WBS 1.3.4.2.1.1 - Design and Integration

Base costs total roll-up: $441.1K

Notes: This WBS element is responsible for oversight and coordination of the ND construction. Main duties include:

1. Negotiates MOU's with Fermilab for ND construction, ensure access to key resources.
2. Negotiates MOU with FNAL test beam facility for running of test beam detector.
3. Provides key input to civil construction group on design of ND Hall.
4. Engineering for design of near detector and required components. Controls engineering drawings.
5. Ensures completion of simulation studies required for optimization of upgraded muon spectrometer (field strength, absorber thickness, etc).
6. Sponsors a series of integration and design workshops.

I'll cost some items for this WBS (engineering time), but much of this will be non-costed.

I. WBS 1.3.4.2.1.1.1 - R&D
Base costs roll-up: $287.5K

Goals: So, we need oversight of the R&D program. The main goals here include providing key input to the civil construction group on design of the ND hall, internal design reviews in preparation for CD2, and production of engineering drawings for the detector construction.

-.1 - Negotiate relevant MOUs with Fermilab

M&S:
Labor: ND L3 manager @ 5%
ND L2 manager @ 5%
Duration: 20 weeks
Base costs: 0
Contingency: 5 weeks on duration

Notes: So, any institution participating in the ND effort will eventually negotiate an MOU/SOW with the ND project management. While the process is routine for most institutions, the Fermilab MOU is particularly important. The ND effort is an experiment taking place physically at Fermilab, but the project management is sited at LANL. Fermilab is the most important physical facility in the experimental program, and negotiating access to facilities and resources will be key to the success of the ND effort. In particular, the ND effort will need to secure access to the MINERvA detector at some point indicated by the schedule. This may be an agreement between FNAL, LBNE, and the MINERvA collaboration. The agreement needs to detail how the ND effort gains stewardship over the MINERvA detector. The issue is important, and will need to deal with issues such as when does MINERvA need to stop running (no more run extensions), nature of access to the detector before that point for R&D purposes, etc.

On-site outfitting is an important engineering task. Required lab space and the intermediate surface facility used during installation will need to be identified so outfitting plans can be made.

Also to be negotiated is an MOU with the FNAL test beam facility. Test beam time is often scheduled years in advance, and the usual mechanism for establishing a test beam effort is an MOU. It is currently anticipated that we will required test beam time in 2014.

-.2 - Monitor civil design of ND facilities

M&S:
Labor: ND L3 manager @ 3%
ND L2 manager @ 3%
Detector coordinators @ 3%
Installation coordinator @ 3%
ME @ 3%
Tim Wyman and others from Civil Construction

Duration: 78 weeks
Base costs: $7.5K
Contingency: 20 weeks on duration
Notes: This task really needs to be done by a committee of people. Relevant L2 and L3 managers are involved by default, but the task also needs input from folks more familiar with the detector systems. As installation also places constraints on the design of the ND hall and surface building, the installation coordinator should also be present. Meetings should be held at least quarterly with more frequent meetings called as needed (at the discretion of the L3---times of heightened design activity, etc.)

The costs here cover involvement of the ND mechanical engineer.

-.3 - Detector optimization studies
M&S:
Labor: Physicist @ 50%
Duration: 40 weeks
Base costs: 0
Contingency: 12 weeks on duration
Notes: This task allocates resources to finalize optimization of the detector design. The basic idea is to ensure answers to large design-related questions, such as magnetic field strength, thickness of the muon spectrometer absorber material, etc. This also permits studies of any issues raised in Sam Zeller's simulation efforts.

-.4 - Conceptual design of detector systems
M&S
Labor: Detector coordinators @ 20%
ME @ 100%
Duration: 39 weeks
Base costs: $124.8K
Contingency: 13 weeks
Notes: So, this is simple conceptual design of all detector systems. Costing here was done in consultation with Bob Flight, the engineer responsible for mechanical design of the original MINERvA detector. Bob estimated 1000-2000 hours for the conceptual design, and an equal amount of time to produce detailed drawings for fabrication. I'm costing 1500 hours, and using the 2000 hours guidance to set the contingency at another 500 hours.

-.5 - R&D integration workshop
M&S:
Labor: Collaboration in general, but all L4 or L5 managers responsible for detector construction in particular at 25%
Duration: 3 weeks
Base costs: 0
Contingency: 1 week
Notes: This is a one-day workshop that is really our first chance to discuss integration issues. Ideally, this takes place late in the R&D phase, so that managers are familiar with their systems. The workshop should identify challenges with the current design of the detector (such as integration issues). Findings should geed into the final detector design. While the workshop is 1 day, the duration here gives the L4 or L5 managers time to review their R&D programs and prepare for the workshop.

-.6 - CD2 preparations: Rigorous engineering design
M&S
Labor: Detector coordinators @ 20%
ME @ 100%
Duration: 39 weeks
Base costs: $124.8K
Contingency: 13 weeks

Notes: So, this is detailed design of all detector systems prior to final costing exercise. Costing here is similar to that employed in task -.4.

-.7 - Engineering design review

M&S

Labor: ME @ 100%
EE @ 100%

Duration: 3 weeks

Base costs: $30.5K

Contingency: 1 week on duration

Notes: Review of engineering design. There are many purposes for this step. It allows the collaboration to formally sign off on the detector design prior to the CD2 review. As the detectors will be installed at Fermilab, this step also gives interests from Fermilab a preliminary chance to examine the detector design and express any concerns. The review, then, may involve safety and engineering interests from Fermilab. The duration here gives the engineers time to prepare for the meeting and some time to make adjustments to designs.

II. WBS 1.3.4.2.1.1.2 - TB Design and Integration
Base costs roll up: $124.8K

Notes: So, this step should not be as involved. Test beam MOU should already be in place. The only real duty here is to spec. design of the test beam detector, and handle integration issues.

-.1 - TB detector design workshop

M&S:

Labor: Collaboration in general, but all L4 or L5 managers responsible for detector construction in particular at 25%

Duration: 3 weeks

Base costs: 0

Contingency: 1 week

Notes: So, this is a ~1 day workshop presenting plans for the test beam detector. Conceptual plans will be presented, integration issues will be identified and discussed. The design engineer will be present and will use the workshop as the basis for production of drawings of the test beam detector. Duration here is simply gives some preparation time.

-.2 - Test beam detector engineering

M&S

Labor: Detector coordinators @ 20%
ME @ 100%

Duration: 39 weeks

Base costs: $124.8K

Notes: So, this is detailed design of all detector systems for the TB detector prior to construction. The costing here is based on discussions with Bob Flight, ME responsible for the original MINERvA detector design. He estimates 1000-2000 hours for the conceptual design of that detector, and another 1000-2000 hours for detailed part drawings (kind you would send to a machine shop). I'm estimating 1500 hours for either step, and another 1500 hours (in a single step) total for the test beam detector design. This total should produce part drawings suitable for fabrication. The test beam detector design should be able to build off the already existing drawings from the near detector.

III. WBS 1.3.4.2.1.1.3 - Production Detector Design and Integration
Base costs roll-up: $28.8K

-.1 - Detector Integration Workshop

M&S:

Labor: Collaboration in general, but all L4 or L5 managers responsible for detector construction in particular at 25%
Duration: 3 weeks
Base costs: 0
Contingency: 1 week
Notes: ~1-2 day meeting reviewing the status of the detector design prior to the start of construction. This meeting will focus on lessons learned from prototyping exercises and the TB construction effort. Integration issues will be discussed and addressed. Input may result in some final design changes prior to the start of construction.

-.2 - Final engineering effort
M&S
Labor: Detector coordinators @ 20%
ME @ 100%
Duration: 9 weeks
Base costs: $28.8K
Contingency: 2 weeks on duration
Notes: This task covers final engineering prior to the start of final detector construction. Outcomes of the previous workshop will be considered.

-.3 - Milestone: Detector installation and deployment workshop
M&S:
Labor: Collaboration in general, but all L4 or L5 managers responsible for detector construction in particular at 25%
Duration: 3 weeks
Base costs: 0
Contingency: 1 week
Notes: Final design workshop to develop and review installation and commissioning plans.

WBS 1.3.4.2.1.2 - Facilities and Steel

Base costs total: $1,308K

Goals: This WBS element has responsibility for procurement of steel for the muon spectrometer, and provides heavy steel fixtures for the experiment, including detector stands, lifting fixtures, etc. Detector stands must be provided for both the LBNE near detector hall as well as the intermediate surface building.

I. WBS 1.3.4.2.1.2.1 - R&D
Base costs roll-up: $255K

Goals: Frame production is fairly well understood, so the process does not need much R&D. The bigger issues are monitoring the design of the near detector hall, and dealing appropriately with pieces available from the MINERvA detector construction. There should be detector stands, and a number of strongbacks available, and this WBS needs to secure that material. In addition, the suitability of these fixtures for use on LBNE will need to be evaluated. Anything found unsuitable for purposes will need to be re-engineered and modified.

Notes:

-.1 - Inventory available MINERvA hardware

M&S:	
Labor:	Physicist @ 25%
Duration:	6 weeks
Base costs:	$0
Contingency:	2 weeks

Notes: Locate and inventory available fixtures from MINERvA. Determine what is to be re-used, and what needs to be altered or rebuilt.

-.2 - Design facility outfitting

M&S:	
Labor:	PPD_ME @ 100%
	PPD_Drafter @ 100%
Duration:	8 weeks
Base Costs:	$35.4K
Contingency:	2 week

Notes: Task will produce detailed drawings of outfitted near detector hall, surface building, intermediate surface building, and assembly space for the muon spectrometer. This is not the design of these facilities, but rather plans for outfitting the space for our purposes after beneficial occupancy is granted. These drawings will note the locations of the detector stands and other large facilities. Drawings of the underground hall will also show the location of the detector and associated infrastructure (electronics racks, power supplies, cooling, etc). These drawings are for internal use (layout of experimental and laboratory spaces).

Costing produced by adopting task duration and resources form similar task on MINERvA (Design modifications to MINOS platform). I've scaled the total time allocated in MINERvA by two because the design work here is intended to cover 2-3 facilities

-.3 - Design ND-specific heavy facilities

M&S:	
Labor:	PPD_ME @ 67%
	PPD_Drafter @ 100%
Duration:	30 weeks
Base Costs:	$173.2K
Contingency:	7 weeks on duration

Notes: The intent of this task is to provide some engineering time for design of heavy facilities. This includes detector stands, lifting fixtures, etc. While much of this infrastructure may be re-used from MINERvA or MINOS, some pieces may need to be re-built or modified.

The costing here amounts to half of the design time required for similar tasks required by the initial MINERvA build.

-.4 - PPD technician support for on-site R&D activities

M&S:	$6K
Labor:	PPD_MT @ 200%
	PPD_MT_Supervisor @ 100%
Duration:	4 weeks
Base Costs:	$46.4K
Contingency:	1 week

Notes: Task covers support for on-site R&D activities. While this WBS element may not require a lot of R&D or prototyping, experimental groups using on-site facilities will require mechanical support from PPD technicians for R&D activities. This task was costed by searching the MINERvA project file for tasks requiring PPD mechanical technicians for outfitting, etc. The total was 7.5 technician weeks, which I have rounded up to 12 (roughly a month of a 3-person crew).

II. WBS 1.3.4.2.1.2.2 - Test Beam Detector
Base costs roll-up: $237.7K

Goals: So, this group of tasks covers outfitting and steel for the test beam effort. In particular, the test beam detector stand, calorimetric absorber material, and mechanical technician support for the installation effort will be provided through this WBS element.

-.1 - Mechanical design for Test Beam detector

M&S:	
Labor:	PPD_ME @ 100%
Duration:	26 weeks
Base costs:	$115.4K
Contingency:	6 weeks

Notes: Task duration based on integration of design tasks for MINERvA test beam effort. While the mechanical design of the test beam detector itself is already handled in the "Design and integration" WBS element, this task is more specific to the scope of this WBS task group. In particular, this is the design of the stand, and any mechanical design work needed to outfit the enclosure.

-.2 - Procure stand

M&S:	$63K
Labor:	ME @ 5%
Duration:	16 weeks
Base costs:	$66.5K
Contingency:	$15K on M&S, 4 weeks on duration

Notes: Costs scaled from MINERvA test beam stand fabrication. Costs scaled up by 1.2.

-.3 - Procure absorber/frames

M&S:	$42K
Labor:	ME @ 5%
Duration:	16 weeks
Base costs:	$44.6K
Contingency:	$15K, 4 weeks on duration

Notes: Scaled from costs of MINERvA test beam detector absorber.

-.4 - Install TB modules

M&S:

Labor: PPD_MT @ 200%
Duration: 2 week
Base costs: $11.2K
Contingency: 1 week on duration
Notes: MINERvA test beam detector installation required a team of 2 technicians for a week to hang planes. I've assumed a similar duration here, but added a second week for technician support for the enclosure outfitting and instrumentation effort.

III. WBS 1.3.4.2.1.2.3 - Near Detector Fabrication
Base costs roll up: $815.3K

Goals: So, this group of tasks covers outfitting and steel for the actual near detector itself.

-.1 - Final design
M&S:
Labor: PPD_ME @ 67%
PPD_Drafter @ 100%
Duration: 7 weeks
Base Costs: $40.4K
Contingency: 3 weeks
Notes: This task simply covers any remaining design work required for the production of the muon spectrometer. The task is an opportunity to make final changes based on the outcomes of earlier prototyping exercises.

-.2 - Procure heavy fixtures
M&S: $179K
Labor:
Duration: 26 weeks
Base costs: $179K
Contingency: $45K
Notes: Task covers procurement of heavy fixtures required for construction of the muon spectrometer. Some of this task may be simple modifications to existing MINERvA or MINOS fixtures. Costing is based on as-realized costs for half of the MINERvA fixturing, scaled up by 1.2.

-.3 - Production outfitting of assembly space
M&S:
Labor: PPD_MT @ 100%
PPD_MT_Supervisor @ 100%
PPD_Welder @ 33%
Duration: 3 weeks
Base costs: $24.4K
Contingency: 1 week on duration
Notes: Task allows for mechanical technician support for deployment of fixtures procured in previous step or recovered from MINERvA storage. The MINERvA costing called for 5 technician-weeks and a week of welding. I've estimated 6 technician-weeks and a week of welding here.

-.4 - Procure steel for muon spectrometer frames
M&S: $295K
Labor:
Duration: 6 months
Base costs: $295K
Contingency: $295K M&S, 2 months on duration.
Notes: The costing here is simply 100% of the MINERvA steel costs for frame production. While the muon spectrometer requires much less steel than the entire MINERvA build (<half), steel prices escalated rapidly at points during our build. The costing and 100% contingency allows for a total

escalation of ~400% over the MINERvA costs normalized to tonnage. Steel procurement was a long lead-time item.

-.5 - Muon spectrometer frame fabrication

M&S:	
Labor:	PPD_MT @ 400%
	PPD_Welder at 100%
Duration:	16 weeks
Base costs:	$276.5K
Contingency:	4 weeks on duration

Notes: This is higher than what's in the MINERvA project file. While discussing the frame production costs with Jim Kilmer, he disclosed that the labor in the project file was inadequate. I've updated the labor profile here to reflect actual staffing levels during the build. The rate here assumes a production of one frame every 1.5 days, for a build of 50 frames.

Resources:

PPD_ME	$111/hour
PPD_Drafter	$70/hour
PPD_MT_Supervisor	$83/hour
PPD_Welder	$152/hour

WBS 1.3.4.2.1.3 - Scintillator Extrusion

Base costs total: $550.9K

Notes on costing: The costing of this section was completely reviewed by Anna Pla.

I. WBS 1.2.3.2.1.3.1 - R&D
Base costs roll-up: $255.6K

Predecessor link: Availability of 2011 R&D funds

Goals: R&D co-extruded WLS fiber and decide on technology (co-extruded or not). Produce spec. for shape of extrusions. Evaluate WLS fiber from Kuraray and Bicron, and develop final spec.. Produce 1500 channels of scintillator for preliminary R&D at other production sites.

-.1 - Procure pellets, dopants, fiber, fiber feeder, and die.
M&S:: $91K
Labor: PPD -Chemist @ 5%
Duration: 6 weeks
Base costs: $91K
Contingency: $45K M&S
Notes: Costs based on estimates provided by Anna Pla, worked up for May 2008 R&D proposal. Contingency high here as this project represents work that has not been done before.

-.2 - Rework extruder line
Labor: PPD-MT @ 100%
PPD-Coex @ 200%
Duration: 4 weeks
Base costs: $19.2K
Contingency: 50% on duration.
Notes: This task covers resources to reconfigure the extruder line for co-extruding the WLS fiber.

-.3- Optimize extrusion process with fiber feed.
Labor: PPD-Coex @ 100%,
PPD-MT @ 100
PPD-Chemist @ 50%
Duration: 16 weeks
Base costs: $76.8K
Contingency: 50% on duration
Notes: Time to optimize the extrusion process for co-extruding the fiber.

-.4- Tune die; optimize scintillator shape
M&S: $50K M&S
Labor: PPD-chemist @ 5%
Duration: 8 weeks
Base costs: $50K
Contingency: 20% on duration.

-.5 - Optical studies of sample scintillator
Labor: Physicist, 100%
Technician, 50%
Duration: 4 weeks
Base costs: $8K
Contingency: 30% on duration.

Notes: This is simply a few resources to perform source tests of some scintillator samples with co-extruded WLS fiber. We'll map the attenuation length and study the optical transmission properties of the samples.

-.6 - Milestone: Decision on scintillator technology - co-extruded WLS fiber or not.

-.7 - Extrude R&D scintillator

Labor:	PPD-Coex @ 200%
	PPD-MT-Spec @ 200%
	PPD-chemist @ 10%
Duration:	1 week
Base costs:	$10.6K
Contingency:	20% on duration

Notes: Staffing levels proposed by Anna Pla. FNAL extruder produces ~1500 pieces in a week-long run.

II. WBS 1.2.3.2.1.3.2 - Test Beam Detector Extrusion
Base costs roll-up: $84.3K

Goals: Produce scintillator for test-beam detector.

-.1 - Procure required consumables:

M&S:	$40.3K
Labor:	PPD -Chemist @ 5%
Duration:	6 weeks
Base costs:	$40.3K

Notes: Procure scintillator-related consumables for TB detector, and arrange purchases for remainder of build if possible. Scintillator consumables costs ($12K) here are MINERvA TB detector expenses scaled up by 20%. WLS fiber ($28.3K) is TP fiber expense scaled by 0.4.

-.2 - Final die tuning based on R&D studies

M&S:	$10K M&S
Labor:	PPD-chemist @ 5%
Duration:	8 weeks
Base costs:	$10K
Contingency:	$30K if major die rework needed.

-.3 - Extrude TB scintillator

Labor:	PPD-Coex @ 200%
	PPD-MT_Spec @ 200%
	PPD-chemist @ 10%
Duration:	3 weeks
Base costs:	$32K
Contingency:	20% on duration

-.4 - Ship scintillator to production site

M&S	$2K
Duration:	2 weeks
Contingency:	25%
Base costs:	$2K

Notes: Includes crating and shipment to production site(s).

III. WBS 1.2.3.2.1.3.3 Extrude scintillator for US muon catcher.
Base costs roll-up: $211K

Goals: Produce scintillator for upgraded muon tracker.

-.1 - Procure required consumables

M&S::	$161.2K
Labor:	PPD -Chemist @ 5%
Duration:	6 weeks
Base costs:	$161.2K

Notes: $18K for polystyrene, dopants, etc. $143.2K for WLS fiber. Costs are MINERvA (TP) expenses scaled up by 20% for inflation, and divided by 3.

-.2 - Extrude production scintillator

Labor:	PPD-Coex @ 200%
	PPD-MT_Spec @ 200%
	PPD-chemist @ 10%
Duration:	4 weeks
Base costs:	$42.6K
Contingency:	20% on duration

-.3 - Ship scintillator to production sites.

M&S:	$7.2K
Duration:	2 weeks
Contingency:	25%
Base costs:	$7.2K

Resources and rates:

PPD-chemist	Chemist	0
PPD-MT	Mechanical technician	$70/hr
PPD-MT-Spec	Mechanical specialist	$83/hr
PPD-Coex	Extruder technician	$50/hr

WBS 1.3.4.2.1.4 Scintillator Packaging and Characterization

Base costs total: $804K

I. WBS 1.3.4.2.1.4.1 - R&D
Base costs roll-up: $179.7K

Goals: R&D program should begin by recreating the MINERvA scintillator packaging techniques. As a result, part of the R&D phase will include gaining access to jigs and facilities left over from the MINERvA construction. Once scintillator is available from Fermilab with co-extruded fiber, then packaging techniques are refined. Source testing of packaged arrays is demonstrated with the MINERvA module mapper, which has to be adapted to work with the updated SiPM photosensors and prototype electronics.

In general, the initial R&D phase is to first recreate and master the MINERvA packaging techniques. Once scintillator, photosensors, and electronics are available from Fermilab, then the R&D becomes more specific to the technologies chosen. The packaging will change to accept SiPM's, the mapper will have to be updated, etc.

An important step is acquisition of appropriate laboratory space from the sponsoring institution (or from Fermilab if work is performed on site).

-.1 - Arrange appropriate laboratory space
Labor: Physicist @ 15%
Duration: 8 weeks
Base costs: $0
Contingency: 3 weeks
Notes: Includes time to procure space (either from FNAL or home institution).

-.2 - Outfit laboratory space for R&D.
M&S: $60K
Labor: Physicist @ 20%
Mechanical Engineer @ 25%
Technician @ 50%
Duration: 8 weeks
Base costs: $74.4K
Contingency: $15K M&S
4 weeks schedule
Notes: Job includes location of existing MINERvA materials, retrieval from storage, and shipment to lab site. $60K M&S also covers initial outfitting of laboratory space - MINERvA used multiple sites for this work, each site required approximately $60K outfitting.

-.3 - Recreate MINERvA scintillator packaging techniques -
M&S: $10K
Labor: Physicist @ 30%
Technician @ 100%
Duration: 16 weeks
Base costs: $42K
Contingency: 4 weeks on duration.
Notes: Task is simply mechanical assembly of a scintillator plane using MINERvA-style techniques. If scintillator uses co-extruded WLS fiber, then we won't use these techniques in the final production. However, this is a cost-effective way to get the institution to start thinking about the process, with the goal to improve upon techniques that have already been developed. Experience must also include use of the MINERvA glue machine to couple fiber to scintillator. We want to be able to fall back on these techniques if the co-extruded WLS fiber is unfeasible. Costs scaled from production of first MINERvA prototype scintillator plane.

-.3 - Modifications to MINERvA module mapper

Labor: PPD_EE @ 100%
Duration: 4 weeks
Base costs: $17.8K
Contingency: 50% on duration

Notes: Includes updates to the MINERvA mapper control system to function with updated photosensors and electronics. Needs predecessor: Availability of electronics and photsensors. Costs here based on discussion with Al Baumbaugh, engineer who authored original software interface for MINERvA module mapper.

-.4 - R&D scintillator dressing

M&S $10K
Labor: Physicist @ 30%
Technician @ 50%
ME @ 33%
Duration: 8 weeks
Base costs: $26.5K
Contingency: 25%

Notes: This is an R&D task to investigate how to dress the ends of the scintillator bars. With co-extruded WLS fiber, we will need to determine how to polish the readout end of the scinitllator (presumably it will be polished, but how?). The other end of the scintillator will also need some thought. Does this end also need to be polished? Does it need to have reflective material (either aluminized mylar or a reflective paint applied)? Where does this fit into the production schedule? What are the costs and performance differences in each technique. I've costed engineering and $10K M&S for design and fabrication of fly-cutter fixturing for polishing ends of scintillator. Note: Needs predecessor availability of scintillator with co-extruded WLS fiber.

-.5 - Produce functional prototype scintillator plane

M&S $3K
Labor: Physicist @ 50%
Technician @ 200%
Duration 4 weeks
Base costs: $19K
Contingency 2 weeks

Notes: This is production of the first scintillator plane using scintillator with co-extruded WLS fiber. The costs are based on typical duration of R&D tasks from MINERvA prototyping phase.

II. WBS 1.3.4.2.1.4.2 - Test Beam Module Production
Base costs roll-up: $224.2K

Goals: This task will produce modules for the test beam detector. The scintillator will be packaged, light-tightened, and mapped with the MINERvA module mapper. For costing purposes, we'll assume 3K channels of scintillator, corresponding to about 5 tons of extruded polystyrene. This translates to roughly 24 planes. While I envision the TB detector to be different from the construction of the DS muon catcher, I have assumed the production of 24 MINERvA planes for costing purposes.

-.1 - Build TB scintillator planes

M&S $54,488
Labor: Physicist @ 100%
Technician @ 400%
Duration: 15 weeks
Base costs: $174.5K
Contingency:
Notes:

From MINERvA project file for prototype plane production:
Total M&S: $107,000

Labor: $253,051
For a build of 44 planes, yields per plane costs are $2431 M&S, $5751 labor. This is total scintillator costs (ID and OD) normalized by the number of planes produced for the TP build. Let's scale by .9 assuming some cost escalation for inflation, but 25% savings in labor and M&S due to co-extruded WLS fiber. TB planes then cost $2187 M&S and $5175 labor. If we assume $50/hour for technician labor, then this amounts to 100 hours labor per plane. Let's assume we do the equivalent of 24 modules worth for the TB detector, then this amounts to totals of $54,488 M&S, $124,200 labor. Assuming 4 technicians, then we have a 15 week build.

-.2 - Assemble TB modules

M&S: $24,000
Labor: Physicist @ 40%
Technician @ 200%
Duration: 6 weeks
Base costs: $26.4K
Contingency:
Notes: Estimated by R. Bradford based on experience from MINERvA build. MINERvA prototype build required comparable M&S, labor. Based on build rate of 3 modules/week.

-.3 - Map TB modules

M&S $7200
Labor Physicist @ 25%
Technician @ 100%
Duration: 8 weeks
Base costs: $23.3K
Notes: Estimated by R. Bradford, based on expeience with MINERvA scanner. Each module required about 10 hours technician time.

III. WBS 1.3.4.2.1.4.3 Assemble muon tracker modules
Base costs roll-up: $400.1K

-.1 - Package scintillator

M&S $57850
Labor: Physicist @ 100%
Technician @ 400%
Duration: 25 weeks
Base costs: $257.9K
Contingency:
Notes:
From the MINERvA build, production planes required:
Total M&S: $260,965
Labor: $903,736
Per plane costs then translate to $1285 M&S, $4452 labor (combined total of $5737). So, we scale the numbers by .9 to get $1157 M&S and $4007 labor per plane. Assume a build of 50 planes. We have a total cost then of $57850 M&S, $200,350 labor. Assume a 25 week build (80 hours/plane at 4 technicians).

-.2 - Assemble production modules

M&S $50,000
Labor: Physicist @ 40%
Technician @ 200%
Duration: 15 weeks
Base costs: $110K
Contingency:
Notes: Estimated by R. Bradford based on experience from MINERvA build. MINERvA prototype build required comparable M&S, labor. Based on build rate of 3.5 modules/week.

-.3 - Map TB modules

M&S	$7200
Labor	Physicist @ 25%
	Technician @ 100%
Duration:	12.5 weeks
Base costs:	$32.2K

Notes: Estimated by R. Bradford, based on expeience with MINERvA scanner. Each module required about 10 hours of technician time (overhead crane usage, setup, etc).

Resources:

Physicist:	non-costed
Technician:	$50/hour
Mechanical Engineer:	$80/hr
PPD-EE:	$111/hr

WBS 1.3.4.2.1.5: Photosensors

Total base costs roll-up: $2,939.2K

I. WBS 1.3.4.2.1.5.1 - R&D
Base costs roll-up: $113.7K

Goals: R&D program has to include selection of exact make/model of photosensor. This will entail acquisition of samples from various vendors, establishment of testing procedures, and evaluation of the sensors. Upon this experience, one photosensor will be selected for the entire detector.

R&D will also include design and testing of prototype sensor mounts. There are two types which will have to be fabricated. The most common will be used to retrofit portions of the detector which are re-used from MINERvA. All optical components in MINERvA terminated in an optical connector. These connectors were light-tight and provided a mechanical connection for fiber optic cables, which were used to conduct the scintillation light to the Hamamatsu PMT's used for readout. The optics of this system is fairly well understood. The mounting here is more of a replacement of the old PMT boxes - a similar assembly containing an optical connector, photosensors, and associated eletronics. In the new downstream muon spectrometer, the optics are different, as the SiPM will mount directly to the end of each scintillator extrusion. These second mounts will hold the photosensors mechanically and light-tighten the sensors and scintillator. Electronics will be mounted remotely. The mounts will have to be designed mechanically and tested optically.

-.1 - Procure supplies for SiPM evaluation.

M&S $35K
Labor: Physicist @ 20%
Duration: 6 weeks
Contingency: $10K for M&S, 3 weeks on duration.
Base costs: $35K
Notes: Task includes procurement of evaluation SiPM's, some electronics and test equipment. Hamamatsu's web page quotes a single piece price of $128 per SiPM. (http://sales.hamamatsu.com/en/products/solid-state-division/si-photodiode-series/mppc/part-s10362-11-050u.php). Assume we procure 40 SiPMs from various vendors at the Hamamatsu price - $5120. Electronics and test equipment will be $30K based on discussion with PPD electrical engineer. This equipment will become the basis of the SiPM test stand.

-.2 - Test/evaluate SiPM samples

M&S $3K
Labor: Physicist @ 50%
Undergraduate student @ 75%
Duration: 8 weeks
Base costs: $7.1K
Contingency: $1K for M&S, 3 weeks on duration.
Notes: Costing here is modeled after testing for the MINERvA detector.

-.3 - Milestone: Choose SiPM sensor
Notes: This has to be done early as many downstream tasks will be designed around the specific photosensor.

-.4 - Design prototype SiPM mounts

M&S 0
Labor: Mechanical Engineer @ 50%
Duration: 12 weeks
Contingency: 8 weeks
Base costs: $20K

Notes: This design task will produce engineer's drawings of the mechanical components needed to mount the SiPM photosensors and associated electronics. Task duration is long to provide iteration on design based on fabrication and evaluation of prototypes (next 2 tasks). Task should start 2 weeks before -.5 and 4 weeks before -.6. Costing based on duration of similar tasks for MINERvA.

-.5 - Fabricate prototype mounts

M&S	$5K
Labor	Machinist @ 50%
Duration:	12 weeks
Base costs:	$20K
Contingency:	3K M&S, 8 weeks duration.

-.6 - Evaluate prototype mounts

M&S:	$3K
Labor:	Physicist @ 25%
	Undergraduate student @ 50%
Duration:	12 weeks
Contingency:	$1K M&S, 8 weeks duration.
Base costs:	$6.8K

Notes: This is for in-house testing and evaluation of both types of SiPM mounts. This will include re-instrumentation of the MINERvA benchtop scintillator array ("VST").

-.7 - Test prototype mounts with scintillator packaging factory (WBS

M&S:	$5K
Labor:	Physicist @ 75%
Duration:	2 weeks
Contingency:	$2K M&S, 1 week on duration.
Base costs:	$5K

Notes: There needs to be a link here to WBS 1.3.4.2.1.4.1.4, which is R&D of scintillator dressing. We'll provide prototype mounts to the scintillator packaging factory, and receive feedback which will be used in the design process. This task should be coincident with the previous task (linked start-to-start). The M&S here is for travel to the scintillator packaging site.

-.8 - Test prototype mounts on MINERvA detector

M&S	$5K
Labor:	Technician @ 100%
Duration:	4 weeks
Contingency:	$3K M&S, 1 week on duration.
Base costs:	$13K

Notes: Includes removal of old PMTs and associated hardware from 4 MINERvA modules and installation of SiPM photosensors. Will require use of scaffolding to access the face of modules behind the MINERvA veto wall. I contacted a vendor (Sunbelt Rentals) and got rough estimates for scaffolding (~$1K for a month). The remaining M&S is for hardware and any small machining jobs required to mount the new sensors. This task will need to be linked to changes in the MINERvA DAQ.

-.9 - Manufacture and ship R&D SiPM mounts to scintillator packaging facility.

M&S:	$2K
Labor:	Machinist @ 50%
Duration:	1 month
Contingency:	$1K M&S, 1 week on duration
Base costs:	$6.8K

Notes: Task will provide final SiPM mounts to the scintillator packaging facility for their own R&D purposes. Costs here are scaled from production of early MINERvA PMT boxes.

II. WBS 1.3.4.2.1.5.2 - Test Beam Photosensors

Base costs roll-up: $391.5K

-.1 - Procure photosensors for TB detector

M&S: $250K
Labor: Physicist @ 5%
Duration: 8 weeks
Contingency: $125K M&S, 4 weeks on duration
Base costs: $250K
Notes: This will require the acquisition of 5K SiPMs for the test beam detector. In the scintillator section, I specified that the test beam detector would have 3K channels. To be conservative here, we'll plan an order of 5K SiPMs.

I would prefer to negotiate the contract for the entire purchase at this point. To retrofit the old sections of the MINERvA detector, supply the test beam detector and build the new muon spectrometer, we will need approximately 47K SiPM's. After discussions with a Hamamatsu sales rep, I've assumed a cost of $50/channel for an order of a few thousand SiPMs.

Contingency is ~50% as we're dependent on fluctuations in the exchange rate.

-.2 - QC Test Beam SiPMs

M&S: $500
Labor: Technician @ 100%
Duration: 5 weeks
Contingency: $300 M&S, 50% on duration
Base costs: $10.5K
Notes: Assumes a testing rate of 25 SiPM/hour for 5K TB SiPMs.

-.3 - Produce Mounts for Test Beam Detector

M&S: $75K
Labor: Technician @ 200%
Duration: 13 weeks
Contingency: $40K M&S, 5 weeks on duration
Base costs: $127K
Notes: Scaled from MINERvA prototype PMT box costs, which were $22/chanel. I rounded up to $25/channel (inflation). The M&S vs. labor breakdown is an assumption of $15 machining/channel and $10 labor/channel. The basic idea is that the mounts will require a large number of machined parts, and some technician labor to complete the final assembly.

-.4 - Ship Test Beam materials

M&S: $3K
Labor Technician @ 25%
Duration: 2 weeks
Contingency: $1K M&S, 1 week on duration.
Base costs: $4K
Notes: In general, I assume $1-1.5K for a freight shipment. This includes a crate in addition to the actual shipment costs. I have no idea what the shipment size and weight of 5K photodiodes + mounts will be, so I've padded the costs here in case we need to make two shipments.

III. WBS 1.3.4.2.1.5.3 - Full Detector Photosensors
Base costs roll-up: $2,434K

-.1 - Procure photosensors for full detector

M&S: $840K
Labor: Physicist @ 5%
Duration: 8 weeks
Contingency: $420K M&S

Base costs: $840K

Notes: This will require the acquisition of 42K SiPMs for the final detector. Price here comes from rough costing numbers from Hamamatsu. After speaking with the local sales rep (Dan Lowe, 847-825-6046), I was told we could achieve costs of $16-17 per SiPM for an order of 42K. I've rounded this up to $20/channel. The contingency is high as we're dependent on the exchange rate, and costs may escalate over the next 5 years.

-.2 - QC SiPMs

M&S: $4,200
Labor: Technician @ 100%
Duration: 42 weeks
Contingency: $2100 M&S, 50% on duration
Base costs: $88.2K

Notes: Assumes a testing rate of 25 SiPM/hour for 42K SiPMs. Costing here assumes a technician, but this job is probably best done by the Fermilab chip testing robot.

-.3 - Produce Mounts for Full Detector

M&S: $1,050,000
Labor: Technician @ 300%
Duration: 70 weeks
Contingency: $560,000 M&S, 27 weeks on duration.
Base costs: $1,470K

Notes: Based on the same costing as the test beam detector mounts. We assume a cost of $25/channel (scaled from production of prototype MINERvA PMT boxes). The M&S vs. labor breakdown is an assumption of $15 machining/channel and $10 labor/channel. The basic idea is that the mounts will require a large number of machined parts, and some technician labor to complete the final assembly.

-.4 - Ship full detector photosensors

M&S: $27K
Labor Technician @ 25%
Duration: 18 weeks
Contingency: $12K M&S, 6 weeks on duration.
Base costs: $36K

Notes: I've scaled costs here from shipment of the TB diodes shipping task. This task will need a predecessor link to the production scintillator packaging task.

Resources:
Machinist: $60/hour (Rochester shop rate)
Technician: $50/hour
Undergraduate: $16/hour

WBS 1.3.4.2.1.6: Electronics and DAQ

Base cost total: $2387.5K

I. WBS 1.3.4.2.1.6.1 - R&D
Base cost roll-up: $568.8K

Goals: The electronics are another leading R&D initiative. Prototype electronics need to be produced and delivered early as a predecessor to many downstream tasks.

Notes: Costs here developed after review of MINERvA as-realized costs for prototype electronics, with input from Bob Demaat (PPD EE Department Chair) and Paul Rubinov (who designed the MINERvA electronics).

-.1 - Spec. electronics for detector

Labor:	PPD_EE @ 20%
Duration:	8 weeks
Contingency:	4 weeks
Base costs:	$7.1K

Notes: In this task, the design engineer develops a spec. for the new electronics. Considerations include an evaluation of the current MINERvA electronics, photosensor, and input from the collaboration. Task will produce a conceptual design for the entire electronics system for the detector (including front-end and high level electronics).

-.2 - Design prototype electronics

Labor:	PPD_EE @ 100%
	PPD_ET @ 100%
Duration:	40 weeks
Contingency:	8 weeks on duration.
Base costs:	$284.8K

Notes: Costs are scaled from the MINERvA prototype electronics design, with updated labor rates.

-.3 - Procure prototype electronics

M&S	$75K
Labor:	PPD_EE @ 5%
Duration:	22 weeks
Contingency:	$20K M&S
Base costs:	$79.9K

Notes: Costs scaled from MINERvA prototype electronics procurement.

-.4 - Test/QC prototype electronics

M&S	$10K
Labor	PPD_EE @ 100%
	PPD_ET @ 50%
	Physicist @ 50%
	Student @ 75%
Duration:	22 weeks
Contingency:	$5K M&S, 6 weeks on duration.
Base costs:	$137K

Notes: Includes development of test stand, actual testing of prototype electronics, and associated integration work. Costs scaled from development of MINERvA electronics test stand, testing costs, and integration costs.

-.5 - Support development of experimental test stands

Labor	PPD_EE @ 100%

PPD_ET @ 100%
Duration: 8 weeks
Contingency: 2 weeks on duration.
Base costs: $60K
Notes: Covers support required to implement prototype electronics in early test s stands. This includes modifications to the MINERvA source mapper, and the SiPM test stand, instrumentation of the MINERvA test bench array (VST), and troubleshooting of the re-instrumented MINERvA module set. Costs scaled from MINERvA test stand support.

-.6 - Modify MINERvA DAQ for SiPM electronics
Labor: Physicist @ 100%
Duration: 24 weeks
Contingency: 24 weeks
Base costs: $0
Notes: One of the major R&D tasks is re-instrumentation of 4 MINERvA modules using SiPM's and prototype electronics. These modules will be integrated into the MINERvA readout and used for data-taking. This task supports modifications to the MINERvA DAQ software to permit readout of the new electronics, and assimilation into the standard data stream. Duration here is from conversation with developer of MINERvA DAQ software.

II. WBS 1.3.4.2.1.6.2 - Test Beam Detector Electronics
Base costs roll-up: $437.8K

Goals: These tasks will produce electronics for the TB detector. This is 6K channels of electronics.

-.1 - Final electronics design work
Labor: PPD_EE @ 100%
PPD_ET @ 50%
Duration: 13 weeks
Contingency: 3 weeks on duration.
Base costs: $75.1K
Notes: Task allows for final iteration on design of electronics before first large production run for the TB detector. Costs are scaled from final design work on MINERvA electronics, with updated labor rates.

-.2 - Procure TB electronics
M&S $240K
Labor: PPD_EE @ 5%
Duration: 22 weeks
Contingency: $50K M&S
Base costs: $245K
Notes: Costs scaled from MINERvA Tracking Prototype electronics procurement. Includes front-end and higher level electronics, LV distribution system. The Tracking Prototype was a prototype detector incorporating a similar number of channels. Actual costs scaled up 20% to account for inflation.

-.3 - Test/QC TB electronics
M&S $3K
Labor: Physicist @ 20%
Student @ 500%
Duration: 6 weeks
Contingency: $1K M&S, 2 weeks on duration.
Base costs: $22.2K
Notes: Costs scaled from testing of MINERvA electronics testing.

-.4 - Procure TB DAQ system
M&S: $50K

Labor: Physicist @ 5%
Duration: 12 weeks
Contingency: $13K M&S, 3 weeks on duration.
Base costs: $50K
Notes: Includes procurement of computers, slow controls, rack protection system, UPS, etc. Costs scaled from MINERvA Tracking Prototype DAQ costs.

-.5 - Design TB Installation
M&S $10K
Labor: PPD_EE @ 100%
Duration: 8 weeks
Contingency: $2K M&S, 2 weeks on duration
Base costs: $45.5K
Notes: Task covers design of electronics installation for TB. This includes layout of electronics racks, cable routing (spec. on cable lengths, layout, etc), design and production of cable labels, and production of graphics documenting the layout. M&S costs cover cable ties, label media, and procurement of cables for various systems.

-.6 - TB electronics/DAQ integration support
M&S $5K
Labor: PPD_EE @ 100%
Physicist @ 50%
Duration: 4 weeks
Contingency: 2 weeks on duration
Base costs: $22.7K
Notes: Task covers support of electronics and DAQ system during commissioning of the TB detector.

III. WBS 1.3.4.2.1.6.3 - Full detector electronics
Base cost roll-up: $1380.9K

Goals: These tasks will produce electronics for the full detector (total 41K channels of electronics).

-.1 - Final electronics design work
M&S: $3K
Labor: PPD_EE @ 100%
Duration: 7 weeks
Contingency: $1K M&S, 3 weeks on duration.
Base costs: $34K
Notes: The electronics should be in near final state by now. This task is simply some engineering to resolve any issues exposed during the Test Beam detector run.

-.2 - Procure electronics
M&S $977K
Labor: PPD_EE @ 5%
Duration: 22 weeks
Contingency: $200K M&S
Base costs: $982K
Notes: Costs scaled from MINERvA production electronics procurement. Includes front-end and higher level electronics, LV distribution system. Final numbers developed by scaling MINERvA as-built costs by 1.2% for inflation, and then 1.32 for the number of channels in the upgraded detector.

-.2 - Test/QC electronics
M&S $2K
Labor: Physicist @ 60%
Student @ 100%

Duration: 30 weeks
Contingency: $1K M&S, 10 weeks on duration.
Base costs: $21.2K
Notes: Costs scaled from testing of MINERvA electronics testing.

-.3 - Procure DAQ system
M&S: $138K
Labor: Physicist @ 5%
Duration: 12 weeks
Contingency: $35K
Base costs: $138K
Notes: Includes procurement of computers, slow controls, rack protection system, UPS, etc. Costs scaled from MINERvA Tracking Prototype DAQ costs.

-.4 - Design Electronics Installation
M&S $10K
Labor: PPD_EE @ 75%
Duration: 52 weeks
Contingency: $2K M&S, 17 weeks on duration
Base costs: $183K
Notes: Task covers design of electronics installation for full detector. This includes layout of electronics racks, cable routing (spec. on cable lengths, layout, etc), design and production of cable labels, and production of graphics documenting the layout. M&S costs cover cable ties, label media, and procurement of cables for various systems. Duration based on similar service rendered during year-long MINERvA installation.

-.6 - Electronics/DAQ integration support
M&S $5K
Labor: PPD_EE @ 100%
Physicist @ 50%
Duration: 4 weeks
Contingency: 2 weeks on duration
Base costs: $22.7K
Notes: Duration based on experience with MINERvA detector.

Resources:

PPD_EE	$111/hr
PPD_ET	$67/hr
Electrical Technician	$35/hour
Student (undergraduate)	$16/hour

WBS 1.3.4.2.1.7: Installation and Instrumentation

Base cost total: $962.2K

I. WBS 1.3.4.2.1.7.1 - R&D

Base cost roll-up: $204.3K

Goals: Installation and instrumentation is the last step in the detector construction, so this WBS element should naturally lag behind the other elements in the schedule. This element is tied more critically to the physical facilities, so part of the R&D is to monitor the facilities and ensure that they are appropriate for our needs. This group will also have responsibility for all large prototyping efforts and will handle related integration issues.

Notes: Costs generally extrapolated from MINERvA construction. Durations for tasks involving mechanical engineer estimated by R. Flight, UofRochester mechanical engineer.

-.1 - Spec. physical facilities requirements

Labor: Physicist @ 25%
Mechanical Engineer @ 15%
Duration: 24 weeks
Contingency: 8 weeks on duration
Base costs: $11.5K

Notes: This task provides engineering support for installation related outfitting of physical facilities. While we already have groups monitoring the civil construction interface and providing heavy facilities (detector stands, etc), this task is specific to outfitting for installation. Where appropriate, the engineer and physicist provide input to the groups responsible for these other tasks. Concerns falling outside the scope of the other efforts can be designed explicitly here. Duration developed from discussion with R. Flight.

-.2 - Spec integration of various system components, monitor prototype construction

M&S: $8K
Labor: Physicist @ 100%
Mechanical Engineer @ 100%
Duration: 8 weeks
Contingency: $2K M&S, 2 week on duration
Base Cost: $33.6K

Notes: This task is intended to facilitate early integration work. Ideally, the task provides the installation coordinator (physicist) a chance to talk with component suppliers, familiarize himself with deliverables, and discuss integration and installation issues. The mechanical engineer will provide drawings to help address integration issues. M&S is for travel to production sites as needed. This is an important planning step in the installation planning. The outcome of these discussion will include things like determination of what small hardware will be required for installation of various systems, and who will provide the pieces. Based on similar tasks performed for MINERvA construction.

-.3 - Design preliminary installation procedure

M&S: $15K
Labor: Physicist @ 50%
Technician @ 50%
Mechanical engineer @ 25%
Duration: 16 weeks
Contingency: 4 weeks on duration
Base costs: $43.8K

Notes: Bit of a hybrid task, this task will allow the responsible physicist, lead technician, and a mechanical engineer to think through the details of the installation procedure. Ideally, the group brainstorms through a preliminary procedure, based on the MINERvA procedure, and makes modifications to accommodate the new detector hall, etc. The available M&S allows for unclear points, such as cable routing in the new muon spectrometer, to be mocked up with a scale model. Engineering will produce a

preliminary hall layout and conceptual designs for fixtures or required hardware (racks used to mount front-end electronics, etc). Other details of the assembly procedure (cable lengths, routing designs) will be fleshed out in a hands-on way.

Costs scaled from a similar study conducted on MINERvA.

-.4 - Design required installation hardware, fixturing.

Labor: Mechanical engineer @ 100%
Duration: 12 weeks
Contingency: 3 weeks on duration
Base costs: $38.4K

Notes: This is simply a final round of engineering to finalize design of prototype hardware based on outcomes of task -.2. Costs based on similar task from MINERvA.

-.5 - Procure prototype installation hardware

M&S: $50K
Labor: Physicist @ 5%
Duration: 8 weeks
Contingency: 2 weeks on duration
Base costs: $50K

Notes: This task covers fabrication and procurement of prototype installation hardware designed in the previous task. The hardware will be used to outfit the re-instrumented MINERvA modules, and will also be used to instrument the first 4 muon spectrometer modules (tasks -.6 and -.7)

-.6 - Re-instrument MINERvA modules with new readout

M&S: $1.5K
Labor: Physicist @ 50%
Technician @ 300%
Duration: 2 weeks
Contingency: 1 week on duration.
Base costs: $13.5K

Notes: Will re-instrument 4 modules of the actual MINERvA detector in the Numi near detector hall. Duration is based on as-realized rates from the MINERvA installation.

-.7 - Surface instrumentation of first 4 muon spectrometer modules

M&S: $1.5K
Labor: Physicist @ 50%
Technician @ 300%
Duration: 2 weeks
Contingency: 1 week on duration.
Base costs: $13.5K

Notes: Will instrument 4 modules from the new muon spectrometer on the surface. Duration is based on as-realized rates from the early MINERvA instrumentation effort.

II. WBS 1.3.4.3.2.7.2 - Test Beam Detector Installation
Base costs roll-up: $129K

-.1 - Specify requirements for TB enclosure

Labor: Physicist @ 25%
PPD_EE @ 10%
Duration: 2 weeks
Contingency: 3 days on duration.
Base costs: $0.9K

Notes: This task is the beginning of the test beam detector installation effort. Task involves becoming familiar with the test beam enclosure, mapping the locations of key services (quiet power), and identifying constraints on the detector installation. Some requests may be made of the facility.

-.2 - Design TB installation procedure

M&S: $15K
Labor: Physicist @ 50%
Technician @ 50%
Mechanical engineer @ 25%
Duration: 16 weeks
Contingency: 4 weeks
Base costs: $43.8K

Notes: While the installation procedure should be established from the R&D effort, there may be some modifications for the TB effort. Task is to review installation plans, noting any changes needed. Engineering time is for design of any special fixtures or hardware.

-.3 - Procure TB installation hardware

M&S: $12.2K
Labor: Mechanical engineer @ 5%
Duration: 12 weeks
Contingency: 3 weeks on duration
Base costs: $15K

Notes: Costs here scaled from similar MINERvA task (hardware procurement for prototype detector).

-.4 - Receive TB hardware from production sites

Labor: Technician @ 15%
Duration: 12 weeks
Contingency: 4 weeks
Base costs: $3.6K

Notes: Technician coordinates receipt and storage of material. Unpacks deliverables, and inspects for shipping damage. Labor requirements estimated from discussion with technician performing similar job on MINERvA.

-.5 - Install TB modules

Labor: PPD_MT @ 120%
PPD_MT_Supervisor @ 40%
Duration: 7 weeks
Contingency: 2 week
Base costs: $32.8K

Notes: Assumes installation of 2 modules/day. Labor requirements taken from MINERvA installation effort. Module installation requires a crew of 3 technicians, and a supervisor, but they are not working every day. After 4 modules are installed, there is a 3 day brake for instrumentation. Durations based on as-realized rates for the MINERvA Tracking Prototype installation.

-.6 - Install TB instrumentation

M&S $4K
Labor: Technician @ 180%
Duration: 7 weeks
Contingency: 2 weeks
Base costs: $29.2K

Notes: Assumes instrumentation rate of 3 days for every 4 modules. In practice, requires a crew of 3, but there are periodic days where no instrumentation takes place as modules are hung. Durations based as-realized rates for the MINERvA installation. Should be linked to start 2 days after previous task.

-.7 - Checkout TB modules

Labor: Technician @ 25%
Physicist @ 75%
Duration: 7 weeks

Contingency: 2 weeks
Base costs: $3.5K
Notes: Commissioning MINERvA required substantial input from physicists. Some technician time was used to repair light leaks Should be linked to start 1 week after task -.5.

III. WBS 1.3.4.3.7.3 - Final Detector Installation
Base costs roll-up: $628.9K

-.1 - Specify final hall outfitting
Labor: Physicist @ 25%
Mechanical Engineer @ 15%
Duration: 24 weeks
Contingency: 8 weeks on duration
Base costs: $11.5K
Notes: This task picks up where task 1.3.4.2.1.7.1.1 left off. The earlier task was an initial attempt to spec. our needs for the detector hall before construction. After installation prototyping, and the TB effort, we should have a better handle on the outfitting needs.

-.2 - Design final installation procedure
Labor: Physicist @ 25%
Mechanical engineer @ 100%
Duration: 4 weeks
Contingency: 1 week
Base costs: $12.8K
Note: Task provides engineer final opportunity to modify installation fixtures and hardware. Costs extrapolated from similar MINERvA task, and duration specified by UofR mechanical engineer.

-.3 - Procure final installation hardware and fixturing
M&S: $40K
Labor: Mechanical engineer @ 5%
Duration: 12 weeks
Contingency: 3 weeks on duration
Base costs: $42K
Notes: Costs here scaled from similar MINERvA task. Costs were inflated by a factor of 1.2, and then scaled by number of channels in the larger detector, and then rounded up to $40K to account for any new items needing to be designed.

-.4 - Receive detector components from production sites
Labor: Technician @ 15%
Duration: 12 weeks
Contingency: 4 weeks
Base costs: $3.6K
Notes: Technician coordinates receipt and storage of material. Unpacks deliverables, and inspects for shipping damage. Labor requirements estimated from discussion with technician performed similar job on MINERvA.

-.5 - Install electronics racks
Labor: PPD_MT @ 200%
Duration: 1 week
Contingency: 2 days
Base costs: $5.6K
Notes: MINERvA currently has 5 electronics racks. We assume that the upgraded detector has 8. Installation of a rack typically requires a crew of 2 to crane the rack down the shaft and mount it in the detector hall. Let's assume they can install 2 racks/day (consistent with module installation rate). I'll round

up to a week. Note that this task simply covers the rigging crew for rack installation. Any special needs (power feeds, rack layout and construction) come from other WBS elements.

-.6 - Remove instrumentation from MINERvA

M&S	7K
Labor:	Technician @ 130%
Duration:	20 weeks
Contingency:	5 weeks
Base costs:	$59K

Notes: Labor requirements based on experience with MINERvA. It took ~1.5 days for a team of 3 technicians to un-instrument a module set. This includes removing all PMTs, clear fiber cables, LI fiber, and the PMT racks. Cables were checked for damage. Everything is organized and packed for the move. The labor profile here is actually a team of 3 technicians. They work 1.5 days to un-instrument modules, and then there is a break of 2 days while 4 modules are moved.

-.7 - Remove MINERvA modules and stage in surface building

Labor:	PPD_MT @ 175%
	PPD_MT_Supervisor @ 60%
Duration:	20 weeks
Contingency:	5 weeks
Base costs:	$138K

Notes: Labor requirements based on MINERvA module installation. The operation typically required a team of 3 technicians. Modules were transferred at a rate of 2 per day. This task and -.6 are coupled - a set of 4 modules requires 3.5 days of labor - 2 days to transfer and 1.5 days to un-instrument. For both tasks, the technician crews do not work every day.

-.8 - Move muon spectrometer modules from assembly hall to ND hall

Labor:	PPD_MT @ 120%
	PPD_MT_Supervisor @ 40%
Duration:	12 weeks
Contingency:	3 weeks
Base costs:	$56.3K

Notes: Labor requirements based on experience with MINERvA. Modules are always transferred at a rate of 2/day. This schedule assumes that the instrumentation work does not proceed on days that modules are transferred. It requires 1 week to transfer and instrument a set of 4 modules (2 days to move modules, and 3 days to instrument). So, the labor here is a crew of 4 technicians for days on which modules are moved. Based on as-realized installation rates for the MINERvA detector.

-.9 - Instrument muon spectrometer modules

M&S	$5K
Labor:	Technician @ 180%
Duration:	12 weeks
Contingency:	3 weeks
Base costs:	$48.2K

Notes: It requires a team of 3 technicians 3 days to instrument a set of 4 modules, so we have a team of three technicians instrumenting modules 60% of the time. Based on as-realized instrumentation rates for the MINERvA detector.

-.10 - Move MINERvA modules from surface building to ND hall

Labor:	PPD_MT @ 120%
	PPD_MT_Supervisor @ 40%
Duration:	29 weeks
Contingency:	7 weeks
Base costs:	$136K

Notes: Assumes a transfer rate of 2 modules/day. Labor scaled from module installation needs during actual MINERvA installation.

-.11 - Instrument MINERvA modules

M&S	$10K
Labor:	Technician @ 180%
Duration:	29 weeks
Contingency:	7 weeks
Base costs:	$114.4K

Notes: Assumes an instrumentation rate of 3 days per set of 4 modules. Labor scaled form module instrumentation needs during actual MINERvA installation.

-.12 - Turn on, check-out modules after instrumentation

Labor:	Physicist @ 75%
	Technician @ 25%
Duration:	29 weeks
Contingency:	7 weeks
Base costs:	$14.5K

Notes: Physicist support is required to turn on and check-out modules. Team of 2 required for underground work. Team will troubleshoot electronics, take pedestal data, and analyze for light leaks.

-.13 - Milestone: CD4 deliverables complete

Resources:

Mechanical engineer	$80/hr
Technician	$50/hr
PPD_MT	$70
PPD_MT _Supervisor	$83

Costing notes:

In general, production site - 4 weeks of ME for outfitting. Includes both fixture/deliverable design and input on production.

WBS 1.3.4.2.1.8: Safety

Base cost total: $895.5K

I. WBS 1.3.4.2.1.8.1 - R&D
Base cost roll-up: $399.6K

Goals: So, the safety coordinator has to be involved at the design phase Out of eight L4 WBS elements in this schedule, six groups will provide hardware or services for the near detector effort, requiring safety oversight (The remaining two are management and safety themselves). At the R&D phase, the safety coordinator's basic duty will be to establish working relationships with the other WBS elements. The safety coordinator will be required to familiarize him- or her-self with the design of hardware deliverables and procedures, assisting the responsible L4 managers to identify and plan for safety risks within their system. The coordinator will help ensure designs are appropriate for underground installation, and help coordinate reviews with appropriate on-site experts (burn tests; engineering reviews for pressure vessels, lifting fixtures, etc). The coordinator will implement a policy of periodic reviews with L4 managers, authoring HA's and ITNA's for on-site R&D tasks. The coordinator takes ownership of ITNA's for all ND-related personnel for the duration of the experiment, and uses discussions with the L4's to ensure ITNA's are appropriate for current duties. Finally, the coordinator authors safety-related documents required by the DOE review process.

Notes: The R&D phase for the near detector effort stretches through 2014. I imagine that the safety coordinator's effort will be heavier at first as he/she tries to become familiar with the project. I'm guessing this is 1 FTE time for the R&D phase, and then 3/4 time for the duration of the project, through 2018. Check resource graph to ensure safety-coordinator allocation is appropriate for the time period.

This little costing exercise has taken a lot of work at Fermilab; it's something different than the lab's usual safety SOP's. I've spoken with Nancy Grossman, Jim Strait, and Eric McHugh about the concepts and costing. The overall strategy here is to support .75-1 FTE of a safety coordinator for the duration of the project, after discussion with Eric McHugh. I've costed 1.0 FTE for the R&D phase which runs from mid 2011-the end of 2013. The project then supports .75 FTE through late 2017.

-.1 - Initial hazard analysis for R&D phase
Labor: ESH_coordinator @ 25%
Duration: 12 weeks
Contingency: 3 weeks
Base costs: $8.1K
Notes: The ESH coordinator meets initially with each L4, helping identify hazards associated with easy system. Hazards may stem from the hardware deliverables themselves, or from the planned construction activities.

-.2 - L4 orientation on FNAL safety policies and experiment-specific procedures.
Labor: ESH_coordinator @ 50%
Duration: 6 weeks
Contingency: 2 weeks
Base costs: $8.1K
Notes: After the initial survey, the ESH coordinator plans a training for the L4's covering basic Fermilab, DOE and experiment-specific safety practices. The training is a general orientation so the L4's understand the expectations of the laboratory (identifying hazards, lab training requirements, ITNA's, implementing safety measure in a production site). The training also gives the coordinator the chance to implement any experiment-specific practices (reporting accidents occurring at other institutions, what safety-related documents need to be provided before material can be moved to FNAL, lab engineering and safety reviews, etc).

-.3 - Support DOE review process
Labor: ESH_coordinator @ 100%
Duration: 75 weeks

Contingency: 8 weeks
Base costs: $202.2K
Notes: Authors safety documentation required by the DOE review process. This includes writing the TDR safety chapter. Time to prepare for reviews, as necessary.

-.4 - Update R&D-related ITNA's for on-site personnel
Labor: ESH_coordinator @ 25%
Duration: 5 weeks
Contingency: 2 weeks
Base costs: $3.4K
Notes: Safety coordinator contacts on-site personnel to enquire about job duties. ITNA's will then be updated to ensure proper training is required. This will be a periodic duty of the safety coordinator. ITNA's will be updated when job responsibilities change, as indicated by the responsible L4. Safety coordinator will interview all experiment-related personnel recently applying for a Fermilab ID to discuss training needs.

-.5 - Approval for on-site R&D work
Labor: ESH_coordinator @ 100%
Duration: 20 weeks
Contingency: 4 weeks
Base costs: $53.9K
Notes: Prior to work commencing on-site, the safety coordinator will ensure that all safety requirements are in place. Hazards are to have been identified in step -.1, and this step supports the commencement of on-site work. The safety coordinator will ensure that all training requirements are met, that all mitigation measures are in place (PPE, etc). The safety coordinator will also ensure that all administrative measures are implemented - HA's, MSDS sheets are provided, etc.

-.6 - ES&H support for on-site work
Labor: ESH_coordinator @ 100%
Duration: 35 weeks
Contingency: 4 weeks
Base costs: $94.4KK

-.7 - Coordinate ORC, engineering reviews for R&D hardware
M&S $10K
Labor: ESH_coordinator @ 25%
PPD_EE @ 30%
PPD_Mechanical Engineer @ 30%
PPD_Electronics technician @ 30%
PPD_MT @ 30%
Duration: 4 weeks
Contingency: 2 weeks
Base costs: $29.5K
Notes: As hardware is completed, the safety coordinator will organize appropriate engineering and ORC reviews. The main R&D initiatives requiring ORC reviews will be the bench-top scintillator array, and the re-instrumented set of 4 MINERvA modules. As this is a more technical task, I have scheduled 6 days of engineering support for each review (3 days each for mechanical and electrical). To resolve any issues mentioned by the review committees, I have also scheduled 6 days of technician time for each review. The engineering support was estimated after discussions with Linda Bagby, who coordinated ORC reviews for MINERvA electronics.

II. WBS 1.3.4.2.1.8.2 - Test Beam Detector
Base costs roll-up: $195.4K

-.1 - Initial hazard analysis for TB phase

Labor: ESH_coordinator @ 25%
Duration: 12 weeks
Contingency: 3 weeks
Base costs: $8.1K
Notes: The ESH coordinator meets initially with each L4, helping identify hazards associated with easy system. Hazards may stem from the hardware deliverables themselves, or from the planned construction activities.

-.2 - Approval for on-site TB work
Labor: ESH_coordinator @ 75%
Duration: 20 weeks
Contingency: 4 weeks
Base costs: $40.5K
Notes: Prior to work commencing on-site, the safety coordinator will ensure that all safety requirements are in place. Hazards are to have been identified in step -.1, and this step supports the commencement of on-site work. The safety coordinator will ensure that all training requirements are met, that all mitigation measures are in place (PPE, etc). The safety coordinator will also ensure that all administrative measures are implemented - HA's, MSDS sheets are provided, etc.

-.3 - Safety oversight for on-site TB work
Labor: ESH_coordinator @ 75%
Duration: 58 weeks
Contingency: 15 weeks
Base costs: $117.3K
Notes:

-.4 - Coordinate ORC, engineering reviews for TB Detector hardware
Labor: ESH_coordinator @ 25%
PPD_EE @ 30%
PPD_Mechanical Engineer @ 30%
PPD_Electronics technician @ 30%
PPD_MT @ 30%
Duration: 4 weeks
Contingency: 2 weeks
Base costs: $29.5K
Notes: As hardware is completed, the safety coordinator will organize appropriate engineering and ORC reviews. The TB detector itself will undergo and ORC review at this point.. As this is a more technical task, I have scheduled 6 days of engineering support for each review (3 days each for mechanical and electrical). To resolve any issues mentioned by the review committees, I have also scheduled 6 days of technician time for each review. The engineering support was estimated after discussions with Linda Bagby, who coordinated ORC reviews for MINERvA electronics.

III. WBS 1.3.4.2.1.8.3 - Full Detector Production
Base costs roll-up: $300.5K

-.1 - Initial hazard analysis for full detector phase
Labor: ESH_coordinator @ 25%
Duration: 12 weeks
Contingency: 3 weeks
Base costs: $8.1K
Notes: The ESH coordinator meets initially with each L4, helping identify hazards associated with easy system. Hazards may stem from the hardware deliverables themselves, or from the planned construction activities.

-.2 - Approval for on-site construction work
Labor: ESH_coordinator @ 75%

Duration: 20 weeks
Contingency: 4 weeks
Base costs: $40.5K

Notes: Prior to work commencing on-site, the safety coordinator will ensure that all safety requirements are in place. Hazards are to have been identified in step -.1, and this step supports the commencement of on-site work. The safety coordinator will ensure that all training requirements are met, that all mitigation measures are in place (PPE, etc). The safety coordinator will also ensure that all administrative measures are implemented - HA's, MSDS sheets are provided, etc.

-.3 - Safety oversight for on-site TB work

Labor: ESH_coordinator @ 75%
Duration: 110 weeks
Contingency:
Base costs: $222.4K
Notes:

-.4 - Coordinate ORC, engineering reviews for TB Detector hardware

M&S: $10K
Labor: ESH_coordinator @ 25%
PPD_EE @ 30%
PPD_Mechanical Engineer @ 30%
PPD_Electronics technician @ 30%
PPD_MT @ 30%
Duration: 4 weeks
Contingency: 2 weeks
Base costs: $29.5K

Notes: As hardware is completed, the safety coordinator will organize appropriate engineering and ORC reviews. As this is a more technical task, I have scheduled 6 days of engineering support for each review (3 days each for mechanical and electrical). To resolve any issues mentioned by the review committees, I have also scheduled 6 days of technician time for each review. The engineering support was estimated after discussions with Linda Bagby, who coordinated ORC reviews for MINERvA electronics.

Resources:

ESH_coordinator $67.4/hour