# Work Authorization Document

## NSTX Upgrade Project

| | | | |
|---|---|---|---|
| **Control Account #:** | 5000 | **Title:** | CSU Power Systems |
| **WBS** | 1.5.5 | **Title:** | Power System |
| **Period of Performance:** | 23 February 2009 through 25 September 2014 | | |
| **Authorized Budget:** | $5,735 | **Control Account Manager:** | Raki |
| **Revision #:** | 0 | **Revision Date:** | July-11 |

**Authorized Work Description:**

This WBS element covers general power systems activities including interaction with the designers of other WBS elements, design review support and procedure preparations as well as the administrative and supervisory efforts for the NSTX Power Systems.

The Center stack upgrade entails the TF feed to be 1kV, 129.8kA for 7.45 seconds every 2400 seconds. Design shall be such that the pulse period can be reduced to 1200 seconds. This requires complete redesign of the TF power system. Replacement of the fault detector (FD) and the Firing generator (FG) is required for fast and reliable response to fault conditions. The HCS will be upgraded with a PLC. The OH power supply will be also redesigned to have the capability of 8kV, +/-24kA; the FD and FG of the OH system will also be changed. OH CLRs will be replaced with calculated optimum requirements. A Digital Coil Protection (DCP) System will be designed and implemented.

**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.

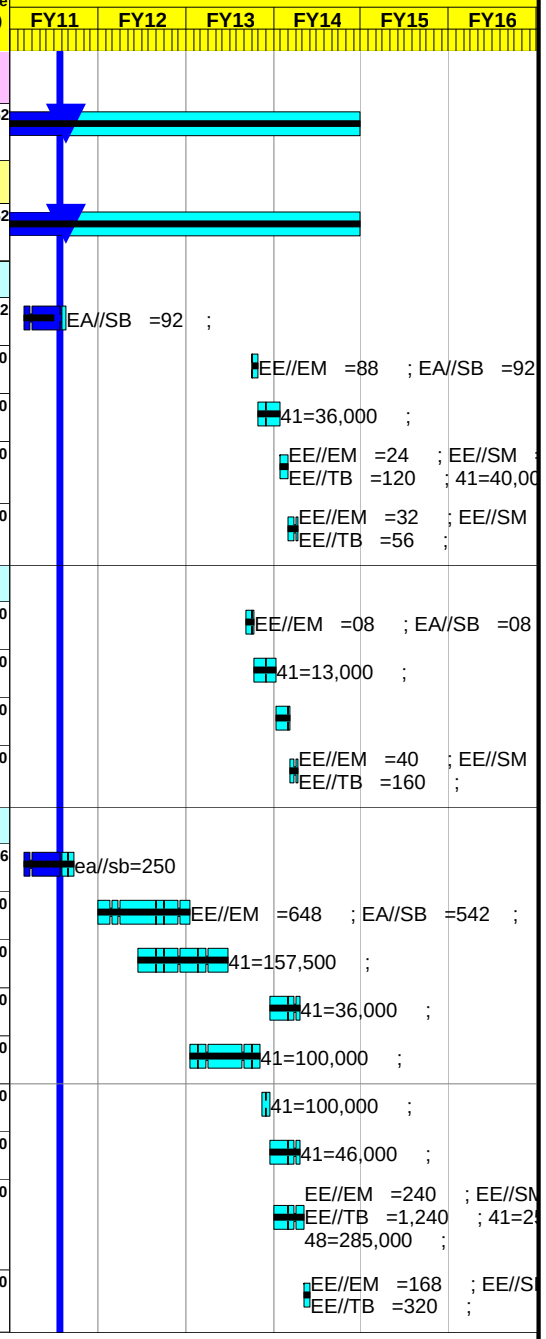
**Control Account History**

| ECP# | Implement Date | Prior Budget | New Budget | Signature |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| Approvals | Name | Signature | Date |
|---|---|---|---|
| NSTX-U Project Manager | R. Strykowsky | | |
| Control Account Manager | Raki | | |
| Functional Manager | A. vonHalle | | |

# NSTX Upgrade Project

| Activity ID | Activity Description | Work Days | BASELINE START | Forecast Start | BASELINE FINISH | Forecast Finish | Schedule Slip (Days) | Total Float | Budgeted Cost | PPCT | Earned value cost (BCWP) | Planned value cost (BCWS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subtotal | | 1,398 | 23FEB09A | 23FEB09A | 25SEP14 | 25SEP14 | 0 | 1,490 | 5,734,357.30 | | 296,501.85 | 1,336,982.52 |
| **Job: 5000 - CSU Power Systems-RAKI** | | | | | | | | | | | | |
| Subtotal | | 1,398 | 23FEB09A | 23FEB09A | 25SEP14 | 25SEP14 | 0 | 1,490 | 5,734,357.30 | | 296,501.85 | 1,336,982.52 |
| **51 - AC Power** | | | | | | | | | | | | |
| 510-003 | 51- AC Power -FINAL DESIGN PREP | 115* | 01DEC10* | 01DEC10A | 28MAR11 | 18MAY11 | -37 | 579 | 11,491.72 | 80 | 9,193.38 | 11,491.72 |
| 510-005 | 51- AC Power -procedures, specs, revision | 20 | 01JUL13* | 01JUL13* | 30JUL13 | 30JUL13 | 0 | 51 | 29,901.28 | | 0.00 | 0.00 |
| 510-009 | 51- AC Power -Procurement | 65 | 31JUL13* | 31JUL13* | 30OCT13 | 30OCT13 | 0 | 51 | 47,885.54 | | 0.00 | 0.00 |
| 510-013 | 51- AC Power -Installation | 20 | 31OCT13 | 31OCT13 | 27NOV13 | 27NOV13 | 0 | 51 | 84,847.52 | | 0.00 | 0.00 |
| 510-017 | 51- AC Power -Test&Commission | 20 | 02DEC13 | 02DEC13 | 08JAN14 | 08JAN14 | 0 | 51 | 19,037.68 | | 0.00 | 0.00 |
| **52 - AC/DC Converters** | | | | | | | | | | | | |
| 520-005 | 52 - AC/DC Converters - Dsn | 20 | 10JUN13* | 10JUN13* | 09JUL13 | 09JUL13 | 0 | 46 | 2,667.44 | | 0.00 | 0.00 |
| 520-009 | 52 - AC/DC Converters -Procurement | 65 | 10JUL13* | 10JUL13* | 09OCT13 | 09OCT13 | 0 | 46 | 17,202.00 | | 0.00 | 0.00 |
| 520-013 | 52 - AC/DC Converters -Reactivate | 40 | 10OCT13 | 10OCT13 | 06DEC13 | 06DEC13 | 0 | 46 | 0.00 | | 0.00 | 0.00 |
| 520-017 | 52 - AC/DC Converters -Test&Commission | 20 | 09DEC13 | 09DEC13 | 15JAN14 | 15JAN14 | 0 | 46 | 37,936.40 | | 0.00 | 0.00 |
| **531 - FCPC DC PF1 & TF Systems** | | | | | | | | | | | | |
| 531-004 | 531- FCPC DC Systems FINAL DESIGN PREP | 140* | 01DEC10* | 01DEC10A | 23JUN11 | 23JUN11 | 0 | 121 | 31,227.50 | 70 | 21,859.25 | 22,751.46 |
| 531-005 | 531- FCPC DC Systems procedures, specs, revision | 263 | 04OCT11* | 04OCT11* | 19OCT12 | 19OCT12 | 0 | 51 | 197,333.60 | | 0.00 | 0.00 |
| 531-013 | 531- FCPC DC Systems-Procure 1000MCM Cable&Tray | 260 | 13MAR12* | 13MAR12* | 27MAR13 | 27MAR13 | 0 | 142 | 205,337.60 | | 0.00 | 0.00 |
| 531-017 | 531- FCPC DC Systems Cabling Changes | 80 | 16SEP13* | 16SEP13* | 17JAN14 | 17JAN14 | 0 | 24 | 48,451.50 | | 0.00 | 0.00 |
| 531-021 | 531- FCPC DC Systems -Procure OH Reactors | 195 | 22OCT12 | 22OCT12 | 06AUG13 | 06AUG13 | 0 | 51 | 132,000.00 | | 0.00 | 0.00 |
| 531-021A | 531- Clear FCPC | 20 | | 16AUG13 | | 13SEP13 | 0 | 24 | 0.00 | | 0.00 | 0.00 |
| 531-025 | 531- FCPC DC Systems -OH React Install | 80 | 16SEP13* | 16SEP13* | 17JAN14 | 17JAN14 | 0 | 24 | 61,910.25 | | 0.00 | 0.00 |
| 531-029 | 531- FCPC DC Systems-Install cable & misc h/w | 80 | 01OCT13* | 01OCT13* | 03FEB14 | 03FEB14 | 0 | 13 | 913,018.00 | | 0.00 | 0.00 |
| 531-033 | 531- FCPC DC Systems -Test&Commission | 20 | 04FEB14 | 04FEB14 | 03MAR14 | 03MAR14 | 0 | 13 | 100,676.24 | | 0.00 | 0.00 |




**Data Date** 30APR11
**Run Date** 20MAY11 11:01



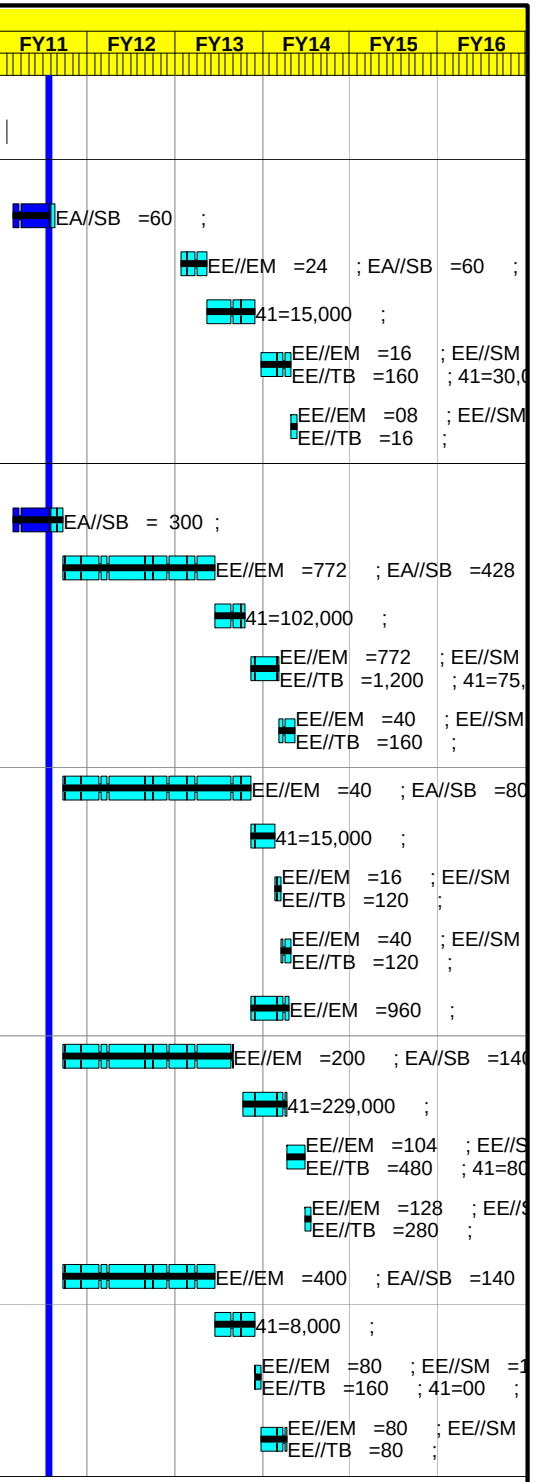
1105

**NSTX UPGRADES**
**RESOURCE LOADED SCHEDULE**
**CD-2 Schedule**
**April 2011**

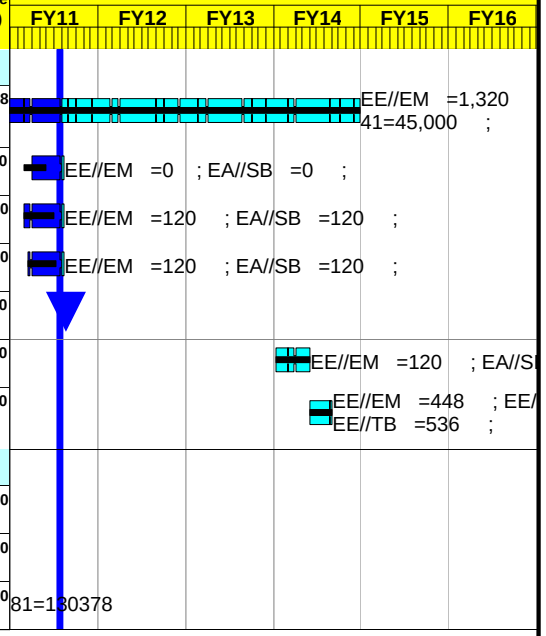


Early Bar
Progress Bar
Critical Activity

| Activity ID | Activity Description | Work Days | BASELINE START | Forecast Start | BASELINE FINISH | Forecast Finish | Schedule Slip (Days) | Total Float | Budgeted Cost | PPCT | Earned value cost (BCWP) | Planned value cost (BCWS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **532 - FCPC PF5 DC Systems*NOT IN PROJECT SCOPE**** | | | | | | | | | | | | |
| 530XXX | | 1 | 01OCT10 | 01NOV10A | 01OCT10 | 01NOV10A | -21 | | 0.00 | 100 | 0.00 | 0.00 |
| **532 - TA-NTC DC Systems** | | | | | | | | | | | | |
| 532-003 | 532- PCTS Changes -FINAL DESIGN PREP | 115* | 01DEC10* | 01DEC10A | 26APR11 | 18MAY11 | -16 | 399 | 7,494.60 | 90 | 6,745.14 | 7,494.60 |
| 532-005 | 532- PCTS Changes -procedures, specs, revision | 65 | 31OCT12* | 31OCT12* | 11FEB13 | 11FEB13 | 0 | 34 | 8,391.60 | | 0.00 | 0.00 |
| 532-009 | 532- PCTS Changes -Procurement | 140 | 12FEB13* | 12FEB13* | 29AUG13 | 29AUG13 | 0 | 34 | 19,800.00 | | 0.00 | 0.00 |
| 532-013 | 532- PCTS Changes -Installation | 80 | 23SEP13* | 23SEP13* | 24JAN14 | 24JAN14 | 0 | 19 | 73,484.41 | | 0.00 | 0.00 |
| 532-017 | 532- PCTS Changes -Test&Commission | 20 | 27JAN14 | 27JAN14 | 21FEB14 | 21FEB14 | 0 | 19 | 4,594.16 | | 0.00 | 0.00 |
| **54 - Control & Protection System** | | | | | | | | | | | | |
| 541-001 | Control & Protection Systems- FINAL DESIGN PREP | 140* | 01DEC10* | 01DEC10A | 23JUN11 | 23JUN11 | 0 | 38 | 37,473.00 | 80 | 29,978.40 | 27,301.76 |
| 541-005 | 541 - Electrical Interlocks -proced, specs, revs | 433 | 24JUN11 | 24JUN11 | 21MAR13 | 21MAR13 | 0 | 46 | 203,256.67 | | 0.00 | 0.00 |
| 541-009 | 541 - Electrical Interlocks -Procurement PLC | 80 | 22MAR13* | 22MAR13* | 16JUL13 | 16JUL13 | 0 | 46 | 134,640.00 | | 0.00 | 0.00 |
| 541-013 | 541 - Electrical Interlocks -Installation | 80 | 19AUG13* | 19AUG13* | 11DEC13 | 11DEC13 | 0 | 23 | 389,491.44 | | 0.00 | 0.00 |
| 541-017 | 541 - Electrical Interlocks -Test&Commission | 40 | 12DEC13* | 12DEC13* | 17FEB14 | 17FEB14 | 0 | 23 | 30,744.40 | | 0.00 | 0.00 |
| 542-005 | 542 - Kirk Key Interlocks -Dsn | 536 | 24JUN11 | 24JUN11 | 16AUG13 | 16AUG13 | 0 | 38 | 18,490.16 | | 0.00 | 0.00 |
| 542-009 | 542 - Kirk Key Interlocks -Procurement | 65 | 19AUG13* | 19AUG13* | 18NOV13 | 18NOV13 | 0 | 38 | 20,042.31 | | 0.00 | 0.00 |
| 542-013 | 542 - Kirk Key Interlocks -Installation | 20 | 19NOV13 | 19NOV13 | 18DEC13 | 18DEC13 | 0 | 38 | 22,054.48 | | 0.00 | 0.00 |
| 542-017 | 542 - Kirk Key Interlocks -Test&Commission | 20 | 19DEC13 | 19DEC13 | 27JAN14 | 27JAN14 | 0 | 38 | 26,857.60 | | 0.00 | 0.00 |
| 543-005 | 543 - Real Time Control -Develop algorithms | 100 | 15AUG13* | 15AUG13* | 16JAN14 | 16JAN14 | 0 | 45 | 190,109.57 | | 0.00 | 0.00 |
| 545-005 | 545 - Instrumentation -Dsn | 480 | 24JUN11 | 24JUN11 | 28MAY13 | 28MAY13 | 0 | 74 | 56,776.90 | | 0.00 | 0.00 |
| 545-009 | 545 - Instrumentation -Procure Transducers | 120 | 15JUL13* | 15JUL13* | 13JAN14 | 13JAN14 | 0 | 43 | 306,001.25 | | 0.00 | 0.00 |
| 545-013 | 545 - Instrumentation -Installation | 50 | 14JAN14 | 14JAN14 | 24MAR14 | 24MAR14 | 0 | 43 | 198,469.52 | | 0.00 | 0.00 |
| 545-017 | 545 - Instrumentation -Test&Commission | 20 | 25MAR14 | 25MAR14 | 21APR14 | 21APR14 | 0 | 43 | 68,646.64 | | 0.00 | 0.00 |
| 546-005 | 546 - Coil Analog Protection Dsn | 431 | 24JUN11 | 24JUN11 | 19MAR13 | 19MAR13 | 0 | 51 | 94,196.36 | | 0.00 | 0.00 |
| 546-009 | 546 - Coil Analog Protection -Procurement | 112 | 20MAR13* | 20MAR13* | 27AUG13 | 27AUG13 | 0 | 51 | 10,560.00 | | 0.00 | 0.00 |
| 546-013 | 546 - Coil Analog Protection -Installation | 20 | 28AUG13* | 28AUG13* | 25SEP13 | 25SEP13 | 0 | 51 | 58,349.60 | | 0.00 | 0.00 |
| 546-017 | 546 - Coil Analog Protection -Test&Commission | 65 | 26SEP13 | 26SEP13 | 08JAN14 | 08JAN14 | 0 | 51 | 29,492.94 | | 0.00 | 0.00 |



| Activity ID | Activity Description | Work Days | BASELINE START | Forecast Start | BASELINE FINISH | Forecast Finish | Schedule Slip (Days) | Total Float | Budgeted Cost | PPCT | Earned value cost (BCWP) | Planned value cost (BCWS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **55 - Systems Design & Integration** | | | | | | | | | | | | |
| 551-001 | 551 - Sys Dsgn -design support, analysis (LOE) | 1,098* | 03MAY10A | 03MAY10A | 25SEP14 | 25SEP14 | 0 | 1,490 | 412,014.46 | LOE | 93,527.28 | 93,434.98 |
| 551-001A | 551 - FDR Transition Area | 96* | 01DEC10* | 03JAN11A | 28FEB11 | 16MAY11 | -55 | 149 | 0.00 | 50 | 0.00 | 0.00 |
| 551-008 | 551 - FDR PF1a | 113* | 01DEC10* | 01DEC10A | 31MAR11 | 16MAY11 | -32 | 96 | 35,736.00 | 50 | 17,868.00 | 35,736.00 |
| 551-009 | 551 - FDR TF/OH | 103* | 15DEC10* | 15DEC10A | 07APR11 | 16MAY11 | -27 | 96 | 35,736.00 | 40 | 14,294.40 | 35,736.00 |
| 551-009A | CSU Power System - Peer review | 0 | | | | 18MAY11* | 0 | 147 | 0.00 | | 0.00 | 0.00 |
| 552-001 | 552 - System Testing -Prepare Procedures | 90 | 15OCT13 | 15OCT13 | 03MAR14 | 03MAR14 | 0 | 13 | 41,367.60 | | 0.00 | 0.00 |
| 552-003 | 552 - System Testing -Testing | 65 | 04MAR14 | 04MAR14 | 03JUN14 | 03JUN14 | 0 | 13 | 156,125.36 | | 0.00 | 0.00 |
| FY095000 | FY09 Actual Cost | 22* | 23FEB09A | 23FEB09A | 30SEP09A | 30SEP09A | 0 | | 385,771.00 | 100 | 385,771.00 | 385,771.00 |
| FY105000 | FY10 Actual Cost | 143 | 01OCT09A | 01OCT09A | 30APR10A | 30APR10A | 0 | | 623,027.00 | 100 | 623,027.00 | 623,027.00 |
| FY105000A | FY10 Actual Cost | 130 | 01APR10A | 01APR10A | 30SEP10A | 30SEP10A | 0 | | 94,238.00 | 100 | 94,238.00 | 94,238.00 |



| 5000 CSU Power Systems (Raki) | START | 28FEB2009 | 31MAR2009 | 30APR2009 | 31MAY2009 | 30JUN2009 | 31JUL2009 | 31AUG2009 | 30SEP2009 | 31OCT2009 | 30NOV2009 | 31DEC2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BCWS | 0 | 12 | 55 | 55 | 50 | 55 | 55 | 52 | 52 | 96 | 83 | 74 |
| CUM BCWS | 0 | 12 | 67 | 122 | 172 | 226 | 281 | 334 | 386 | 482 | 564 | 638 |
| BCWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CUM BCWP | 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 ACWP | 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 | . | -12. | -67. | -122. | -172. | -226. | -281. | -334. | -386. | -482. | -564. | -638. |
| 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 |

| 5000 CSU Power Systems (Raki) | | 31JAN2010 | 28FEB2010 | 31MAR2010 | 30APR2010 | 31MAY2010 | 30JUN2010 | 31JUL2010 | 31AUG2010 | 30SEP2010 | 31OCT2010 | 30NOV2010 | 31DEC2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BCWS | 87 | 87 | 100 | 112 | 21 | 23 | 22 | 23 | 22 | 7 | 7 | 29 |
| | CUM BCWS | 726 | 813 | 913 | 1,025 | 1,046 | 1,069 | 1,091 | 1,115 | 1,137 | 1,144 | 1,151 | 1,179 |
| | BCWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,161 |
| | CUM BCWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,161 |
| | ACWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,165 |
| | CUM ACWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,165 |
| | CV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -4 |
| | SV | -726. | -813. | -913. | -1025. | -1046. | -1069. | -1091. | -1115. | -1137. | -1144. | -1151. | -18. |
| | CPI | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 1. |
| | SPI | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.98 |

| 5000 CSU Power Systems (Raki) | | 31JAN2011 | 28FEB2011 | 31MAR2011 | 30APR2011 | 31MAY2011 | 30JUN2011 | 31JUL2011 | 31AUG2011 | 30SEP2011 | 31OCT2011 | 30NOV2011 | 31DEC2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BCWS | 41 | 39 | 45 | 21 | 17 | 19 | 23 | 25 | 24 | 39 | 42 | 42 |
| | CUM BCWS | 1,221 | 1,260 | 1,305 | 1,326 | 1,343 | 1,363 | 1,385 | 1,410 | 1,433 | 1,472 | 1,514 | 1,556 |
| | BCWP | 16 | 31 | 55 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM BCWP | 1,177 | 1,208 | 1,263 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 |
| | ACWP | 1 | 6 | 12 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM ACWP | 1,166 | 1,173 | 1,185 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 |
| | CV | 10 | 36 | 78 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 |
| | SV | -44. | -51. | -42. | -41. | -58. | -77. | -100. | -125. | -148. | -187. | -229. | -271. |
| | CPI | 1.01 | 1.03 | 1.07 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 |
| | SPI | 0.96 | 0.96 | 0.97 | 0.97 | 0.96 | 0.94 | 0.93 | 0.91 | 0.9 | 0.87 | 0.85 | 0.83 |

| 5000 CSU Power Systems (Raki) | | 31JAN2012 | 29FEB2012 | 31MAR2012 | 30APR2012 | 31MAY2012 | 30JUN2012 | 31JUL2012 | 31AUG2012 | 30SEP2012 | 31OCT2012 | 30NOV2012 | 31DEC2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BCWS | 42 | 40 | 52 | 55 | 61 | 55 | 58 | 61 | 53 | 61 | 60 | 57 |
| | CUM BCWS | 1,597 | 1,637 | 1,689 | 1,745 | 1,806 | 1,861 | 1,919 | 1,980 | 2,033 | 2,094 | 2,154 | 2,211 |
| | BCWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM BCWP | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 |
| | ACWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM ACWP | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 |
| | CV | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 |
| | SV | -312. | -352. | -404. | -460. | -520. | -576. | -634. | -695. | -748. | -809. | -869. | -926. |
| | CPI | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 |
| | SPI | 0.8 | 0.78 | 0.76 | 0.74 | 0.71 | 0.69 | 0.67 | 0.65 | 0.63 | 0.61 | 0.6 | 0.58 |

| 5000 CSU Power Systems (Raki) | | 31JAN2013 | 28FEB2013 | 31MAR2013 | 30APR2013 | 31MAY2013 | 30JUN2013 | 31JUL2013 | 31AUG2013 | 30SEP2013 | 31OCT2013 | 30NOV2013 | 31DEC2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BCWS | 62 | 55 | 62 | 66 | 69 | 60 | 114 | 166 | 284 | 536 | 560 | 491 |
| | CUM BCWS | 2,273 | 2,328 | 2,390 | 2,456 | 2,525 | 2,585 | 2,699 | 2,865 | 3,149 | 3,686 | 4,246 | 4,737 |
| | BCWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM BCWP | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 |
| | ACWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM ACWP | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 |
| | CV | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 |
| | SV | -988. | -1043. | -1105. | -1171. | -1240. | -1300. | -1414. | -1580. | -1864. | -2401. | -2961. | -3452. |
| | CPI | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 |
| | SPI | 0.57 | 0.55 | 0.54 | 0.52 | 0.51 | 0.5 | 0.48 | 0.45 | 0.41 | 0.35 | 0.3 | 0.27 |

| 5000 CSU Power Systems (Raki) | | 31JAN2014 | 28FEB2014 | 31MAR2014 | 30APR2014 | 31MAY2014 | 30JUN2014 | 31JUL2014 | 31AUG2014 | 30SEP2014 | 31OCT2014 | 30NOV2014 | 31DEC2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BCWS | 436 | 212 | 142 | 112 | 61 | 13 | 9 | 8 | 7 | 0 | 0 | 0 |
| | CUM BCWS | 5,172 | 5,384 | 5,526 | 5,638 | 5,698 | 5,711 | 5,720 | 5,728 | 5,735 | 5,735 | 5,735 | 5,735 |
| | BCWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM BCWP | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 | 1,285 |
| | ACWP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUM ACWP | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 | 1,213 |
| | CV | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 |
| | SV | -3887. | -4099. | -4241. | -4353. | -4413. | -4426. | -4435. | -4443. | -4450. | -4450. | -4450. | -4450. |
| | CPI | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 |
| | SPI | 0.25 | 0.24 | 0.23 | 0.23 | 0.23 | 0.23 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |

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

includes power cabling changes, DC Reactor changes, associated raceway changes, and changes required in the Power Cable Termination Structure (PCTS) inside the NSTX Test Cell.

**WBS Element: 1.5.4** **WBS Level: 3**
**WBS Title: Control and Protection System**
Definition: The scope of the Control and Protection System WBS element is to control and protect the power loop components for all magnet circuits. This includes the design of hardwired interlock system, kirk-keys, real time controls, the PC Link, Firing Generator, and Fault Detector changes, measurement of signals, changes to existing coil protection devices and design of a new digital coil protection system.

**WBS Element: 1.5.5** **WBS Level: 3**
**WBS Title: General Power Systems and Integration**
Definition: This WBS element covers general power systems activities including interaction with the designers of other WBS elements, design review support and procedure preparations as well as the administrative and supervisory efforts for the NSTX Power Systems.

*The Center stack upgrade entails the TF feed to be 1kV, 129.8kA for 7.45 seconds every 2400 seconds. Design shall be such that the pulse period can be reduced to 1200 seconds. This requires complete redesign of the TF power system. Replacement of the fault detector (FD) and the Firing generator (FG) is required for fast and reliable response to fault conditions. The HCS will be upgraded with a PLC. The OH power supply will be also redesigned to have the capability of 8kV, +/-24kA; the FD and FG of the OH system will also be changed. OH CLRs will be replaced with calculated optimum requirements. A Digital Coil Protection (DCP) System will be designed and implemented.*
{NSTX Center Stack Upgrade Power Systems (Job 5000)}

**WBS Element: 1.6** **WBS Level: 2**
**WBS Title: Central Instrumentation and Controls (I&C)**
Definition: The scope of this WBS element is to develop a Central Instrumentation and Control (I&C) System that will provide remote control, monitoring, data acquisition and data management for the NSTX subsystems during machine operation. The Central I&C System will be developed, to varying degrees, in conjunction with all other WBS elements and will consist of two major elements: the Control System and the Data Acquisition System. Local I&C system controllers, field instrumentation and wiring are included in the individual subsystems.

The NSTX Upgrade will be capable of producing plasmas on the order of 10 seconds; to-date they are less than two seconds. This WBS element includes the modifications to the Central I&C System to support the NSTX Upgrade. For dozens of CAMAC and PC-based data acquisition systems this will require an upgrade, and in some cases replacement. The

# Work Approval Form (WAF)

**Cost Center:** 9417
**Job Number:** 5000 (Covers elements 5100 - 5500)
**Job Title:** NSTX Center Stack Upgrade - Power System
**Job Manager:** S. Ramakrishnan
**Rev 1 6/15/2010**

**Description:**

The Center stack upgrade entails the TF feed to be 1kV, 129.8kA for 7.45 seconds every 2400 seconds. Design shall be such that the pulse period can be reduced to 1200 seconds. This requires complete redesign of the TF power system. The HCS will be upgraded with a PLC. The OH power supply is designed to have the capabiity of 6kV, +/-24kA. OH CLRs will be replaced with calculated optimum requirements. A Digital Coil Protection (DCP) System will be designed and implemented.

**Schedule:**

Refer to Primavera Data-Base

**Approvals:**

7/26/10
Job Manager

8/3/10
Project Manager

8/3/10
Engineering Department Head

| | |
|---|---|
| **Cost Center:** | 9417 |
| **Job Number:** | 5000 (Covers elements 5100 - 5500) |
| **Job Title:** | 9417 |
| **Job Manager:** | S. Ramakrishnan |

NSTX CENTER STACK UPGRADE - PS CHANGES 130kA part capability 8 parallels -------060710 nopf

*1. TF WILL BE PULSED AT 129.778kA FOR 7.6 SECONDS EVERY 2400 SECONDS*

| | | | | | | | | | | | | | | | | | M&S | | | | Design/ Procurement | | Installation | | | | | | Commissioning | | | | Line Total | Names of req'd skills if known | Basis of Estimate Category | % Cont'cy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Duration days | Start date | Finish date | Mult | Qty | excl factor | Qnty | Units | Qty | Units | Unit Cost (k$/unit) | Cost ($K) | Spare Units | Spare Cost ($K) | EEEM (md) | Dm (md) | EEEM (md) | EESM (md) | EETB (md) | SC ($K) | EEEM (md) | EESM (md) | EETB (md) | | | | | | | |
| **51- AC Power** | **$62.122** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 511- Experimental AC Power | $62.1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | Grounding | | Misc. grounding | design/instal grd. | 5 | 4/1/2012 | 4/30/2012 | 1 | | 1 | | | 1 | lot | 1.000 | 3.00 | | | 1 | 1 | 2 | 1 | 2 | 5 | | 1 | 2 | 2 | 19.1 | Ramkri | 2 | 10 |
| | | | D-site Pulsed AC Power Distribution | | Lockouts/protection/reactivate | activate | 8 | 4/1/2012 | 4/30/2012 | 1 | | 1 | | | 1 | lot | 5.000 | 5.00 | | | 3 | 3 | 2 | 8 | 10 | | | 3 | 3 | 5 | 43.1 | Baker | 2 | 10 |
| **52 - AC/DC Converters** | **$48.085** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 521 - Reactivation Converters | $48.1 | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| | | | Coil Power Supplies | Transrex PS Maintenance | Reactivation | activate | 10 | 4/1/2012 | 4/30/2012 | 1 | | 1 | | | 12 | PSS | 1.000 | 12.00 | 1.000 | 1.000 | 1 | 1 | | | | | 5 | 10 | 20 | 48.1 | Ramkri | 2 | 10 |
| **53 - DC Systems** | **$1,648.552** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 531-FCPC DC Changes | $1,648.6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 531.1 PF1a Changes | $252.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | NSTX PF1a Changes | Design & Supervision | | design | 30 | 4/1/2012 | 8/1/2012 | 1 | | 1 | | | | | | | | | 10 | 20 | 5 | 5 | 5 | | 5 | 5 | 10 | 68.7 | Ramkri | 2 | 10 |
| | | | NSTX PF1a Changes | Ripple reactors & Recabling | | remove reactors | 5 | ######## | 5/15/2012 | 1 | | 1 | | | | | 1.000 | 1.00 | | | 3 | 4 | 2 | 5 | 20 | 50 | 1 | 1 | 2 | 94.1 | Ramkri | 4 | 15 |
| | | | NSTX PF1a Changes | task of TF reactor enclosures | | build enclosure | 10 | ######## | 6/15/2012 | 1 | | 1 | | | | | 1.000 | 20.00 | | | 4 | 4 | 2 | 15 | 30 | 10 | 1 | 1 | 2 | 89.5 | Perry | 4 | 15 |
| **531 - FCPC TF DC Systems** | **$778.3** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 531.2- TF Changes | $778.3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | TF DC Changes FCPC | Design & Supervision | | design | 60 | ######## | 6/15/2013 | 1 | | 1 | | | | | | | | | 40 | 40 | 5 | 5 | 15 | | 5 | 5 | 10 | 135.7 | Ramkri | 2 | 15 |
| | | | | Materials & Installation | 1000MCM SKV Cable For PSS | procure cable | 5 | 9/1/2011 | 5/1/2012 | 1 | 40 | 1 | 100 | ft/PS S | ### | ft | 0.030 | 135.00 | | | 5 | 5 | | | | | | | | 170.7 | Ramkri | 6-Apr | |
| | | | | | Cable Tray in FCPC | tray procure | 5 | ######## | 5/1/2012 | 1 | | 1 | | | 150 | ft | 0.050 | 7.50 | | | 2 | 2 | | | | | | | | 13.5 | Ramkri | 2 | 15 |
| | | | | | Install Tray in FCPC | tray install | 5 | ######## | 7/15/2012 | 1 | | 1 | | | 150 | ft | 0.100 | 15.00 | | | 2 | 2 | | | | | | | | 22.3 | Ramkri | 2 | 15 |
| | | | NSTX TF Power cabling changes | Task of NSTX TF PS cabling changes | | cable install | 90 | ######## | ######## | 1 | | 1 | | | | | | 10.00 | | | 3 | 4 | 2 | 5 | 40 | 320 | 1 | 1 | 2 | 436.1 | Ramkri | 4 | 30 |
| | 531.3- Removing cabling | $87.0 | Removing cabling | Misc | | cable remove | 20 | ######## | ######## | 1 | | 1 | | | | | | 5.00 | | | 3 | 4 | 2 | 5 | 20 | 40 | 1 | 1 | 2 | 87.0 | Ramkri | 4 | 30 |
| | 531.4 DC Reactors | $375.4 | DC Reactors for TF & OH | Design & Specification | | design | | ######## | ######## | 1 | | 1 | | | | | | | | | 6 | 10 | | | | | | | | 17.8 | Ramkri | | |
| | | | | Procurement OH Reactors | | procure reactor | | ######## | ######## | 1 | | 1 | | | 2 | units | 50.000 | 100.00 | | | | | | | | | | | | 117.8 | Ramkri | 6 | 15 |
| | | | | TF reactor Installation | | install reactor | | ######## | 7/15/2012 | 1 | | 1 | | | | | | | | | | | 5 | 10 | 10 | 20 | 3 | 5 | 5 | 62.7 | Viola | | |
| | | | | OH Reactor Installation | | install reactor | | ######## | 7/15/2012 | 1 | | 1 | | | | 2 | 20.000 | 40.00 | | | | | 5 | 10 | 5 | 80 | 3 | 5 | 5 | 177.1 | Viola | 6 | 15 |
| | 531.5 TA Cabling Changes | $52.1 | Transition area cabling PF/CHI | Misc | | | | | | 1 | | 1 | | | | | | 6.00 | | | 3 | 4 | 2 | 5 | 10 | 15 | 1 | 1 | 2 | 52.1 | Ramkri | 2 | 20 |
| **533 - TA-HTC DC Systems** | **$103.5** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | $103.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 533.1 PCTS Changes | | PCTS Changes | PCTS Changes | | work on PCTS | | ######## | ######## | 1 | | 1 | | | 1 | | 15.000 | 15.00 | | | 3 | 15 | 2 | 10 | 20 | 30 | 1 | 1 | 2 | 103.5 | Ramkri | 2 | 25 |
| **54 - Control & Protection Systems** | **#REF!** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 541 - Electrical Interlocks | $682.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Design | | design | | 4/1/2012 | 8/1/2013 | 1 | | 1 | | | 1 | units | 2.000 | 2.00 | | | 8 | 16 | | 5 | 15 | 40 | | | | 91.8 | Zhao/Ramkri | 2 | 10 |
| | | | | PLC | | procure PLC | | ######## | ######## | 1 | | 1 | | | 1 | units | 98.000 | 98.00 | | | 180 | 40 | | 5 | 120 | | | | | 487.9 | Zhao | 4 | 20 |
| | | | | Install interlocks/cabling | | Install | | ######## | 4/1/2013 | 1 | | 1 | | | 1 | units | 2.000 | 2.00 | | | 5 | 10 | | 5 | 15 | 35 | | | | 76.0 | Zhao/Ramkri | 4 | 15 |
| | | | | Test Modified NSTX HCS | | HCS testing | | 4/1/2013 | 6/1/2013 | 1 | | 1 | | | | | | | | | | | | | | | 5 | 5 | 20 | 26.3 | Zhao/Ramkri | 2 | 15 |
| | 542 - Kirk Key Interlocks | $75.8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Kirk Keys | | kirk key changes | | 4/1/2013 | 6/1/2013 | 1 | | 1 | | | 1 | lot | 15.000 | 15.00 | | | 5 | 10 | 2 | 5 | 15 | | 5 | 5 | 15 | 75.8 | Ramkri/Baker | 4 | 15 |

**Cost Center:** 9417
**Job Number:** 5000 (Covers elements 5100 - 5500)
**Job Title:** 9417
**Job Manager:** S. Ramakrishnan

NSTX CENTER STACK UPGRADE - PS CHANGES 130kA part capability 8 parallels -----060710 nopf

1. TF WILL BE PULSED AT 129.778kA FOR 7.6 SECONDS EVERY 2400 SECONDS

| | | | | | | | | | | | | | | | M&S | | | | Design/ Procurement | | Installation | | | | Commissioning | | | | Line Total | Names of req'd skills if known | Basis of Estimate Category | % Cont'cy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Duration days | Start date | Finish date | Mult | Qty | excl factor | Qnty | Units | Qty | Units | Unit Cost (k$/unit) | Cost ($K) | Spare Units | Spare Cost ($K) | EEEM (md) | Dm (md) | EEEM (md) | EESM (md) | EETB (md) | SC ($K) | EEEM (md) | EESM (md) | EETB (md) | ($K) | | | | |
| | 543 - Real Time Control | $165.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | 165.5 | Neumeyer | 2 | 20 |
| | | | | Develop Control Algorithms | algorithm develp | 1/1/2013 | 6/1/2013 | 1 | | 1 | | | | | | | | | 120 | | | | | | | | | | | | |
| | 545 - Instrumentation | $563.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | DC Current Transducers (DCCTs) | | | 4/1/2012 | ######## | 1 | | 1 | | | 2 | units | 70.000 | 140.00 | | | 5 | 10 | 4 | 8 | 20 | | 3 | 3 | 15 | 227.6 | Ramkri | 6 | 15 |
| | | | DC Current Transducers (DCCTs) | | | 4/1/2012 | ######## | 1 | | 1 | | | 8 | units | 10.000 | 80.00 | | | 5 | 10 | 4 | 8 | 20 | | 3 | 3 | 15 | 156.9 | Ramkri | 6 | 15 |
| | | | Signal Conditioning & Associated Cabling | | | 4/1/2012 | 8/1/2013 | 1 | | 1 | | | 1 | lot | 9.000 | 9.00 | | | 15 | 10 | 5 | | 20 | 80 | 10 | 5 | 5 | 178.5 | Mozulay/Ramkri | 4 | 15 |
| | 546 - Coil Analog Protection | $197.6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | *Overload Protection & Associated Cabling(TF)* | | | 4/1/2012 | 8/1/2013 | 1 | | 1 | | | 5 | units | 4.000 | 20.00 | 1.000 | 4.000 | 50 | 30 | 10 | 20 | 20 | | 10 | 4 | 10 | 197.6 | Mozulay/Ramkri | 2 | 25 |
| ***Design and Integration*** | | $669.718 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 551 - System Design | $500.7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | Design Drawings & Drawings changes , as-builts | New drawings & Misc. updates | | ######## | 4/15/2014 | 1 | | 1 | | | | | | | | | 90.00 | 70.00 | | | | | | | | 190.7 | Ramkri | 2 | 10 |
| | | | | Analysis | | 7/1/2009 | 7/1/2010 | 1 | | 1 | | | | | | | | | 70 | | | | | 15 | | | | 114.2 | Ramkri | | |
| | | | CDR Power system | All power systems | | ######## | | 1 | | 1 | | | | | | | | | 15.00 | 15.00 | | | | | | | | 34.9 | Ramkri | 2 | 10 |
| | | | PDR Power system | All power systems | | ######## | | 1 | | 1 | | | | | | | | | 15.00 | 15.00 | | | | | | | | 34.9 | Ramkri | 2 | 10 |
| | | | FDR 1 | PF1a | | ######## | | 1 | | 1 | | | | | | | | | 15.00 | 15.00 | | | | | | | | 34.9 | Ramkri | 2 | 10 |
| | | | FDR 2 | TF/OH | | ######## | | 1 | | 1 | | | | | | | | | 15.00 | 15.00 | | | | | | | | 34.9 | Ramkri | 2 | 10 |
| | | | Calculations | Calculations - documentation | | ######## | 4/15/2014 | 1 | | 1 | | | | | | | | | 15.00 | | | | | 30 | | | | 56.0 | Neumeyer | 2 | 10 |
| | 552 - System Testing | $169.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | Procedures PTPs, ISTPs | New Procedures | | | | 1 | | 1 | | | | | | | | | 15.00 | 15.00 | | | | | | | | 34.9 | Ramkri/Baker | 2 | 10 |
| | | | | DC Circuit Inputs and Impedance Measurements | | | | 1 | | 1 | | | | | | | | | | | | | | | 3 | | 8 | 9.5 | Ramkri/Baker | 2 | 10 |
| | | | | Electrical Interlock Testing | | | | 1 | | 1 | | | | | | | | | | | | | | | 3 | | 8 | 9.5 | Ramkri/Baker | 2 | 10 |
| | | | | Kirk Key Interlock Testing | | | | 1 | | 1 | | | | | | | | | | | | | | | 2 | | 3 | 4.8 | Ramkri/Baker | 2 | 10 |
| | | | | Instrumentation Test & Calibration | | | | 1 | | 1 | | | | | | | | | | | | | | | 2 | | 2 | 4.1 | Ramkri/Baker | 2 | 10 |
| | | | | Real Time Control System Testing | | | | 1 | | 1 | | | | | | | | | | | | | | | 3 | | 3 | 6.1 | Ramkri/Baker | 2 | 10 |
| | | | | Coil Protection System Testing | | | | 1 | | 1 | | | | | | | | | 15 | | | | | | 3 | | 3 | 26.8 | Ramkri/Baker | 2 | 10 |
| | | | | Coil Power Supply Dummy Load Testing | | | | 1 | | 1 | | | 10 | PS | | | | | | | 5 | | 20 | | 20 | 10 | 20 | 73.3 | Ramkri/Baker | 2 | 10 |
| | | | TOTALS | | | | | | | | | | | | | 740.50 | | $6 | 747 | 401 | 65 | 141 | 455 | $765 | 103 | 76 | 196 | 4112.4 | | | |
| | | | | | | | | | | | | | | | M&S --> | 872.31 | | 6.000 | 1030 | 381 | 90 | 170 | 304 | $901 | 142 | 92 | 130.95936 | 4118.4 | | | |

*Notes:*

*SCOPE COVERED*
*1. TF WILL BE PULSED AT 130kA FOR 7.3 SECONDS EVERY 2400 SECONDS*
*2 Sub-contract estimates based on bids and a projected increase of cost*
*3. PC LINK CHANGES INCLUDED*
*4. Cost in 2010 Dollars*
*5. SCHEDULE WILL AFFECT COST*

***Summary of Basis of Estimate***

***A Work Breakdown Structure has been developed for the project under which the Power System is classified as WBS5.***

***This Cost Estimate has been developed based on the following:***

- ***Prior Experience***
- ***Similar tasks previously executed***
- ***Input from Vendors***

**CATEGORIZATION CODES:**
1 - National Standards
2 - Engineering Judgement/Experience
3 - Estimates/Data from External Sources (e.g., W7X, ATF, etc.)
4 - Previous PPPL/ORNL Experience (e.g., TFTR, NSTX, PLT, etc.)
5 - Prototype Data/Test Results
6 - Catalogue Price/Vendor Quote
7 - Placed Contracts
8 - Actual experience for NCSX Work

| | |
|---|---|
| **Cost Center:** | 9417 |
| **Job Number:** | 5000 (Covers elements 5100 - 5500) |
| **Job Title:** | 9417 |
| **Job Manager:** | S. Ramakrishnan |

NSTX CENTER STACK UPGRADE - PS CHANGES 130kA part capability 8 parallels -------060710 nopf

*1. TF WILL BE PULSED AT 129.778kA FOR 7.6 SECONDS EVERY 2400 SECONDS*

- *Engineering Judgment*
- *Other aspects*
- *Costs are essentially center -of-the-error bars*
- *Areas of risk judged ; constraints noted*

| | | | | | | | | | | | | M&S | | | | | Design/ Procurement | | Installation | | | | Commissioning | | | | Line Total | Names of req'd skills if known | Basis of Estimate Category | % Cont'cy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Duration | Start date | Finish date | Mult | Qty | excl factor | Qnty | Units | Qty | Units | Unit Cost (k$/unit) | Cost ($K) | Spare Units | Spare Cost ($K) | EEEM (md) | Dm (md) | EEEM (md) | EESM (md) | EETB (md) | SC ($K) | EEEM (md) | EESM (md) | EETB (md) | ($K) | | | |
| | | | | days | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | 9 - Other | | | | | | | | | | | | |

| | K$/Day | FY2010 Hourly Rates |
|---|---|---|
| *EEEM* | 1.3794 | 172.4 |
| *EESM* | 1.2049 | 150.6 |
| *EETB* | 0.6682 | 83.5 |
| *G&A (MHX)* | 1.1780 | 1.178 |
| *Dm* | 0.9504 | 118.8 |

564

| | | ΣMD | Rate | $K | ΣFTE | Years | FTE/yr |
|---|---|---|---|---|---|---|---|
| cross check | EEEM | 915 | 1.379 | 1261 | 4.2 | 4 | 1.04 |
| | EESM | 217 | 1.205 | 261 | 1.0 | 2 | 0.49 |
| | EETB | 651 | 0.668 | 435 | 3.0 | 2 | 1.48 |
| | EADM | 401 | 0.950 | 381 | 1.8 | 3 | 0.61 |
| | M&S | | | 1773 | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost Center:** | 9417 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Job Number:** | 5000 (Covers elements 5100 - 5500) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Job Title:** | 9417 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Job Manager:** | S. Ramakrishnan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | *TASK DESCRIPTION* | | | *M&S* | | | | | | | | | | *Design/ Procurement* | | *Installation* | | | | *Commissioning* | | | | *Line Total* | Names of req'd skills if known | Basis of Estimate Category | % Cont'cy |
| | | | | | | Multiplier | Qnty | Units | Qnty | Units | Qnty | Units | Unit Cost (k$/unit) | Cost ($K) | Spare Units | Spare Cost ($K) | EEEM (md) | EASB (md) | EEEM (md) | EESM (md) | EETB (md) | Subcontract ($K) | EEEM (md) | EESM (md) | EETB (md) | ($K) | | | |
| *347 - Digital Coil Protection (DCP)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | DCP design | Design & Supervision | | 1 | | | | | | | | | | | 95.0 | 90.0 | | | | | | | | $216.6 | Woolley | 2 | 40 |
| | | | | Hardware | | 1 | | | | | 2 | | $210.0 | $420.0 | | | 2.0 | 2.0 | | 4.0 | 8.0 | | | 10.0 | 10.0 | $528.3 | Lawson | 2 | 40 |
| | | | | I&C support | (P.Sichta | 1 | | | | | | | | | | | 75.0 | | | | | | | 40.0 | 5.0 | $155.0 | Sichta | 2 | 40 |
| | | | | Software | | 1 | | | | | | | | | | | 140.0 | | | | | | | 50.0 | 2.0 | $254.7 | Lawson/Que | 2 | 40 |
| | | | | Cabling/Raceways | | 1 | | | | | 1 | | $18.0 | $18.0 | | | | | 12.0 | 50.0 | 100.0 | $40.0 | | 2.0 | 2.0 | $215.7 | | | 40 |
| | *392 - System Testing* | *$13.01C* | *$13.01C* Procedures | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | PTPs, ISTPs | Procedures | | 1 | | | | | | | | | | | 2.0 | 2.0 | | | | | | | | $5.2 | | | 30 |
| | | | | Pwr Supply PTP | | 1 | | | | | | | | | | | | | | | | | 2.0 | 2.0 | 4.0 | $7.8 | | | 30 |
| | | | TOTALS | | | | | | | | | | | ###### | | | 314.0 | 94.0 | 12.0 | 54.0 | 108.0 | $40.0 | 2.0 | 104.0 | 23.0 | ###### | | | |

**CATEGORIZATION CODES:**

1 - National Standards
2 - Engineering Judgement/Experience
3 - Estimates/Data from External Sources (e.g., W7X, ATF, etc.)
4 - Previous PPPL/ORNL Experience (e.g., TFTR, NSTX, PLT, etc.)
5 - Prototype Data/Test Results
6 - Catelogue Price/Vendor Quote
7 - Placed Contracts
8 - Actual experience for NCSX Work
9 - Other

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *RATES* | *K$/Day* | | | | | | | | | | | | M&S --> | 478 | | | | | | | | | | | | | | | |
| *EEEM* | *1.37936* | | | | | | | | | | | | | ###### | | | | | | | | | | | | | | | |
| *EESM* | *1.20485* | | | | | | | | | | | | | 47.120 | | | | | | | | | | | | | | | |
| *EETB* | *0.66816* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *G&A* | *1.178C* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *EASB* | *0.9504* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | EEEM | 328 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | EESM (D) | 94 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | EESM | 158 | |
| | | FY2009 Hourly Rates | | | | | | | | | | | | | | | | | | | | | | | | | EETB= | 131 | |
| ***EEEM*** | 1.4211 | 177.6 | 1.4211 | 1.3680 | | | | | | | | | | | | | | | | | | | | | | | M&S | | |
| ***EESM*** | 1.2028 | 150.4 | 1.2028 | 1.1600 | | | | | | | | | | | | | | | | | | | | | | | Total | | |
| ***EETB*** | 0.6595 | 82.4 | 0.6595 | 0.6400 | | | | | | | | | | | 1557 | | | | | | | | | | | | | | |
| ***G&A (MHX)*** | 1.2260 | 1.281 | | 1.2500 | | | | | | | | | | | | | | | | | | | | | | | | | |
| ***DM*** | 1.0132 | 126.7 | 1.0132 | 0.9900 | | | | | | | | | | | | | | | | | | | | | | | | | |

| WBS 5 BREAKDOWN WITH COST WITHOUT CONTINGENCY | | | | | | | k$ | k$ |
|---|---|---|---|---|---|---|---|---|
| ➢51 | AC POWER | | | | | | $62.1 | |
| | ✂✂ | Experimental AC Power | | | | | | $62.1 |
| ➢52 | AC/DC CONVERTERS | | | | | | $48.1 | |
| | ➢521 | Reactivate Converters | | | | | | $48.1 |
| ➢53 | DC SYSTEMS | | | | | | #REF! | |
| | ➢531 | FCPC DC Systems | | | | | | |
| | | ➢531.1 | NSTX PF1a PS loop changes | | | | | $252.2 |
| | | ➢531.2 | TF PS Power Cabling/Changes | | | | | #REF! |
| | | ➢531-3 | Removing Cabling | | | | | #REF! |
| | | ➢531.4 | DC Reactors | | | | | #REF! |
| | | ➢531.5 | TA Cabling Changes | | | | | $52.1 |
| | ➢532 | TA to NTC and NTC changes | | | | | | |
| | | ➢532.1 | PCTS Changes | | | | | $103.5 |
| ➢54 | CONTROL & PROTECTION SYSTEM | | | | | | #REF! | |
| | ➢541 | Electrical Interlocks | | | | | | $682.0 |
| | ➢542 | Kirk Key Ingterlocks | | | | | | $75.8 |
| | ➢543 | Real Time Control | | | | | | $165.5 |
| | ➢544 | PC Link/FD/FG Changes | | | | | | #REF! |
| | ➢545 | Instrumentation | | | | | | $563.0 |
| | ➢546 | Coil Protection | | | | | | $197.6 |
| | ➢547 | Machine Protection System | | | | | | $1,383.3 |
| ➢55 | System Design & Integration | | | | | | $669.7 | |
| | ➢551 | System Design | | | | | | $500.7 |
| | ➢552 | System Testing | | | | | | $169.0 |
| ➢FY09 | ActualFY09 | | | | | | $385.8 | $385.8 |
| | | | | GRAND TOTAL | | | #REF! | #REF! |

Note: M&S Cost: 2242k$; Sub-contractor for Installation: 1012k$ - Included above.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost Center:** | | 9417 | | | | | | | | | | | | | | | | |
| **Job Number:** | | 5000 (Covers elements 5100 - 5500) | | | | | | | | | | | | | | | | |
| **Job Title:** | 9417 | NSTX Center Stack Upgrade - Power System | | | | | | | | | | | | | | | | |
| **Job Manager:** | | S. Ramakrishnan | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| **Uncertainty of the Estimate** | | | | | | | | | | | | | | | | | | |
| | | | | High | Medium | Low | Uncertainty Range (%) | Comments/Other Considerations | | | | | | | | | | |
| | Design Maturity | | | | x | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | Design Complexity | | | | x | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| **Residual Impacts** | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | Cost Impact | | Schedule Impact | |
| | Risk Description | | | | | | Likelihood of Occurring | Mitigation Plan | | | Basis of estimate | | | | Low ($K) | High ($K) | Low (weeks) | High (Weeks) |
| 1 | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Notes: | | | | | | | | | | | | | | | | | | |
| (1) | Cost impacts should NOT include standing army costs which are separately calculated from the schedule impact | | | | | | | | | | | | | | | | | |
| (2) | The schedule impacts should be entered as the min and max impacts on the critical path. | | | | | | | | | | | | | | | | | |
| | If there is no critical path impact then the schedule entries should be zero. | | | | | | | | | | | | | | | | | |
| (3) | Likelihood of occurrence should be entered consistent with our risk classification methodology, i.e. | | | | | | | | | | | | | | | | | |
| | 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%) | | | | | | | | | | | | | | | | | |

| Design Maturity | Design Complexity | | | | | |
|---|---|---|---|---|---|---|
| | Low | | Medium | | High | |
| Low | -15% | +25% | -20% | +40% | -30% | +60% |
| Medium | -10% | +15% | -15% | +25% | -20% | +40% |
| High | -5% | +10% | -10% | +15% | -15% | +25% |

**Design Maturity Definition**

| | |
|---|---|
| High | |
| | Final design available. All design features/requirements well known. No further design development or evolution expected that will impact estimate. |
| Medium | |
| | Preliminary design available. Some additional design evolution likely. Further developments can be somewhat expected or anticipated and reflected in estimate. |
| Low | |
| | No better than conceptual design basis currently available. Design details, procedures, etc. still need much development and evolution of requirements beyond estimate basis is likely 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-a-kind assembly or work tasks. No good basis for estimating work exists so there is a high degree of estimate uncertainty. |
| | Based on standard industry and DOE estimate classifications (Per AACEI Recommended |