for WBS4 ends at the distribution Power Panels . All disciplines shall plan accordingly.
2. Existing Motor Control Centers (480V) shall be used to feed the loads as required by other WBS elements. For all new motors requiring additional starters, the corresponding WBS element shall arrange to fund and purchase the starters. Other WBS elements shall also provide the list of loads to be fed by WBS4 Auxiliary AC system.

3. Specific provision shall be made for a limited number of cabling by WBS4 for the Diagnostics (WBS3) within the Test Cell. Any additional cabling requirements shall be funded by WBS3.
4. Grounding:
WBS4 shall arrange to provide the grounding for the NCSX Test Cell including the grounding for the Vessel.

Specifications

1. GROUNDING FOR PERSONNEL & EQUIPMENT SAFETY - NCSX-CSPEC-411-00 signed out on 02/06/08.
2. NCSX DC Disconnect & Ground Switch Specification NCSX-CSPEC-433-01 dated 5/28/04
3. NCSX DC Power Cable Specification NCSX-CSPEC-43-01-00 dated 5/18/04
4. NCSX Systems Requirements Document (SRD) – Electrical Power System (WBS4) – NCSX-BSPEC-4-00 Draft F dated 02/24/08
5. Design Description – Electrical Power System – WBS4 draft 3/16/07

Schematics and other drawings
See List NCSXDWGLIST attached

Models
Not Applicable

Drawings
See List NCSXDWGLIST 070705 attached

Analyses
See attached

Testing
1. C-Site power supplies were tested on Dummy Load per procedure ESAT Power Supply Dummy Load and Insulation Testing: C-NCSX-ECS-OP-760

2. Insulation Testing of Robicon and P=EI Power Supply Transformers: C-NCSX-PTP-ECS-057

Costs
Not Applicable

Remaining Work

1. Revise the schematics and Control Wiring diagrams to reflect the latest power supply assignment and the cabling changes.
2. Prepare physical drawings for trays and conduits
3. Prepare grounding drawings
4. Prepare Kirk Key drawings
5. Prepare PLC related documentation

6. Conduct PDR & FDR on all sub-systems including Protection
7. Prepare Installation Procedures, PTPs & ISTPs
8. Repair PEI power supply
9. All installation work
10. All Testing work

Lessons Learned: There have been several changes in the scope of the WBS4 task which resulted in added work. Scope shall be clearly defined before taking up detailed work.

Conclusion: The WBS4 tasks currently are reasonably well defined. It is important that input from Coil Designers are obtained to finalize the protection scheme. It is important to work as a team to get the coil protection and control implemented properly. The Power system design can be developed in a systematic way and the system installed & tested.

C-Site Rectifiers - Voltage drop calculations 01/12/2006 R1 with corrected X, assuming a 60% diversity factor. Note that IF has dedicated feeder reactor. 5/31/2006 C site robicon transformer test data with impedance with 30MVA trfr 053106.xls

Unit	Sl# of Trmr	KVA	%Z	Vpri - 3ph.L to L	Ip in Cont	Ip in pulsed	Vsec no load L-L	%X of CLR1&2 & XQT2 referred to the ckt.	Is RMS Cont	Is RMS pulsed	Pri Res. (mOhm)	Pri Res. (mOhm) referred to secondary	Sec. Res. (mOhm)	Total Res*.(ref. Sec)(mOhm)	Ideal DC no load Volts	Rated DC Volts	kVA (Idc=Is*(m^0.5)) - Amps	Rated pulsed DC Current-kA	Z base (Ohms)	Z sec side	X Sec side	L	L/2	Kimbark 6fL	Total Eq. Resis - ohms	Volt Drop	Percent drop
T1	86-1258	225	6.07	4160	31.2	124.91	255	7.53	509.43	2038	838	3.1487	1.64	5.3634	344.37	300	4991.34	5	0.289	0.0175423	0.038476	0.00010206	5.103E-05	0.03674144	**0.042105**	105.26	30.57
T1	86-1264	225	6.23	4160	31.2	124.91	255	7.53	509.43	2038	832	3.1262	1.68	5.3829	344.37	300	4991.34	5	0.289	0.0180047	0.038954	0.00010333	5.166E-05	0.03719876	**0.042582**	106.45	30.91
T2	86-1260	225	5.91	4160	31.2	124.91	255	7.53	509.43	2038	841	3.1600	1.66	5.3984	344.37	300	4991.34	5	0.289	0.0170799	0.037978	0.000100739	5.037E-05	0.03626593	**0.041664**	104.16	30.25
T2	86-1262	225	6.12	4160	31.2	124.91	255	7.53	509.43	2038	831	3.1224	1.76	5.4683	344.37	300	4991.34	5	0.289	0.0176868	0.038593	0.000102372	5.119E-05	0.03685408	**0.042322**	105.81	30.72
T3	86-1259	225	5.99	4160	31.2	124.91	255	7.53	509.43	2038	837	3.1450	1.66	5.3816	344.37	300	4991.34	5	0.289	0.0173111	0.038227	0.000101399	5.07E-05	0.03650373	**0.041885**	104.71	30.41
T3	86-1263	225	5.95	4160	31.2	124.91	255	7.53	509.43	2038	830	3.1187	1.67	5.3633	344.37	300	4991.34	5	0.289	0.0171955	0.038111	0.000101092	5.055E-05	0.03639328	**0.041757**	104.39	30.31
T4	86-1261	225	6.25	4160	31.2	124.91	255	7.53	509.43	2038	836	3.1412	1.65	5.3662	344.37	300	4991.34	5	0.289	0.0180625	0.03902	0.000103504	5.175E-05	0.03726158	**0.042628**	106.57	30.95
T4	86-1265	225	6.15	4160	31.2	124.91	255	7.53	509.43	2038	834	3.1337	1.74	5.4586	344.37	300	4991.34	5	0.289	0.0177735	0.038688	0.000102623	5.131E-05	0.03694413	**0.042403**	106.01	30.78
DF	86-1256	300	6.85	4160	41.6	166.54	170	7.53	1018.85	4075	625	1.0437	0.594	1.8343	229.58	200	9982.68	10	0.09633	0.0065988	0.013597	3.60659E-05	1.803E-05	0.01298373	**0.014818**	74.09	32.27
DF	86-1257	300	6.92	4160	41.6	166.54	170	7.53	1018.85	4075	632	1.0554	0.578	1.8294	229.58	200	9982.68	10	0.09633	0.0066663	0.013668	3.62557E-05	1.813E-05	0.01305206	**0.014881**	74.41	32.41
IF	86-1175	1505	5.96	4160	208.9	835.49	426	7.53	2039.70	8159	50.3	0.5275	0.714	1.3905	575.30	500	19984.9	20	0.12058	0.0071867	0.016136	4.28009E-05	2.14E-05	0.01540832	**0.016799**	167.99	29.20
IF	86-1176	1505	5.72	4160	208.9	835.49	426	7.53	2039.70	8159	50.6	0.5306	0.706	1.3850	575.30	500	19984.9	20	0.12058	0.0068973	0.015841	4.20208E-05	2.101E-05	0.01512748	**0.016512**	165.12	28.70
PEI	DELTA	342	1.2	4160	50.0	199.89	407.40	7.53	513.00	2052	174.74	1.6759	2.74	4.0073	550.18	500	2513.18	2.5	0.48531	0.0058237	0.040789	0.000108195	5.41E-05	0.03895035	**0.042958**	107.96	19.62
	WYE	342	1.2	4160	50.0	199.89	407.40	7.53	513.00	2052	174.74	1.6759	0.95	2.0025	550.18	500	2513.18	2.5	0.48531	0.0058237	0.042032	0.000111492	5.575E-05	0.04013718	**0.042140**	105.90	19.25

Total pulsed current in the feeder to Q1B5A through E 3403.10 A

401.79

Total voltage drop in XQT2,CLRs1&2 if all pulsed simulteneously at peak with 66% diversity factor 169.22 V

(G18/E3)*100

Summary of the equivalent resistance to compute voltage drop

Unit	Sl# of Trmr	KVA	Volt drop on full load	Re*	Average Drop	Av. Re per tmfr or wdg(PEI)	Rec per CKT; Rec=Re/2
					Volts	Ohms	Ohms
T1	86-1258	225	105.262	0.042105			
	86-1264	225	106.454	0.042582	105.9	0.042343	0.021172
T2	86-1260	225	104.161	0.041664			
	86-1262	225	105.806	0.042322	105.0	0.041993	0.020997
T3	86-1259	225	104.713	0.041885			
	86-1263	225	104.392	0.041757	104.6	0.041821	0.020910
T4	86-1261	225	106.569	0.042628			
	86-1265	225	106.007	0.042403	106.3	0.042515	0.021258
DF	86-1256	300	74.09	0.014818			
	86-1257	300	74.4075	0.014881	74.2	0.014850	0.007425
IF	86-1175	1505	167.988	0.016799			
	86-1176	1505	165.125	0.016512	166.6	0.016656	0.008328
PEI	Delta	342	88.1491	0.042958			
	Wye	342	86.4706	0.042140	87.3	0.042549	0.021274

*** Equivalent Resistance Re per tmfr.**
The drop in the Interphase transformer is not included in the above.

Load assignment 1/3/2006

Load Coil	Supply	Amp max	Ideal Volts	Cable#	Cabling Loop resis.	Eff.Loop resis.to coil term.	Adjusted Resis*. mohms	Total Resis. mohms	Volt drop	Forcing Volt for coil	Shunt in Supply	Coil Resis	Total ckt. Resis-no kimbark	Coil Inductance	Total ckt. Inductance	L/R		Volt drop with 50A
M2+M3	T1 ‖ T4	10000	344.37	41875CA	4.87	3.14744	3.53	14.07	140.67	203.70	50mV= 1.5kA	0.01399	0.01751	0.02096	0.02104	1.20117	12275.2422	0.875606425
					4.92													
PF4	T2	5000	344.37	41856CA	4.87	10.44	11.69	53.88	269.39	625.17	50mV= 1.5kA	0.00311	0.01480	0.01520	0.01528	1.03176	6042.6799	0.74024
	PEI**	5000	550.18		4.87						50mV= 1.5kA							
M1	DF	10000	229.58	41805CA	3.34	4.04	4.52	11.95	119.50	110.08	50mV= 2.5kA	0.00778	0.01230	0.01500	0.01508	1.22543	11638.0499	0.61509
PF1a	IF	20000	575.3	41816CA	1.67	2.37	2.65	10.98	219.64	355.66	50mV= 5 5kA	0.00067	0.00332	0.00080	0.00087	0.26232	49389.5389	0.16602
PF6	T3	5000	344.37	41826CA	4.87	5.57	6.2384	27.15	135.74	208.63	50mV= 1.5 kA	0.00284	0.00908	0.00624	0.00632	0.69561	11483.256	0.45392

* Adjusted (12%) to compensate for temp. - arbitrary
** Assumed cable loop resistance of 4.87mOhms; Design should be such that the T3 supply can be connected to feed & test TF

PEI TRANSFORMER DATA FROM EARNIE SCHOOP						JANUARY 04 2006			
2500MW (pulsed) power supply at 500V dc- PEI part# 11345; PEI Job# 90-027 S/N 01									
Three winding transformer with Delta primary comprising of two parallel windings and WYE & DELTA secondaries									
Power delivered (Pulsed)	2500.00	kW							
DC Voltage (open circuit)	549.64	V	(Calculated from data furnished)						
DC Volt (Pulse Loaded)	500.00	V	(Based on nameplate?)						
kVA -RMS	684.00	kVA							
kVA -Pulsed	2736.00	kVA							
Primary Voltage	4160.00	V	(+/- 5%)						
Secondary Volt - Delta	407.40	V	(+/- 5%)						
Secondary Volt - Wye	407.40	V	(+/- 5%)						
Voltage Ratio	10.21								
Impedance	1.20	%							
Note: The primary voltage required to inject full RMS current in both secondaries is 49.76V with the secondaries shorted.									
Primary Current	29.20	A	in each of the two parallel primary windiings						
Primary Line current	101.15	A							
Sec. Line Current-Delta	513.00	A							
Sec. Line Current-Wye	513.00	A							
Primary Resis.- Parallel 1	331.53	mOhms	per phase						
Primary Resis.- Parallel 2	369.50	mOhms	per phase						
Pri. Resis.(both parallels)	174.74	mOhms	per phase						
Secondary Delta Resis.	2.74	mOhms	per phase						
Secondary Wye Resis.	0.95	mOhms	per phase						
Insulation tests: primary to ground at 10kV; Primary to Secondary at 10kV; Secondary (Wye) to ground at 2.5kV									
Secondary (Delta) to Ground at 2.5kV; Also passed induced voltage tests									

0.289 0.251049416

0.0175423

GENERAL

Vdo = 3*(6^0.50)*Eln/Pl		1.35*E Line to Line		2.34* E Line to Neutral		
		% Impedance =(IZ/V)*100=(V^2*Z/VA)*1			OR	Z/Zbase
		Z= %Z*((V/I)/100)				
Is = Idc/(m^0.5)		Kimbark = 6fLc		Drop = I*(Kimbark+Res.)		

0

XQT2		Q bus CLR	XQT2 CLR	Total%	based on 20MVA
MVA S/S	30	0.0500	0.0300		
%Imp	7.5	0.5021	3.0026	11.045	7.534
Ifull load	4164				
I at 2/3 load	2776				
Sev.Volt	4160				
Z of trmr.	0.0753	Ohms			
IZ	209				

Others	0.502098832
IF	0.482915654

	t(s)	M1	M2/3	PF1A	PF4	PF6	TF	Plasma
Start charging coils	-4	0	0	0	0	0	0	0.00
Dwell	0	9115	9115	0	0	0	0	0.00
Start Ip ramp	0.05	9115	9115	0	0	0	0	0.00
Heat to high beta	0.12	9115	9115	18109	2947	227	0	-26068.00
Hold at high beta	0.123	9115	9115	18466	3005	231	0	-26068.00
Start discharging coils	0.13	9115	9115	19299	3141	241	0	-26068.00
Coils discharged	2.63	0	0	0	0	0	0	0.00
MVA		2.09262	3.13893	11.102715	2.80979	0.0829932		
MVA Total								19.22705
MW		1.02207	1.45496	1.2366876		0.0005273		
MW (Total)								3.714252
PF								0.193178
From Wayne on 05/16/06								
	0.385							
	3.3							

DRAWING NUMBER	REV	SIGNED OUT	DRAWING NAME
B-4F1005 SH 1800C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1/2,3,4,TF AND M1,2,3 COIL BLOCK DIAGRAM SCHEMATIC
B-4F1005 SH 1800C-v1	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1/2,3,4,TF AND M1,2,3 COIL BLOCK DIAGRAM SCHEMATIC
B-4F1005 SH 1800CV4	R0		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1/2,3,4,TF AND M1,2,3 COIL BLOCK DIAGRAM SCHEMATIC
B-4F1005 SH 1800CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1/2,3,4,TF AND M1,2,3 COIL BLOCK DIAG SCH (NOT SIGNED)
B-4F1800_SH1	PDR		NCSX DC SYSTEMS C-SITE DC SYS COILS SIMPLIFIED SCH INITIAL PHASE (TYP CKT FOR SLIDE)
B-4F1800_SH2	PDR		NCSX DC SYSTEMS C-SITE DC SYS COILS SIMPLIFIED SCH FINAL PHASE (TYP CKT FOR SLIDE)
B-4F1800R5-0814031	PDR		NCSX DC SYSTEMS C-SITE DC SYS COILS SIMPLIFIED SCH (TYP CKT FOR SLIDE)
B-4F1005 SH 1801	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL SCHEMATIC
B-4F1005 SH 1801C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL SCHEMATIC
B-4F1005 SH 1801CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL SCHEMATIC
B-4F1005 SH 1801CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL SCHEMATIC (NOT SIGNED)
B-4F1005 SH 1805	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1805CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1805CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL CONTROL WIRING DIAGRAM (NOT SIGNED)
B-4F1005 SH 1806	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M2 AND M3 COIL SCHEMATIC
B-4F1005 SH 1807	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M2 AND M3 COIL SCHEMATIC
B-4F1005 SH 1811	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF5U AND PF5L COIL SCHEMATIC
B-4F1005 SH 1811C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS TF COIL SCHEMATIC
B-4F1005 SH 1812C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1 AND PF2 COIL PARALLEL SCHEMATIC
B-4F1005 SH 1812C-v1	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1 AND PF2 COIL SERIES SCHEMATIC
B-4F1005 SH 1812CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1a COIL SCHEMATIC
B-4F1005 SH 1812CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1a COIL SCHEMATIC (NOT SIGNED)
B-4F1005 SH 1815	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COILCONTROL WIRING DIAGRAM
B-4F1005 SH 1815C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS TF COILCONTROL WIRING DIAGRAM
B-4F1005 SH 1816C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1 AND PF2 COIL SCHEMATIC
B-4F1005 SH 1816CV1	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1 AND PF2 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1816CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1a COIL CONTROL WIRING DIAGRAM (NOT SIGNED)
B-4F1005 SH 1816CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1a COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1823	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COIL SCHEMATIC
B-4F1005 SH 1823C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1 COIL SCHEMATIC
B-4F1005 SH 1823Cv4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COIL SCHEMATIC (NOT SIGNED)
B-4F1005 SH 1823Cv4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COIL SCHEMATIC
B-4F1005 SH 1825	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF5 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1826	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1826C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1826CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COIL CONTROL WIRING DIAGRAM (NOT SIGNED)
B-4F1005 SH 1826CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF6 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1843	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF5U AND PF5L COIL SCHEMATIC
B-4F1005 SH 1845	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF5U COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1845-ALT	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M3 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1846	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF5L COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1846-ALT	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF3 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1853	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1/2, PF3, PF4 COIL SCHEMATIC
B-4F1005 SH 1853C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF3 COIL SCHEMATIC
B-4F1005 SH 1854C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF4 COIL SCHEMATIC
B-4F1005 SH 1854CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS PF4 COIL SCHEMATIC
B-4F1005 SH 1854CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF4 COIL SCHEMATIC (NOT SIGNED)
B-4F1005 SH 1855	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1, PF2, PF3 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1855C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF3 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1856	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF4 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1856C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF4 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1856CV1	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS PF4 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1856CV1	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF4 COIL CONTROL WIRING DIAGRAM (NOT SIGNED)
B-4F1005 SH 1861	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1/2, 3, 4 COIL SCHEMATIC
B-4F1005 SH 1865	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M2 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1871C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1,M2,M3 COIL SCHEMATIC
B-4F1005 SH 1871CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS M2,M3 COIL SCHEMATIC
B-4F1005 SH 1871CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M2,M3 COIL SCHEMATIC (NOT SIGNED)
B-4F1005 SH 1875C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M1,M2,M3 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1875CV4	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS PF1 AND PF2 COIL CONTROL WIRING DIAGRAM

B-4F1005 SH 1875CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS M2 AND M3 COIL CONTROL WIRING DIAGRAM
B-4F1005 SH 1875CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS M2 AND M3 COIL CONTROL WIRING DIAGRAM (NOT SIGNED)
B-4F1005 SH 1885CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS TRANSMISSION COIL CURRENT SENSORS (NOT SIGNED)
B-4F1005-1899	P1		NCSX DC SYSTEMS POWER SYSTEM ONE-LINE
B-4F1005 SH 1899	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS TEST CELL PENETRATIONS
B-4F1005 SH 1899opp_1	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS TEST CELL PENETRATIONS
B-4F1005 SH 1899opp_v1	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS TEST CELL PENETRATIONS
B-4F1005 SH 1899CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS TEST CELL PENETRATIONS
B-4F1005-1900	PDR		NCSX DC SYSTEMS C-SITE DC SYSTEMS POWER SYTEM ONE LINE FOR PDR SLIDE 100103
B-4F1005-1900-1	PDR		NCSX DC SYSTEMS C-SITE DC SYSTEMS POWER SYTEM ONE LINE FOR PDR SLIDE 100103
B-4F1005 SH 1900C	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS POWER SYTEM BLOCK DIAGRAM
B-4F1005 SH 1900CV4	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS ONE LINE DIAGRAM
B-4F1005 SH 1900CV4	R1		NCSX DC SYSTEMS C-SITE DC SYSTEMS ONE LINE DIAGRAM (NOT SIGNED)
2003-080-S1-SKETCH	P1		NCSX D-SITE TO C-SITE CABLE BRIDGE THOUGHTS
2003-080-S2-SKETCH	P1		NCSX D-SITE TO C-SITE CABLE BRIDGE THOUGHTS
2003-080-S5-SKETCH	P1		NCSX D-SITE TO C-SITE CABLE BRIDGE THOUGHTS
BUSMGROOM	P1		NCSX C-SITE MG TUNNEL ROW C AND E PENETRATIONS (CONCEPT)
FCPCSE-1	P1		NCSX-FCPC POWER CABLE TRAY CONCEPT
NB4F1900	P1		PDR SLIDE
P7180002 THRU 9			PICTURES OF C-SITE MG TUNNEL PENETRATIONS
PS-ASSIGN-C-SITE-082504			EXCEL SPREAD SHEET FOR POWER SUPPLY ASSIGNMENTS
PSS-ASSIGN-BUSSTUB-021505			EXCEL SPREAD SHEET FOR POWER SUPPLY BUS STUBS
NCSX-CSITE-CABLE-LIST.XLS	P1		CABLE LIST SPREAD SHEET
S410E001	R2	X	NCSX C-CITE AC POWER TEST CELL ARRANGEMENT 1ST FLOOR ELEVATION AT 98'-0"
S410E002	R1	X	NCSX C-CITE AC POWER DISTRUBUTION TEST CELL ARRANGEMENT PLATFORM ELEVATION AT 110'-0"
S410E002	R0	X	NCSX C-CITE AC POWER SYSTEM TEST CELL CONDUIT-DISTRIBUTION SYSTEM MG BUILDING ELEVATION AT 98'-6"
S410E004	R0	X	PLT-141 - WIRING DIAGRAM SH.1
S410E005	R0	X	PLT-142 - WIRING DIAGRAM SH.1
S410E006	R0	X	PLT-333 - WIRING DIAGRAM SH.1
S412E001	P1		CCMGB-EE-1001, 120V, AC POWER CWD
SE431E001-1	P1		NCSX C-SITE DC TRANSMISSION, TRAY LAYOUT
SE431E001-2	R0	X	NCSX C-SITE DC SYSTEMS, C-SITE POWER BUILDING CONDUIT AND TRAY LAYOUT
SE431E001-3	R0	X	NCSX C-SITE DC SYSTEMS, C-SITE POWER BUILDING CONDUIT AND TRAY LAYOUT SECTIONS
S431E003	R1	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS CS BUILDING BSM'T GENERAL ARRG'T.
S431E004	R1	X	NCSX DC SYSTEMS C-SITE COIL POWER SUPPLIES, POWER CABLE CONNECTION DETAILS
S431E005	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS POWER SUPPLY SWITCH CONNECTION
S431E006	R0	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS 20KA SW. S-1F (M1, M2, M3) CONNECTION
S431E007	R1	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS BUS & CABLE TRANSITION PLATES
S431E008	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS NCSX POWER SYS. TRAY & CONDUIT
S431E009	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS TRANSFORMER MOUNTING DETAIL
S431E010	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS 4KA SHUNT ASSEMBLY
S431E011	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS 10KA SHUNT ASSEMBLY
S431E012	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS 20KA SHUNT ASSEMBLY
S431E013	R1	X	NCSX DC SYSTEMS C-SITE DC SYSTEMS RACEWAY LAYOUT & BUS TRANSITION
S431E014	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS SHUNT MONITOR SYS. CWD M1, M2, M3, PF3
S431E015	P1		NCSX DC SYSTEMS C-SITE DC SYSTEMS SHUNT MONITOR SYS. CWD PF6, PF1,2, TF, PF4
SE432E001	P1		NCSX C-SITE TO D-SITE DC TRANSMISSION TRAY LAYOUT (AUGUST 1, 2003)
SE432E001REV	P1		NCSX C-SITE TO D-SITE DC TRANSMISSION TRAY LAYOUT (DECEMBER 1, 2003)
SE432E002_1	P1		NCSX C-SITE TO D-SITE DC TRANSMISSION TRAY AND CABINET GND DIAGRAM (SEPT 30, 2003)
SE-433~2-N (SHEETS 1, 3, 4)	P1		NCSX D-SITE FCPC BLDG EL 118'-9" CONDUIT, TRAY, EQUIPMENT AND PENETRATION LAYOUT CONCEPT
SE433E001-1	R0	X	D-SITE FIELD POWER CONVERSION BUILDING EL 118'-9" CONDUIT AND TRAY LAYOUT (JULY 19, 2004 BID)
SE433E001-2	P1		D-SITE FIELD POWER CONVERSION BUILDING EL 118'-9" TRAY SECTIONS AND DETAILS (FEB 25, 2004)
SE433E001-3	P1		D-SITE FIELD POWER CONVERSION BUILDING EL 118'-9" GENERAL ARRANGEMENT EQUIPMENT LAYOUT (JULY 9, 2004)
SE433E001-4	P1		D-SITE FIELD POWER CONVERSION BUILDING EL 118'-9" FLOOR AND ELEVATION PENETRATION LAYOUT AUGUST 1, 2004)
6864-B-150-PL	R4	X	LP-31
6864-B-264-PL	R3	X	LDP-142
6864-B-265-PL	R2	X	LDP-143

6864-B-768-PL	R1	X	LP-181
6864-B-769-PL	R2	X	LP-182
6864-B-770-PL	R0	X	LP-183
6864-B-771-PL	R0	X	LP-184
6864-B-772-PL	R1	X	LP-185
6864-B-773-PL	R1	X	LP-186
6864-B-774-PL	R0	X	LP-187
6864-B-775-PL	R0	X	LP-188
6864-B-776-PL	R1	X	LP-189
6864-B-777-PL	R1	X	LP-191
6864-B-778-PL	R1	X	LP-192
6864-B-779-PL	R2	X	LP-195
6864-B-497-PL	R2	X	LP-889
6864-D-263-OL	R3	X	PP141
C-NCSX-IP-2985	R0	X	NCSX C-SITE DC SYSTEM RACEWAY AND CABLE INSTALLATION
C-NCSX-IP-2986	R0	X	NCSX COIL SYSTEM DC BUS PREPERATION
C-NCSX-IP-2991	R0	X	NCSX DC BUS FABRICATION AND WELDING
D-NCSX-AP-0010.DOC	R0		ACCESS PROCEDURE, NCSX COIL TEST FACILITY
D-NCSX-IP-0001.DOC	P1		INSTALLATION OF NCSX DISCONNECT SWITCH CABLES TO NSTX DISCONNECT SWITCH
D-NCSX-IP-0002.DOC	P1		NCSX INSTALLATION PROCEDURE
D-NCSX-IP-0003.DOC	P1		NCSX INSTALLATION PROCEDURE
D-NCSX-IP-0004.DOC	P1		NCSX INSTALLATION PROCEDURE
D-NCSX-IP-0005.DOC	P1		NCSX INSTALLATION PROCEDURE
D-NCSX-IP-0006.DOC	P1		INSTALLATION OF NCSX DISCONNECT SWITCH CABLES TO NSTX DISCONNECT SWITCH
SOW021103.DOC			
NSTX-NCSX-PS-ASSIG-042704.XLS	P1		POWER SUPPLY NOMENCLATURE LIST
202-080-TOC.DOC	R0		DC TRANSMISSION SYSTEMS TABLE OF CONTENTS
202-080-01010.DOC	R0		DC TRANSMISSION SYSTEMS SUMARY OF WORK
202-080-01270.DOC	R0		DC TRANSMISSION SYSTEMS UNIT PRICES
202-080-02466.DOC	R0		DC TRANSMISSION SYSTEMS DRILLED PIERS
202-080-05120.DOC	R0		DC TRANSMISSION SYSTEMS STRUCTURAL STEEL
202-080-09912.DOC	R0		DC TRANSMISSION SYSTEMS PAINTING
202-080-16139.DOC	R0		DC TRANSMISSION SYSTEMS CABLE TRAY
PPPL NCSX SPEC COVER.DOC	R0		PPPL NCSX SPEC COVER
2003-080-E1			The burns group - NCSX DC TRANSMISION, ELECTRICAL SITE PLAN
2003-080-E2			The burns group - NCSX DC TRANSMISSION, ELECTRICAL BUILDING D52 PLAN AND ELEVATION CABLE TRAY SYSTEM
2003-080-E3			The burns group - NCSX DC TRANSMISSION ELECTRICAL CABLE TRAY DETAILS AT COLUMNS
2003-080-G1			The burns group - NCSX DC TRANSMISSION COVER SHEET
2003-080-S1			The burns group - NCSX DC TRANSMISSION STRUCTURAL SITE PLAN
2003-080-S2			The burns group - NCSX DC TRANSMISSION STRUCTURAL TRAY SUPPORTS #1, #2 AND #2A SECTIONS AND DETAILS
2003-080-S3			The burns group - NCSX DC TRANSMISSION STRUCTURAL TRAY BRIDGE #1 SUPPORT PLAN SECTIONS AND DETAILS
2003-080-S4			The burns group - NCSX DC TRANSMISSION STRUCTURAL TRAY BRIDGE #2 SUPPORT PLAN SECTIONS AND DETAILS
2003-080-S5			The burns group - NCSX DC TRANSMISSION STRUCTURAL BUILDING D52 SUPPORT PLAN AND SECTIONS
2003-080-S6			The burns group - NCSX DC TRANSMISSION STRUCTURAL BUILDING D52 SUPPORT ENLARGED PLAN, SECTIONS AND DETAILS
2003-080-S7			The burns group - NCSX DC TRANSMISSION STRUCTURAL BUILDING D52 SUPPORT ENLARGED PLAN, SECTIONS AND DETAILS
2003-080-S8			The burns group - NCSX DC TRANSMISSION STRUCTURAL BUILDING D52 SUPPORT ENLARGED PLAN, SECTIONS AND DETAILS
2003-080-S9			The burns group - NCSX DC TRANSMISSION STRUCTURAL BUILDING D52 FOUNDATION AND PENETRATION DETAILS
2003-080-S10			The burns group - NCSX DC TRANSMISSION STRUCTURAL BUILDING C52 PENETRATION DETAILS
COMMENT - SIGNED OFF DRAWINGS ARE STORED IN P:\DEPARTMENTS\CADD\ARCHIVE			
COMMENTS - WORK IN PROGRESS - PRELIMINARY AND UPDATED, BUT NOT SIGNED ARE STORED IN P:\DEPARTMENTS\CADD\ARCHIVE\NCSX DC TRANSMISSION_COIL POWER			

Electrical Power Systems (WBS 4)

S. Ramakrishnan

NCSX PWR System

April 08 2008

Content of Presentation

- Requirements
- Interfaces
- Design status or plans
- Procurement status or plans
- Cost and schedule estimates
- Staffing
- Risks and mitigation
- Responses to past review recommendations

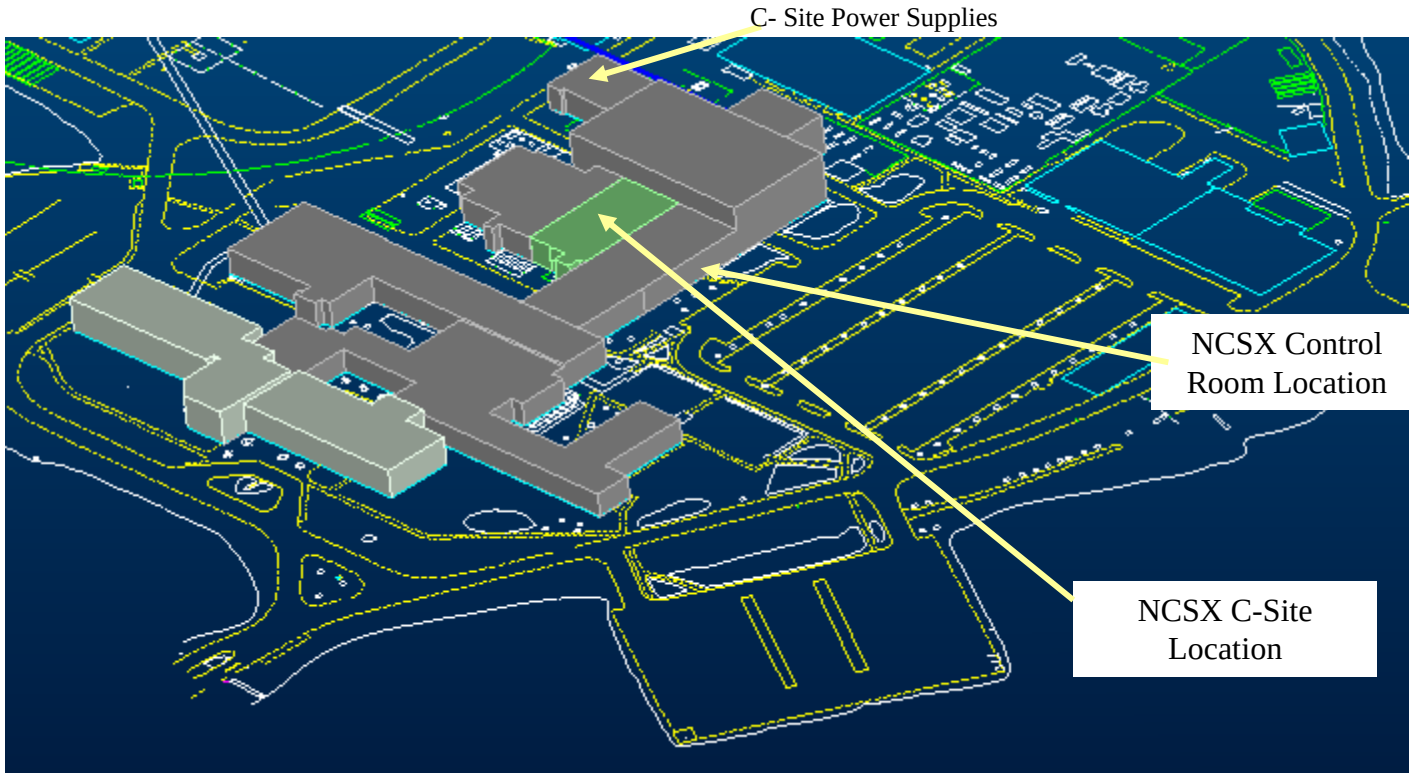
ELECTRICAL POWER SYSTEM
REQUIREMENTS

- **Provide Source of all Electric Power for NCSX**
  - **All AC Power**
    - **At all Distribution Voltage levels**
      - » **4.16kV,480V, 208/120V**
      - » **Includes Experimental AC Power**
      - » **Includes AC Power to NB**
      - » **Includes all Auxiliary AC Power up to Power Panels**
  - **All DC Experimental Power**
    - **Provide DC power for stellarator coil systems**
      - **2 Modular, and 3 PF coil circuits**
        - » **PS requirements based on Initial Ohmic Scenario**
        - » **Clear path for future upgrades (other scenarios, flexibility)**
- **Provide Diagnostics support for Sensor cabling**
- **Grounding**

REQUIREMENTS CONTD.

• AC SYSTEM	- USE EXISTING C- SITE SYSTEM WITH NEW 480/120 SYSTEM FOR TEST CELL
• ESAT RECTIFIERS	- USE EXISTING – 6 ROBICONS/ 1 PEI
	- RECONFIGURE
•	- ASSIGN FOR NCSX LOADS AS NEEDED
• SDS	- USE EXISTING UNITS IN TEST CELL BASEMENT WITH CHANGES REQUIRED
	- NEW PWR CABLING FROM SDS TO COILS
• HCS	- PURCHASE AND INSTALL PLC.
	- NEW CABLING AS NEEDED
• MEASUREMENTS	- USE SHUNTS/DCCTs IN PWR SUPPLIES
	- USE NEW FIBER OPTIC TRANSMITTERS
• CONTROLS	- PLC , CABLING AS IS & MODIFIED
• PROTECTION	- USE EXISTING WITH CHANGES & ADDITIONS
	- NEW CABLING AS NEEDED
• KIRKEYS	- USE EXISTING WITH CHANGES

PPPL Site Plan



INTERFACES – SALIENT DETAILS

- ALL WBS
  - LIST OF LOADS TO BE FED WITH LOAD DETAILS
  - PHYSICAL LOCATION OF LOADS IN GENERAL ARRANGEMENT
- WBS1 (Stellarator Core)
  - CURRENT CAPABILITY & i^2*t CAPABILITY
  - OVERCURRENT & i^2*t SETTINGS TO TRIP
  - PERMISSIVE - PERMIT TO PS
  - TRIP COMMAND TO PS
  - PHYSICAL LOCATION OF COIL LEADS TERMINAL BOXES
  - GROUNDING PADS ON EACH CONTIGUOUS METALLIC STRUCTURE OF MACHINE TO ACCEEPT GROUNDING CABLES (NEMA LUGS)
- WBS 5 (Control I&C)
  - HARDWIRED INTERLOCK SYSTEM INTERFACE
    - INCLUDES, PERMISSIVE, ARM/DISARM, ENABLE/DISABLE, E-STOP
    - COMMAND TO WBS5 PLC TO OPEN AND CLOSE DISCONNECTS
    - PRE-PROGRAMMED CURRENT PROFILE
- WBS 8 (TC Prep & Machine Assembly)

  PENETRATIONS AND FIRESEALS WILL BE REQUESTED BY WBS4.

DESIGN STATUS/PLANS

- C-site Rectifier power supplies used for Coil circuits
- Six (6) Robicon Rectifier Supplies. Each of (2) 6-pulse, 2-quadrant converters in parallel - 12-pulse rectified DC output.
- One (1) PEI Rectifier Supply. Two 6-pulse rectifier bridges in parallel - 12-pulse DC output

- Sufficient power available for First Phase
- Future upgrades with D-Site Supplies
- Completed testing (Dummy Load) on six out of seven C-Site supplies

Typical Circuit Arrangement

- **Disconnect and grounding switches provided for each circuit**
- **Some of Existing cables used from Rectifier Supplies to Disconnects in Test Cell Basement**
- **New Cables (4/c- 500mcm, 600V) from "Disconnects" TO "Box of Coil Terminals"**
- **Current/ Voltage transducers will be provided**
- **Changeover to LTX possible by disconnecting Jumpers at top of Disconnects.**

NCSX National Compact Stellarator Experiment

Power Supplies Assignment

1st plasma & Magnetic Configuration				
Circuit	Power Supply	Current 1.5s / 180s	Volts	Peak MW
M1	P10	10kA	200V	2
M2 + M3	P5-1 & 4 (parallel)	10kA	300V	3
PF4	P5-2 in series with PEI	5kA	800V	4
PF6	P5-3	5kA	300V	1.5
PF1a	P20	20kA	500V	10

PS Control and Coil Protection

- **PS Control**
  - PLC will be provided for Controls
  - Modern PLC based system
    - Additional interlocks as needed
    - Some protective features included
  - Current profile will be received from WBS4

- **PROTECTION**
  - Coil / Pwr. Loop protection provided
    - Overcurrent (Built-in the Pwr. Supplies)
    - Ground fault
    - Pulse duration & period (PDP) limit

WBS BREAKDOWN & COST

WBS	SYSTEM	M&S	LABOR	TOTAL COST	Design Maturity	Design Complexity
		k$	k$	k$		
411	Auxiliary AC Power	38	111	154	*High*	*Low*
431	C-site AC/DC Converters	199	386	581	*High*	*Low*
441	Control & Interlocks	115	372	471	*Medium*	*Low*
442	Kirk Key Interlocks	18	55	72	*Medium*	*Low*
443	Real Time Control	0	14	14	*Medium*	*Low*
444	Instrumentation	28	196	241	*Medium*	*Low*
445	Coil Protection	31	244	273	*Medium*	*Low*
451	System Design	0	320	320	*High*	*Low*
452	Electrical Systems Support	3	195	199	*High*	*Low*
453	System Testing	33	353	386	*High*	*Low*
		465	2255	2720		

PROCUREMENT STATUS & PLANS

WBS4 PROCUREMENT WILL START IN 2010.

- MISC. SPARES FOR POWER SUPPLIES AS NEEDED
- POWER & CONTROL CABLES AS REQUIRED PER SCHEDULE
- POWER CABLE INSTALLATION CONTRACT WILL BE AWARDED PER SCHEDULE.
- PLC PER SCHEDULE
- KIRK KEY INTERLOCKS
- POWER PANELS, BUSBARS, DCCTS & SIGNAL LINKS

SCHEDULE & COST/ STAFFING

- ALL TASKS WILL COMMENCE 10/01/08 AND FINISH BY 09/01/11
- TOTAL IN-HOUSE LABOR (including overheads)
  - 2255K$
- TOTAL M&S (INCLUDES CONTRACT LABOR)
  - 465K$
- TOTAL ETC (May 01 2007) COST
  - 2,720K$
- SEE WAF FOR DETAILED BREAKDOWN

➢ STAFFING

- **ALL PERSONNEL ARE PLANNED TO BE MULTI-TASKED BETWEEN PROJECTS**
- **S.RAMAKRISHNAN, R. MARSALA, R. HATCHER, M. AWAD, E.BAKER, J. LAWSON, M. CROPPER, D. MCBRIDE, F.JONES, R. VAN KIRK, J. NELSON, TECH SHOP CREW, SUB-CONTRACTORS**

RISK & MITIGATION

Response to past Reviews

- **Using existing C-site Rectifier supplies for First Plasma is cost-effective for powering NCSX coils**
  - **These supplies have been used for other machines earlier**
  - **Existing AC power distribution system at C-site will feed other loads & have been used for PBX/PLT/LTX**
- **Clear Upgrade path provided for final stage.**

- **Technical & cost risks ARE MINIMAL**
  - **Since this is standard electrical work**
  - **Cost is based on industry feedback &**

    PPPL experience on past projects – Similar tasks in NSTX completed on time within budget
  - **Is performed by experienced personnel who worked in similar tasks in NSTX/ LTX, TFTR & upgrades**
  - **Careful planning will mitigate schedule risk**
  - **Multitasking individuals have been properly planned. Other projects like NSTX also been successfully completed in this way.**
  - **Highest priority to Personnel Safety**

- **Response to past reviews:**
  - **The schedule has been advanced as recommended in the earlier review**
  - **A peer review on Protection has been completed. Twenty chits generated – being addressed**

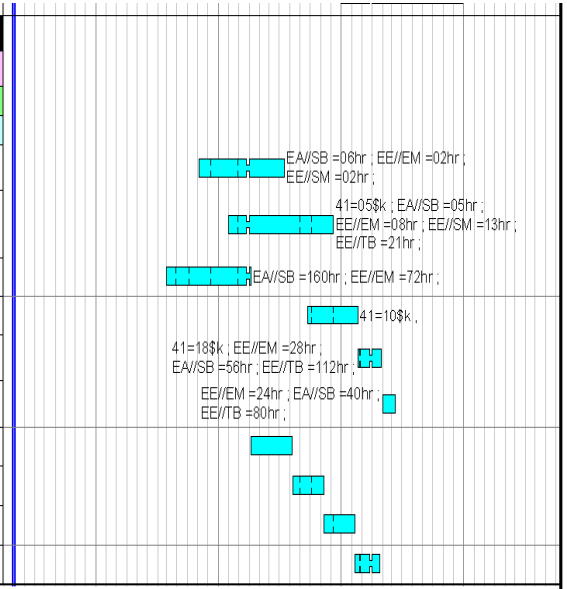
RESOURCE LOADED SCHEDULE

41 - AC Power

Job: 4101 - AC Power-RAMAKRISHNAN

411 - Auxiliary AC Power Systems

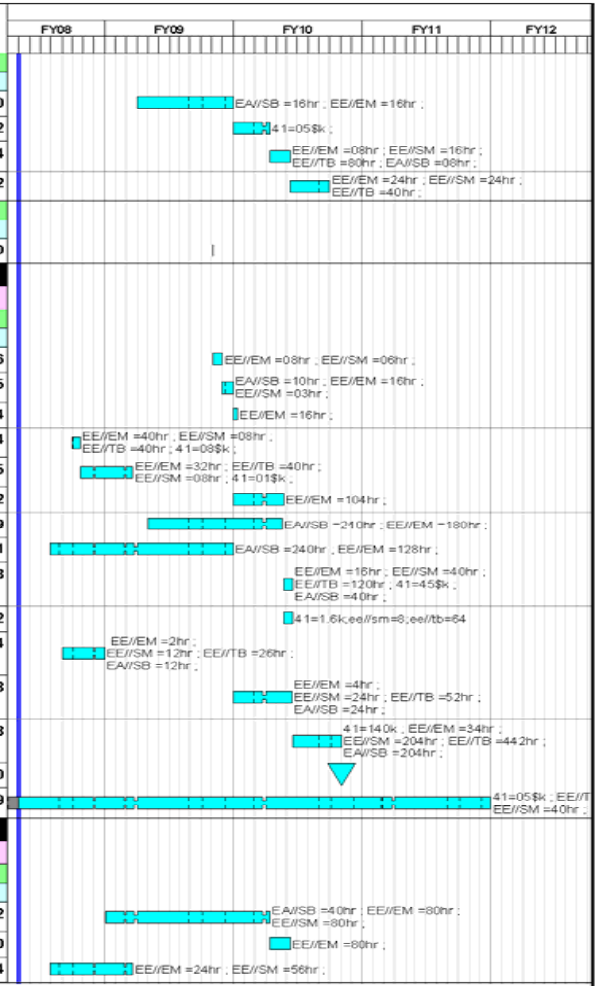
4101-100.1		Prepare Preliminary One line diagram	173		03AUG09*	15APR10	133	1,371.84
411-1-100		Ex-Test cell AC pwr-Reactiv.&new instl	210		02NOV09*	08SEP10	223	12,285.52
411-2-2		Grounding-Dsn	165		01MAY09*	05JAN10	205	31,659.40
411-2-4		Grounding-Procure	107		21JUN10*	18NOV10	133	13,477.94
411-2-6		Grounding-Install	43		19NOV10*	28JAN11	133	45,808.84
411-2-8		Grounding-Commission	29		31JAN11*	10MAR11	133	16,324.08
411-3-2		Test Cell AC Power Distr-Dsn**GPP**	90		04JAN10*	07MAY10	178	0.00
411-3-4		TC AC Pwr Distr-Procure(pnls&xfrmrs)**GPP**	65		10MAY10	10AUG10	178	0.00
411-3-6		Test Cell AC Power Distr-Install**GPP**	65		11AUG10	10NOV10	178	0.00
411-3-8		Test Cell AC Power Distr-Commission**GPP**	45		11NOV10*	24JAN11	178	0.00



RESOURCE LOADED SCHEDULE –Contd.

NCSX National Compact Stellarator Experiment

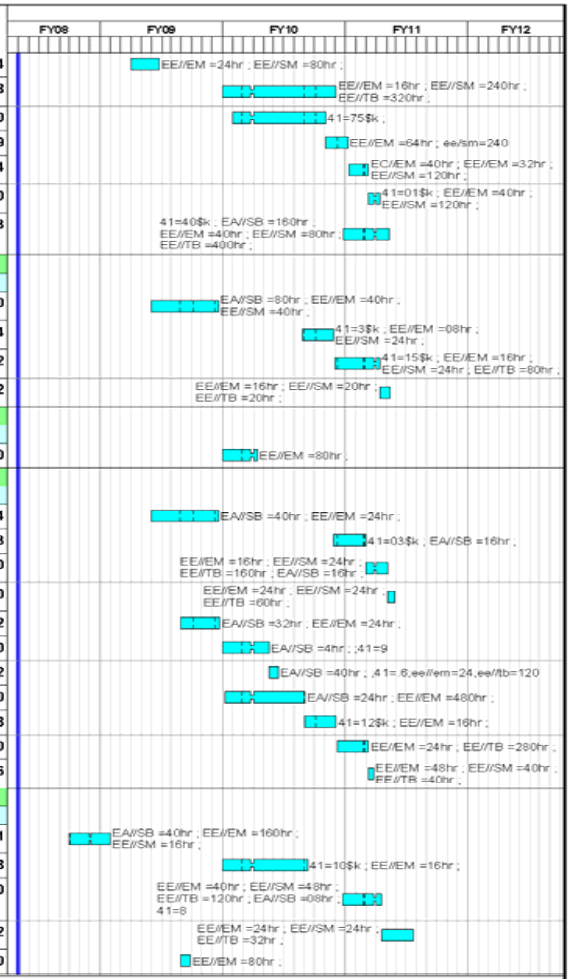
Activity ID	MILE -STONE LEVEL	Activity Description	Duration (work days	SHIFTS	Forecast Start	Forecast Finish	Total Float	Cost to Complete
412 - Experimental AC Power Systems								
412-1-2		C-site Pulsed AC Power Distr-Dsn	190		02JAN09*	29SEP09	265	4,615.20
412-1-4		C-site Pulsed AC Power Distr-Procure	65		30SEP09	12JAN10	318	6,682.62
412-1-6		C-site Pulsed AC Power Distr-Install	40		13JAN10	09MAR10	318	11,156.64
412-1-8		C-site Pulsed AC Power Distr-Commission	78		10MAR10	28JUN10	318	10,897.92
x			1		03AUG09	03AUG09	133	0.00
43 - DC Systems								
Job: 4301 - DC Systems-RAMAKRISHNAN								
431 - C-Site DC Systems								
431-200		Condition/spare parts inventory	20		03AUG09*	28AUG09	433	2,202.46
431-210		Organize & verify documentation	20		31AUG09*	28SEP09	433	4,322.55
431-215		Document status	10		29SEP09*	12OCT09	433	2,757.54
431-225		Reactivate DF & PEI units	15		01JUL08*	22JUL08	634	20,332.24
431-230		Duumy Load test of DF & PEI units	105		23JUL08	19DEC08	634	10,683.15
431-240		Simulate each of 6 pwr loops in PSCAD	90		01OCT09*	17FEB10	234	18,026.32
431-250		c-site dc sys DGS dsn documentation	259*		02FEB09*	16FEB10	235	59,717.19
431-261		Redo power loop design	355		01MAY08*	30SEP09	324	49,537.71
431-265		Fabricate bus components	20		18FEB10*	17MAR10	234	83,399.88
431-274		Penetrations through floor	20		18FEB10	17MAR10	234	8,460.32
431-275A		Power cabling & Installation FY08	85*		02JUN08*	30SEP08	1,521	4,407.34
431-275B		Power cabling & Installation FY10	107		01OCT09*	12MAR10	1,165	11,361.68
431-275		Power cabling & Installation	97		18MAR10*	03AUG10	234	283,754.28
431-275M	2	C-site DC Systems Installed	0			03AUG10	234	0.00
431-276		Maint of C-site rectifiers	997*		01OCT07A	30SEP11	774	20,234.19
44 - Control and protection Systems								
Job: 4401 - Control & Protection-RAMAKRISHNAN								
441 - Electrical Interlocks								
441-095		Design Interlock sys	310		03OCT08*	11JAN10	338	29,853.12
441-097		Install Interlock sys	40		14JAN10*	10MAR10	336	25,602.40
441-100		PLC Specification	160		01MAY08*	17DEC08	311	11,584.74



RB08 NCSX Project Sheet 52 of 73 21MAR08 16:15

RESOURCE LOADED SCHEDULE- Contd.

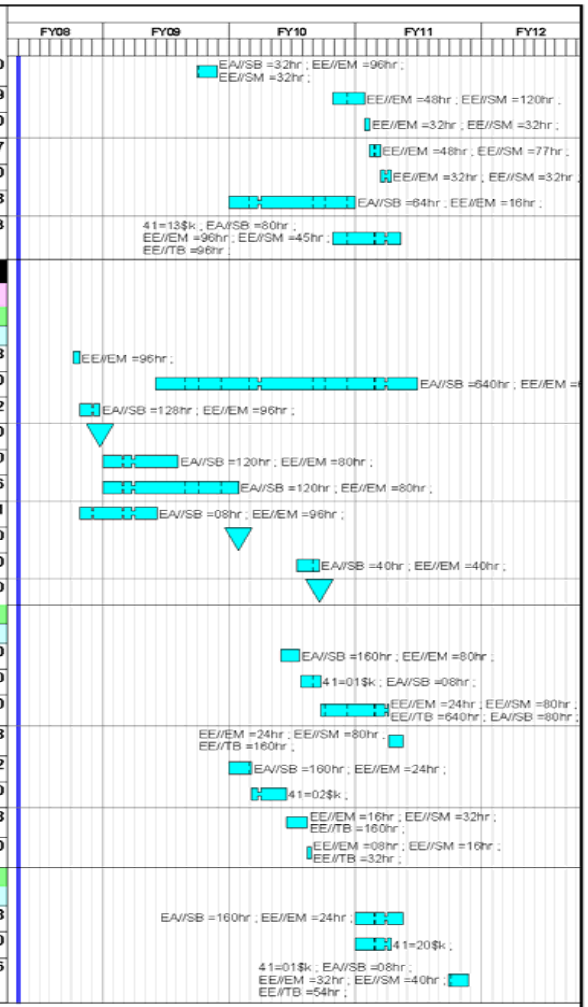
Activity ID	MILE -STONE LEVEL	Activity Description	Duration (work days	SHIFTS	Forecast Start	Forecast Finish	Total Float	Cost to Complete
441-105		Prep Block diagrams	60		02JAN09*	26MAR09	307	15,444.24
441-110		PLC CWD's & Cabling	228		01OCT09*	01SEP10	116	63,718.88
441-115		deliver PLC	187*		02NOV09*	05AUG10	100	100,275.00
441-120		Program PLC Logic	45		06AUG10	08OCT10	100	46,613.89
441-125		Program Control pages	40		11OCT10	07DEC10	100	30,369.84
441-130		Pre-commissioning tests	20		08DEC10	12JAN11	100	27,150.40
441-135		Install I/O Cabling control & protection	90		27SEP10	09FEB11	100	128,771.03
442 - Kirk Key Interlocks								
442-1-2		Kirk Keys-Dsn	140		02MAR09*	16SEP09	276	22,040.80
442-1-4		Kirk Keys-Procure	65		27MAY10*	27AUG10	106	8,918.44
442-1-6		Kirk Keys-Install	90		30AUG10*	13JAN11	106	33,632.42
442-1-8		Kirk Keys-Commission	20		14JAN11	10FEB11	106	7,686.72
443 - Real Time Control Systems								
443-1-2		Develop Control Algorithms-Dsn	65		01OCT09*	13JAN10	376	13,866.40
444 - Instrument Systems								
444-2-2		DC Potential Transducers (DCPTs)-Dsn	140		02MAR09*	16SEP09	331	8,843.44
444-2-4		DC Potential Transducers (DCPTs)-Procure	65		27AUG10*	30NOV10	97	6,113.43
444-2-6		DC Potential Transducers (DCPTs)-Install	40		01DEC10	02FEB11	97	22,211.60
444-2-8		DC Potential Transducers (DCPTs)-Commission	15		03FEB11	23FEB11	97	13,140.60
444-3-2		DCCT Design	81		01JUN09*	23SEP09	338	7,883.12
444-3-4		Procure DCCT	88		01OCT09*	15FEB10	333	12,527.20
444-3-6		Install DCCT	20		16FEB10*	15MAR10	333	19,555.72
444-4-2		Signal Conditioning & Cabling-Dsn	160*		08OCT09*	03JUN10	136	86,163.60
444-4-4		Signal Conditioning & Cabling-Procure	65		04JUN10*	03SEP10	136	18,817.28
444-4-6		Signal Conditioning & Cabling-Install	65		07SEP10	08DEC10	136	27,658.90
444-4-8		Signal Conditioning & Cabling-Commission	10		09DEC10	22DEC10	136	18,287.36
445 - Coil Protection Systems								
445-1-2		Ground Fault Protection-Dsn	87		01JUL08*	31OCT08	352	32,648.51
445-1-4		Ground Fault Protection-Procure	170		01OCT09*	10JUN10	126	16,143.28
445-1-6		Ground Fault Protection-Install	75		22SEP10*	14JAN11	55	36,681.60
445-1-8		Ground Fault Protection-Commission	70		17JAN11	22APR11	55	10,774.32
445-2-105		Overload Protect-Write spec and approve	20		01JUN09*	26JUN09	337	13,472.80



RB08 NCSX Project Sheet 53 of 73 21MAR08 16:15

RESOURCE LOADED SCHEDULE – Contd.

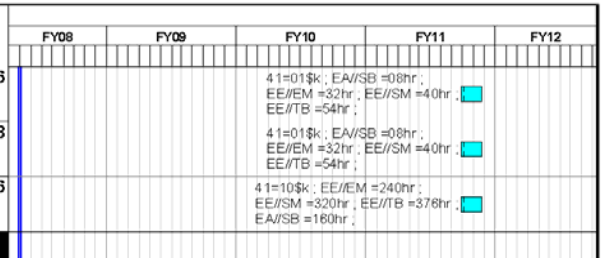
Activity ID	MILE -STONE LEVEL	Activity Description	Duration (work days	SHIFTS	Forecast Start	Forecast Finish	Total Float	Cost to Complete
445-2-110		Overload Protect-Design	40		29JUN09	24AUG09	337	24,569.60
445-2-115		Overload Protect-Fabr 4 chassis	65		28JUL10*	27OCT10	129	26,307.79
445-2-120		Overload Protect-Test 4 units	10		28OCT10	10NOV10	129	10,760.00
445-2-125		Overload Protect-Install & Rack wiring	20		11NOV10	10DEC10	129	20,609.77
445-2-130		Overload Protect-Write & perform ISTP	15		13DEC10	10JAN11	129	10,760.00
445-2-135		Overload Protect-Documentation	246		01OCT09*	28SEP10	1,026	10,680.48
445-2-140		Overload Protection&cabling design,procure instl	130		28JUL10*	07FEB11	109	59,842.63
45 - Power System Design and Integration								
Job: 4501 - Power Sys Dsn & Integr-RAMAKRISHNAN								
451 - System Design & Interfaces								
451-0-2		Develop SRD	15		07JUL08*	25JUL08	311	15,276.48
451-3-2		Dwgs,asbuilts -Elect Dsn Integration	520		02MAR09*	31MAR11	902	190,706.70
451-2-2		PDR Prep Power system -Dsn	40		28JUL08	22SEP08	311	29,795.52
451-2-3	2	Power system - PDR	0	R		22SEP08	311	0.00
451-6-2		Final design C-Site -Cabling	149		01OCT08*	08MAY09	424	27,877.60
451-2-2.1		Final Design C-Site	268		01OCT08*	27OCT09	305	27,935.36
451-1-2		Calculations-Dsn	149		28JUL08*	05MAR09	470	16,836.31
451-202.2	2	Power systems C-Site - FDR	0	R		27OCT09	305	0.00
451-4-2		Final Dsn AC auxiliaries & grounding-Dsn	45		16APR10*	18JUN10	133	11,875.20
451-402.1		AC auxiliaries & grounding - FDR	0	R		18JUN10	133	0.00
452 - Electrical Systems Support								
452-1-2		Diagnostics AC Power Distr-Dsn	40		01MAR10*	23APR10	163	33,634.40
452-1-4		Diagnostics AC Power Distr-Procure	40		26APR10	21JUN10	163	2,325.40
452-1-6		Diagnostics AC Power Distr-Install	130		22JUN10	03JAN11	163	79,033.00
452-1-8		Diagnostics AC Power Distr-Commission	30		04JAN11	14FEB11	163	30,222.88
452-2-2		Diagnostics sensor cabling-Dsn	43		01OCT09*	02DEC09	339	23,927.92
452-2-4		Diagnostics sensor cabling-Procure	65		03DEC09	15MAR10	339	2,674.00
452-2-6		Diagnostics sensor cabling-Install	43		16MAR10	13MAY10	339	20,336.48
452-2-8		Diagnostics sensor cabling-Commission	10		14MAY10	27MAY10	339	6,307.60
453 - System Testing (PTP's)								
453-1-2		New Procedures	90		01OCT10*	15FEB11	103	25,140.48
453-1-3		Preop Testing-Procure test equipt	65		01OCT10*	11JAN11	128	27,400.00
453-1-4		TF Coil Test	40		27JUN11	22AUG11	11	18,965.06



RB08 NCSX Project Sheet 54 of 73 21MAR08 16:15

RESOURCE LOADED SCHEDULE – Contd.

Activity ID	MILE -STONE LEVEL	Activity Description	Duration (work days	SHIFTS	Forecast Start	Forecast Finish	Total Float	Cost to Complete
453-1-5		PF Coil Test	40		27JUN11	22AUG11	11	18,965.06
453-1-6		Trim Coil Coil Test	40		27JUN11	22AUG11	11	136,368.68
453-1-8		Testing PTPs, ISTPs	40		27JUN11	22AUG11	11	159,275.76
51 - Network and Fiber Infrastructure								



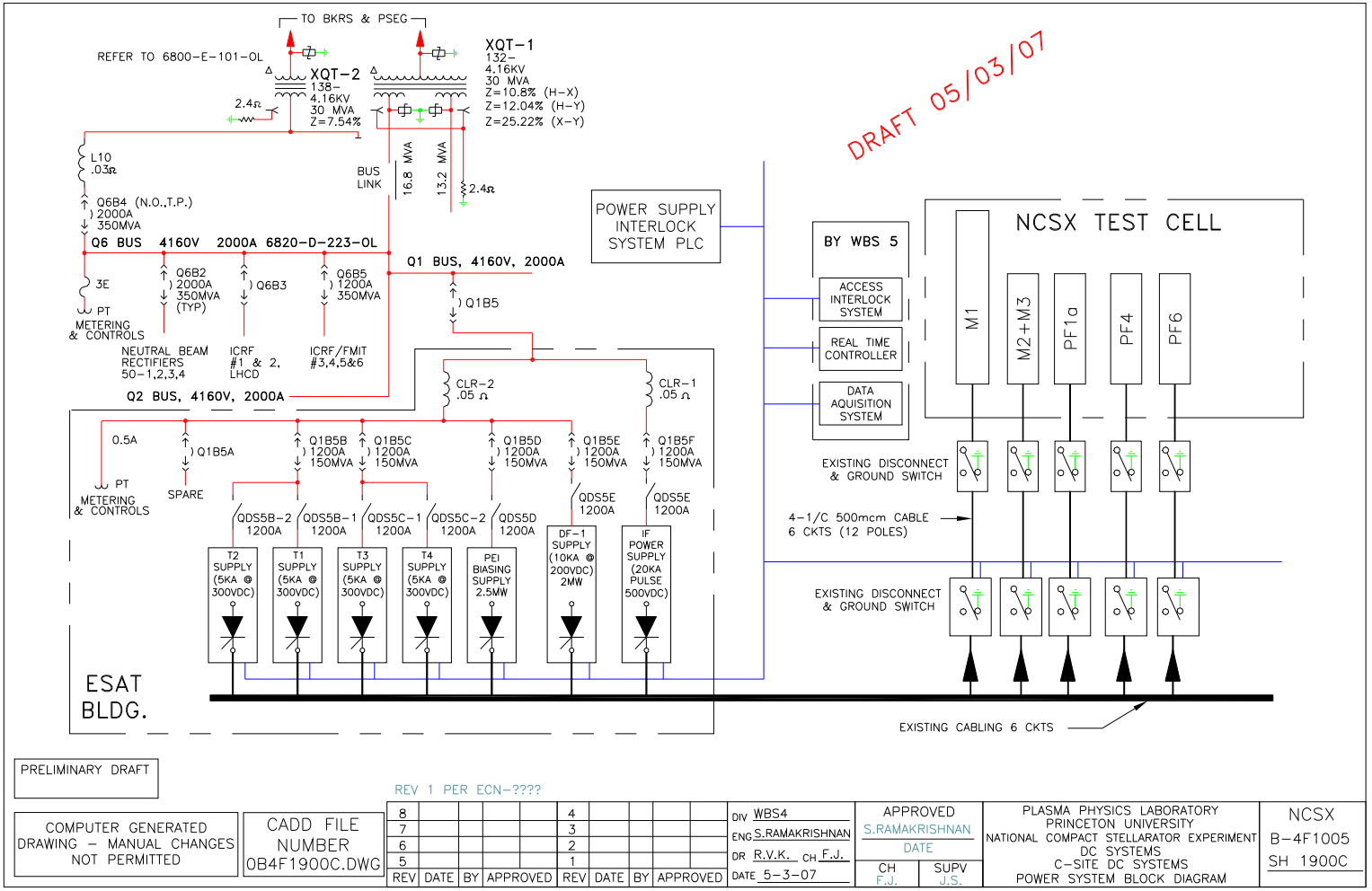
C- SITE SUPPLIES

Back-up slides

C- SITE SUPPLIES

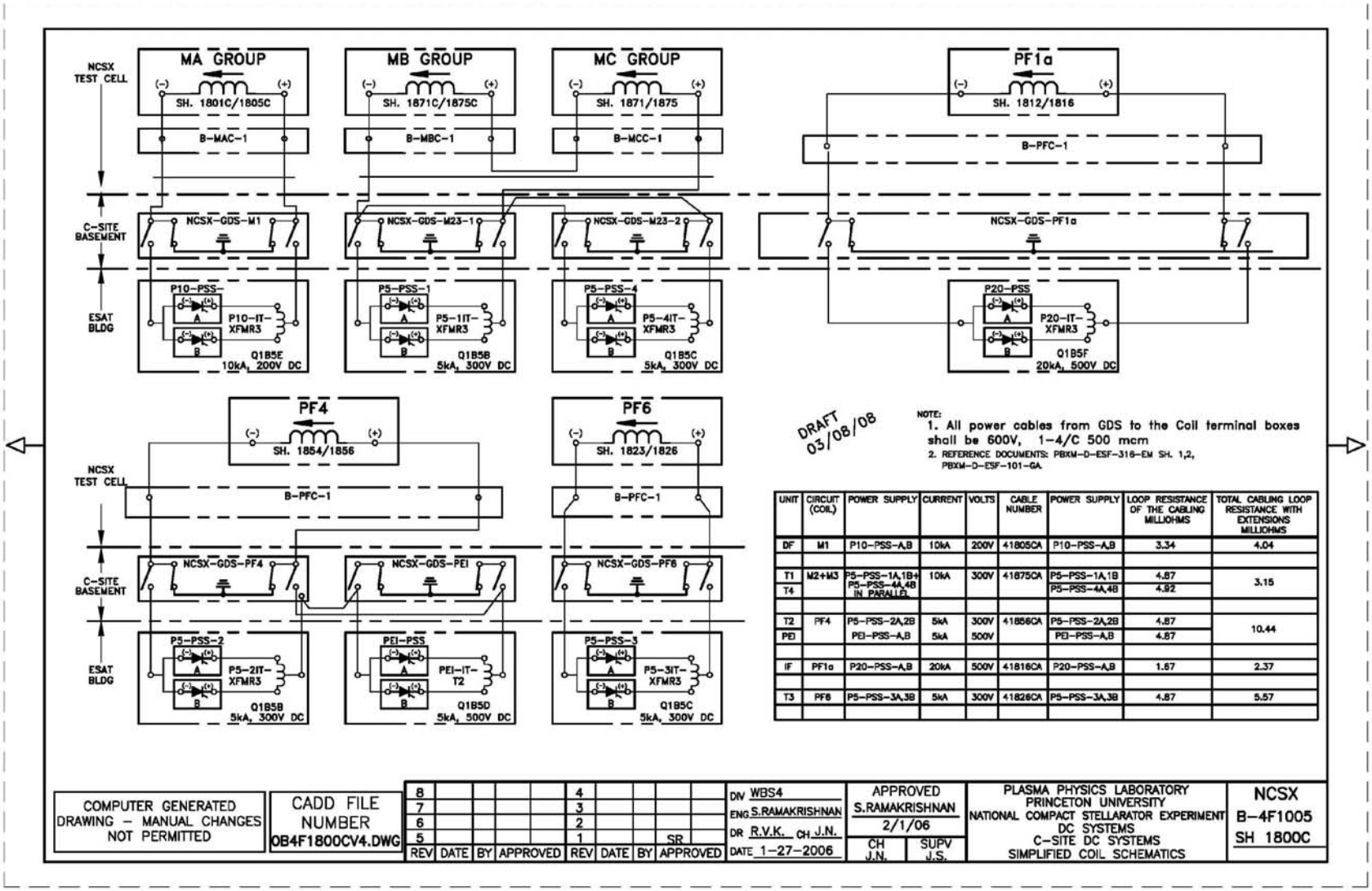
Back-up slides

POWER SYSTEM BLOCK DIAGRAM



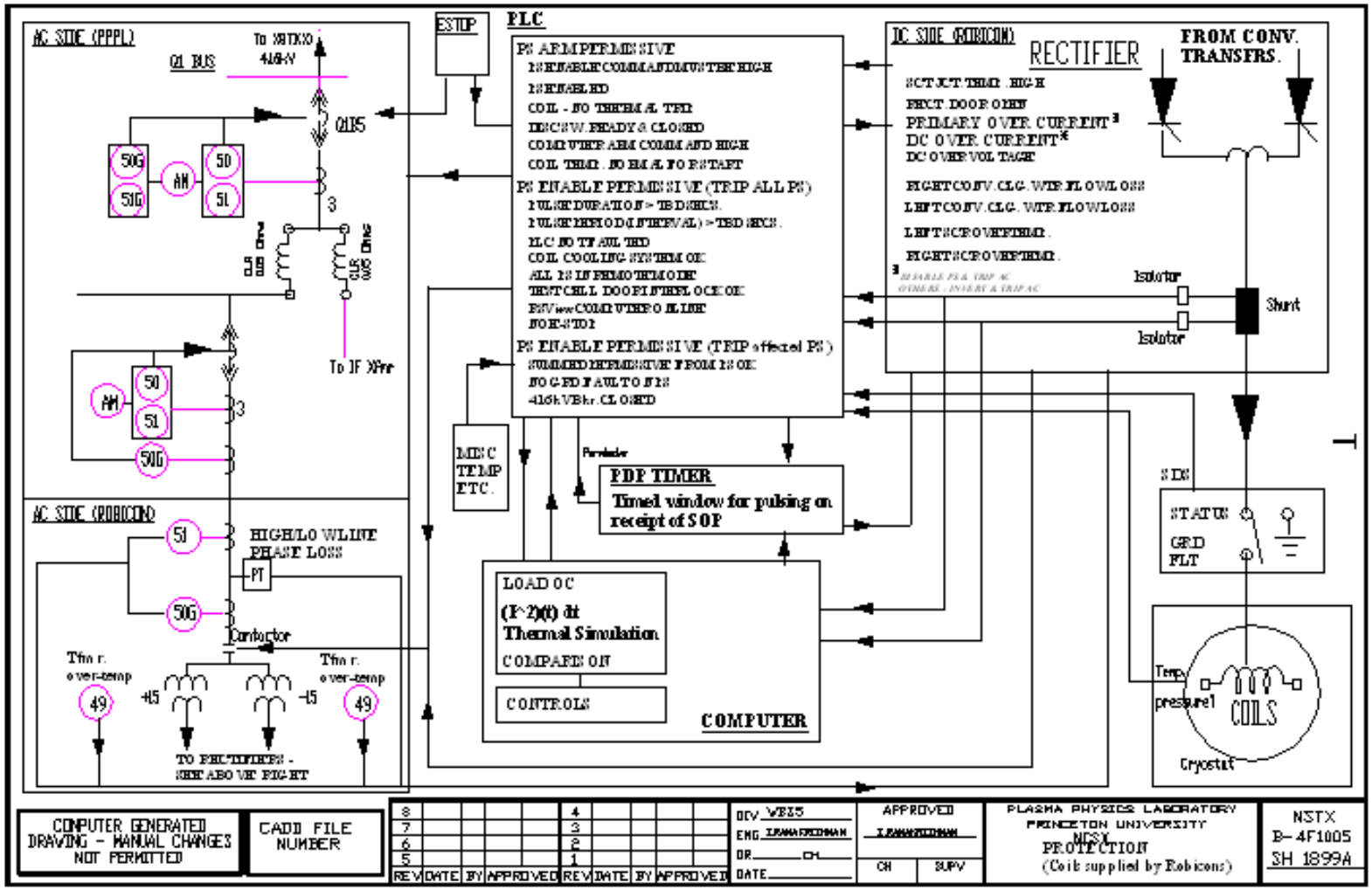
Back-up slides

SIMPLIFIED SCHEMATIC



Back-up slides

PROTECTION BLOCK DIAGRAM



UPGRADE PLAN

- Upgrade plan
- Logical Plan to proceed to Upgrade
  - -- D-Site supplies will be used
  - – Will use D-Site supplies for SIX coil ckts
  - – Two coil ckts will use C-Site supplies
  - – ONE additional DC SUPPLY from C-Site, along with H-Bridges (SPA) to feed Trim Coils