		٧	ork Authorization Document
			NSTX Upgrade Project
Control Account #:	2300	Title:	ECH Analysis
wbs	1.2.3	Title:	Electron Cyclotron Heating
Period of Perform	ance:	01 April 2010 thro	ough 06 June 2011
Authorized Budge	et:	\$84	Control Account Manager: Titus
Revision #:	ı		Revision Date: July-11

Authorized Work Description:

The Electron Cyclotron Heating System provides breakdown and startup assist through an electron cyclotron heating system. The system will be composed of an AC/DC power conversion system, gyrotron source, transmission system, vacuum window and launcher. Any ECH specific diagnostics will be included and interfaced to Central I&C.

This scope of the WBS element for the NSTX Upgrade covers the ECH and other antenna systems, and miscellaneous diagnostics and components attached to the vessel which will be affected by the increases in EM and thermal loading. Disruption loads on the ECH waveguide will be evaluated for the Center Stack Upgrade Fields and field transients. Discussions with heating system experts regarding the performance of the ECH system for the higher Center Stack Upgrade fields indicate that no modification to the resonant frequency or other operational characteristic for the system will require upgrade. Only disruption qualification is planned. No previous qualification has been identified, so the resources include creation of a new calculation – not a review of an existing calculation as is the case for ICRH.

Attachments:

- 1- A detailed Control Account schedule showing all work packages and planning packages.
- 2- Budgeted Cost by month.
- 3- Original Work Authorization Form (WAF)
- 4- WBS Dictionary sheet that defines the scope of work for this WBS element.

			Control Account History	
ECP#	Implement Date	Prior Budget	New Budget	Signature
Approv	/als	Name	Signature	Date
NSTX-U Proje	ct Manager	R. Strykowsky		
Control Accoun	nt Manager	Titus		
Functional N	Manager	P. Heitzenroeder		

Activity ID		Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days) I		Budgeted Cost	PPCT	Earned value cost (BCWP)		FY11	FY	12 F	Y13	FY14	FY15	FY16
	Description	Days	OTAIL	Otart	T III COL	1 1111311	Onp (Days)	lout	COST		oost (Botti)	cost (Borro)	піпіпі	mmini	ifinhii	miim			
	Jpgrade Project																		
ıbtotal		310	01APR10A	01APR10A	06JUN11	24JUN11	-14	121	84,191.50		58,233.11	70,710.96							
Job: 230	00 - Other Analysis-TITUS													_					
Subtotal		310	01APR10A	01APR10A	06JUN11	24JUN11	-14	121	84,191.50		58,233.11	70,710.96							
2300-0010A	Analyses of RF MHD Shield Disruptive Loads	37*		25MAR11A		16MAY11	0	125	0.00	85	0.00	0.00			200				
	Run Other GRD disruptions for the HHFW		01JUN10A		31AUG10A		-163		0.00		0.00	0.00		A//EM		;			
	antenna Updat HHFW Antenna												<u> </u>	A//EM	=000	;			
	•		01JUN10A			28APR11A	-163		0.00		0.00	0.00		A//EM	=00 ;				
	Maintain/Update Diagnostic Database		01JUN10A		31AUG10A	16MAY11	-175	125	0.00		0.00	0.00		A//EM	=200	;			
	File Preliminary Database/Study		01JUN10A		31AUG10A	16MAY11	-175	146	0.00		0.00	0.00		A//EM	=100	;			
	Check/Complete Disruption and Thermal Analyses				01APR11	16MAY11	-31	125	19,013.72		16,115.13	18,958.98		A//EM	=100	;			
	Present/track recommentdations					28FEB11A	24		18,897.18	100	18,958.98	18,958.98	K EA	//EM =	100 ;				
2300-0018	FDR Prep	21*	04APR11	19MAY11	27MAY11	17JUN11	-14	123	19,268.00		0.00	9,634.00	-	EA//EM	=100	;			
	Other Analysis - Peer review	0				18MAY11*	0	123	0.00		0.00	0.00							
2300-0019	CONDUCT FDR	3	31MAY11	22JUN11*	06JUN11	24JUN11	-14	121	3,853.60		0.00	0.00	·	EM//EC	=20	;			
FY102300	FY10 Actual Cost	22	01APR10A	01APR10A	30APR10A	30APR10A	0		3,904.00	100	3,904.00	3,904.00							
FY102300A	FY10 Actual Cost	110	03MAY10A	03MAY10A	30SEP10A	30SEP10A	0		19,255.00	100	19,255.00	19,255.00	81=2 <mark>2</mark> 9	966					

Data Date
Run Date

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NSTX UPGRADES
RESOURCE LOADED SCHEDULE
CD-2 Schedule
April 2011



2300 ECH Analysis (Titus)	START	28FEB2009	31MAR2009	30APR2009	31MAY2009	30JUN2009	31JUL2009	31AUG2009	30SEP2009	31OCT2009	30NOV2009	31DEC2009
BCWS	0	0	0	0	0	0	0	0	0	0	0	0
CUM BCW3	0	0	0	0	0	0	0	0	0	0	0	0
BCWP	0	0	0	0	0	0	0	0	0	0	0	0
CUM BCWI	0	0	0	0	0	0	0	0	0	0	0	0
ACWP	0	0	0	0	0	0	0	0	0	0	0	0
CUM ACWI	0	0	0	0	0	0	0	0	0	0	0	0
CV	0	0	0	0	0	0	0	0	0	0	0	0
SV	•		•		•	•				-		
CPI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SPI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ECH Analysis (Titus)	31JAN2010	28FEB2010	31MAR2010	30APR2010	31MAY2010	30JUN2010	31JUL2010	31AUG2010	30SEP2010	31OCT2010	30NOV2010	31DEC2010
BCW	S 0	0	0	4	4	4	4	4	9	6	5	5
CUM B	OWS 0	0	0	4	8	12	15	19	28	34	39	44
BCW	P 0	0	0	0	0	0	0	0	0	0	0	27
CUM B	OWP 0	0	0	0	0	0	0	0	0	0	0	27
ACW	P 0	0	0	0	0	0	0	0	0	0	0	27
CUM A	OWP 0	0	0	0	0	0	0	0	0	0	0	27
CV	0	0	0	0	0	0	0	0	0	0	0	0
SV				-4.	-8.	-12.	-15.	-19.	-28.	-34.	-39.	-17.
CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	.99
SPI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.61

2300 ECH Analysis (Titus)	31JAN2011	28FEB2011	31MAR2011	30APR2011	31MAY2011	30JUN2011	31JUL2011	31AUG2011	30SEP2011	31OCT2011	30NOV2011	31DEC2011
BCWS	6	5	6	10	10	3	0	0	0	0	0	0
CUM BCWS	49	55	61	71	81	84	84	84	84	84	84	84
BCWP	12	18	0	2	0	0	0	0	0	0	0	0
CUM BCWP	38	56	56	58	58	58	58	58	58	58	58	58
ACWP	0	2	0	0	0	0	0	0	0	0	0	0
CUM ACWP	27	29	29	29	29	29	29	29	29	29	29	29
CV	11	27	27	29	29	29	29	29	29	29	29	29
SV	-11.	2.	- 5.	-13.	-23.	-26.	-26.	-26.	-26.	-26.	-26.	-26.
СРІ	1.42	1.95	1.95	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
SPI	0.77	1.03	0.93	0.82	0.72	0.69	0.69	0.69	0.69	0.69	0.69	0.69

Annex I – WBS Dictionary

This Work Breakdown Structure (WBS) organizes and defines the scope of the NSTX Upgrade using the WBS as established by the original NSTX project and modified to accommodate the NSTX Upgrade.

WBS			
<u>L1</u> 1	<u>L2</u>	<u>L3</u>	Description NSTX UPGRADE PROJECT
	1.1	1.1.0 1.1.1 1.1.2 1.1.3	Torus Systems Project Integrated Model Plasma Facing Components Vacuum Vessel and Support Structure Magnet Systems
	1.2	1.2.1 1.2.2 1.2.3 1.2.4	Plasma Heating and Current Drive Systems High Harmonic Fast Wave (HHFW) Coaxial Helicity Injection (CHI) Current Drive Electron Cyclotron Heating (ECH) Neutral Beam Injection (NBI)
	1.3	1.3.1 1.3.2 1.3.3 1.3.4 1.3.5	Auxiliary Systems Vacuum Pumping System Coolant Systems Bakeout Heating System Gas Delivery System Glow Discharge Cleaning System
	1.4	1.4.1	Plasma Diagnostics Plasma Diagnostics
	1.5	1.5.1 1.5.2 1.5.3 1.5.4 1.5.5	Power Systems AC Power Systems AC/DC Converters DC Systems Control and Protection System General Power Systems and Integration
	1.6	1.6.1 1.6.2	Central Instrumentation and Controls (I&C) Control System Data Acquisition System
	1.7	1.7.1 1.7.2 1.7.3	Project Support & Integration Project Management and Integration Project Physics Integrated Systems Tests
	1.8	1.8.1 1.8.2	Site Preparation and Assembly Site Preparation Torus Assembly and Construction

Annex I – WBS Dictionary

WBS Element: 1.2 WBS Level: 2

WBS Title: Plasma Heating and Current Drive Systems

Definition: The heating and current drive systems include all the auxiliary plasma

heating and current drive systems. This WBS element includes the High Harmonic Fast Wave (HHFW) Current Drive System, the Coaxial Helicity Injection (CHI) Current Drive System, the Electron Cyclotron Heating (ECH) System, and the Neutral Beam Injection (NBI) System. Only ECH (WBS 1.2.3) and Neutral Beam Injection (WBS 1.2.4) are impacted by the NSTX Upgrade Project. The scope of the work contains engineering design, R&D, mockups, procurement activities, component fabrication, installation, and System Testing. Installation of the WBS 2 systems is included in the individual WBS 2, level 3 elements.

WBS Element: 1.2.1 WBS Level: 3

WBS Title: High Harmonic Fast Wave (HHFW)

Definition: The High Harmonic Fast Wave System provides radio frequency (rf)

energy to the plasma for the purpose of plasma heating and current drive. The components of such a system include generators, transmission lines, tuning systems, antennas and their associated diagnostic and control systems. The system includes components inside the vacuum vessel (antennas and feed-throughs) in the test cell (transmission and tuning components) and in the RF power rooms (AC/DC power conversion system, RF generators, switches and loads). There are no changes to the

HHFW System as part of the NSTX Upgrade Project.

WBS Element: 1.2.2 WBS Level: 3

WBS Title: Coaxial Helicity Injection (CHI) Current Drive

Definition: The Coaxial Helicity Injection System is to provide helicity injection to

aid startup and provide edge current profile control. The main hardware elements required fall under other WBS's. These include a ceramic break in the vacuum vessel (WBS 1.1.3) the poloidal coil system (WBS 1.1.3) and a power supply (WBS 1.5). In this WBS element the task is to assure that the various components of the system are compatible with helicity injection and that the Central I&C required is provided. There are no

changes to the CHI System as part of the NSTX Upgrade Project.

WBS Element: 1.2.3 WBS Level: 3

WBS Title: Electron Cyclotron Heating (ECH)

Definition: The Electron Cyclotron Heating System provides breakdown and startup assist through an electron cyclotron heating system. The system will be

assist through an electron cyclotron heating system. The system will be composed of an AC/DC power conversion system, gyrotron source, transmission system, vacuum window and launcher. Any ECH specific

diagnostics will be included and interfaced to Central I&C.

This scope of the WBS element for the NSTX Upgrade covers the ECH and other antenna systems, and miscellaneous diagnostics and components attached to the vessel which will be affected by the increases in EM and

Annex I – WBS Dictionary

thermal loading. Disruption loads on the ECH waveguide will be evaluated for the Center Stack Upgrade Fields and field transients. Discussions with heating system experts regarding the performance of the ECH system for the higher Center Stack Upgrade fields indicate that no modification to the resonant frequency or other operational characteristic for the system will require upgrade. Only disruption qualification is planned. No previous qualification has been identified, so the resources include creation of a new calculation – not a review of an existing calculation as is the case for ICRH.

{Electron Cyclotron Heating (Job 2300)}

WBS Element: 1.2.4 WBS Level: 3

WBS Title: Neutral Beam Injection (NBI)

Definition: The Neutral Beam Injection System Upgrade provides a second Neutral Beam as part of the NSTX Upgrade Project. The second NBI is identical to the one already installed on NSTX. An existing TFTR beam will be decontaminated, refurbished, and installed on NSTX. This WBS element includes the NBI source refurbishment; the TFTR beamline decontamination, refurbishment and relocation to the NSTX Test Cell; the 2nd NBI Services; the NBI armor modifications; the 2nd NBI Power, Controls and Instrumentation; the 2nd NBI Duct and vacuum vessel modifications; and the NSTX Test Cell equipment removals and relocations necessary to accommodate the 2nd NBI. Vacuum Pumping System Modifications necessary to accommodate the 2nd NBI are included in WBS element 1.3. NBI Management and Health Physics support are

included in element WBS 1.7.

WBS Element: 1.2.4.2 WBS Level: 4

WBS Title: NBI Source Refurbishment

Definition: This WBS element includes the activities to refurbish three neutral beam

ion sources for the 2nd Neutral beamline, as currently being performed for

the installed Neutral beamline 1. {Source Refurbishment (Job 2420)}

WBS Element: 1,2,4,3 WBS Level: 4

WBS Title: NSTX Beamline 2 Decontamination

Definition: This WBS element includes the disassembly and decontamination

activities of a TFTR Neutral Beam beamline in preparation for beamline

refurbishment and reuse as an NSTX upgrade. {NSTX Beamline 2 Decontamination (Job 2430)}

WBS Element: 1.2.4.4 WBS Level: 4

WBS Title: NBI Beamline Refurbishment and Relocation

Definition: This WBS element includes refurbishment of a TFTR NBI and its

relocation to the NSTX test cell.

Included in this WBS element are the activities necessary to refurbish a TFTR Neutral Beam beamline for use on NSTX. This scope includes

Work Approval Form (WAF)

Cost Center:

9417

Job Number:

2300

Job Title:

Miscellaneous Diagnostic and Antenna Qualification

Job Manager:

P. Titus

Description:

At the beginning of the CDR, this task covered the ECH and other antenna systems, and was expanded to include miscellaneous diagnostics and components attached to the vessel which will be effected by the increases in EM, thermal, nuclear, dynamic loading and space allocation. A data base of antennas and diagnostics was created and elements sensitive to CSU changes were investigated. This included thin sheet metal shutters that may have thermal issues with higher power and eddy current loading.

Schedule:

See Tab B or attached

Approvals:

Project Manager

ob Manager

Engineering Department Head

				٠		Names of Basis of req'd skills if Estimate known Category		_								80	8					8						_			CATEGORIZATION CODES:	2 - Engineering Judgement/Experience	3 - Estimates/Data from External Sources (e.g., W7X, ATF	4 - Previous PPPL/ORNL Experieince (e.g., TFTR, NSTX,	ga l	910	
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	Diagnostic/waveguide has a present weakness that hasn't been seen in operation	waveguide has a present wea hasn't been seen in operation	resent weak	ness that	High	Rein	Reinforce	= -				×	
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(3)	If there is no critical path impact then the schedule entries should be zero. Likelihood of occurrence should be entered consistent with our risk classification methodology, i.e.	rence shot	act then the	scneaure ed consist	entries snoula be ent with our risk o	zero. slassification met	thodology, i.e.						
	VL= Very Likely (P.	>80%), L=L	ikely (80%>1	>40%), U:	=Unlikley (40%>P;	10%), VU=Very L	Jnlikely (P<10%)	VL= Very Likely (P>80%), L=Likely (80%>P>40%), U=Unlikley (40%>P>10%), VU=Very Unlikely (P<10%), NC=Non-credible (P<1%)					

-30%	-30%	-30%	-20%	Design Maturity Definition	High	Final design available. All design features/requirements well	High known. No further design development or evolution expected that	will impact estimate.	+80% Medium	Preliminary design available. Some additional design evolution	likely. Further developments can be somewhat expected or	+40% anticipated and reflected in estimate.	Low	No better than conceptual design basis currently available. Design	details, procedures, etc. still need much development and	expected.	Design Complexity Definition	Low	Work is fairly well understood either standard construction or	repetition of activities performed in past. Little likelihood of	estimate not being well understood and requirements not being	well defined.	Medium	More complex work requirements that have potential to impact	cost and schedule estimates. Limited experience performing	similar tasks, so ability to estimate accurately is somewhat suspect	High	Extremely challenging tasks and/or requirements. Unique or firstof-	The same of the sa
	Medium -20% +4 -10% +1 +1	w Medium +25% -20% +4 +15% -15% +2 +10% -10% +1	Low Medium -15% +25% -20% +4 -10% +15% -15% +2 -5% +10% -10% +1		XIC		Ī		%UE- %U	200		200 -20%	707																

Cost Center: Job Number: Job Title: Job Manager:

Materials and Subcontracts (M&S)

Description:

Miscellaneous Diagnostic and Antenna Qualification P. Titus

9417

Basis of Estimate

CATEGORIZATION CODES: 2. Engineering JudgementExperience
3. Estimates/Data from External Sources (e.g., W7X, ATF, etc.)
4. Previous PPPL/ORNL Experience (e.g., TFTR, NSTX, PLT, etc.)
5. Prototype DataTest Results
6. Catelogue PriceVendor Quote
7. Placed Contracts
8. Actual experience for NCSX Work
9. Other

TOTALS

#DIV/0

NSTX UPGRADE WAF STATUS 9/1/2009

			9/1/20	<u>09</u>								
Cost Center	Work Package	Job#	WBS	Responsi ble Job Manager	WAF Forecast Completion	WAF Received	WAF Input to P3	Prelim. Estimate (\$K)	WAF Reviewed	Analysis Engr Tasks Engr	Prelim Design Hrs	Final Design Hrs
			1.2 Plasma Heating and Current Drive Sys	tems								
1180	2***	2310	1.2.1 High Harmonic Fast Wave	P. Titus						}		
1180	2*** 2***	2310 2310	1.2.2 Coaxial Helicity Injection Currer 1.2.3 Electron Cyclotron Heating	nt P. Titus P. Titus								
1180	2	2310	1.2.3 Electron Cyclotron Fleating	1.11445				_		】 Disruption ≀Ellis/Zha	ng 300	300
			1.2.4 Neutral Beam Injection	T.Stevens	•					Document Simmon	40	40
1180	2***	2410	1.2.4.1 NBI Project Support	8T. Stevenso	44.4	44.4			-			
1180	2***	2420	1.2.4.2 NBI - Sources	M. Cropper	14-Aug-09 14-Aug-09	14-Aug-09 14-Aug-09						
1180	2***	2430	1.2.4.3 NBI - Decontaminati		14-Aug-09	14-Aug-09						
1180	2***	2440	1.2.4.4 NBI - Beamline Relo		14-Aug-09	14-Aug-09						
1180	2***	2450	1.2.4.5 NBI - Services	М.	14-Aug-09	14-Aug-09						
1180	2***	2460	1.2.4.6 NBI - Armor/Protecti	Denault v C Priniski		147449-05						
	-		1.2.4.7 NBI - Power & Contr	о						l		
1180	2***	2470	1.2.4.7.1 NBI - Por	w Raki	14-Aug-09	14-Aug-09						
1180	2***	2475	1.2.4.7.2 NBI - Co	nt M. Cropper	14-Aug-09	14-Aug-09						
1180	2***	2480	1.2.4.8 NBI - Nozzle/Duct	C. Priniski	14-Aug-09	14-Aug-09		_				
1180	2***	2490	1.2.4.9 NBI - Equipment Re	m E. Perry	6-Aug-09	6-Aug-09	******					
			1.3 Auxiliary Systems	W.Blanch ard								
1170	3***	?	1.3.1 Vacuum Pumping Systems	L. Dudek M.Denaul	?							
			1.3.2 Coolant Systems	t								
1170	3***	3200	System mods for	W.Blanch ard L. Dudek	11-Sep-09							
1170	3*••	3300	CSU - Includes upgrade to the power supply system to permit ohmic heating of the center stack casing for 350 C bakeout c the CS Tiles	i i								
1170	3***	3400	1.3.4 Gas Delivery Systems Gas Delivery System Mods for CSU - Includes the design, fabricatior and installatior of the Gas Delivery System on the new Centersta ck.	d n n s	11-Sер-09							
		n/a	1.3.5 Glow Discharge Cleaning System 1.4 Plasma Diagnostics	r L. Dudek R.Kiata				ev in genut elijoid ja ta				
					100	Charles A. A.			9 to 1 973 1			

1170	4	1.4.1 Plasma Diagnostics Center Stack Diagnos cs for CSU Includes design and fabricati s of CS magneti diagnost s to replace units removec with old center stack	on es c	11-Sep-09	Disruption I Zhang 40	
		1.5 Power Systems	Raki		•	
1170	5*** 5***	5100 1.5.1 AC Power Systems	Raki Raki	11-Sep-09 11-Sep-09	1	
1170	5***	5200 1.5.2 TF Power Conversion Systems 5300 1.5.3 PF/OH Power Conversion Systems		11-Sep-09	4	
1170 1170	5***	5300 1.5.3 PF/OH Power Conversion System 5400 1.5.4 CHI Power Conversion System	Raki	11-Sep-09	-	
1170	5***	5500 1.5.5 General Power Systems and In		11-Sep-09	ĺ	
1170	5***	COIL BUS RUNS - Includes design and fabrication f bus runs/sup orts for theOH/ TF/ Innet PF and CHI Includes bus from coils to a cooled bus in te- cell west side	ir-	11-Sep-09	·	
1170	6***	6100 1.6 Central Instrumentation & Control 1.6.1 Control System 1.6.2 Data Acquisition System	P. Sichta P. Sichta P. Sictha		Bus Loren Bryant	60
		1.7 Project Support & Integration	E.Perry		ı	
1170	7***	7100 1.7.1 Project Management & Integrat	o L. Dudek	?	1	
1170	7***	7200 1.7.2 Project Physics	J. Menard		1	
1170	7***	7300 1.7.3 Integrated Systems Test	C. Gentile	?	,	
		1.8 Site Preparation and Torus Assembly	E.Perry			
1170	8***	8100 1.8.1 Site Preparation	E.Perry	?		
1170	8***	1.8.2 Torus Assembly Centerst ck and Coil structure installation - Cover the materials and labor to install the centersta k and related hardware and the upgraded coil support structures.	o s			
	L			?	l	
					Analysis of Willard	100

380 580 Hrs 3.166667 4.833333 Man-Months