WBS: 4.2

WBS Name: TPC

Definition: The TPC is the main detector of the STAR experiment and is designed to detect, identify and measure charged particle momenta for $|\eta| < 1.0$. It provides tracking alone over $1.0 < |\eta| < 2.0$. These measurements allow the study of a variety of particle characteristics.

This WBS includes the following lower levels:

.1 Outer field cage (OFC)

.2 Central membrane (High voltage plane)

.3 Inner field cage (IFC)

.4 Sector

.5 Wheel (Sector support)

.6 Laser system

.7 Gas system

.8 Cooling system

.9 Transport fixtures/shipping

.10 TPC assembly & test

.11 TPC project management

This top–level WBS includes all the effort and components necessary to design, fabricate, assemble, test and ship the TPC. This WBS does not include electronics which are in 4.7.1.2 TPC Detector Electronics. The interface with 4.7.1.2.1 Front end electronics is at the connector mounted onto the back of the pad plane. FEE will provide the surface–mounted connector for the back of the pad plane multilayer board. The TPC cooling system will provide the front end electronics cooling backing plates and assembly labor for attaching these plates. The TPC interface with the STAR detector is with 4.4.1 Solenoid as it is supported off of this component. It also has several interfaces with 4.7 Electronics. Expenditure of resources in the WBS concludes when the TPC arrives at the STAR assembly hall at RHIC. The TPC is expected to initially support the Trigger (4.7.3) and later the Time of Flight Detector, (TOF) 4.3.

WBS: 4.2.1

WBS Name: Outer Field Cage

Definition: This WBS includes the following components:

.1 OFC Supporting structure

.2 OFC Insulation

.3 OFC Voltage gradient system

.4 OFC Fabrication equipment

.5 OFC Fabrication and test

This component provides the outer boundary of the precision electrical field gradient required for accurate measurement of particle track x, y and z positions. The voltage gradient system includes a gradient cage which will be held at a high voltage which varies linearly in z. This voltage will be supplied by a power supply connected to a high voltage distribution system consisting of a cable and a resistor chain. The OFC support structure includes a central honeycomb support structure and end rings that provide attachment points and stiffening. Since the inner surface of the support structure will be at ground, an insulator must be between the voltage gradient cage and the support structure. Fabrication of the OFC requires specialized equipment and a large work area. A large winding machine will be required to lay up the voltage gradient cage, and wind the insulation layers and the inner skin of the support structure onto a mandrel. The outer skin of the support structure may be wound layers or thick sheets of glued aluminum. The design effort and the required material and equipment for this assembly is in OFC fabrication equipment. The OFC assemble and test WBS is for the effort and equipment required for fabrication, assemble and test of the complete OFC. Only one outer field cage will be required per TPC. Details of the lower level components can be found in EXCEL spreadsheet "OFC Worksheet".

The OFC interfaces with 4.2.2 Central membrane, 4.2.5 Wheel, 4.2.8 Cooling system, and is designed to support 4.3 Time of Flight. The interface for the central membrane is the joint between the voltage gradient cage and the central membrane support flange. Tubes from the cooling system may be attached to the outside of the support structure to provide temperature control. The tube–wheel interface is where they will be bolted together at the tube end rings.

WBS: 4.2.1.1

WBS Name: OFC Supporting Structure

Definition: The OFC supporting structure consists of a central tube and two end support rings. This structure maintains the voltage gradient cage and its insulation at the proper position during operation. It also provides the support for the initial trigger segments and later for the TOF upgrade. This WBS provides the effort required to design the OFC support tube and the end support rings. The material required for this element is an inner and outer aluminum skin, honeycomb center, OFC/TOF support rails. adhesives and some miscellaneous items. These material costs are included in this WBS. In addition, the costs of material for WBS 4.2.1.2 OFC insulation is in this WBS. This is because the insulation cost is small. The material amount and labor required is listed on EXCEL spreadsheet "OFC Worksheet".

The OFC support structure interfaces with 4.2.5 Wheel, , 4.2.8 Cooling system and 4.3 Time of flight when it is installed.

WBS: 4.2.1.2

WBS Name: OFC Insulation

Definition: This WBS includes the cost of parts for the insulation required between the voltage gradient system and the grounded support structure. It includes mylar and adhesive. Since the total cost of the material is very low, it is included in WBS 4.2.1.1 OFC Supporting structure.

WBS: 4.2.1.3

WBS Name: OFC Voltage Gradient System

Definition: The OFC voltage gradient system provides a means of obtaining a precise electric field along the z axis. Electrons generated by the passage of particles, drift toward the sectors due to this field. The voltage gradient cage provides electrode rings, joined by resistors, that clamp the field accurately in z. A power supply, High Voltage cable and a resistor chain is included in this WBS. It was assumed that a sufficient amount of cu/Kapton material would be purchased to allow the construction of two OFCs. This is because the setup cost and delivery time could be saved if the first OFC did not perform properly. All the other materials are readily available. The cost of an uninterruptable power supply (UPS) is included in 4.9, Electrical Utilities. The material amount and labor required is listed on EXCEL spreadsheet "OFC Worksheet".

The voltage gradient system interfaces with the OFC insulation, WBS 4.2.1.2, Central membrane WBS 4.2.2 and WBS 4.9 Detector Conventional Systems.

WBS: 4.2.1.4

WBS Name: OFC Fabrication Equipment

Definition: The fabrication of the OFC will require the use of a large winder which resembles a large lathe. The winder head will ride on a carriage and a large mandrel will rotate on a shaft. The relative movements of these two components will be dictated by motor controllers. In addition, some environmental control will be required due to the adhesives used. A room will be constructed that will cover the winder volume. This WBS provides the effort required to design the winding machine components and to layout the winding room. The effort to then setup and test the winder is in WBS 4.2.1.5 OFC Fabrication and test. The modifications to the winding room are included in the cost of this WBS. The mandrel, spokes to hold it round, all components of the winder, material for the room and other miscellaneous costs are in this WBS. The labor effort to actually do the setup and fabrication is in the next WBS. The material amount and labor required is listed on EXCEL spreadsheet "OFC Worksheet".

WBS: 4.2.1.5

WBS Name: OFC Fabrication and Test

Definition: This WBS includes the effort to setup and test the OFC winder as well as the effort required to fabricate and test the completed outer field cage. Installation of the OFC/TOF support rails and subsequent manifolds is included in this WBS. The installation of the high voltage cable and the resistor chain is also included. A small amount of miscellaneous funds are allocated for fixtures, etc. This WBS ceases when the OFC is placed upon the test stand and initial mechanical and electrical tests are complete that verify proper construction.

WBS: 4.2.2

WBS Name: Central Membrane

Definition: The central membrane includes the following components:

CM HV membrane

CM Support frames

CM fab and test

The central membrane is used to extend a voltage plane radially across one half of the TPC at z = 0. The high voltage cable attaches to this plane and holds it at a negative potential. Foam and aluminum support flanges and hangers will be used to support and allow adjustment of the membrane so that it will be wrinkle free. This WBS includes the effort to design, fabricate and test fit the membrane in the OFC. The cost of parts is also included in this WBS. The high voltage power supplies, cable and resistor chain are in 4.2.1.1 Outer field cage. Effort on the WBS ceases when the central membrane has been fabricated and the hangers and supports have been preassembled into the OFC.

The central membrane interfaces and is aligned with 4.2.1 Outer field cage. It may not be electrically or structurally connected to the inner field cage.

WBS: 4.2.3

WBS Name: Inner Field Cage (IFC)

Definition: The inner field cage includes the following components and activities:

.1 IFC Supporting structure

.2 IFC Voltage gradient system

.3 IFC Fabrication equipment

.4 IFC Fabrication and test

The inner field cage with the outer field cage and the central membrane provide the electric field required to cause electrons to drift toward the pad planes. It is composed of a voltage gradient cage and its support tube, a resistor chain that clamps the electric field to precise values in z and a high voltage cable that carries the required voltage to the z center of the cage. The high voltage power supply is in WBS 4.2.1.1 OFC tube. The labor to fabricate and test the IFC is included in this WBS.

The inner field cage interfaces with 4.2.5 Wheel, 4.2.6 Laser system, and 4.1. SVT .

WBS: 4.2.3.1

WBS Name: IFC Supporting Structure

Definition: The IFC supporting structure has the same role as that described for the OFC supporting structure. The structure is only a small layer of foam. This is to minimize the radiation length of the IFC. This WBS only includes the cost of the foam, the adhesive, the 2 end flanges and the two seals. There is no solid insulation required as there will be a gas between the IFC and ground. This WBS includes the cost of the material and the design effort for the tube and its flanges. The cost of the IFC Voltage gradient cage which provides stiffness to the supporting structure is in the next WBS.

The tube with its flanges connects to 4.2.5.1 Wheel. The SVT tube/cone support, 4.1 will be connected to the IFC Supporting structure.

WBS: 4.2.3.2

WBS Name: IFC Voltage Gradient System

Definition: The IFC Voltage gradient system has the same role as that described for the OFC. The voltage gradient cage will be fabricated from aluminum/Kapton sheets similar to those used for the OFC. The use of aluminum electrodes reduces the radiation length of the tube. The engineering and design effort for design of the IFC Voltage gradient system is included in this WBS. The cost of the high voltage cable and the resistor chain is in this WBS. The al/Kapton sheets, when glued to 4.2.3.1 Supporting structure foam, provide a composite configuration that can support its own weight and a slight over pressure.

WBS: 4.2.3.3

WBS Name: IFC Fabrication Equipment

Definition: This WBS includes a mandrel for fabricating the IFC and other required laminating equipment. It is anticipated that the OFC winder will be used for fabrication of the IFC and only small amounts of additional equipment will be required. This WBS includes the design effort and the material costs for this equipment.

WBS: 4.2.3.4

WBS Name: IFC Fabrication and Test

Definition: This WBS includes labor to test the winder for the IFC, fabricate the IFC, install the high voltage cable and resistor and inspect and test the completed component. Some design time is added to update drawings. The winder setup and component costs are in WBS 4.2.1.3 OFC assemble and test. A small amount of funds are added for miscellaneous.

WBS: 4.2.4

WBS Name: Sector

Definition: The sectors include the components necessary to detect signals generated by the electrons as they drift to the anode wires. The sectors include the following WBS components:

.1 Mechanical support structures

.2 Electrical structures

.3 Sector assemble equipment

.4 Sector assemble

.5 Sector test

This WBS is for the design, fabrication and testing of the required sectors plus 4 spares. A sector consists of pad planes, a rigid aluminum support structure, seals, wires and wire mounts, flexible wire connectors, anode bias distribution (ABDB) and gated grid boards, feed–throughs that carry the signals to the back side of the pad planes and cooling tubes and manifolds that maintain the proper sector temperature. Sector assembly stations and fixtures are included in this WBS. Sector blank–off plates will be provided to allow testing of a small number of assembled sectors. The details for this WBS can be found in EXCEL spreadsheet "Sector Worksheet". The sectors interface with 4.2.5.1 Wheel, 4.2.8 Cooling system and 4.7.1.2 TPC detector electronics.

WBS: 4.2.4.1

WBS Name: Mechanical Support Structures

Definition: This WBS includes the cost of the following:

Sector casting/supports

Sector blank–off plates

Sector wire mounts

Sector wires

Sector seals

Sector manifolds, and cooling tubes

It includes the cost of the sector support casting, vacuum impregnation and machining. It includes the effort required to design the above parts and to make subassembly drawings.

Mechanical structures interface with 4.2.4.2 Electrical structures, 4.2.5.1 Wheel, 4.2.8 Cooling system, and 4.7.1.2 TPC Detector electronics.

WBS: 4.2.4.2

WBS Name: Electrical Structures

Definition: The electrical structures for the sectors include the pad plane multilayer board, the ABDB, feed–throughs, an anode power control and supply, gated grid PC board and drives, flexible PC cables and the effort to design these components. Funds are allocated for some prototype boards and also for writing the specifications for the various boards. The pad plane/FEE connectors are included in WBS 4.7.1.2 TPC FEE. The pad plane interfaces with the sector support and the connectors interface with 4.7.1.2 TPC FEE. The details are on EXCEL spreadsheet "Sector Worksheet". Some funds are added for miscellaneous.

WBS: 4.2.4.3

WBS Name: Sector Assemble Equipment

Definition: This WBS includes the cost for the following:

Sector winder modifications

Sector assembly room modifications

Sector assembly stations/fixtures

This WBS includes the design effort and equipment required for the assembly stations and their fixtures. Although the sector assembly will be accomplished in an existing clean room, some effort and funds are allocated for room modifications. The existing winder will be modified and additional winding bobbins will be fabricated. Several fixtures will be required to facilitate production. The effort required to setup the assembly stations is in this WBS. Engineering effort for developing procedures is also included.

WBS: 4.2.4.4

WBS Name: Sector Assemble

Definition: This WBS includes the costs for all necessary tasks to assemble the sectors, including wire winding effort. It includes 10% rework time per sector. This WBS expires when all the electrical boards are installed. The FEE boards are not installed under this WBS.

WBS: 4.2.4.5

WBS Name: Sector Test

Definition: This WBS includes the costs to hookup cables to individual sector's ABDBs and to power up these components. Tests are then run to determine is the fabrication was satisfactory. A 10% retest time was included. It was assumed that two stations with two techs/station were required. The FEE boards are installed under this WBS.

WBS: 4.2.5

WBS Name: Wheel (Sector Support)

Definition: The wheels provide support for the 48 sectors and hold them in position relative to the outer field cage. They also are the attachment points for the TPC support off of the magnet iron end rings. The Wheel contains the following components:

Wheel

TPC/Iron Support

Sectors will be attached to the wheels which in turn will be connected to the OFC tube. One end of the TPC/iron supports will be attached to a wheel and the other to 4.4 Solenoid Magnet end rings. These supports will be offset from the horizontal to allow TOF modules to be inserted between the TPC and the solenoid without moving the TPC. The details of this WBS can be found in EXCEL spreadsheet "Wheel Worksheet".

This WBS includes the wheel casting, machining, alignment pins, seals, some cooling manifolds and the wheel design effort. It also includes the costs for the TPC/iron support design and components.

WBS: 4.2.5.1

WBS Name: Wheel

Definition: The wheels support the sectors and maintain their positions relative to the outer field cage, the inner field cage and the other STAR subsystems. The large support wheels have 12 sectors divided into two radial areas. Sectors will be attached to the wheel which will be connected to the OFC tube end ring. The wheels will have cooling tubes on them to maintain the overall temperature variation below the maximum allowed.

This WBS includes the wheel casting, machining, alignment pins, seals, some cooling manifolds and the wheel design effort.

WBS: 4.2.5.2

WBS Name: TPC/Iron Support

Definition: This component supports the TPC at 4.4.1 Solenoid Coil. It supports the weight of the TPC and any other subsystem that may be placed on the wheel or the OFC. It provides adjustments for the TPC relative to the solenoid. This WBS includes the support flange, a short beam, adjustable platform, preassemble and test of the supports and the design effort.

WBS: 4.2.6

WBS Name: Laser System

Definition: The UV laser system generates straight line ionized tracks in the drift volume of the TPC for checking the spatial calibration. As shown in the accompanying figure the laser system injects beams at well defined angles radiating out from the center interaction point. The beams are used to determine the following parameters governing the drift path of the electrons:

drift velocity

wt

E and B field alignment angle

In addition the straight tracks provide a check for other drift distortions and the distortion correction routines. The laser tracks are at well defined relative angles but the absolute positions in space are only moderately controlled.. There are a total of 60 beams in the gas volume.

The laser system consists of lasers, optics, adjustable optic mounts, covers, beam distribution rings (splitters) and quadrant position detectors. Also included are funds for safety interlocks for the laser. Costs have not been included for alignment, since this will be done by physicists and students.

Lower level components included in this system:

.1 Beam source

.2 Beam transport

.3 Beam fan–out

.4 Beam injection

.5 Quad detector readout system

.6 Safety interlocks

Overview drawing of this system:

Fig. 4.2.6

WBS: 4.2.6.1

WBS Name: Beam Source

Definition: There are two identical beam source systems located at either end of the TPC. The laser beam source system includes the laser, harmonic generators, harmonic separator, polarization variable attenuator, power monitor and components required to steer the beam into the beam transport subsystem. Engineering, design and technical effort is included in this WBS for custom built components. Assembly costs for mounting commercially supplied components are not included since this will be performed by physicists and students. This WBS also includes effort required to write the operational safety procedures.

Lower level components included in this system:

.1 Nd:Yag laser
.2 harmonic generator
.3 harmonic separator
.4 power split and dump
.5 polarization rotator
.6 polarizer for attenuation
.7 beam dump
.8 telescope
.9 motor driven beam steering
.10 energy monitor
.11 optics breadboard
.12 cover
.13 interlock circuitry
.14 dry nitrogen connection
.15 support structure
.16 operational safety procedure document

Drawing of this system:

Fig. 4.2.6.1

WBS: 4.2.6.1.1

WBS Name: Nd:Yag Laser

Definition: Q switched, unstable resonator, Nd:Yag laser with Gaussian optics. Model GCR–130–10, Spectra Physics.

WBS: 4.2.6.1.2

WBS Name: Harmonic Generator

Definition: A system with two doubling crystals to quadruple the frequency and produce a 266 nm UV beam.

WBS: 4.2.6.1.3

WBS Name: Harmonic Separator

Definition: Commercial unit to remove the IR and green components from the beam and leave the UV. This uses 266 nm dichroic beam splitters and a beam dump.

WBS: 4.2.6.1.4

WBS Name: Power Split and Dump

Definition: Dielectric beam splitter and power dump to reduce UV beam power to 10–50%. The standard ND:Yag lasers with enough power to frequency quadruple produce more power than is safe for the down stream optics. This WBS includes commercial mounting hardware.

WBS: 4.2.6.1.5

WBS Name: Polarization Rotator

Definition: 1/2 wave plate on a remotely driven rotation stage. This is used in conjunction with a polarizer to adjust the UV beam power. This WBS includes commercial mounting hardware.

WBS: 4.2.6.1.6

WBS Name: Polarizer for Attenuation

Definition: Calcite beam polarizer transmits the desired component and directs the discarded component to a beam dump. This WBS includes a commercial optic plus mounting hardware.

WBS: 4.2.6.1.7

WBS Name: Beam Dump

Definition: Beam dump for the discarded component.

WBS: 4.2.6.1.8

WBS Name: Telescope

Definition: Two lens telescope ~200 mm ~–75 mm, quartz UV grade, kinematic mount with z motion on one and a translation mount on the other. This reduces the 6 mm beam to a 1–2 mm diameter waist in the TPC gas volume.

WBS: 4.2.6.1.9

WBS Name: Motor Driven Beam Steering

Definition: Two dielectric mirrors on kinematic mounts with remote control micrometer motors. This provided complete control of the beam angle and position as it leaves the beam source system.

WBS: 4.2.6.1.10

WBS Name: Energy Monitor

Definition: Power meter and readout to monitor the beam energy.

WBS: 4.2.6.1.11
WBS Name: Optics Breadboard
Definition: Commercial optics breadboard for mounting all of the beam source components.

WBS: 4.2.6.1.12
WBS Name: Cover
Definition: Dust tight cover to protect optics components and shield personnel from the UV beam. This is a custom piece requiring design and construction effort.

WBS: 4.2.6.1.13
WBS Name: Interlock Circuitry
Definition: Interlock switches and wiring to automatically turn off the laser when the cover (WBS 4.2.6.1.12) is opened.

WBS: 4.2.6.1.14
WBS Name: Dry Nitrogen Connection
Definition: Nitrogen plumbing for the beam source box. Positive pressure reduces dust contamination.

WBS: 4.2.6.1.15
WBS Name: Support Structure
Definition: Mounting fixtures to support the beam source system.

WBS: 4.2.6.1.16

WBS Name: Operational Safety Procedure Document

Definition: Operational safety procedure document to fulfill BNL requirements for operation of a class lV laser system.

WBS: 4.2.6.2

WBS Name: Laser Beam Transport

Definition: Mirrors, kinematic mounts, housings and mounts to transport the laser beam from the source outside the magnet iron into the laser beam fanout system on the front of the wheel.

Lower level components included in this system:

.1 tubes and flanges

.2 supports for optics mounts

.3 optics plus kinematic mounts

.4 supports for tubes

Overview drawing of this system:

Fig. 4.2.6.2

WBS: 4.2.6.2.1

WBS Name: Tubes and Flanges

Definition: Tubes to shield personnel from the beam and protect the optics from dust. Includes aluminum tubes and coupling pieces.

WBS: 4.2.6.2.2

WBS Name: Supports for Optic Mounts

Definition: Aluminum boxes with covers for containing and supporting the kinematic mirror mounts.

WBS: 4.2.6.2.3
WBS Name: Optics Plus Kinematic Mounts
Definition: Commercial dielectric mirrors and fully adjustable mirror mounts.

WBS: 4.2.6.2.4
WBS Name: Supports for Tubes
Definition: Mounting fixtures for supporting the tubes.

WBS: 4.2.6.3
WBS Name: Laser Beam Fan Out
Definition: This system directs the beam around a loop and splits 6 beams off directing them inward along the inner field cage. The system is composed of dielectric splitters, prisms, silicon quadrant position detectors and support structures and covers.

Lower level components included in this system:

.1 custom optics breadboard

.2 breadboard mounting fixtures

.3 breadboard cover

.4 entrance reflector

.5 loop, quadrant reference assemblies

.6 loop prism assemblies

.7 split off assemblies

.8 split off quadrant reference assemblies

Overview drawing of this system:

Fig. 4.2.6.3

WBS: 4.2.6.3.1

WBS Name: Custom Optics Breadboard

Definition: Standard style optics breadboard with two aluminum skins separated by aluminum honey comb. This board has the normal matrix of drilled and tapped holes for mounting optic holders.

WBS: 4.2.6.3.3

WBS Name: Breadboard Cover

Definition: Dust tight cover protecting the optics mounted on the custom optics bread board.

WBS: 4.2.6.3.4

WBS Name: Entrance Reflector

Definition: Dielectric mirror plus kinematic mount for redirecting the beam around the loop

WBS: 4.2.6.3.5

WBS Name: Loop, Quadrant Reference Assemblies

Definition: Each assembly consists of a beam splitter and a silicon quadrant detector. There are two devices per loop to define the loop position. This allows resetting of the entrance reflector and laser source to restore original loop geometry.

WBS: 4.2.6.3.6

WBS Name: Loop Prism Assembly

Definition: 5 anti−reflection coated prisms are positioned around the ring to transport the beam around the loop.

WBS: 4.2.6.3.7

WBS Name: Split Off Assemblies

Definition: Dielectric mirror to split loop beam directing the beam along the inner field cage. Cost includes optics, kinematic mount and other mounting hardware.

WBS: 4.2.6.3.8

WBS Name: Split Off Quadrant Reference Assemblies

Definition: Reference point for each end of the 12 beams directed down the axis of the TPC. The assembly consists of a quadrant detector, a beam splitter on a kinematic mount and a fixed support for both the quadrant detector and the kinematic mount.

WBS: 4.2.6.3.9

WBS Name: Windows and Ports in the Sector Wheel

Definition: 12 holes with windows must be designed into the wheel structure to pass the laser beams into the gas volume.

WBS: 4.2.6.4

WBS Name: Laser Beam Injection

Definition: The laser beam injection system is mounted on the inner field cage where it splits beams off the axial rays and projects them into the drift volume along lines that intersect with the central interaction region. There are a total of 12 identical units arranged around the inner field cage, six on each end.

Lower level components included in this system:

.1 splitter reflectors

.2 reflector mounts

.3 reflector field shaping covers

Drawing of this system: Fig. 4.2.6.4

WBS: 4.2.6.4.1

WBS Name: Splitter Reflectors

Definition: These splitters are constructed from two mirrors joined at a very well defined angle such that the split beam has a precise angle independent of the exact positioning of the reflector unit. The reflectors are designed and positioned to produce tracks that project back to the origin and span the theta acceptance. A penta prism is used to produce the one beam that is 90 deg to the TPC axis. There are 4 of the mirror pairs and one penta prism in a set and there are total of 12 of these sets.

WBS: 4.2.6.4.2

WBS Name: Reflector Mounts

Definition: A mounting structure secures the reflectors to the field cage. Unlike the rest of the optic mounts in the system these mounts will not be adjustable.

WBS: 4.2.6.4.3

WBS Name: Reflector Field Shaping Covers

Definition: The reflector field shaping covers are constructed out of copper striped Kapton in the same pattern as the field cage and are arranged as ears on the side of the optics. These elements are necessary to prevent field distortion due to charge build up on the optic elements.

WBS: 4.2.6.5

WBS Name: Quadrant Detector Readout System

Definition: The quadrant detector readout system collects signals from all of the quadrant detectors in the laser system and generates computer displays showing beam positions at all the detectors. This system will be used when the laser beams are aligned and it will monitor beam drift during operation.

Lower level components included in this system:

.1 cables

.2 amplifiers

.3 camac ADC's

.4 camac crate

.5 Kamax software and camac interface

.6 Mac computer

WBS: 4.2.6.5.1

WBS Name: Cables

Definition: Cables and connectors coupling the amplifiers to the detectors and the ADCs

WBS: 4.2.6.5.2

WBS Name: Amplifiers

Definition: Crate of amplifiers, 4 channels per quadrant detector, to prepare quadrant detector signals for ADCs. We assume that with the large signals local preamps at the detector location will not be necessary and the amplifiers can be built with 8 channels per module.

WBS: 4.2.6.5.3

WBS Name: Camac ADCs

Definition: Either peak sensing or charge integrating ADCs.

WBS: 4.2.6.5.3
WBS Name: Camac Crate
Definition: One crate

WBS: 4.2.6.5.3
WBS Name: Kamax Software and Camac Interface
Definition: Software to read out camac ADCs and the interface cards to connect the Mac computer to camac. This could instead be a PC and required interface plus Lab View software.

WBS: 4.2.6.5.3
WBS Name: Mac Computer
Definition: High–end computer for interaction with the camac interface.

WBS: 4.2.6.6
WBS Name: Safety Interlocks
Definition: This WBS includes access control boxes on all doors leading into the main assembly hall and the beam vault area. These will be used when the laser system is being used with protective covers removed. Included is the wiring from the access control boxes to the laser unit (WBS 4.2.6.1.1).

WBS: 4.2.7

WBS Name: Gas System

Definition: This system provides the gas mixture required by the TPC, controls the flow, recirculates gas, regulates the TPC pressure, disposes of the used gas and monitors the properties of the gas. This WBS includes the design and technician effort and the component cost for a complete gas system. It includes a building to house the system, and to provide a skid-mounted gas supply to be used during TPC testing at LBL. The following 9 subsystems are included:

.1 Component gas supply

.2 Gas mixer

.3 Gas recirculating

.4 TPC Pressure regulation

.5 Gas monitor

.6 Exhaust

.7 Gas system building

.8 Slow control crate and processor

.9 Temporary setup at LBL

WBS: 4.2.7.1

WBS Name: Component Gas Supply Sub-System

Definition: The Gas supply subsystem supplies input gases to the mixer from liquid or high pressure bulk supplies. It includes argon and nitrogen supply cylinders, dewars, methane cylinders, evaporators which use electrically heated tubing, pressure regulators and valves required to control the flow into the next subsystem, the gas mixer, WBS 4.2.7.2. Design and technician time is included as well as miscellaneous plumbing supplies. These plumbing supplies include the valving to ensure a safe operation. In addition, slow control interfaces provided which consists of pressure sensors, switches and a flow switch.

WBS: 4.2.7.2

WBS Name: Gas Mixer Subsystem

Definition: The gas mixer subsystem utilizes mass flow controllers to produce a stable gas mixture. These controllers are under the direction of an electronic controller. This WBS includes air valves, temperature control, flow controllers and pressure controllers. A slow control interface (IEEE 488) is provided as well as miscellaneous plumbing components. This subsystem receives argon, methane and nitrogen gas from the gas supply 4.2.7.1 and sends the appropriate mixture or nitrogen to the TPC wheel 4.2.5.1.

WBS: 4.2.7.3

WBS Name: Gas Recirculating Subsystem

Definition: The gas recirculating subsystem circulates ~ 400 l/min of gas through the TPC in order to keep the gas uniform in both mixture ratio and density. A special sealed centrifugal blower is included as well as air valves and a self servoing valve (smart valve) with a flow sensor. Slow control interfaces are also provided. Miscellaneous plumbing components are provided to connect the system and provide for safe operation. Design and tech effort is included as part of the cost of this WBS. It interfaces with the gas inlet and outlet of the TPC which is on the wheel 4.2.5.1.

WBS: 4.2.7.4

WBS Name: TPC Pressure Regulation Subsystem

Definition: This important subsystem uses active control with redundant pressure sensors to maintain the TPC at a pressure slightly above atmosphere independent of flow rate. Connections are made to the TPC 4.2 at four places. One includes a control valve to relieve internal pressure if an abnormal pressure is detected. Control electronics and slow control interfaces are included as well as an air valve and a pump. Miscellaneous plumbing components and a slow control interface are also provided.

WBS: 4.2.7.5

WBS Name: Gas Monitor Subsystem

Definition: This subsystem monitors the gas at the supplies for oxygen and water contamination. It measures the drift and electron life time in the gas at the mixer output, and TPC 4.2 input and output and monitors these locations for oxygen and water contamination. It includes an oxygen and water meter, velocity test and electronic life chambers, pressure, flow and temperature controllers, valves, low-power laser, high voltage supplies, gas pumps and slow control interfaces. Miscellaneous plumbing supplies are included for connection and safe operation. Design and tech effort is also included in this WBS.

WBS: 4.2.7.6

WBS Name: Exhaust Subsystem

Definition: This is an active suction exhaust in which waste gas is rapidly diluted with air to a safe concentration and removed from the buildings. It includes blowers, vent stacks, miscellaneous plumbing components and a slow control interface. It interfaces with the TPC wheel 4.2.5.1 and monitor system and provides an exhaust system for both of them. Design and tech effort are included.

WBS: 4.2.7.7

WBS Name: Gas System Building

Definition: This WBS consists of a 200 ft^2 heated building to contain the major components of the gas system along with a 200 ft^2 enclosed unheated section for storage of gas cylinders. Building design effort is included.

WBS: 4.2.7.8

WBS Name: Slow Controls Crate and Processor-

Definition: This WBS contains a VME crate with a standard processor to act as master and to interface to the main slow controls system. Individual gas system components will connect to modules in this crate.

WBS: 4.2.7.9

WBS Name: Temp. Setup at LBL

Definition: In order to test the TPC at LBL it will be necessary to move the major components of gas system to LBL, setup and operate the system for the test period, then return it to BNL and do the final installation. This WBS includes the shipping costs and some modifications to the system to make it more portable.

WBS: 4.2.8

WBS Name: Cooling System

Definition: The cooling system must maintain the temperature of the TPC gas to within a narrow range. This system consists of circuits that feed fluid cooled channels placed on the sector aluminum framework, the wheels, and trace lines on the outer field cage aluminum support cylinder. The cooling system includes provisions for cooling the front end electronic boards. It includes (one system for each end) a chiller, tanks, piping, valves, controls, pumps and various fittings. These items are part of this WBS. Also included is the design effort required to specify the system and the technician effort to preassemble and test various parts of the system. Slow controls specification and component costs are also in this WBS.

The Cooling system interfaces with 4.2.1 Outer field cage, 4.2.4 Sectors, 4.9.1 Mechanical Utilities, and 4.9.2 Electrical utilities. The interface for Mechanical Utilities is at the primary side of the chiller and for the Electrical utilities, at the wall plug or equivalent.

WBS: 4.2.9

WBS Name: Transport Fixtures/Shipping

Definition: This WBS includes the following elements:

.1 Transportation fixtures

.2 Shipping

Design and fabrication of shipping containers and the cost of transportation are provided in this WBS. These containers will limit the acceleration to a low level while the completed assemblies are in transit to RHIC. Shipping the TPC as an assembled unit is the baseline method. A special shock isolation pallet is included as well as modifications to the test stand. The test stand must have special shock isolation pads added to protect the TPC during shipment. Containers for the laser, cooling system and miscellaneous are also included in this WBS. The details for this WBS are contained in EXCEL spreadsheet "Trans/ship Worksheet".

WBS: 4.2.9.1

WBS Name: Transportation Fixtures

Definition: Design and fabrication of shipping containers are provided in this WBS. It is assumed that there will be one shipping container for each sector not shipped in the assembled TPC. A special shock isolation pallet is included for these sectors. Special shock isolation pads for the test stand are in this WBS to provide additional protection for the assembled TPC. Two covers are required to protect the FEE during shipment. Containers for the laser and cooling systems as well as miscellaneous parts are also included in this WBS. Effort for the modification to the test stand is included.

WBS: 4.2.9.2

WBS Name: Shipping

Definition: The cost of the trucks to ship the TPC components across the United States is included in this WBS as well as the effort for an engineer to accompany the load.

WBS: 4.2.10

WBS Name: TPC Assemble and Test

Definition: This WBS includes the following elements:

.1 Assembly fixtures

.2 Sector removal tool

.3 TPC Assembly

.4 TPC Test

This WBS provides the tools, equipment and effort to assemble and test the TPC, then partially disassemble and pack the various components using 4.2.9 components. Specialized assembly equipment will be required including a test stand and other fixtures, a sector removal tool, measuring devices such as targets, and fiducial transfer fixtures. Some calibration equipment may be required.

The area designated for the TPC tests will require some preparation which includes installation of cable ways, pipes for cooling and also pipes for connection to the gas system.

Installation of the TPC into the solenoid will be by use of a beam placed in the center. Supports at each end of the beam will be required as well as rollers attached to the TPC wheel. The design and cost of this beam and supports are in this WBS.

After being assembled, the TPC will be tested for several months. then partially disassembled and loaded onto a truck. Some room cleanup is required at the completion of the TPC shipping. These efforts are also included in this WBS.

WBS: 4.2.10.1

WBS Name: Assembly Fixtures

Definition: After fabrication of the OFC has been completed, it will be placed on a test stand. After major components of the TPC have been completed and tested, they will be assembled together on this test stand. The stand is assumed to be constructed of large beams with pads incorporated to hold the OFC. This WBS includes the material costs, and the design and testing effort for this stand. After the TPC has been reassembled and tested at RHIC, this stand also may be used as an insertion device.

The installation of the TPC into the solenoid will use a large beam placed through the center of the TPC. Rollers will be attached to the wheels that will allow the TPC to roll along the beam. Several supports are required to hold the beam into position during the installation. Some adjustment in the beam or rollers is required. This WBS includes the design costs as well as the costs of beams, rollers, and flanges. Some effort for verification testing the completed insertion system is included.

It is assumed that various handling fixtures will be needed during the assembly and testing of the TPC. The fixtures that are identified as required for lifting and moving include one for the wheel and four for the sectors. A miscellaneous cost is added for those not yet identified. The effort for the fixture design and for writing lifting procedures is included in this WBS.

WBS: 4.2.10.2

WBS Name: Sector Removal Tool

Definition: A sector removal tool will be required for initially installing the sectors on the wheel and for removing and replacing them when operations begin. The design of this tool will be similar to that presently in use at ALEPH. It is assumed that at least 4 degrees of freedom will be required. Costs are included for the design, fabrication, assembly and testing of this tool.

WBS: 4.2.10.3

WBS Name: TPC Assemble

Definition: Some assembly area preparation is required prior to the TPC assembly. This includes the installation of cable ways and pipes for connecting to the cooling system and the gas system. The racks and cables will be provided by WBS 4.7 electronics. Some time will be required for installation of scaffolds for access to the TPC. The remaining part of this WBS is primarily composed of technician time required to assemble the TPC. It also includes some miscellaneous funds for initial testing and repair. The design effort to make assembly drawings is also included in this WBS. Costs in this WBS start with the installation of the central membrane into the OFC and end with the completion of initial tests after a laser calibration line has been installed. The TPC is ready for long–term testing at this time.

WBS: 4.2.10.4

WBS Name: TPC Test

Definition: After the initial tests on the TPC have been completed, effort will be required to recheck the critical component locations and then do the primary calibration. This WBS is primarily technician time to do the calibration. Miscellaneous funds are allocated for unexpected repairs.

After the TPC is declared calibrated, it must be partially disassembled for shipment to RHIC. This WBS includes this effort. The containers to be used for this shipment are included in 4.2.9 Transport fixtures/shipping. Some miscellaneous funds are provided. In addition, some room cleanup must be completed to allow the area to be used by other programs.

WBS: 4.2.11

WBS Name: TPC Project Management

Definition: During the course of the project, effort is required to determine the state of the project and report both schedule and fiscal progress to higher levels. This WBS includes effort by an engineer and an engineering associate for the life of the project to provide these reports.

WBS: 4.4

WBS Name: Solenoid Magnet

Definition: The STAR solenoid magnet has a Cu coil with an ID of 5.24 meters, and is 6.2 meters long. The maximum field is 0.5 Tesla. Trim coils are used to obtain a very uniform field over the volume occupied by the TPC in order to minimize corrections in TPC coordinates . The coil is made up of 10 pancake packages, which allows fibers from the Electromagnetic Calorimeter to be routed to photo multiplier tubes outside the return yoke. The total coil weight is 160 tons, and the return yoke weighs 814 tons.

WBS: 4.4.1

WBS Name: Conventional Coil

Definition: The coil is made up of 10 pancakes assemblies with Cu conductor. At 0.5 Tesla there are 2.47 million ampere–turns, with a DC power of 1.9 megawatts.

WBS: 4.4.1.1

WBS Name: Coils

Definition: The coil is wound with 4.76 cm x 4.76 cm Cu conductor with a 1.91 cm diameter hole for cooling water. In order to cool efficiently the coils will be wound Two –in –hand, with two cooling paths for each double layer. Each pancake package will be made up of 4 double layers . Electrically the pancakes will be run in series with a current of 5146 amps (376 volts) at the full field of 0.5 Tesla. The total cooling water flow will be 1320 gpm with a pressure drop of 105 psi across the coils providing a 10 degree rise across each pancake.

WBS: 4.4.1.2
WBS Name: Coil Clamps and Indexing Equipment
Definition: These are used to locate the coil packages inside the magnet iron.

WBS: 4.4.1.3
WBS Name: Coil Spacer Rings
Definition: These serve two purposes, to separate the coil packages and to support the EMC.

WBS: 4.4.1.4
WBS Name: Water Manifolds, Buss, Interlocks
Definition: The manifolds are used to distribute the cooling water to the 80 parallel water paths. The buss carries the electric current from pancake to pancake along the magnet. Interlocks are required to automatically protect the magnet in case of cooling water loss, overvoltage, overcurrent, excessive temperatures, etc.

WBS: 4.4.2
WBS Name: Return Steel
Definition: The return steel is needed to return the magnetic flux, to support the coil and the internal detectors, and to help shape the magnetic field. A total of 814 tons of steel are used in the end caps and return barrel

WBS: 4.4.2.1

WBS Name: Backleg Steel and End Rings

Definition: The primary purpose of the return yoke is to provide a low–reluctance path for the magnetic field lines. It also serves as the main support for the coils and the equipment inside the magnet. As a compromise between mechanical strength and matching the segmentation of the EMC, the return is supplied by 30 steel bars, with a cross sectional area to give 15 KGauss in the iron. The end rings support the return yoke and match with the endcaps. The total weight of the return yoke is 588 tons, and each end ring weighs 39 tons. Also included in the element is assembly equipment.

WBS: 4.4.2.2

WBS Name: Pole Tips

Definition: The pole tips are used to shape the magnetic field, and also support the trim coils used to achieve the desired field quality. They must also be removable in–situ to permit servicing of the TPC endcap and other apparatus inside the magnet. Each endcap weighs 75 tons. Also included in the element is assembly equipment.

WBS: 4.4.3

WBS Name: Power Supply and Controls

Definition: For a field of 0.5 Tesla, the magnet needs a power supply to deliver 5146 amps at 376 volts. The regulation should be better than one part in ten thousand.

WBS: 4.4.3.1

WBS Name: Power Supply

Definition: A 12 phase power supply has been selected, with regulation of one part in ten thousand. The coil parameters permit the use of relatively low voltage SCR's, which gives a cost advantage. the long time constant of the magnet provides current filtering, but provision has been made for a filter to reduce voltage ripple which might interfere with low level amplifiers in the detector.

WBS: 4.4.3.2

WBS Name: Controls

Definition: During data taking the magnet will be controlled as part of the accelerator so interfaces are needed with the local power supply control system. In addition interfaces are required with STAR data acquisition to allow monitoring of the apparatus.

WBS: 4.4.3.3

WBS Name: Power Cabling

Definition: Cables are used to transport the current from the power supplies to the magnet. Provision has been made to power the magnet in the assembly building as well as in its final location. Currently envisioned as a 200 foot run of 500 MCM locomotive cable with connectors

WBS: 4.4.4

WBS Name: Magnetic field measuring system

Definition: The field will be mapped to permit accurate determination of coordinates in the TPC . The system chosen is based on NMR probes on a rotating fixture. The system was scaled up from PEP4.

WBS: 4.4.4.1

WBS Name: Modifications to existing ALEPH probe positioning system

Definition: The modifications consist of adapting the mounting of the existing system to the STAR coil and pole tip structure, and possible provision of an alternate power supply for motors and electronics (50 Hz/60 Hz problem).

WBS: 4.4.4.2

WBS Name: Hall probes (replacements)

Est. Type: Engineering judgement

Definition: Hall probes are used to measure the three components of the magnetic field at numerous points in the TPC volume. The Hall probes are sensitive to 0.1 G and reproducible to ~ 1 G. The Hall probes enumerated here are replacement spares for those on the existing sytem.

WBS: 4.4.4.3

WBS Name: Data Acquisition and Storage System

Definition: A workstation with a 8mm cartridge tape, Ethernet connection and an interface connection to the existing electronics system will be used to control the mapping system and to acquire and store the magnetic field data. The same workstation will be used to transform the field data into maps usable

WBS: 4.4.4.4

WBS Name: Assembly and Test

Definition: Assembly, test, and calibration of the complete mapping system at BNL.

WBS: 4.4.4.5

WBS Name: Shipping

Definition: Packing and shipment of the ALEPH mapper from CERN to BNL and return to CERN. (Customs and brokers fees are included.)

WBS: 4.4.5

WBS Name: Support System

Definition: All structures used to support, anchor against unwanted movement, and hold in alignment, the entire weight of the detector. It also includes any similar support structures for the magnet poletips. Also includes such additional mechanical hardware as Hillman type rollers, hydraulic jacks and the associated hydraulic compressor, plumbing and controls. It does not include supports for individual components or supports used for major assembly or installation purposes.

WBS: 4.4.5.1

WBS Name: Main Yoke Support

Definition: This includes all fabricated structures use to support, stabilize, and translate the return yoke plus detector on the floor.

WBS: 4.4.5.2

WBS Name: Pole Tip Support

Definition: This includes all fabricated structures used to support, stabilize and translate the magnet poletips when they are disconnected from the return yoke for detector servicing.

WBS: 4.7.1.2

WBS Name: TPC Front End Electronics

Definition: The TPC Front End Electronics consists of two types of circuit boards: a "Front End Electronics" (FEE) board containing custom analog ICs that detect, amplify, and store the signals from the TPC pad plane and a TPC Readout board (abbreviated to RDO) that collects the digitized signals, compresses the data, and transmits the data to the DAQ system. The FEE boards connect to the TPC pad plane and to the TPC Readout Boards (RDO) and are fastened to the TPC rib support structure. The rib support structure provides cooling of the FEE as well as support. This WBS element includes the following lower level components:

.1 FEE Board and Cables

.2 Readout Electronics

.3 FEE and Readout Power Supplies

.4 On Chamber Mounting and Cooling

.5 Power Supply Interlocks and Monitoring

.6 Shipping

.7 System Debug and Test

.8 Subproject Management

.9 Prototypes

.10 Engineering Models

.11 Subsystem Documentation

.12 Clock/Trigger Distribution

.13 TPC Slow Controls Interface

WBS: 4.7.1.2.1

WBS Name: FEE Boards

Definition: The FEE Boards contain the custom analog ICs that detect, amplify, store, and digitize the signals from the TPC pad plane. This WBS element includes the following lower level components.

.1 Front End Board Assembly.

.2 Preamp & Shaper (PASA) IC development

.3 SCA & ADC IC development

.4 FEE Assembled Board

.5 Tested Board

.6 FEE Data/Power Cables

WBS: 4.7.1.2.1.1

WBS Name: Front End Board

Definition: This WBS is for the system design of the front end board which will be physically connect to the pad planes of the TPC. There will be 193 front end boards per sector, with 32 pads per board. Thus, there will be a total of 4632 boards in the detector. Allowance is made for 5% spares, bringing the board total to 4865 boards.

The front end board will interface with the readout board described in WBS 4.7.1.2.2 via cable and connector.

WBS: 4.7.1.2.1.2

WBS Name: PASA Integrated Circuit

Definition: This WBS is for the costs associated with development, production, and test of the preamp/shaper amp (PASA) integrated circuit. This WBS element includes the following lower level components.

.1 PASA Integrated Circuit

.2 PASA Integrated Circuit test at BNL

WBS: 4.7.1.2.1.2.1

WBS Name: PASA Integrated Circuit

Definition: This WBS is for the costs for development, production, and test of the preamp/shaper amp (PASA) integrated circuits. This IC amplifies and shapes the signal out of the TPC pad plane. Approximately 10,650 good ICs will be needed for the FEE boards. This WBS includes engineering charges for IC development for STAR requirements beyond the "proof of concept" IC funded by RHIC R&D. In addition, this line item includes engineering to develop a dedicated test station for the IC testing.

WBS: 4.7.1.2.1.2.2

WBS Name: PASA Integrated Circuit test at BNL

Definition: This WBS line item is for the manpower needed to test the production run of PASA ICs at BNL.

WBS: 4.7.1.2.1.3

WBS Name: SCA+ADC Integrated Circuit

Definition: This WBS is for the costs associated with development, production, and test of the integrated SCA and ADC integrated circuit. This WBS element includes the following lower level components.

.1 SCA+ADC Integrated Circuit

.2 SCA+ADC Integrated Circuit test at BNL

WBS: 4.7.1.2.1.3.1

WBS Name: SCA/ADC Integrated Circuit

Definition: This WBS is for the costs for development, production, and test of the SCA/ADC integrated circuits. This IC comprises an analog storage unit (the SCA) and a digitizer after the storage (the ADC). Approximately 10, 650 good ICs will be needed for the FEE boards. This WBS includes engineering development costs for IC development beyond the "proof of concept" ICs funded by RHIC R&D and for development of a specialized tester for IC testing.

WBS: 4.7.1.2.1.3.2

WBS Name: SCA+ADC Integrated Circuit test at BNL

Definition: This WBS line item is for the manpower needed to test the production run of SCA+ADC ICs at BNL.

WBS: 4.7.1.2.1.4

WBS Name: Front End Board assembly.

Definition: This estimate is for the assembly of the TPC Front End Electronics board by an outside assembly house (Promex quote of 9/11/92).

WBS: 4.7.1.2.1.5

WBS Name: Front End Board assembly and test.

Definition: This estimate is for test equipment (hardware and software) development and testing expense and technician effort required in final testing.

WBS: 4.7.1.2.1.6

WBS Name: FEE Data/Power Cables

Definition: These cables bus together two FEE cards onto the TPC Readout Board. The cable bus carries signals and power to the two FEE cards. There are a total of 2433 cables and each cable consists of 3 IDC connectors on a flat, 50 conductor ribbon cable.

WBS: 4.7.1.2.2

WBS Name: Readout Board

Definition: The Readout Board collects the digitized signals from the FEE boards, zero suppresses the data, and transmits the data off the chamber through a T9000 transputer data link. There are 13 Readout boards per sector, for a total of 312 boards on the detector. Allowing 5% spares, we provide for a total of 328 boards. This WBS element contains the following lower level components:

.1 Readout Board Assembly (Board Design)

.2 Tested Readout Board

WBS: 4.7.1.2.2.1
WBS Name: Readout Board Assembly

Definition: This WBS is for the system design of the Readout board. Two design iterations have been allowed. The manpower allocations include the design effort for a zero suppression ASIC to be developed.

WBS: 4.7.1.2.2.2
WBS Name: Tested Readout Board

Definition: This estimate is for test equipment (hardware and software), tester development, testing expense, and technician effort required in final testing.

WBS: 4.7.1.2.3
WBS Name: Front End and Readout Power

Definition: This WBS element is for the power supplies and power cables needed to power both the FEE and RDO boards. Because the FEE boards are powered parasitically by the RDO boards, the power for both boards originates from the same place. This WBS element includes the following lower level components:

.1 Power Supplies and Cables

.2 Power Supply Interlocks and Monitoring

WBS: 4.7.1.2.3.1
WBS Name: Power Supplies and Cables

Definition: This WBS is for the system design of a power supply chassis with supervisory logic for supplying power to the Readout Boards described in WBS 4.7.1.2.2 and to the Front End Boards described in WBS 4.7.1.2.1. Each chassis contains eight power supply modules. Each power supply module powers 2 Readout Boards and associated FEE electronics. Assuming each Readout Board requires 60 watts and each Readout Board powers 18 FEE cards at 3.5 watts each, for a total power budget of 123 watts, the power supply module must supply 250 watts at +5v for the two Readout Boards. Assuming a 20% power loss in the cable due to IR drop, a 7 volt supply rated at 50 amps will be sufficient for each module.

WBS: 4.7.1.2.3.2

WBS Name: Power Supplies Interlocks and Monitoring

Definition: This WBS is for the power supply system interlocks and internal monitoring of air flow, coolant flow, line voltage, etc.

WBS: 4.7.1.2.4

WBS Name: On Chamber Mounting and Cooling

Definition: This WBS is for the manpower required to determine the mounting and cooling of the Readout and Clock/Trigger boards within the TPC.

WBS: 4.7.1.2.5

WBS Name: Interlocks

Definition: This WBS is for the design and implementation of an interlock system for the TPC electronics. These interlocks are external to the power supply interlock system and include such interlocks as clocks, cooling, etc. The power supply interlock system is costed in 4.7.1.2.3.2.

WBS: 4.7.1.2.6

WBS Name: Shipping

Definition: This WBS is for the packaging and transportation of ICs, Front End electronics, and Readout Electronics between LBL and BNL.

WBS: 4.7.1.2.7

WBS Name: Final Debug and Test

Definition: This WBS is for Final Debug and Test for the final debug and test of the Front End electronics and Readout boards. It assumes that physicists will do most of the installation, cabling, and initial test of the electronics.

WBS: 4.7.1.2.8

WBS Name: Sub project Management

Definition: This WBS is for the sub project management associated with the TPC Front End electronics.

WBS: 4.7.1.2.9

WBS Name: Prototypes

Definition: This WBS is for the design and development of a prototype sector and FEE and Readout boards in support of early sector prototype characterization and DAQ system development. It includes the following lower level components:

.1 Prototype Sector

.2 Prototype Electronics

WBS: 4.7.1.2.9.1

WBS Name: Prototype Sector

Definition: This WBS is for the purchase of materials and manpower to assemble a prototype sector pad plane and structural support frame. This prototype sector will be used to check cabling, mounting configurations, and provide a test bed for the prototype electronics described in WBS 4.7.1.2.9.2

WBS: 4.7.1.2.9.2

WBS Name: Prototype Electronics

Definition: This WBS is for the materials and manpower needed for construction of prototype FEE board and Readout boards. It assumes that there will be 40 FEE boards, 2 Readout boards, and a small power supply chassis constructed in support of this protoype stage. In addition to these electronics, some cost has been added to purchase commercial test equipment in support of this protoype work.

WBS: 4.7.1.2.10

WBS Name: Engineering Models

Definition: This WBS is for the materials and manpower needed for construction of mechanical, electrical, or display models of the TPC Front End Electronics.

WBS: 4.7.1.2.11

WBS Name: System Design Documentation

Definition: This WBS is for the system design documentation not otherwise covered under individual WBS numbers. It includes such global documentation as chassis configurations, cable layouts, system descriptions, safety procedures, etc.

WBS: 4.7.1.2.12

WBS Name: Clock/Trigger Distribution

Definition: This WBS is for the design and manufacture of 28 clock and trigger fanout modules. These modules provide a 14–wide fanout capability to drive the 13 readout boards with one spare channel. These modules are mounted one per sector with a single module fanning out to drive the twelve modules mounted one per sector. Consequently, there are 13 of these fanout modules per TPC end cap and 2 spares.

WBS: 4.7.1.2.13

WBS Name: Slow Controls Interface

Definition: This WBS is for the materials and manpower needed to provide an interface into the STAR Slow Controls system. It is assumed that the interface is into a VME crate and that an Allen–Bradley industrial monitoring system will be adequate for the slow controls interface. The manpower estimates include manpower to design the Allen–Bradley system into the TPC electronics and to provide adequate manpower to the Slow Controls effort to help define the control points, software interface, menus for use with TPC electronics, and Alarms and logging information.

WBS: 4.7.1.2.14

WBS Name: Engineering Workstations

Definition: This WBS is for two engineering workstations for use in circuit board design and development, IC development, PCB development, and in support of software diagnostics. A workstation with approximately 25 MIPS processing power, 32MB RAM, 19" color display, and 1.5 GB of disk storage would be adequate: the recently announced Sparcstation LX appears to be a good match to these needs. A small component of manpower is budgeted for initial machine setup and for software maintenance and backup.

WBS: 4.7.2

WBS Name: STAR Data Acquisition (DAQ)

Definition: DAQ provides the capability to configure and read out the front end electronics corresponding to the various detector subsystems. In the baseline detector, only one subsystem (TPC) is present. Its principal responsibilities are to:

1) assemble data originating from digitizers on each detector subsystem into events in a form suitable for recording on a logging medium, and

2) allow for information arising from the detector systems to play a role in the decision to keep or reject each event, on a time scale short compared with the time required for event building.

An essential requirement for the DAQ is to be able to provide the capability to reduce the event **rate**, using software triggers, from the input rate, limited by the readout time (~10 msec), to the rate which can be supported by available taping technology (0.5–1.0 Hz).

This WBS element includes the following lower level components:

1. DAQ Receiver crate system
2. Tape system
3. File server
4. Network interface
5. Workstations
6. Software

WBS: 4.7.2.1

WBS Name: DAQ Receiver Crate System

Definition: This WBS includes the following lower levels:

1. Powered VME crates
2. VME event builder boards

The receiver crate system contains enough VME boards (39) to make connections to the 312 readout boards. Each board provides fiber–optic connections for up to 8 readout boards. The VME boards contain the T9000 transputers (8 per board) and C104 routers (2 per board) which comprise the event builder and the software trigger farm. They will also house the interface to the tape logging system (WBS 4.7.2.2) and the high speed network interface (WBS 4.7.2.4).

WBS: 4.7.2.1.1

WBS Name: Powered VME Crates

Definition: This item represents the VME crates and their power supplies. It also includes memory (separate VME modules) for collecting the events prior to taping. It is assumed here that the crates contain only 8 VME event builder boards (4.7.2.1.2) each, as well as a 68040 CPU outfitted with Ethernet and SCSI to provide for easy interface of the crate to the management software (WBS 4.7.2.6) running in workstations (WBS 4.7.2.5).

WBS: 4.7.2.1.2

WBS Name: VME Event Builder Boards

Definition: Each VME board contains fiber optic–to–electrical conversion for 8 links connecting to the readout boards. It also contains 8 T9000 transputers, each with enough local memory to allow it to collect modest event fragments, as well as 2 C104 routers, which provide the connection fabric. Each board contains a VME master interface to allow event fragments to be built into a complete event in a large memory in the same crate.

WBS: 4.7.2.2

WBS Name: Tape System

Definition: Tape system consists of a high speed digital tape recording system with interface to the VME bus. A recording speed capability of 8 MByte/sec is the minimum acceptable. Two systems are priced in order to provide hot spares capability; that is, 2 tape drives will be in use to facilitate rewinding, but the system is capable of operating with only one functioning drive.

WBS: 4.7.2.3

WBS Name: File Server

Definition: This element is the platform which hosts the database management system, as well as software tools such as cross–compilers, simulators, and calibration and configuration files. Requirements for this machine are:

- ω 100 MIPS computing power
- ω high speed interface to 10 GByte of disk
- ω UNIX operating system
- ω 64 MByte RAM

WBS: 4.7.2.4

WBS Name: Network Interface

Definition: Network interface represents a connection to a high–performance network. For the purpose of the Basis of Estimate, FDDI is used, but it is reasonable to expect a network with even higher performance, at about the same price, by 1995. This network will be used to provide the connection between the event builder and the on–line monitoring tasks running on workstations. The connection to FDDI is a single attach device, which can be the basis of a point–to–point connection to the network event server provided by Computing (WBS 4.8), or it can be connected to an FDDI concentrator hub, also provided under WBS 4.8.

WBS: 4.7.2.5

WBS Name: Workstations

Definition: This element is required to provide the platforms for development of the software running in DAQ, as well as the interface to the DAQ system while it is running. When STAR is on–line, one of these workstations will be reserved as a hardware diagnostics and repair station. The capabilities represented by a Sun Sparcstation II are adequate for the envisioned uses. The application requires a workstation with the following characteristics:

- ω UNIX operating system 19 inch color display
- ω 25 MIPS minimum CPU power
- ω 1 GByte minimum disk storage capacity
- ω 32 MByte minimum RAM

Required: 5 workstations

WBS: 4.7.2.6

WBS Name: Software

Definition: This WBS includes the following lower levels:

1. Event builder software
2. Readout board software
3. Command interface software
4. Network interface software
5. Tape system software
6. Controls interface software

WBS: 4.7.2.6.1

WBS Name: Event Builder Software

Definition: This element represents the development of the software running on a portion of the T9000s on the VME event builder board. This software will be responsible for assembling events from fragments delivered by the readout boards into a buffer within the VME crate, where it will be accessed by the network interface software (WBS 4.7.2.6.4) and the tape system software (WBS 4.7.2.6.5). It will also provide a framework for software trigger algorithms to allow events to be discarded depending on calculations performed on the digitized information in the event fragments.

WBS: 4.7.2.6.2

WBS Name: Readout Board Software

Definition: This element represents the software running in the T9000 on the readout board. It will be responsible for configuring and managing the ASICs on the readout board, which includes downloading the requisite pedestal and threshold values. It will also be responsible for formatting and delivering the event fragment produced on its readout board to the destination event builder CPU as well as the software trigger CPU.

WBS: 4.7.2.6.3

WBS Name: Command Interface Software

Definition: This element covers the software required to interface to the user in as graphical a way as possible in order to provide configuration tools for the readout boards, to provide experiment and tape command interfaces. Part of this software will run on the workstations; the other part will run on the T9000s and the 68040 CPUs in each VME crate.

WBS: 4.7.2.6.4

WBS Name: Network Interface Software

Definition: This element represents the software necessary to interface to the network hardware interface and to configure and manage it. It also will provide an event server to interface to a single network client. The single client will be implemented by Computing (WBS 4.8); it will be responsible for distributing copies of events to its clients.

WBS: 4.7.2.6.5

WBS Name: Tape System Software

Definition: This element covers the software necessary to interface to the tape system hardware interface and to configure and manage it. It will provide all of the lower level functionality required: loading and unloading tapes, rewinding, skipping files, reading and writing data records. Higher level functionality, e.g., recording tape contents in a database, will be performed by the Command interface (WBS 4.7.2.6.3).

WBS: 4.7.2.6.6

WBS Name: Controls Interface Software

Definition: This element represents the software running on the T9000s and the 68040 CPUs in each VME crate which provides both a client and a server interface to the Controls system (WBS 4.7.4). This interface will respond to queries by the Controls system about the status of data acquisition. It will also provide the mechanism for obtaining the Controls information required to be embedded in the logged event stream.

WBS: 4.7.2.6.7

WBS Name: Prototype DAQ Software

Definition: This element represents the software required for the proper functioning of the prototype DAQ system. This system will be constructed using the prototype Readout Board for the TPC (WBS 4.7.1.2.2), and an existing T9000 development board interfaced to an existing Sun workstation. The elements of this software will include configuration of the Readout Board hardware, software pedestal management, event building for a portion of a TPC prototype sector, and a simple command interface. Rudimentary data logging will also be performed using low–speed tape hardware (Exabyte 8500).

WBS: 4.7.2.7

WBS Name: DAQ Engineering Management

Definition: This element represents the high–level engineering oversight required to integrate DAQ efforts with other, e.g., WBS 4.7.1, engineering efforts. This element covers design reviews. Schedule coordination, cost reporting, and quality assurance standards enforcement will also be handled under this WBS element.

WBS: 4.7.3

WBS Name: Trigger System

Definition: This comprises the detectors (central trigger barrel, endcap MWPC, vertex position detector and veto calorimeters) and the electronics used to trigger the STAR detector system. Interfaces include connection to the TPC endcap anode wires plane and the data acquisition system at 4 trigger points and to deliver the trigger detector data.

WBS: 4.7.3.1

WBS Name: Vertex Position Detector (VPD)

Definition: This consists of two separate detectors each of which contains 24 photomultiplier tubes viewing small Pb-Ck radiator sandwiches designed to detect photons from the interaction and locate the vertex in the Z direction by difference in photon arrival times on the two detectors. The detector is located on the beamline +/-3m from the center of the diamond and interfaces to the experiment through the trigger electronics.

WBS: 4.7.3.1.1

WBS Name: VPD Radiators

Definition: The 48 radiators (55 with spares) consist of 1cm of Pb on the 1cm thick quartz face of the PMT's.

WBS: 4.7.3.1.2

WBS Name: VPD Phototubes (PMTs)

Definition: Each VPD contains 24 Hamamatsu R2490-05 mesh anode PMT which is designed to operate in axial fields to 10kG or more.

WBS: 4.7.3.1.3

WBS Name: VPD Phototube Bases

Definition: Each PMT has an independent base consisting of local HV generation from +24V, local charge digitization (10 bit), local time digitization (10 bit), fast and slow communications via optical fiber.

WBS: 4.7.3.1.4

WBS Name: VPD Cables

Definition: Each PMT is connected to the electronics trolley via two separate fiber links, one fast (250 MHz) and one slow (10MHz), and via a multi-conductor cable carrying +24, and +/-8V DC.

WBS: 4.7.3.1.5

WBS Name: VPD Slow Controls

Definition: This consists of the interface to the STAR slow control system for setting and recording HV on each PMT.

WBS: 4.7.3.1.6

WBS Name: VPD Mounting Fixture

Definition: Each VPD is mounted around the beam pipe like a clam. Each can be translated along the pipe in the region from 2 to 8 m from the diamond center.

WBS: 4.7.3.1.7

WBS Name: VPD Assembly and Testing

Definition: This includes assembling the two concentric rings of 8 and 16 PMTs into each VPD, testing the mechanical and electronic operation of the detector as a whole.

WBS: 4.7.3.1.8

WBS Name: VPD Project Management

Definition: Design, fabrication, test and document preparation, schedule, and cost oversight are among the tasks coordinated for this trigger detector.

WBS: 4.7.3.2

WBS Name: Central Trigger Barrel (CTB)

Definition: This detector consists of 240 slats of scintillator each 1m long viewed by a single PMT. The CTB is located in the 12cm cylindrical space between the TPC and the magnet coil. Interface with STAR is through the trigger electronics.

WBS: 4.7.3.2.1

WBS Name: CTB Radiators

Definition: Each of 240 radiators consists of a slat of Bicron 408 scintillator 2cm thick by 20 cm wide by 100 cm long.

WBS: 4.7.3.2.2

WBS Name: CTB Phototubes

Definition: Each slat of the CTB is viewed by a Hamamatsu R2490-05 mesh anode PMT.

WBS: 4.7.3.2.3

WBS Name: CTB PMT bases

Definition: Each PMT has an independent base consisting of local HV generation from +24V, local charge digitization (10 bit), and fast and slow communications via optical fiber.

WBS: 4.7.3.2.4

WBS Name: CTB Cables

Definition: Each PMT is connected to the electronics trolley via two separate fiber links, one fast (250 MHz) and one slow (10MHz), and via a multi-conductor cable carrying +24, and +/-8V DC.

WBS: 4.7.3.2.5

WBS Name: CTB Slow Controls

Definition: This consists of the interface to the STAR slow control system for setting and recording HV on each PMT.

WBS: 4.7.3.2.6

WBS Name: CTB Mechanical Support

Definition: Two slats are located in each mechanical tray. Each tray contains cooling capable of dissipating more than 100 watts of heat in anticipation of the time-of-flight system heat load. Trays slide into location in the space between the TPC and magnet.

WBS: 4.7.3.2.7

WBS Name: CTB Assembly and Testing

Definition: The barrel will be assembled and tested at BNL during installation of the TPC.

WBS: 4.7.3.2.8

WBS Name: CTB Project Management

Definition: Design, fabrication, test and document preparation, schedule, and cost oversight are among the tasks coordinated for this trigger detector.

WBS: 4.7.3.3

WBS Name: Veto Calorimeter (VC)

Definition: This consists of two separate hadron calorimeters, very simple detectors, each located 15m from the diamond just downstream of the first RHIC dipole magnet in the beamlines. Each calorimeter consists of a 1m deep stack of 5cm thick Fe with 2.5cm thick scintillator sandwiches. Light is read out from the scintillators via fibers connected to two PMTs. Interface to STAR is through the trigger electronics.

WBS: 4.7.3.3.1

WBS Name: VC Radiators

Definition: Each radiator consists of a sheet of scintillator 2.5 cm thick 15 or 30 cm wide and 40 cm high. Wave shifter fibers are placed along the edges to pipe the light out to a PMT.

WBS: 4.7.3.3.2

WBS Name: VC Phototubes

Definition: There are two phototubes viewing each VC, one on the neutron side and one on the proton side, connected to the VC through wave-shifter fiber.

WBS: 4.7.3.3.3

WBS Name: VC Absorbers

Definition: Each absorber is 5 cm thick by 15 or 30 cm wide by 40 cm high and made of steel.

WBS: 4.7.3.3.4

WBS Name: VC Cables

Definition: Each VC pmt will have a base like the CTB and VPD and will be connected to the electronics trolley via fast and slow fibers as well as multiconductor cable carrying +24 and +/-8 V DC.

WBS: 4.7.3.3.5

WBS Name: VC Mounting

Definition: Each VC is mounted 15m from the diamond center and covers the neutral region on one side of the pipe and the proton region on the other side.

WBS: 4.7.3.3.6

WBS Name: VC Assembly

Definition: The VCs will be delivered from Frankfurt complete but will need to be placed in their running location and tested in situ.

WBS: 4.7.3.3.7

WBS Name: VC Project Management

Definition: There is a direct connection between VC mounting and RHIC dipole/beamline design that must be watched because of the tight space constraints on the VC. This is in addition to normal management of design, fab, documentation and cost control.

WBS: 4.7.3.4

WBS Name: Endcap MWPC

Definition: The field wires of each endcap are instrumented to pick up the charge induced during avalanche of the track segment from penetrating particles. Each endcap sector is divided into four segments and signals from all wire in the segment fed to a preamplifier and then to a standard PMT digitizer for shipment each crossing time back the trolley. The electronics interfaces to the TPC through preamplifiers and then to STAR through the trigger electronics.

WBS: 4.7.3.4.1

WBS Name: MWPC Front End Electronics

Definition: This consists of the amplifiers, shapers, and summing sections that present charge to the flash ADC, as well as the communications that send the ADC levels to the trolley.

WBS: 4.7.3.4.2

WBS Name: MWPC Cables

Definition: This consists of the optical fibers to deliver signals to the trolley as well as low voltage power for the local electronics.

WBS: 4.7.3.4.3

WBS Name: MWPC Assembly and Test

Definition: The electronics will be integrated with the TPC electronics and tested in situ.

WBS: 4.7.3.4.4

WBS Name: MWPC Project Management

Definition: This is primarily a coordination effort with TPC electronics and CTB ADC development, and will include design, fab, and schedule coordination as well as documentation.

WBS: 4.7.3.5

WBS Name: Trigger Controller (TC)

Definition: This subsystem accepts digital signals from the trigger detectors, routes them through the various trigger levels and communicates with the outside world. It provides the interface to each trigger detector as well as to all elements of the data acquisition system through a hardware interface, an output register which can be strobed each RHIC crossing.

WBS: 4.7.3.5.1

WBS Name: Trigger Processor

Definition: This unit views to contents of the trigger word as it is placed in the trigger word pipe (RAM) 9 crossings behind the interaction, looks at the prescale and busy status for this value of trigger word and places appropriate output in the output register.

WBS: 4.7.3.5.2

WBS Name: RAM-FPGA Board

Definition: Digital signals from each trigger detector are sent via 250 MHz fiber to this board where the signals are received as serial bits, paralleled and strobed with the next RHIC clock into a 40MHz RAM and into a field-programmable-gate-array (FPGA). The gate array is expected to form simple sums of 16 inputs at step one, but the later steps can be programmed to operate on other functions.

WBS: 4.7.3.5.3

WBS Name: RHIC Strobe Distribution

Definition: The RHIC clock drives the whole trigger system in lock-step and must be distributed to all detectors as well as to each RAM board. It will be distributed via fiber or ECL pair depending on destination.

WBS: 4.7.3.5.4

WBS Name: TC CPU

Definition: The trigger will be controlled by a high level computer running interactive processes to display various trigger information and allowing user setting of different trigger properties such as prescale.

WBS: 4.7.3.5.5

WBS Name: LED Pulser

Definition: This system is designed to provide a light pulse or a charge pulse to each detector of the trigger as a means of testing detector operations.

WBS: 4.7.3.5.6

WBS Name: VME Electronics

Definition: The trigger is implemented in VME to take advantage of its local bus and standards. The RAM boards are VME boards with trigger level 1 communication taking place on the VME bus.

WBS: 4.7.3.5.7

WBS Name: NIM Electronics

Definition: Distribution of trigger signals will be done via standard NIM electronics.

WBS: 4.7.3.5.8

WBS Name: System Software

Definition: Programming of FPGA as well as programming of the trigger processor will require system level expertise. A single system programmer will aid in definition of software modules with code written by software technicians and students.

WBS: 4.7.3.5.9

WBS Name: Assembly

Definition: The trigger system will occupy 6 VME crates and at least 2 NIM bins and will require many levels of interconnection.

WBS: 4.7.3.5.10

WBS Name: Project Management

Definition: Design, fabrication, testing and documentation as well as cost and schedule control will be the responsibility of the project manager.

WBS: 4.7.4

WBS Name: Slow Controls

Definition: Slow Controls is defined as the subsystem within the STAR detector that monitors subsystem conditions, adjusts subsystem parameters, and provides alarm status when a failure or safety problem shows up. Slow Controls has been defined to run on a low−cost Unix workstation running the software package called EPICS. EPICS (for Experimental Physics and Industrial Control System) is a fast, easy interface to instrumentation for data acquisition, supervisory control, and steady−state control through a table entry database. EPICS runs under Unix and is designed to interact with processors running VxWorks in a VME or VXI crate system.

EPICS itself is free to national laboratories, VxWorks is available for a nominal license charge. The bulk of the development effort will be software, with the hardware component being purchased off−the−shelf.

This WBS element contains the following lower level components:

.1 Hardware

.2 Software

.3 Miscellaneous

WBS: 4.7.4.1

WBS Name: Slow Controls Hardware

Definition: This WBS entry is for the Slow Controls Hardware components. It contains the following lower level components:

.1 Commercial Workstation

.2 Commercial VME crate & components

WBS: 4.7.4.1.1

WBS Name: Commercial Workstation

Definition: This WBS entry is for the purchase of a commercial Unix workstation and additional peripherals (such as additional memory and disks) to support the database requirements of EPICS. This workstation will be used for software development and with the EPICS software to control the processors in the VME crates.

WBS: 4.7.4.1.2

WBS Name: VME Crates

Definition: This WBS entry is for costing the VME crates and commercial processors used at each subsystem as the Slow Controls interface. There are currently 5 subsystems identified for Slow Controls (Magnet, TPC, TPC power, DAQ, and Trigger). One crate is allocated as a spare, bringing the total crate count to 6.

WBS: 4.7.4.2

WBS Name: Software

Definition: This WBS entry covers commercial software and custom software development in support of Slow Controls. EPICS itself is free to national laboratories, while VxWorks is available for a nominal license charge. This entry has the following lower level entries:

.1 Commercial Software

.2 Custom Software

WBS: 4.7.4.2.1

WBS Name: Commercial Software

Definition: This WBS entry covers the cost of a commercial database package to support the storage and handling of STAR detector configuration information and the cost of VxWorks licenses. In addition, this entry covers the cost of manpower to install this software and the cost of software maintenance.

WBS: 4.7.4.2.2

WBS Name: Custom Software

Definition: This WBS entry covers the cost of custom software development for STAR Slow Controls. The software development effort is supported by LBL in the form of training and use of EPICS and custom kernel development for VxWorks. The collaborator (most likely Creighton State University) will provide the bulk of the development work. This entry has the following lower level entries:

.1 Custom Software (LBL)

.2 Custom Software (Creighton State)

WBS: 4.7.4.2.2.1

WBS Name: Custom Software (LBL)

Definition: This WBS entry covers the cost of LBL engineering in support of Slow Controls. LBL will provide training in EPICS use and management and custom VxWorks kernel requirements for Slow Controls. The manpower estimate covers 20% of an LBL engineer for the duration of the project.

WBS: 4.7.4.2.2.2

WBS Name: Custom Software (Creighton State)

Definition: This WBS entry covers the development effort at Creighton State for STAR Slow Controls software development. The bulk of this effort will be in configuring EPICS for the peculiarities of the Slow Controls system. The manpower estimates reflects the contributed effort designated by Creighton State in a STAR Memorandum of Understanding.

WBS: 4.7.4.3

WBS Name: Slow Controls Integration

Definition: The WBS entry covers the final integration of Slow Controls into the detector subsystems. This entry has the following lower level entries:

.1 Shipping

.2 System Setup

.3 System Integration

WBS: 4.7.4.3.1

WBS Name: Shipping

Definition: This WBS entry covers the cost of shipping the slow controls hardware from the collaborator's site to LBL or BNL, as needed.

WBS: 4.7.4.3.2

WBS Name: System Setup

Definition: This WBS entry covers the estimated manpower to help setup and configure the Slow Controls system at BNL.

WBS: 4.7.4.3.3

WBS Name: System Integration

Definition: This WBS entry covers the estimated manpower for integration of the Slow Controls system with the various detector subsystems at BNL.

WBS: 4.8.1.1

WBS Name: Code Development Worksystem

Definition: This WBS includes the following lower levels:

.1 Multi−processor Compute Servers

.2 File Servers

.3 Two−user Workstations

.4 User support and documentation

Workstations enable programmers to simulate data for analysis, develop analysis software, and evaluate the physics potential of the experiment. The system will combine high−performance multiprocessor compute servers, tightly integrated file servers and large graphical user interfaces. Includes sufficient hardware to support ten FTE code developers.

WBS: 4.8.1.1.1

WBS Name: Multi−Processor Compute Server

Definition: This WBS includes sufficient shared computing power to produce simulated STAR event data and analyze that data for workers developing the analysis software. Since the computer is shared multiple processors are efficiently used on separate jobs.

WBS: 4.8.1.1.2

WBS Name: File Server

Definition: The file server provides storage at various levels for programs, simulated event data, analysis results, and files describing the STAR detector. The system is designed to provide rapid access to these files to workstations attached over a network (WAN). These files are needed for the task of developing the analysis code for the experiment.

WBS: 4.8.1.1.3

WBS Name: Two–user Workstations (6)

Definition: These workstations provide the user interface to the servers (4.8.1.1.1,4.8.1.1.2) for the software development task. They should have a local capacity to run small jobs, a local disk for test files, and, of course an ethernet connection to the network. There will be at least 20 to 30 people working on code development, many of whom will have their own workstations. These six are needed to provide for workers traveling to centers of code development (mostly at LBL and BNL) to participate in a combined effort.

WBS: 4.8.1.1.4

WBS Name: Code Development System User Support and Documentation

Definition: This WBS includes acquisition, QA, installation, system support as well as developing and maintaining user documentation and guides for the components of the code development worksystem.

WBS: 4.8.1.2

WBS Name: On–line Hardware Monitoring Systems

Definition: This WBS includes the following lower levels:

.1 SVT Monitor

.2 TPC Monitor

.3 TOF Monitor

.4 Magnet Monitor

.5 EMC Monitor

.6 XTP Monitor

This WBS includes computers to provide diagnostic information on detector performance during pre–RHIC testing on through the experiment. Requires close integration with WBS 4.7.2, Data acquisition, and with each detector subsystem. Each subsystem will need at least one computer of modest CPU power with an integrated high speed DAQ bus. (VME or FASTBUS)

WBS: 4.8.1.2.1

WBS Name: SVT Hardware Monitoring Systems

Definition: To provide diagnostic information on SVT detector performance during pre–RHIC testing and through experiment. Includes a small computer and interface to data acquisition hardware and part time effort by a computer manager. Specification depends primarily on the requirements of the SVT development (WBS 4.1) and the schedule of the SVT slow control system (4.1.4.5), SVT front end electronics (4.7.1.?) and of course on data acquisition design (4.7.2.1).

WBS: 4.8.1.2.2

WBS Name: TPC Hardware Monitoring Systems

Definition: To provide diagnostic information on TPC detector performance during pre–RHIC testing and through experiment. Includes six small computers and interfaces to data acquisition hardware and part time effort by a computer manager. Specification depends primarily on the requirements of the TPC development (WBS 4.2) and the schedule of the TPC slow control system (4.7.4), TPC front end electronics (4.7.1) and of course on data acquisition design (4.7.2.2).

WBS: 4.8.1.2.3

WBS Name: TOF Hardware Monitoring Systems

Definition: To provide diagnostic information on TOF detector performance during pre–RHIC testing and through experiment. Includes a small computer and interface to data acquisition hardware and part time effort by a computer manager. Specification depends primarily on the requirements of the TOF development (WBS 4.3) and the schedule of the TOF slow control system TOF front end electronics (4.7.1.?) and of course on data acquisition system design (4.7.2.3).

WBS: 4.8.1.2.4

WBS Name: Magnet Hardware Monitoring Systems

Definition: To provide diagnostic information on solenoid magnet performance during construction, pre–RHIC testing and through experiment. Includes a small computer and interface to data acquisition hardware and part time effort by a computer manager. Specification depends primarily on the requirements of the Magnet development (WBS 4.4) and the schedule of the Magnet slow control system. This is not part of the field measurement system (WBS 4.4.4) which will have its own computer capacity.

WBS: 4.8.1.2.5

WBS Name: EMC Hardware Monitoring Systems

Definition: To provide diagnostic information on EMC detector performance during pre–RHIC testing and through experiment. Includes a small computer and interface to data acquisition hardware and part time effort by a computer manager. Specification depends primarily on the requirements of the EMC development (WBS 4.5) and the schedule of the EMC slow control system EMC front end electronics (4.7.1.?) and of course on data acquisition system design (4.7.2.5).

WBS: 4.8.1.2.6

WBS Name: XTP Hardware Monitoring Systems

Definition: To provide diagnostic information on XTP detector performance during pre–RHIC testing and through experiment. Includes a small computer and interface to data acquisition hardware and part time effort by a computer manager. Specification depends primarily on the requirements of the XTP development (WBS 4.6) and the schedule of the XTP slow control system XTP front end electronics (4.7.1.?) and of course on data acquisition system design (4.7.2.6).

WBS: 4.8.1.3

WBS Name: On–line Physics Monitoring System

Definition: This WBS includes the following lower levels:

.1 Event Server computer

.2 Event analysis compute server system

.3 Graphical User interface workstations

.4 High speed networking hardware

.5 Management, Engineering, Procurement and Documentation

This computer system provides integrated analysis of a sample of the data in real–time during the experiment, including full event analysis by the reconstruction code. Needed is a major CPU server with high speed tape capability and high speed bus interface to the DAQ (WBS# 4.7.2) through the FDDI interface (WBS # 4.7.2.50.2) . The tape device will be determined by the DAQ choice (WBS # 4.7.2.50.1) To achieve the necessary throughput, this system will involve multiple parallel processors. The interface to the experimenters includes three high performance graphical workstations connected over high speed (FDDI) net as well as many workstations with access over ethernet.

WBS: 4.8.1.3.1

WBS Name: Event Server Computer

Definition:: Data dispatching computer system with large attached disk storage, tape drive compatible with DAQ system tapes and multiple high–speed network connections (to the DAQ system, a major CPU server, and multiple graphical workstations).

WBS: 4.8.1.3.2

WBS Name: Event Analysis Compute Server System

Definition: Multiprocessor computing engine of at least 250 MFlops total CPU. Configured as either a farm of loosely coupled single processor workstations or a multiprocessor compute server.

WBS: 4.8.1.3.3

WBS Name: Graphical User Interface Workstations (3)

Definition: Control room workstations, equipped with high speed network connection to the event server and small local disk storage with a high resolution graphics hardware and software for event and histogram display for on–line physics output monitoring. One acquired two years before RHIC turn–on for development, two more acquired just before RHIC beam circulates.

WBS: 4.8.1.3.4

WBS Name: High Speed Networking Hardware

Definition: Router–Bridge and concentrator devices for the connection of the event server to the DAQ system and to the Graphical workstations (4.8.1.3.3) and the rest of the laboratory and the world.

WBS: 4.8.1.3.5

WBS Name: Management, Engineering, Procurement and Documentation

Definition: This includes the manpower required to support the code development system through the process of specification, purchase QA, delivery, installation, documentation and a low level of user support.

WBS: 4.8.1.4

WBS Name: Off–Line Event Processing Systems

Definition: This WBS includes the following lower levels:

.1 Host distribution computers

.2 DAQ–system–compatible tape drives

.3 SCSI Disk Drives (100 GB)

.4 FDDI – Ethernet hardware

.5 8 mm tape drives

.6 Multiple single–event stream processing nodes.

.7 Management, Engineering and Documentation.

Performs full analysis of the data streams from the simulated data for detector calibration and from the detector for physics output. The major processor capacity of the experiment. Presently envisioned as based of farms of perhaps 200 to 400 RISC processors (5 GFlops total) served by very high performance magnetic tape systems over high speed buses. The tape device will be determined by the DAQ choice (WBS # 4.7.2.50.1). These costs are not part of the total STAR detector budget but are included here for reference since this constitutes the major computing of the experiment.

WBS: 4.8.1.5

WBS Name: Off–Line Physics Analysis Workstations

Definition: Computer system for multiple users to extract the physics from the large database of analyzed events produced by the event processor (WBS 4.8.1.4). This system performs the final acceptance corrections and uncertainty evaluations and produces publication quality representations of the experiment results. This system will be provided by updating and augmenting the code development system (WBS 4.8.1.1).

WBS: 4.8.2

WBS Name: Software

Definition: This WBS includes the following lower levels:

.1 System Definition and Specification

.2 Event Generators

.3 Detector Specific Software

.4 Global Event Reconstruction

.5 Software Management Tools

.6 Processor Farm Control System

.7 Analysis Shell

.8 Magnet Measurement Software

.9 On–line operations system

.10 Data management system

Software refers to the Computer Programming needed to extract physics information from the detector and the ancillary design, specification, tooling, planning, testing, and documentation efforts necessary to create those programs.

WBS: 4.8.2.1

WBS Name: System Definition and Specification

Definition: This WBS includes the following lower levels:

.1 Software Requirements Specification

.2 System Architecture

.3 Data dictionary

.4 User Interface

.5 Graphical Interface

.6 Programmer Interfaces

.7 Messaging Services

.8 Code Library Specifications

.9 Detector Specifications Database

.10 On–line operations system

.11 Data management system

Specification documents must be generated defining the hardware and software requirements. This documentation must be available on–line from the workstation environment of STAR.

WBS: 4.8.2.1.1

WBS Name: Software Requirements Specification

Definition: A document specifying the requirements that must be met by the software to accomplish the purpose of STAR.

WBS: 4.8.2.1.2

WBS Name: System Architecture

Definition: The hardware and software components that will make up the complete STAR computing environment including specification of the computer languages to be used.

WBS: 4.8.2.1.3

WBS Name: Data Dictionary

Definition: This WBS includes the following lower levels:

.1 Parameter File Design

.2 Event Generator File

.3 Detector Data file design

.4 Data summary file design

.5 Histogramming package

.6 Calibration Data design

.7 Raw data format design

A detailed definition of all data objects to be handled by the programs.

WBS: 4.8.2.1.4

WBS Name: User Interface

Definition: A document specifying the STAR computing system as it is to appear to the user including the full command menu structure. Implementation of that interface in code.

WBS: 4.8.2.1.5

WBS Name: Graphical Interface

Definition: Design, documentation and implementation of the systems that will produce the graphic output to support the design and monitoring of the STAR detector.

WBS: 4.8.2.1.6

WBS Name: Software Integration and Programmer Interfaces

Definition: Design, documentation and implementation of the systems that will enable programmers to work on separate subsystems of the code and produce an efficient whole.

WBS: 4.8.2.1.7

WBS Name: Messaging Services

Definition: Design, documentation and implementation of the system for passing messages between software subsystems and from the software to the users and programmers.

WBS: 4.8.2.1.8

WBS Name: Code Library Specifications

Definition: Design, documentation, implementation and maintenance of the library holding all STAR source and object code and most STAR databases.

WBS: 4.8.2.1.9

WBS Name: Detector Specifications Database

Definition: Design, documentation, implementation and maintenance of the database for STAR detector parameters.

WBS: 4.8.2.1.10

WBS Name: On–line Operations System

Definition: Design, documentation, and specification of the software system for controlling, operating and monitoring the experiment as a whole. This includes integration with software described in other sections of the WBS.

WBS: 4.8.2.1.11

WBS Name: Data Management System

Definition: Design, documentation, and specification of the system to manage all data relevant to generating reliable physics results of STAR.

WBS: 4.8.2.2

WBS Name: Event Generators

Definition: Programs using theoretical models of RHIC interactions to compute multiplicity and distribution in rapidity of each species of final state particle. Includes documentation on the use of each program and of the form of the output.

WBS: 4.8.2.3

WBS Name: Detector Specific Software

Definition: This WBS includes the following lower levels:

.2 Time Projection Chamber (TPC) Software

.4 Solenoid Magnet (SMS) Software

.7 Trigger Device Software

Those complete programs and sub–programs associated with a detector subsystem and used in the design, simulation, monitoring, calibration and reconstruction of the data from that subsystem.

WBS: 4.8.2.3.2

WBS Name: Time Projection Chamber (TPC) Software

Definition: This WBS describes software specifically for the TPC (WBS 4.X). It includes the following lower levels:

.1 TPC Simulator

.2 TPC Event Reconstruction

.3 TPC Monitor Program

.4 TPC Calibration Programs

.5 TPC Design Tools

.6 TPC Software Documentation

.7 TPC Control Program

WBS: 4.8.2.3.2.1

WBS Name: TPC Simulator

Definition: Code to simulate the signal from particle interactions for the TPC detector including event participants, machine backgrounds and secondaries from interaction in all detector materials.

WBS: 4.8.2.3.2.2

WBS Name: TPC Event Reconstruction

Definition: This WBS includes the following lower levels:

.1 TPC Hit Reconstruction

.2 TPC Track Reconstruction

.3 TPC dE/dx Particle Identification

.4 TPC Decay Vertex Reconstruction

.5 TPC Primary Vertex Reconstruction

Code to extract, from the data file, the digital signals from the TPC electronics and convert them to lists of hits, tracks, and vertices.

WBS: 4.8.2.3.2.3
WBS Name: TPC Monitor Program
Definition: This WBS includes the following lower levels:

.1 TPC Voltage Monitoring

.2 TPC Gas System Monitoring

.3 TPC Electronics Monitoring

Code to ensure TPC detector voltage, gas system and electronics are operating properly and to warn experimenters of any malfunctions. Build a database recording periods of failure of TPC detector subsystems.

WBS: 4.8.2.3.2.4
WBS Name: TPC Calibration Program
Definition: This WBS includes the following lower levels:

.1 TPC Hit Reconstruction Calibration

.2 TPC Hit Resolution Calibration

.3 TPC dE/dx amplitude calibration

.4 TPC coordinate correction code

.5 TPC dE/dx correction code

Code to control the measurement of the spatial coordinate distortions and resolutions in the TPC data. Code to measure the TPC detection efficiency and to measure the signal amplitude – energy loss calibration Code to apply the necessary corrections to the measured data

WBS: 4.8.2.3.2.5
WBS Name: TPC Design Tools
Definition: Code to optimize TPC detector properties for physics output and determine realistic parameters for TPC design and construction.

WBS: 4.8.2.3.2.6

WBS Name: TPC Software Documentation

Definition: Primary documentation will be included as part of the source code for all software. Tools will be provided to extract this information into useful summary documents. Separate efforts are required to detail the algorithms chosen and the reasons in order to make it possible for users to apply the code and for programmers to maintain it.

WBS: 4.8.2.3.2.7

WBS Name: TPC Control Program

Definition: The program providing the user interface for communicating with the slow controls system for adjusting TPC operational parameters. These include anode wire high voltage, field cage high voltage, etc.

WBS: 4.8.2.3.4

WBS Name: Solenoid Magnet (SMS) Software

Definition: This WBS describes software specifically for the solenoidal magnet (WBS 4.X). It includes the following lower levels:

.1 Magnet Simulator

.2 Magnet Monitor Program

.3 Magnet Calibration Programs

.4 Magnet Design Tools

.5 Magnet Software Documentation

.6 Magnet Control Program

ESTIMATE 330 man–days physicist effort, 230 man–days tech level.

WBS: 4.8.2.3.7

WBS Name: Trigger Device Software

Definition: This WBS describes software specifically for the trigger devices (WBS 4.X). It includes the following lower levels:

.1 Trigger Device Simulators

.2 Trigger Device Signal Reconstruction

.3 Trigger Device Monitoring

.4 Trigger Device Calibration Programs

.5 Trigger Device Design Tools

.6 Trigger Dev. Software Documentation

.7 Trigger Control Program

WBS: 4.8.2.4

WBS Name: Global Event Reconstruction

Definition: Assemble data from detector subsystems to characterize complete events

WBS: 4.8.2.5

WBS Name: Software Management Tools

Definition: This WBS includes the following lower levels:

.1 Software Engineering, Planning and Design

.2 Software Library Management tools

.3 Data Dictionary Software

.4 Software Verification and Testing

.5 Software Documentation tools

.6 Program development tools (purchased)

Provide an infrastructure for the efficient development of the body of software for the experiment. Includes software library management tools database management software, documentation tools, code verification and bottleneck analysis.

WBS: 4.8.2.6

WBS Name: Processor Farm Control System

Definition: Control system for batch mode production data processing on the high speed processor farm (hardware provided by RHIC). It includes event queue handling, error detection, and control.

WBS: 4.8.2.7

WBS Name: Analysis Shell

Definition: Integrates a sub–set of the detector programs (from a single detector test to the complete system) with a uniform user interface of commands, error messages, and graphical outputs. Operates on single processor workstations, larger multi–processor systems and on the large processor farms, in batch and interactive modes.

This WBS includes the following lower levels:

.1 Prototype Analysis Shell

.2 First Prototype Software Bus

.3 Second Prototype Software Bus

.4 User Interface

.5 Data I/O module

.6 Graphics module

.7 Event processing module

8 Software Bus based Analysis Shell

WBS: 4.8.2.7.1

WBS Name: Prototype Analysis Shell

Definition: The preliminary version of the analysis shell used for integrating the simulation programs. It has the same programming interface for the simulation and analysis routines as the final analysis shell, but not the full functionality of the final analysis shell.

WBS: 4.8.2.7.2

WBS Name: First Prototype Software Bus

Definition: The preliminary version of the software bus. This has the same programming interface for software bus modules and user interface routines as the final software bus but without the distributed processing capabilities.

WBS: 4.8.2.7.3

WBS Name: Second Prototype Software Bus

Definition: The second version of the software bus. It includes improvements learned from using the preliminary version and it contains the first version of the distributed application capability.

WBS: 4.8.2.7.4

WBS Name: User Interface

Definition: The routines comprising the user interface for the analysis shell.

WBS: 4.8.2.7.5

WBS Name: Data I/O Module

Definition: The module handling data input, output and network transmission which connects to the software bus.

WBS: 4.8.2.7.6

WBS Name: Graphics Module

Definition: The routines that handle interfacing between the software bus and a histogramming package.

WBS: 4.8.2.7.7

WBS Name: Event Processing Module

Definition: The routines that interface between the software bus and the event–based data analysis and simulation routines.

WBS : 4.8.2.7.8

WBS Name: Software Bus–Based Analysis Shell

Definition: The complete analysis shell based on the software bus with distributed processing capabilities and including all necessary software modules.

WBS: 4.8.2.8

WBS Name: Magnet Measurement Software

Definition: Controls the measurement of the Magnetic field of the STAR solenoid. Provides Quality Assurance for the recorded data to ensure that an accurate field map will be available for the use of tracking programs.

WBS: 4.8.2.9

WBS Name: On–line Operations System

Definition: Provides the overall experiment control for running the detector, taking data, monitoring, logging experimenters comments and alarms, and the overall state of the experiment.

This WBS includes the following lower levels:

.1 Experiment Control

.2 Event Server

.3 Error Logger

.4 Experiment Parameter Log Database

.5 Configuration manager

.6 Configuration Database

.7 State manager

.8 Detector performance history database

WBS: 4.8.2.9.1

WBS Name: Experiment Control

Definition: The program that provides the user interface for running the experiment, including interacting with: the DAQ system (WBS 4.X), the configuration manager (WBS 4.8.2.9.5), the on–line state manager (WBS 4.8.2.9.7), and the logging database (WBS 4.8.2.9.4).

WBS: 4.8.2.9.2

WBS Name: Event Server

Definition: The program that receives samples of data from the data acquisition system (WBS 4.X) and distributes it to any necessary on–line processes.

WBS: 4.8.2.9.3

WBS Name: Error Logger

Definition: The program that receives error messages from the data acquisition system, the slow controls system and all other necessary on–line processes, and logs these messages to an error log database. It includes facilities for filtering, viewing and setting alarms based on the messages received.

WBS: 4.8.2.9.4

WBS Name: Experiment Parameter Log Database

Definition: The design and implementation of the on–line logging database where configuration parameters, run conditions, taping conditions and data taking statistics are stored. This database serves as the primary record of what data is taken under what conditions and is used to guide the selection of data tapes for processing.

WBS: 4.8.2.9.5

WBS Name: Configuration Manager

Definition: The design and implementation of the program that manages the configuration parameters for the experiment. It permits recording configuration parameter sets to the configuration database and recalling previous versions of parameters.

WBS: 4.8.2.9.6

WBS Name: Configuration Database

Definition: The design and implementation of the database where experiment configuration parameters are stored and accessed by on–line programs.

WBS: 4.8.2.9.7

WBS Name: State Manager

Definition: The design and implementation of the software and associated database that manages the state information about the current state of the experiment. This software handles access to the current state information by all on–line control programs. This provides the mechanism to control access to changing parameters of the experiment so that the configuration during data taking is well understood and reliable.

WBS: 4.8.2.9.8

WBS Name: Detector Performance History Database

Definition: The design and implementation of the database used by monitoring programs to keep track of the history of the various parameters used to monitor the performance of the detector.

WBS: 4.8.2.10

WBS Name: Data Management System

Definition: Provides the means of cataloging, tracking and accessing all of the essential data for the experiment.

This WBS includes the following lower levels:

.1 Database software (purchased)

.2 Data management software

WBS: 4.8.2.10.1

WBS Name: Database Software

Definition: This is purchased database software that is used for the on–line databases.

WBS: 4.8.2.9.10.2

WBS Name: Data Management Software

Definition: This is the design and implementation of the programs and software used for managing all data relevant to physics analysis. It provides for keeping track of: raw data tapes, data summary tapes (DSTs), tracking the data processing history of DSTs. It also provides for access to data stored in a mass storage system by referencing data in a meaningful way.

WBS: 4.9

WBS Name: Conventional Systems (CVS)

Definition: The STAR detector Conventional Facility System (CFS) is common to more than one detector subsystem. Preliminary design of the CFS falls under the responsibility of the System Integration (SI) group. Final design and procurement will be handled by RHIC/BNL. The CFS consists of the following:

1. Mechanical Utilities
2. Electrical Utilities
3. Detector Safety System
4. Electronics Trolley
5. Detector Physical Access System
6. Area Shops Equipment

The CFS requirements are derived from the specific subsystem's needs and general detector integration requirements. CFS conceptual design specifications suitable for the cost estimate were completed. The detailed design will be completed as the final design of the detector subsystems becomes available.

WBS: 4.9.1

WBS Name: Mechanical Utilities

Definition: The mechanical utilities system consists of the following subsystems:

1. Modified Chilled Water (MCHW)
2. Conditioned Air (HVAC)
3. Industrial Cooling Water (ICW)

Low Conductivity Water system (LCW) is required for the magnet system only and it is part of the magnet subsystems.

WBS: 4.9.1.1

WBS Name: Modified Chilled Water System

Definition: The MCHW system is required to cool electronics (including upgrades) at the following locations :

SVT and TOF electronics inside the detector

PMTs outside the return iron

XTPC electronics

Electronics racks on the trolley

Electronics racks in the DAQ/Operation building

The Electronics racks are cooled by circulated chilled air which is chilled by the MCHW. TPC ROC electronics inside the detector are cooled by water chilled in a separate local chiller for better temperature control. The chiller's condenser is cooled by industrial cooling water supplied by the SI group (WBS 4.9.1.1.3).

The MCHW requirement includes the cooling needs of systems to be installed as upgrades. A summary of the MCHW requirement is as follows:

Location	**Capacity KW**	**T_{in} ·F**	**T_{out} ·F**	**Flow gpm**	**Max Pres psi**
Detector electronics	56	60	70	38	100
EMC PMT's	62	60	70	42	100
External TPC	12	60	70	8	50
Electronics trailer	166	60	70	113	100
DAQ building	11	60	70	7	100
Total	**307**	**60**	**70**	**209**	

WBS: 4.9.1.1.1
WBS Name: Piping and Fitting
Definition: Copper pipes and fitting for MCHW distribution from the RHIC/BNL manifolds to the subsystem manifolds

WBS: 4.9.1.1.1.1
WBS Name: Distribution Pipes and Tubes
Definition: Copper pipes 4 in to 1.5 in schedule 40 Type L. Fiber glass insulation is included. Total approximate length (all sizes) is 1,700 ft.

WBS: 4.9.1.1.1.2
WBS Name: Fitting and Brackets
Definition: Copper fittings and support brackets for the distribution system (20% of total piping cost)

WBS: 4.9.1.1.1.3
WBS Name: Dielectric Unions and Flanges
Definition: Unions for dissimilar metals (Al– Cu) to prevent galvanic corrosion. Number of union is 39 (including all sizes)

WBS: 4.9.1.1.2
WBS Name: Valves
Definition: Shut–off and Flow Control Valves

WBS: 4.9.1.1.2.1
WBS Name: Shut–Off Valves
Definition: Butterfly Cu valves 53 total

WBS: 4.9.1.1.2.2
WBS Name: Motorized and Actuators
Definition: 8 motorized and actuators flow and pressure control. 8 valves totals

WBS: 4.9.1.1.3
WBS Name: Expansion Tank
Definition: Water expansion tank. 31 gallon capacity ASME rated

WBS: 4.9.1.1.5
WBS Name: Water to Water Heat Exchanger
Definition: Bell and Gossett Tube and shell heat exchanger. 275 gpm at 5 psi.

WBS: 4.9.1.1.6
WBS Name: Instrumentation and Controls
Definition: Instrumentation and controls for flow monitoring

WBS: 4.9.1.1.6.1
WBS Name: Sensor
Definition: Pressure, temperature and flow sensors. Each sensor is complete with signal pickup and processing. Total required is 8

WBS: 4.9.1.1.6.2
WBS Name: Computer
Definition: Desktop computer for process control

WBS: 4.9.1.1.6.3
WBS Name: Software
Definition: Software for process control

WBS: 4.9.1.1.6.4
WBS Name: Local Pressure and Flow Gauges
Definition: Gauges to measure pressure and flow for manual operation. Total required is 20 gauges

WBS: 4.9.1.2
WBS Name: Conditioned Air System
Definition: Air circulation inside the detector is estimated at 150 CFM. This system is not designed to remove any heat load. It is purpose is to maintain uniform temperature and low humidity condition inside the detector. Another safety purpose is to dilute and mix any TPC gases if leak occurs.

Below is a table summarizing the HVAC system specifications:

Location	Capacity	T_{in}	T_{out}
Detector interior	150 CFM	68 ·F	68 ·F

Pressure is slightly positive with respect to the interior of the halls.

WBS: 4.9.1.3

WBS Name: Industrial Cooling Water System

Definition: TPC electronics inside the detector are cooled by chilled water produced by a local chiller (the cost of the chiller is included in the TPC WBS). The condenser of the chiller is cooled by industrial water provided by the SI group. The industrial cooling water (ICW) system is required to cool the condenser of TPC chiller.

ICW system specifications are:

Location	Capacity	T_{in}	T_{out}	Max P
TPC Chiller	30 KW	95·F	110·F	100 psi

WBS: 4.9.2

WBS Name: Electrical Power

Definition: Electrical power is used to run the instrumentation for the various detectors and sub–systems of the STAR experiments. It includes the following lower level components:

1. Filtered power
2. Clean power
3. Uninterrupted power
4. Emergency power.

WBS: 4.9.2.1

WBS Name: Filtered Power

Definition: Filtered power is derived from the Clean power by passing it through a filter and surge suppressor. It contains the following lower level component:

1. Distribution

WBS: 4.9.2.1.1

WBS Name: Distribution

Definition: Filtered power is distributed in the Operations room, and the computer room to power the computers, workstations, tape loggers, laser printers and other electronic equipment. It is also used to power the Electronic shop and Clean room. Power is distributed using cables, conduits, and distribution panels. It includes the following lower level components:

1. Cables and conduit
2. Distribution panels

WBS: 4.9.2.1.1.1

WBS Name: Cables and Conduit

Definition: The cables are used to carry the power to and from distribution panels in the Operations room, the computer room, and the Clean room. They are routed within conduit, and follow the safety requirements of the National Electrical Code. Outlets are provided to power equipment used for the On– line computing and DAQ systems.

WBS: 4.9.2.1.1.2

WBS Name: Distribution Panels

Definition: These panels are used to receive power from the main breakers, and distribute it on feeder circuits. It contains distribution bus bars and circuit breakers. Surge suppessors and filters are located in the Operations room, the computer room, and the Clean room.

WBS: 4.9.2.2

WBS Name: Clean Power

Definition: Clean Power is isolated from the Utility power, so that machinery or other equipment used on that power, does not affect the electronics. Aside from the magnet power supply, it uses the bulk of the power. It contains the following lower level component:

1. Distribution

WBS: 4.9.2.2.1

WBS Name: Distribution

Definition: Clean Power is distributed to racks in the trolley and the Operations room which contain the electronics of the detector sub–systems. It includes the following lower level components:

1. Cables, and wireways
2. Busways
3. Distribution panels
4. Power conditioners

WBS: 4.9.2.2.1.1

WBS Name: Cables and Wireways

Definition: Cables are used to carry the power to and from the distribution panels. They are routed within conduit and follow safety requirements of the National Electrical Code. Power is carried on 6" wireways to eight rows of eight racks. Clean power is also taken on 6"x6" wireways to power the racks in the operations room.

WBS: 4.9.2.2.1.2

WBS Name: Busways

Definition: Power is provided by BNL at a secondary main breaker as 3 phase 208V. A Busway is used to carry 440 W of power to the trolley where it is connected to the main distribution panel in the trolley.

WBS: 4.9.2.2.1.3

WBS Name: Distribution Panels

Definition: These panels are used to receive power from the main breakers, and distribute it on feeder circuits. It contains distribution bus bars and circuit breakers.

The main distribution panel in the trolley receives power from the main breaker, and distributes it on 16 feeder circuits of 102 V and 208 V to each row of racks. Each row further contains a distribution panel with feeder circuits of 208 V and 120 V, @ 20 A each.

WBS: 4.9.2.2.1.4

WBS Name: Power Conditioners

Definition: These units are used to condition the AC power by providing regulation of the AC power to within 1%. In addition, the response time is within a few milliseconds. This level of conditioning is required by sensitive electronic equipment.

WBS: 4.9.2.3

WBS Name: Uninterrupted Power

Definition: Uninterrupted power. This power is derived from the clean power. It provides a temporary back–up for the few critical areas that exist. It contains the following lower level component:

1. Distribution

WBS: 4.9.2.3.1

WBS Name: Distribution

Definition: Uninterrupted power is distributed to electronic equipment in the trolley and the Operations room from the Back–up unit. It includes the following lower level components:

1. Back–up units, fittings

WBS: 4.9.2.3.1.1

WBS Name: Back–up units, Fittings

Definition: Uninterrupted power uses a 1 KVA Uninterrupted power system that can provide 1 hour of backup to the electronics in the trolley. 2 2.5 KVA unit. is used in the control room to provide power for 2 hours. These units sense when the Clean power has dropped out, and switch over to the back–up power within a cycle.

Cables are used to carry power to the load. They are routed within conduit in accordance with the safety requirements of the National Electrical Code.

WBS: 4.9.2.4

WBS Name: Emergency Power.

Definition: This power is used for emergency lighting within the detector during assembly and repairs, to ensure personnel safety during power failures.

It contains the following lower level component:

1. Distribution

WBS: 4.9.2.4.1

WBS Name: Distribution

Definition: Emergency power is carried to the inside of the detector during assembly and repairs.

It includes the following lower level components:

1. Cables and conduit

WBS: 4.9.2.4.1.1

WBS Name: Cables and Conduit

Definition: The cables are used to carry the power to and from the distribution panels. They are routed within conduit and supported by fittings during the time that they are mounted temporarily within the detector.

WBS: 4.9.2.7

WBS Name: Signal Distribution System

Definition: This is a system to transport signals between the detector and electronic equipment. It contains the following lower level component:

1. Distribution

WBS: 4.9.2.7.1

WBS Name: Distribution

Definition: Signals are distributed between the detector, the trolley racks, the operations and the control rooms. The detector and the trolley will be moved between the assembly room and the experimental hall.

Signals taken from the trolley to the racks in the Operations room cannot be disconnected when the trolley is moved between its two positions. A cable carrier made up of links that allow it to be bent in a controlled manner is used for this purpose.

Cables are eventually taken to racks where they are connected to electronic instruments.

Within the operations and control room, workstations and computers are linked up by fiber optic cables that are carried in wireways.

The system includes the following lower level components:

1. Cable distribution: detector to trolley
2. Cable distribution in trolley
3. Cable distribution: trolley to operations room
4. Cable distribution: in operations and control rooms
5. Racks and Chilled Air system

WBS: 4.9.2.7.1.1

WBS Name: Cable Distribution: Detector to Trolley

Definition: This is a system of cable distribution that uses 12"x 12" wireways to carry the cables. These wireways are routed from the detector to the trolley after passing through the shielding wall. Eight wireways are used.

WBS: 4.9.2.7.1.2

WBS Name: Cable Distribution in Trolley

Definition: A wireway system is provided within the sub–floor to organize and route the cables to their respective racks. Wireways are also required to carry cables between floors.

WBS: 4.9.2.7.1.3

WBS Name: Cable Distribution: Trolley to Operations Room

Definition: Cables are carried on two 6" wireways from the trolley to the operations room. The cables are carried in a cable carrier as described above. The wireways would act as a trough to guide and support the carrier.

WBS: 4.9.2.7.1.4

WBS Name: Cable Distribution: in Operations and Control Rooms

Definition: 6" x6" wireways are used to carry signal cables to the racks. The cables between the multiport transceivers in the FDDI ring, the computers and the workstations are carried in 6" wireways.

WBS: 4.9.2.7.1.4

WBS Name: Racks and Chilled Air System

Definition: Racks are used to house the electronic instrumentation. These are 19" standard racks, which also contain a chilled air system. This system has a heat exchanger which carries Chilled Water to cool air warmed by the equipment.. Air is circulated by fans that blows chilled air over the equipment and down ducts that line the sides of the racks.

WBS: 4.11

WBS Name: Installation and Test

Definition: This element is to cover the cost of installing and testing the baseline detector components of STAR in the Wide Angle Hall and its associated buildings at RHIC. The element is subdivided into the following subelements:

1. Installation
2. Test
3. General Purpose Installation & Test Equipment
4. Installation & Test Activities Management

WBS: 4.11.1

WBS Name: Installation

Definition: This element includes all costs associated with assembly and installation of all subsystems of the STAR Detector in the Wide Angle Hall (WAH) and its associated assembly and operations buildings at RHIC. Once a component of the STAR Detector enters the perimeter of the WAH, WAH assembly annex, or WAH operations/ counting house building, the expense of further assembly and installation is budgeted for in this element unless otherwise negotiated with the Project Manager and Chief Engineer. The element includes the cost of all labor used in the hall for subsystem assembly and installation, as well as miscellaneous expense items incurred during these activities.

The EDIA (EN, EA, DR & AD) portion of the cost is for a continuation of engineering support, from the institution that provided the original construction support, during the final assembly (if necessary), installation and test phase. In other words, funds for an engineer who was involved in the design and fabrication effort to spend time at BNL during that subsystems installation.

The element does not include the cost of planning installation activities. This means planning for installation of individual subsystems (included in subsystem WBS's) and overall installation planning (which is included in Systems Integration (4.13) and Project Management (4.12)). The element does include, however, the cost of day to day installation activity management by the lead installation engineer or coordinator. Implicit in the

labor portion of the cost estimate for installation is that a good deal of the signal cable pulling efforts will be done by project physicists, post–docs, grad students, and other "free" labor. All cables carrying relatively hi–voltage or hi–current will be installed by BNL/RHIC electricians, not by physicists.

WBS: 4.11.2

WBS Name: Test

Definition: This element includes all costs associated with testing of all subsystems of the STAR Detector within the Wide Angle Hall (WAH) and its associated assembly and operations buildings at RHIC. Once a component enters the WAH, WAH assembly annex, or WAH operations/counting house building, the expense of all testing is budgeted for in this element unless otherwise negotiated with the Project Manager and Chief Engineer. The element includes the cost of all labor used in the hall for subsystem and system testing, as well as miscellaneous expense items incurred during these activities. This element includes only general purpose test equipment.

The element does not include the cost of planning test activities. This means planning for testing of individual subsystems (included in subsystem WBS's) and overall system test planning (which is included in Systems Integration (4.13) and Project Management (4.12)). The element does include, however, the cost of day to day testing activity management by the lead installation engineer or coordinator.

Implicit in the labor portion of the cost estimate for testing is that a great many of the tests will be done by project physicists, post–docs, grad students, and other "free" labor.

WBS: 4.11.3

WBS Name: General Purpose Installation & Test Equipment

Definition: This element includes the cost of specifying or designing and fabricating or procuring commonly used equipment associated with installation & test.

The element includes the cost of procuring or renting general purpose installation hardware such as:

man–lifts

fork trucks

"coat hangers" and spreader bars

standard rigging hardware (hoist rings, cables and slings)

hand tools

cribbing blocks

The element includes general purpose test equipment such as:

Volt meters

temporary use data loggers

The element includes some money for procurement of minimal alignment equipment which is best kept in the STAR halls.

This element does not include special lifting and handling devices, and insertion hardware which is specific to a single subsystem such as the TPC installation fixturing (beam or beams). It also does not include special test equipment and devices which are specific to a single subsystem such as the super conducting solenoid field mapping equipment.

WBS: 4.11.4

WBS Name: Installation & Test Activities Management

Definition: This element includes the cost of coordination and management of the day to day installation activities. Included is the cost of an on–site installation manager and coordinator along with some clerical support. These people will coordinate the daily activities of all personnel in the assembly and interaction halls and the operations building, insuring that work is well coordinated, that when special support equipment or people are needed they are there, and that the overall installation plan is being implemented.

WBS: 4.12

WBS Name: Project Management

Definition: Project Management is made up of the following lower level WBS elements:

1. Planning
2. Tracking
3. Document Control
4. Quality Assurance
5. Environmental Safety and Health

This WBS element includes the cost of labor and materials necessary to plan, track, manage and distribute drawings and documents, and perform necessary EH&S and QA tasks. The interfaces are at the system vs subsystem level and are better defined at the next lower level.

WBS: 4.12.1

WBS Name: Planning

Definition: This WBS element includes the cost of labor and materials for detector system level planning activities. These activities include summing and reviewing detector cost estimates, detector schedule planning and review, installation cost estimating and schedule planning, budget planning, and other technical management activities.

WBS: 4.12.2

WBS Name: Tracking

Definition: This WBS element includes the cost of labor and materials for detector system level cost and schedule tracking in the DoE PMS or CS/CSC environment. It is expected that in this element we will collect costs from all other WBS elements and summarize them in the required (RHIC) format. We will also on a semi–annual basis update the estimate to complete (ETC) and the project summary schedule. The output of this element will be delivered to RHIC Project Management for inclusion in the RHIC summary reporting to DoE.

WBS: 4.12.3

WBS Name: Document Control

Definition: This WBS element includes the cost of labor and materials for detector system level document control activities. These activities include developing, controlling, and maintaining a library of physics and technical notes and drawings for the STAR detector program at LBL andBNL. It includes the cost of clerical support to assign document numbers, enter the pertinent data (title, author, institution, etc.) on each new document, and to distribute notes to individuals who make specific requests. It also includes labor and materials costs associated with distributing copies of the above to all collaborating institutions on a regular basis (monthly).

WBS: 4.12.4

WBS Name: Quality Assurance (QA) Program

Definition: This WBS element includes the cost of labor and materials for detector system level quality assurance activities. These activities include developing a relevant QA program for STAR based on current DoE requirements, subsequently distributing these requirements to subsystem project leaders, performing QA training if necessary, and internally policing these activities.

WBS: 4.12.5

WBS Name: Environmental Health and Safety

Definition: This WBS element includes the cost of labor and materials for detector system level EH&S activities. These activities include interpreting current DoE/BNL/RHIC EH&S requirements, subsequently distributing these requirements to subsystem project leaders, performing EH&S related training if necessary, managing the PSAR and SAR writing activities, and internally policing the above activities.

WBS: 4.13

WBS Name: System Integration

Definition: This WBS element includes the cost of labor and materials for detector system level detector integration activities. These activities include the following:

Creating and maintaining boundary and interface definition drawings between subsystems.

Developing and maintaining system level drawings of the detector.

Creating and maintaining plumbing and cabling space drawings.

Creating and maintaining detector assembly scenario drawings.

Creating and maintaining detector servicing/maintenance scenario drawings.

Creating and maintaining detector utility and facility requirements lists and drawings.

Planning and scheduling detector installation activities.

WBS: 4.13.1

WBS Name: Mechanical Integration

Definition: This WBS element includes the cost of labor and materials for detector system level mechanical integration activities.

WBS: 4.13.2

WBS Name: Electrical Integration

Definition: This WBS element includes the cost of labor and materials for detector system level electrical and electronics integration activities.

WBS: 4.13.3

WBS Name: Facilities Integration

Definition: This WBS element includes the cost of labor and materials for system level detector facilities integration activities. These activities include aiding in the development of facilities and utilities needs (the Resource Requirements Report, RRR), representing STAR's interests in negotiations with RHIC and BNL conventional facilities people, reporting the results of these negotiations, tracking the Title 1/Title 2 design efforts, tracking the construction progress for facilities and utilities, and ultimately aiding in the installation of the detector conventional systems where they interface with the facility/utilities.