71-970729-CLN-01

TO: M ONO
FROM: C NEUMEYER
SUBJECT: COSTS FOR I&C INTERFACE AND PLASMA CONTROL

Now that we have moved forward with the design of NSTX, some control integration tasks which were not identified or well understood during the conceptual design phase have now gained visibility. The baseline NSTX budget only partially covers these tasks.

In addition, the present NSTX organizational structure does not explicitly identify leadership roles for engineering and physics integration of the real time control of NSTX. I would like to emphasize that these are key roles which need to become active very soon in order that we are ready for first plasma.

The purpose of this memo is to highlight and quantify the above issues so that corrective actions can be taken.

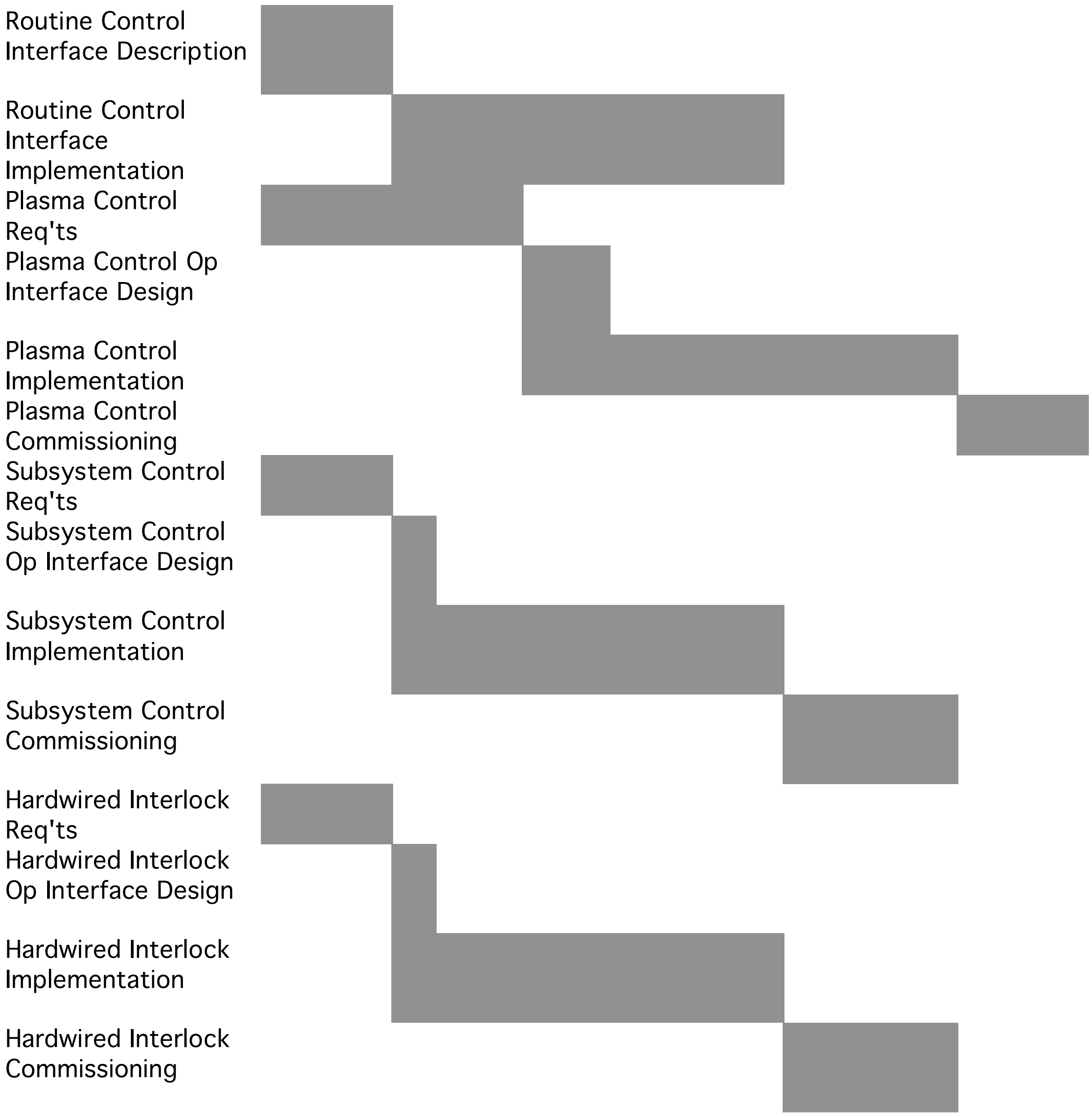
With regard to the control integration tasks, they are outlined in Attachment 1. The work is divided into two categories, namely the routine control interface for each of the WBS elements with WBS 6, and the real time control. Estimates for the routine control interface are developed in Attachment 2, and for the real time control in Attachment 3. These are rough estimates which were developed with inputs from the WBS managers. A summary of the budget situation is given in the following table (in man days).

	WBS1	WBS2	WBS3	WBS4	WBS5	WBS6	Eng Int	Phys Int	∑
Routine Control Interface	24	53	86	0	65	0	0	0	228
Real Time Control	20	30	6	45	45	404	70	119	739
Budget	0	96	0	0	110	0	0	111	317
Shortfall	44	-13	92	45	0	404	70	8	650

As indicated in the table there is a significant budget shortfall, mainly due to the lack of budgeted time for computer programming for the real time control in WBS6 (WBS6 baseline includes the provision of the Skybolt computer hardware and related high speed data links, but does not include programming time).

With regard to the need to commence with the real time control activites and establish leadership roles, the following chart gives an outline of the main tasks and an overall schedule.

FY98 FY99
10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4



I plan to call a meeting next week to discuss corrective actions.

cc:

T Egebo P Heitzenroeder S Kaye R Strykowsky NSTX File

ATTACHMENT 1

Outline and Definition of WBS Tasks
for
NSTX Process Control

1.0 Routine Control and Data Acquisition

Routine Control and Data Acquisition encompasses the manipulation of data which are not involved in critical real time feedback control and are therefore not required to be processed in*synchronous* or *deterministic* fashion.

Synchronous means occuring at a regular interval (e.g. once per millisecond) and *deterministic* means occuring in a repeated pattern or sequence.

1.1 Control

Control refers to the input, output, and processing of digital and analog signals which correspond to *Control Points*.

Control Points are the interface points between the Central I&C (CIC) system and the WBS equipment.

The CIC will provide the input/output (I/O) hardware (e.g. digitial input modules, etc.) to accomodate the Control Points, as well as all racks/wiring up to an interface terminal location (a.k.a. *Cross Connect*). The WBS element will provide the wiring and termination for each Control Point signal on to the Cross Connect.

Control points typically fall into one of four categories:

Digital Input - single bit input from WBS equipment to CIC
Digital Output - single bit output from CIC to WBS equipment
Analog Input - single channel analog input from WBS equipment to CIC
Analog Output - single channel analog output from CIC to WBS equipment

Each Control Point needs to be defined by the WBS element to the CIC in a format prescribed by the CIC. The CIC will maintain a database of the Control Points.

Many Control Points exist already via the D-site CAMAC systems. Still, many new Control Points will be required.

The CIC will transfer the Control Point information from the TFTR CICADA format (Master Device Table) to the new database.

The WBS elements will have to review the transferred data and indicate which is to be used for NSTX and which is not. In addition, modifications may be required for NSTX.

The WBS elements will have to define any new Control Points which they will need for NSTX.

The CIC will provide the hardware and software infrastructure required to:

- collect input data at an interval not greater than a specified time (e.g. ≤ one second between updates) and make the collected data available to *Software Applications* which need to make use of it

- distribute output data when demanded by *Software Applications* which need to control the output data

- provide tools for creating *Software Applications* as required by the WBS operations

Software Applications are programs which process the Control Point input data and act on the Control Point output data. For the most part these are envisioned to consist of the applications which drive *Mimic Diagram* displays for the operator interface.

Mimic Diagrams are graphical displays of the processes underway by the WBS equipment. These displays show the state of the equipment based on the latest Control Point input data and allow the operator to change the state of the equipment via the Control Poing output data.

The WBS elements will determine the requirements of the Software Applications and will construct them using the tools provided by CIC.

Tasks are summarized as follows.

1.1.1 Control Point Database Maintenance

a. Review/modify Control Point database related to existing D-site equipment interfaced via CAMAC

b. Define new NSTX Control Points

1.1.2 Software Applications

a. Create Mimic Diagrams

b. Create Other Applications

1.1.3 Control Point Commissioning - test each Control Point from the Software Application to the WBS equipment

1.2 Data Acquisition

Data Acquisition (in the context of this document) refers to the set up and triggering of high speed digitizers, along with the collection and display of the digitized data, which is related to Process Control. This is not to be confused with the WBS 62 Data Acquisition element.

Data Points are the interface points between the Central I&C (CIC) system and the WBS equipment.

The CIC will provide the input/output (I/O) hardware (e.g. transient digitizers) to accomodate the Data Points, as well as all racks/wiring up to an interface terminal location (a.k.a. *Cross Connect*). The WBS element will provide the wiring and termination for each Data Point signal on to the Cross Connect.

All Data Points are treated as analog input signals from WBS equipment to CIC.

Each Data Point needs to be defined by the WBS element to the CIC in a format prescribed by the CIC. The CIC will maintain a database of the Data Points.

Many Data Points exist already via the D-site CAMAC systems. Still, many new Data Points will be required.

The CIC will transfer the Data Point information from the TFTR CICADA format (Master Device Table) to the new database.

The WBS elements will have to review the transferred data and indicate which is to be used for NSTX and which is not. In addition, modifications may be required for NSTX.

The WBS elements will have to define any new Data Points which they will need for NSTX.

The CIC will provide the hardware and software infrastructure required to:

- set up and distribute through the facility clock system standard *Clock Events* which can be used to initiate triggers, via a *Clock Event Application*

- set up the transient digitizers including trigger time w.r.t. the Clock Events, sampling rate, and pre-trigger data to be retained, if any, via a *Digitizer Set Up Application*

- trigger the transient digitizers at the prescribed times

- collect the digitzer data and display it via a *Display Application*, and make it available to other Software Applications which may need to make use of it

The CIC will provide the Clock Event, Digitizer Set Up, and Display Applications.

The WBS elements will determine the requirements of other Software Applications, if required, which process the acquired data and will construct them using the tools provided by CIC.

1.2.1 Data Point Database Maintenance

a. Review/modify Data Point database related to existing D-site equipment interfaced via CAMAC

b. Define new NSTX Data Points

1.2.2 Software Applications

a. Clock Event, Digitizer Set Up, and Display Applications

b. Special applications, if required

1.2.3 Data Point Commissioning - test each Data Point from WBS equipment to the Display Application.

2.0 Real Time Control

Real Time Control encompasses the manipulation of data which is involved in critical real time control functions and is required to be processed in*synchronous* and *deterministic* fashion.

Synchronous means occuring at a regular interval (e.g. once per millisecond) and *deterministic* means occuring in a repeated pattern or sequence.

The main Real Time Control task for NSTX is *Plasma Control*.

Supporting *Subsystem Control* tasks will exist for various WBS elements (e.g. WBS 5, Power Supplies), such that those elements are able to operate both in conjuction with plasma control and in a stand alone mode (e.g. power supplies, without plasma, using NSTX magnets or dummy loads).

The Plasma and Subsystem Control will be evolutionary, with a minimal system in place for first plasma. However the design of the hardware and software related thereto should anticipate the future control as envisioned.

At present it is assumed that the Plasma Control as well as the power supply Subsystem Control can be accomplished using a SPARC host computer and the Skybolt Shamrock computer presently in use by TFTR for the PP&CC. The feasibility and sensibility of this may or may not prove out as we get deeper into the tasks.

A second Real Time Control task is *Critical Interlocking*. The basic philosophy will be that, while the Plasma Control may include features to avoid undesirable sequences and combinations of events, it shall not be depended on for the protection of equipment or safety of personnel. For protection and safety, there needs to be an interlocking of critical fault detection and annunciation features which are inherent in the subsystems but which need to be coordinated across the board. This system needs to be very simple and reliable.

WBS elements of NSTX involved in Real Time Control are...

a. Plasma (WBS 72)

b. Diagnostics (WBS 4)

c. Magnets (WBS 13)

d. Cooling Water Systems (WBS 34)

e. Power Supplies (WBS 5)

f. HHFW Sources (WBS 21)

g. ECH Source (WBS 22)

h. CHI (WBS 23)

i. NBI (WBS 24, upgrade)

j. Gas Injection (WBS 32)

Following is a discussion of the roles envisioned for each of the above.

Plasma Control

Project Physics will lead the development and integration of Plasma Control, and will be responsible for establishing...

- what variables shall be controlled
- what actuators are required
- what measurements are required
- what measurement interpretation and estimation is required
- how the control should be partitioned
- what control algorithms shall be adopted
- what time scales are required
- what discharge fault detection is required and how to coordinate response
- what the Physics Operator interface should consist of
- what internal control data storage is required

One possible partitioning of the Plasma Control might be as follows...

- overall timing, sequencing, and coordination

- plasma initiation
- fast position control
- shape and total current control
- current profile control
- kinetic control
- divertor control
- stability and limit control

The design of Plasma Control should be such that it facilitates the creation of a simple, minimal system for first plasma but allows for expansion. In addition, the design should permit and facilitate experimentation with a variety of control methodologies for those parts of the control outside of the basic timing, sequencing, and coordination. The latter should be relatively secure compared to the other parts.

For first plasma, it is envisioned that the first four parts listed above are required.

Diagnostics

Numerous diagnostic devices will provide real time measurements of plasma parameters for use by the Plasma Control system. Tasks in the context of Plasma Control will include....

- coordination with Project Physics to establish what signals are to be supplied to Plasma Control, in what form, and at what sampling rate

- coordination with CIC in terms of interface with fast data links

Magnets

Operation of NSTX must respect the limits of the magnets and related components (e.g. the center stack casing) in terms of temperatures and forces/stresses. In some cases temperatures are measured directly (surface of OH coil insulation) or indirectly (cooling water outlet temperature), in others they must be estimated.

It is envisioned that the protection of the magnets will reside in both hardware and software associated with the Power Supply system. Initially, the *Rochester Instruments System (RIS)* system will likely be used. This provides simple overcurrent and $\int i^2(t)dt$ protection. Later, perhaps the more sophisticated *Coil Protection Calculator (CPC)* system may be invoked. In addition to these hardware items, it is envisioned that the Power Supply Subsystem Control software will include simple coil protection algorithms.

Therefore the main task for the Magnets in the context of Plasma Control will be the specification of limits to be respected.

An additional task will relate to the coordination of details of interface of the magnet instrumentation (thermocouples) with CIC, and with real time hardware and software protection. The former falls under the Routine Control and Data Acquisition category, whereas the latter falls under the Real Time Control Critical Interlocking category.

Cooling Water Systems

The magnet cooling water flow status and temperature measurements need to be interfaced with the CIC, and the real time hardware and software protection described above in the section on Magnets. The former falls under the Routine Control and Data Acquisition category, whereas the latter falls under the Real Time Control Critical Interlocking category.

Power Supplies

Real time feedback Subsystem Control software will be required for...

a. power supply operation into dummy load
b. power supply operation into NSTX without plasma
c. power supply operation into NSTX with plasma

This software shall include features to avoid overcurrent and overheating of the magnets, etc.

There will be significant interface between the power supply system and the Real Time Control Critical Interlocking.

It is noted here that the present data links used at D-site for real time data communication, namely the PC Link and the HSDL, along with the interface with the PC SEL computer, are woefully obselete and need to be replaced.

HHFW

Initially, the HHFW RF will require fairly simple control which facilitates the pre-programmed power level and timing information for RF heating. The only real time data exchange will consist of on/off commands and fault status information. As NSTX evolves and gets into using the RF for current drive, things will become much more complex. So, the initial design for real time control should be fairly simple but should anticipate the eventual evolution.

ECH

ECH will require fairly simple control which facilitates the pre-programmed power level and timing information. The only real time data exchange will consist of on/off commands and fault status information.

CHI

Initially, CHI will consist of a capacitor bank discharge. If it works well, a current sustainment mode using some power supplies with feedback may be undertaken as an upgrade. The initial operation will require fairly simple control via the power supply Subsystem Control which facilitates the pre-programmed voltage level and timing information. Because of the very fast time scale there may be some special requirements imposed on the control of the PF coils. Eventually, if the upgrade is undertaken, feedback would be introduced via the power supply.

NBI

The NBI will require fairly simple control which facilitates the pre-programmed power level and timing information for heating. The only real time data exchange will consist of on/off commands and fault status information.

Gas Injection

Initially, the gas injection will likely consist of a preprogrammed injection waveform (presumably one per each of the three valves). Later, it will most likely required feedback control based on density and/or pressure. So, the initial design for real time control should be fairly simple but should anticipate the eventual evolution.

Based on the above, as task summary for the Real Time Control is as follows.

2.1 Plasma Control

a. Define basic requirements for Plasma Control, considering the various phases of its evolution from 1st plasma to the ultimate
b. Coordinate the design of the Plasma Control hardware and software, including the interface with the subsystems
c. Develop designs for Physics Operator interface pages
- control settings input
- waveform generator
- internal variable display

d. Implement the hardware and software
e. Commission the hardware and software

2.2 Subsystem Control

a. Define basic requirements for Subsystem Control, for each system as listed above, considering the various phases of its evolution from 1st plasma to the ultimate
b. Coordinate the design of the Subsystem Control hardware and software, including the interface with the Plasma Control and Critical Interlocking
c. Implement the hardware and software
d. Commission the hardware and software

2.3 Critical Interlocking

a. Define basic requirements for Critical Interlocking, considering the various phases of its evolution from 1st plasma to the ultimate
b. Coordinate the design of the Critical Interlocking hardware and software, including the interface with the Plasma Control and Subsystem Control
c. Implement the hardware and software
d. Commission the hardware and software

ATTACHMENT 2

		WBS1	WBS2	WBS3	WBS4	WBS5	WBS6	
	#Existing Points	0	0	58	0	1813		
	#New Points	100	200	451	0	0	47	
	#Subsystem Controllers	0	1	1	0	0		
	#Pages	4	8	5	0	10	55	
1.1	Help CIC identify each existing TFTR CICADA CAMAC crate required by the NSTX	0	4	4	4	4	X	4hrs each
1.2	Compile a list of existing TFTR CICADA CAMAC crates to be reused by the NSTX subsystem	X	X	X	X	X		
1.3	Generate a TFTR CICADA CAMAC point list for each NSTX subsystem crate.	X	X	X	X	X		
1.4	Add/delete points to/from the TFTR CICADA point list (generated by CIC). Document the NSTX subsystem CAMAC Process I/O Point List Summary in a format prescribed by CIC.	0	0	0.967	0	30.22	X	1min per point
1.5	Document requirements from the NSTX subsystem CAMAC Process I/O Point List Summary in th WBS 6 SRD/SDD	X	X	X	X	X		
1.6	Transfer Process I/O Point information from the TFTR CICADA format (Master Device Table) to the new NSTX database	X	X	X	X	X		
1.7	Review/revise NSTX CAMAC Process I/O Point database records.	0	0	0.58	0	18.13	X	1hr per 1/100 of existing points
1.8	CIC will maintain the NSTX CAMAC Process I/O Point database	X	X	X	X	X		
2.1	Provide guidance to the WBS subsystem to quantify and qualify I/O point requirements.	X	X	X	X	X		
2.2	Identify each new NSTX Process I/O Point that is required to centrally monitor and/or control the subsystem. Establish	100	200	451	0	0	X	1hr per new point

	detailed interface characteristics for each new Process I/O Point							
2.3	Generate the NSTX subsystem Process I/O Point List Summary in a format prescribed by CIC	1.667	3.333	7.517	0	0	X	1min per new point
2.4	Document requirements from the NSTX subsystem Process I/O Point List Summary in the WBS 6 SRD/SDD	X	X	X	X	X		
2.5	Create the NSTX subsystem Process I/O Point database.	X	X	X	X	X		
2.6	Review/revise NSTX Process I/O Point database records.	10	2	4.51	0	0	X	1hr per 1/10 of new points
2.7	CIC will maintain the NSTX Process I/O Point database.	X	X	X	X	X		
3.1	Provide guidance to the WBS subsystem to determine the best way to interface standalone subsystem controllers to CIC.	X	X	X	X	X		
3.2	Identify existing and new standalone subsystem controllers (PLCs, closed loop controllers, etc.) that must be interfaced to CIC.	0	4	4	0	0	X	4 hrs per controller to identify and summarize purpose
3.3	Identify each NSTX Process I/O Point that is required to centrally monitor and/or control the subsystem controller	0	1	1	0	0	X	1hr per point, 25 points per controller
3.4	Generate the NSTX subsystem Standalone Controller Requirements in a format prescribed by CIC.	0	16	16	0	0	X	16 hrs per controller to develop description of basic functions and I/O
3.5	Document requirements from the NSTX subsystem Standalone Controller Requirements in the WBS 6 SRD/SDD.	X	X	X	X	X		
3.6	Create the NSTX	X	X	X	X	X		

	subsystem Standalone Controller database.							
3.7	Review/revise NSTX Standalone Controller database records.	0	12.5	12.5	0	0	X	1/2 hour per point, 25 points per controller
3.8	CIC will maintain the NSTX Standalone Controller database.	X	X	X	X	X		
4.1	Provide CIC racks. Procure/secure, fabricate and install racks to house Process Control System components such as CIC chassis, I/O modules, power supplies, etc.	X	X	X	X	X		
4.2	Provide input to CIC regarding the preferred location of interfaces to subsystem field devices.	0	16	16	0	0	X	16 hrs per controller to settle location issues
4.3	Provide subsystem racks. Procure/secure, fabricate and install racks to house standalone subsystem Process Control System components	X	X	X	X	X		
4.4	Provide connectivity from the CIC system to the WBS subsystem.	X	X	X	X	X		
4.5	Provide CIC rack cross connects. Assign a Cross Connect location for each new Process I/O Point	X	X	X	X	X		
4.6	Wire field devices to the WBS-side of the CIC Cross Connects. Reflect new Process I/O Point cross connect locations on WBS Documentation.	0	0	0	0	0	X	Part of routine WBS work
5.1	Define the number and location of dedicated hardware display monitors	0	4	4	4	4	X	4 hrs each
5.2	CIC will purchase and install the required number of Operator Interface display monitors	X	X	X	X	X		
5.3	Provide Operator Interface Display requirements in a format prescribed by CIC.	In 5.7	In 5.7	In 5.7	In 5.7	In 5.7	X	

5.4	Document the physical location for the Operator Interface display(s)	In 5.1	In 5.1	In 5.1	In 5.1	In 5.1	X	
5.5	Provide the tools for Mimic Page creation.	X	X	X	X	X		
5.6	Provide Operator Interface MAINTENANCE Mimic displays.	X	X	X	X	X		
5.7	Provide subsystem Mimic Pages	64	128	80	0	160	X	16hr per page
6.1	The CIC element will establish an NSTX Process Control System software standard	X	X	X	X	X		
6.2	The CIC element will establish an NSTX hardware standard for NSTX Process Control System interface	X	X	X	X	X		
6.3	Each WBS subsystem is required to comply with the software and hardware standards developed by the CIC element.	No Cost	No Cost	No Cost	No Cost	No Cost	X	
6.4	The CIC element will provide the hardware and software infrastructure	X	X	X	X	X		
6.5	The WBS elements will determine the requirements of the Software Applications and will construct them using the tools provided by CIC.	0	0	0	0	0	X	Explicit Req't
7.1	Test each Process I/O Point from the MAINTENANCE Mimic displays to the CIC-side of the Cross Connect	X	X	X	X	X		
7.2	Test each Process I/O Point from the WBS equipment to the WBS-side of the Cross Connect	Via 7.3	Via 7.3	Via 7.3	Via 7.3	Via 7.3	X	
7.3	Perform End-to-end test from WBS equipment to the WBS mimic pages	16.67	33.33	84.83	0	302.2	X	10 min per point
7.4	Provide assistance to WBS element during end-to-end testing	X	X	X	X	X		
		192.3	424.2	686.9	8	518.5	0	hrs
		24.04	53.02	85.86	1	64.81	0	days

ATTACHMENT 3

	WBS 1	WBS 2	WBS 3	WBS 4	WBS 5	WBS 6	Phys	Engr
Plasma Control								
a. Define Basic Requirements						5	20	20
b. Coordinate Hardware & Software, Including Interface With Subsystem Control & Hardwired Interlock System						20	20	20
c. Develop Designs for Physics Operator Interface Pages							20	
d. Implement the Hardware & Software						120		20
e. Commission the Hardware & Software						20	10	20
Subsystem Control								
a. Define Basic Requirements	5	5	2	10	10			
b. Coordinate Hardware & Software, Including Interfaces With Plasma Control & Hardwired Interlock System	5	10	2	10	20			
c. Develop Designs for Operator Interface Pages	5	5		5	5			
d. Implement the Hardware & Software						120		
e. Commission the Hardware & Software	5	10	2	20	10	60		
Hardwired Interlock System								
a. Define Basic Requirements						5		5
b. Coordinate Hardware & Software, Including Interface With Plasma Control and Subsystem Control						2		2
c. Develop Designs for Operator Interface Pages						2		2
d. Implement the Hardware & Software						40		20
e. Commission the Hardware & Software						10		10
Totals	20	30	6	45	45	404	70	119