Electrical Power Systems (WBS 4)

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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

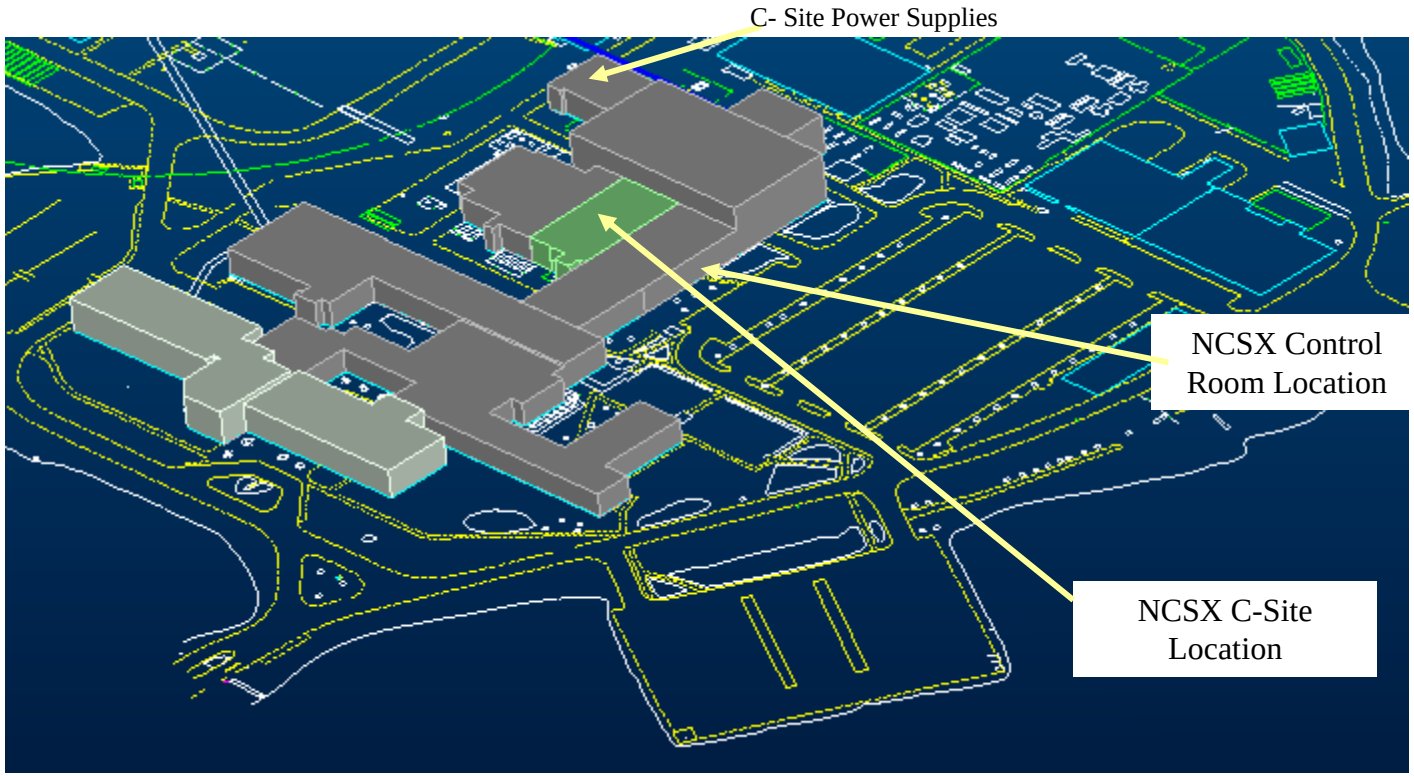
ELECTRICAL POWER SYSTEM
REQUIREMENTS

- **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**

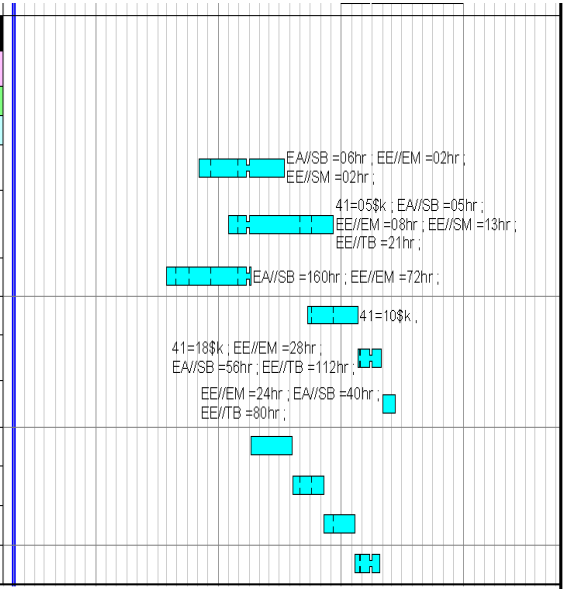
RESOURCE LOADED SCHEDULE

41 - AC Power

Job: 4101 - AC Power-RAMAKRISHNAN

411 - Auxiliary AC Power Systems

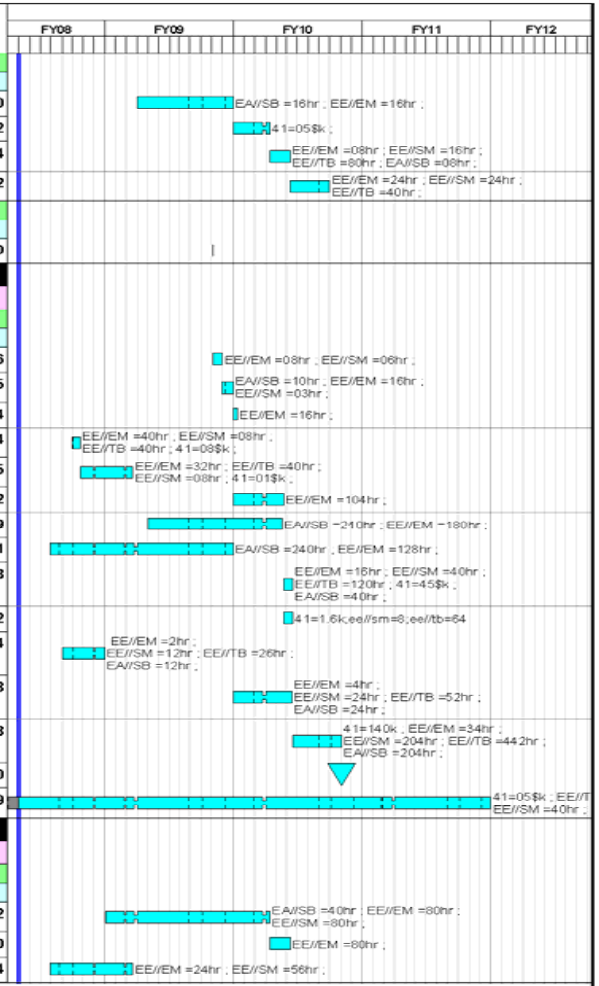
4101-100.1		Prepare Preliminary One line diagram	173		03AUG09*	15APR10	133	1,371.84
411-1-100		Ex-Test cell AC pwr-Reactiv.&new instl	210		02NOV09*	08SEP10	223	12,285.52
411-2-2		Grounding-Dsn	165		01MAY09*	05JAN10	205	31,659.40
411-2-4		Grounding-Procure	107		21JUN10*	18NOV10	133	13,477.94
411-2-6		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



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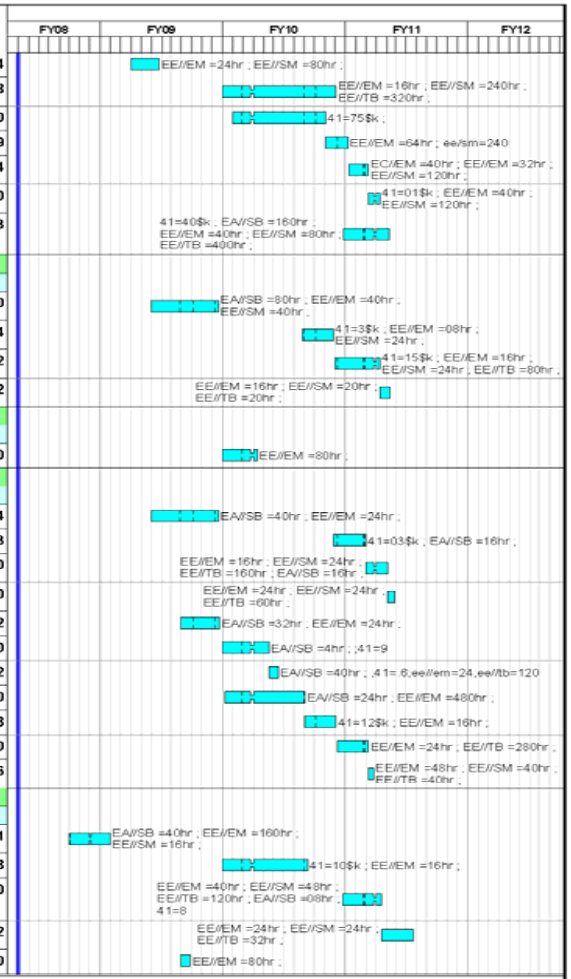
RESOURCE LOADED SCHEDULE- Contd.

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



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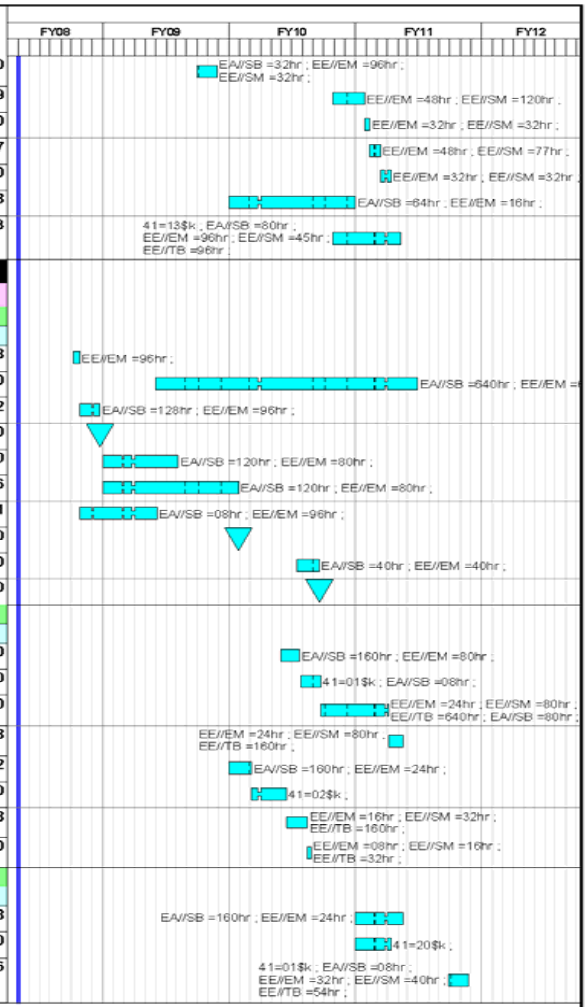
RESOURCE LOADED SCHEDULE – Contd.

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



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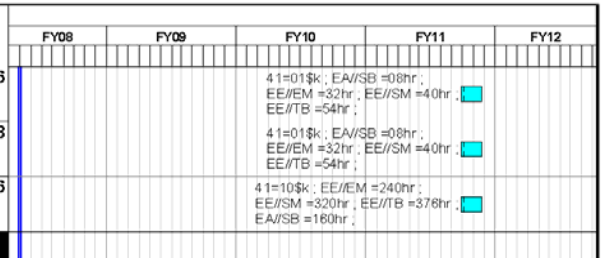
RESOURCE LOADED SCHEDULE – Contd.

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

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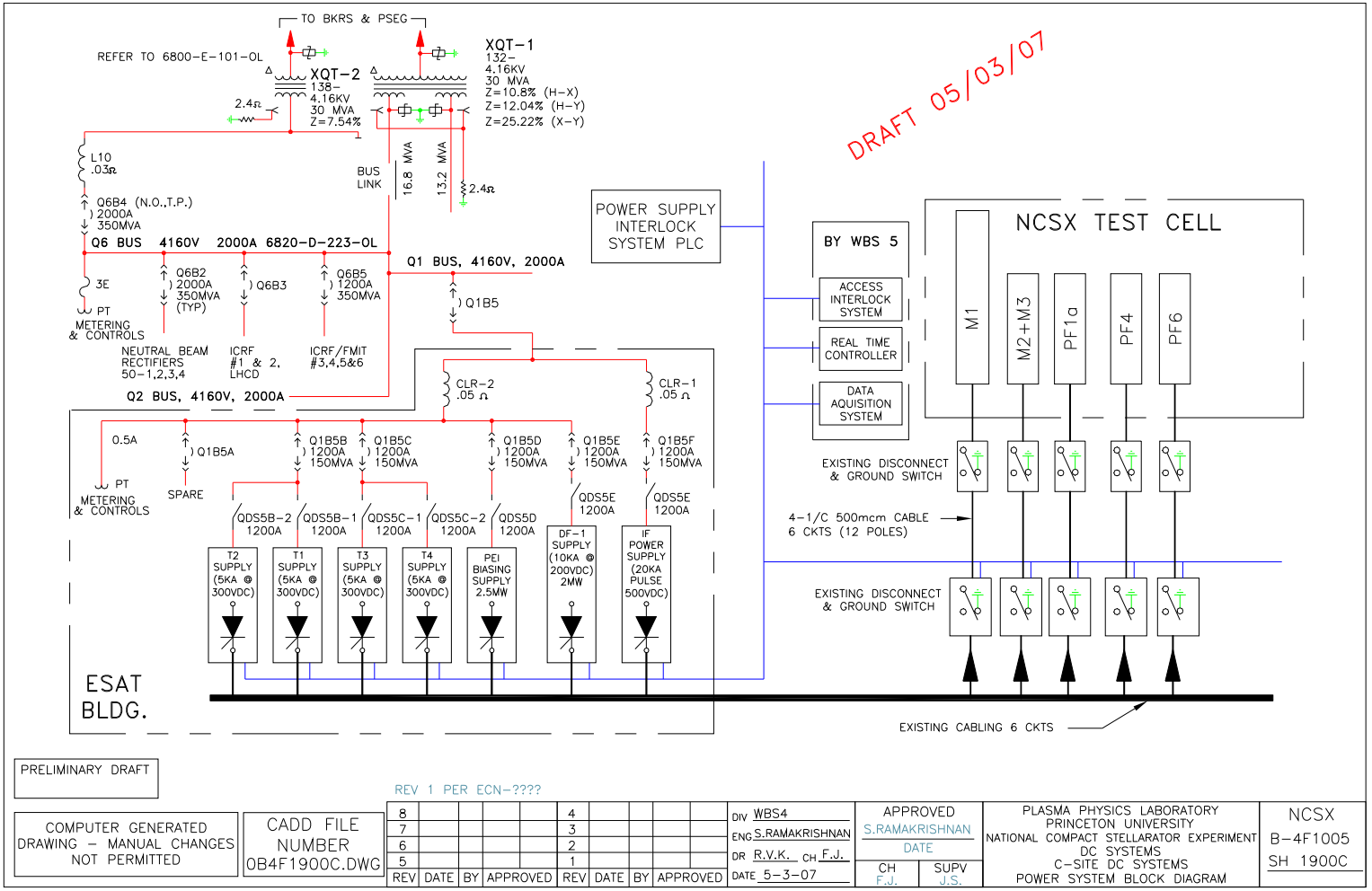
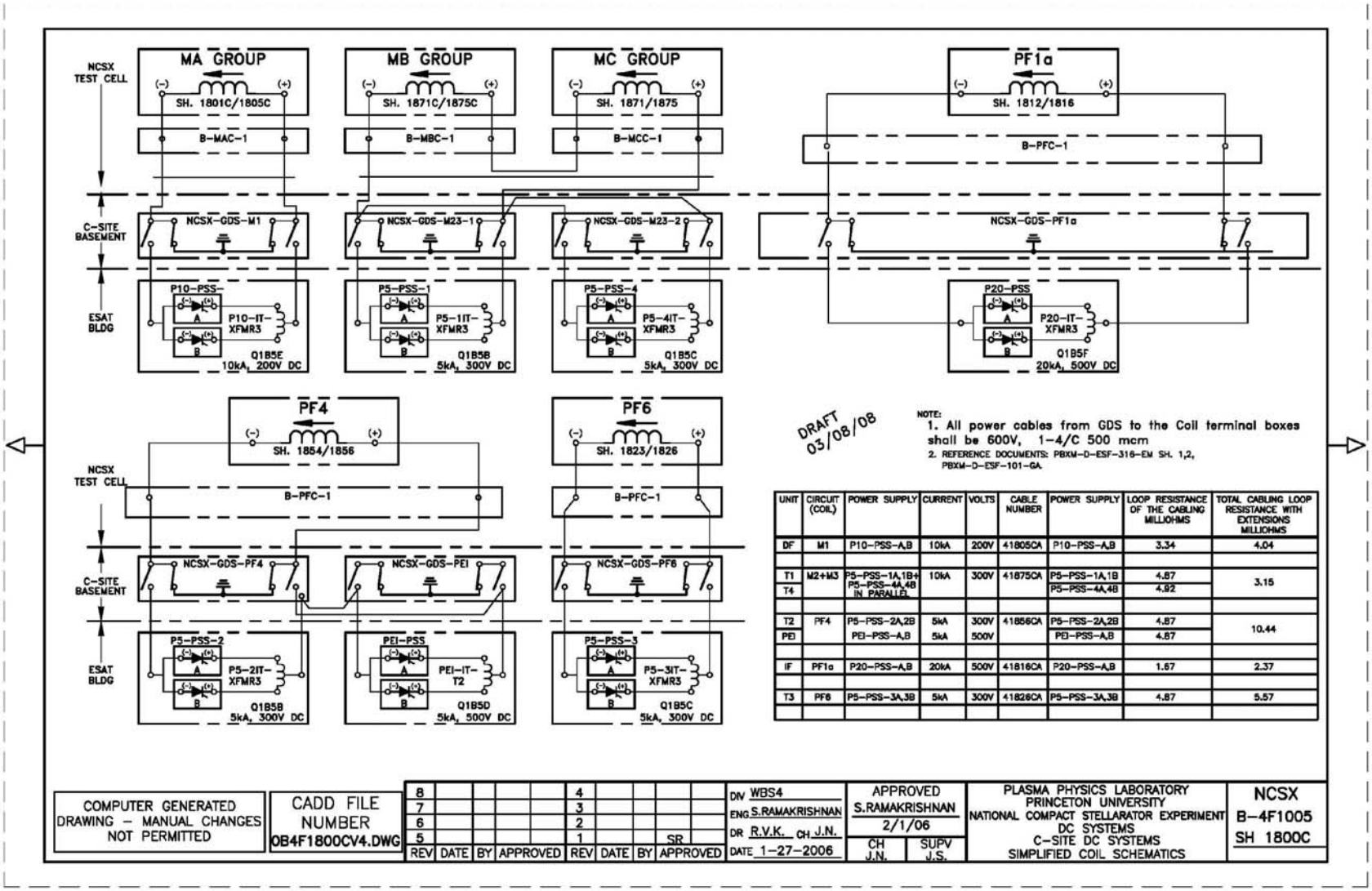
Back-up slides

POWER SYSTEM BLOCK DIAGRAM



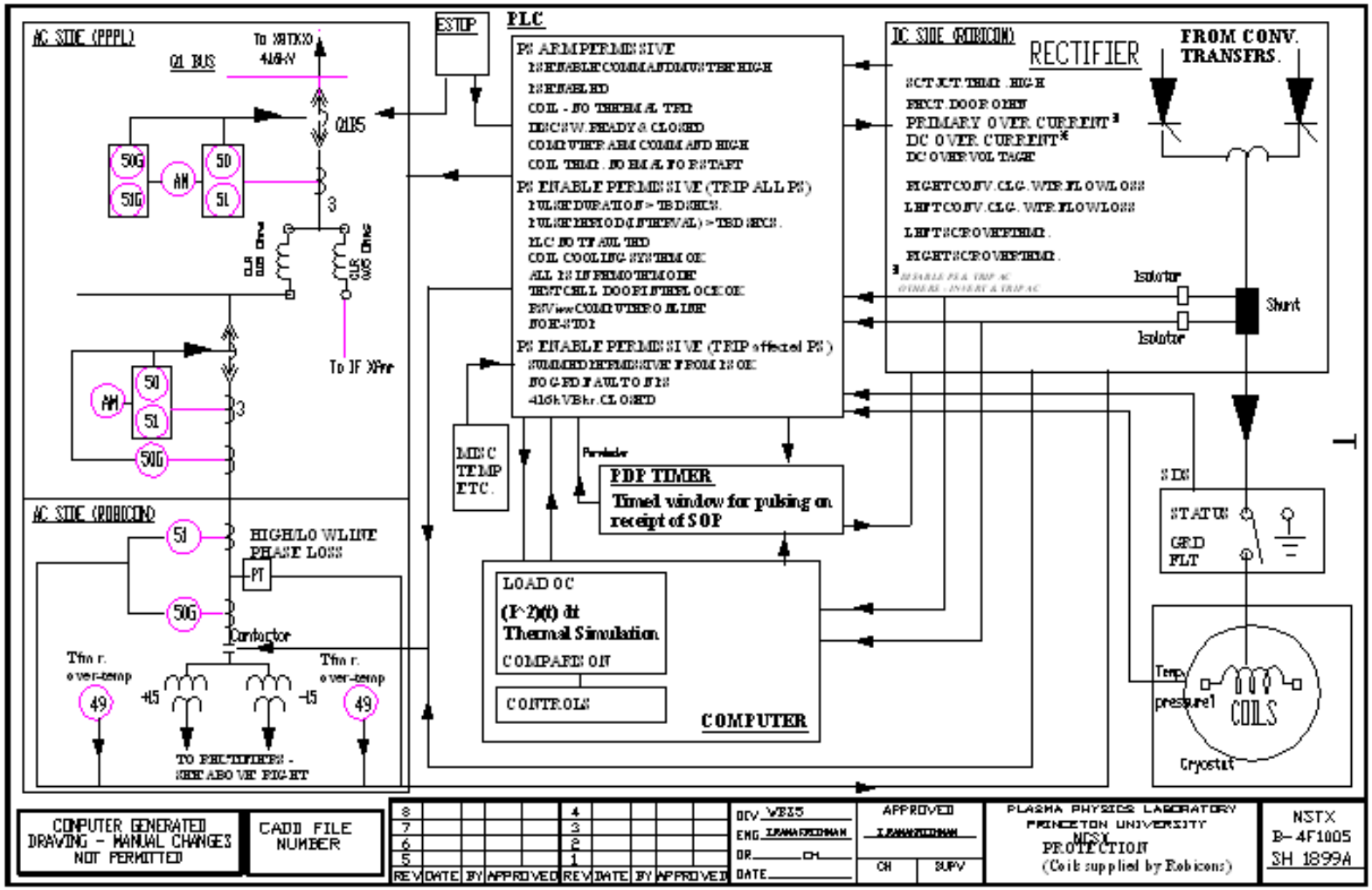
Back-up slides

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