INTRODUCTION

The following is a summary of Work Packages required to evaluate the various new ideas proposed for optimizing costs for the NLC. The overall goal is to make a new model and cost estimate by the end of FYOO.

The Tables on Pages l-2 are a summary of major groupings: Tunnel Electronics, DC Magnet Power, Modulators and Global Systems. The latter includes Controls, Timing (and RF distribution), and Protection Systems. Each table includes reference numbers of items in the "NLC Brainstorming Database" in ACCESS. Each table also indicates goals, milestones and contacts or resources.

Pages 3 and ff. contain short descriptions and discussion of technical and cost issues of each area. The area of Tunnel Electronics is given emphasis because it is considered to be a lever toward significant cost reductions in other areas, including long haul cables, cable tray, racks and cooling. Similarly the DC Power systems are large cost drivers that have already been reduced considerably with magnet stringing models; further large reductions appear possible with a successful permanent magnet implementation in some areas, principally the Main Linacs. At the same time, the PM solution requires many more Movers of a different, perhaps costlier design than the Girder units.

The Work Packages next need to be assigned resources and implemented. Although some preliminary work has been done in resource loading schedules, some of these packages represent additional work that requires an adjustment of priorities as well as additional resources. The goal is to work these out with all concerned by early February.

NLC Electrical Systems Work Package Task Descriptions
R.S. Larsen 01/13/00

1. Tunnel Electronics	**Reference**	**Resp TSETs**	**Major Milestones**	**Resources**
Baseline R&D	46,99,100,101,112 -- 70,103,113,114,122 102,123	BPM LLRF Movers Vacuum	Proof of principle prototypes (end FY01)	Smith, Corredoura, Browne, Porter et al
Tunnel Radiation Modeling	120	Radiation Physics (RP) Tunnel Task Force (TTF)	Evaluate models for gamma neutron dose in linacs, Injection, BD Down-select COTS vs RH by 6/5/00	Rokni et al TTF (TSETS, RP, Conv.Fac. (CF))
Tunnel Structures		TTF	Down-select model by 6/5/00	TTF
Tunnel Electronics Packaging Architectures	120	TTF, RP, CF	Requirements & specs by 6/5/00	TSETS, TTF, FNAL?
Robotics Remote Servicing System	120	TTF, LLNL, Others TBD	Funct. Reqmts by 6/1/00 Cost est. by 9/1/00	TBD
Wireless Communications Systems	121	TTF, Others TBD	Specify requirements all areas by 7/1/00	TBD
CD 0.4 System costs		TTF & TSETS	Complete Preliminaries by 9/1/00	TBD

2. DC Magnet Power	**Reference**	**Resp TSETs**	**Major Milestones**	**Resources**
DC Magnet Power Systems	7,17,18,19,20,34,51	Magnet Systems	Complete ML, Inj & BD conventional models by 3/1/00 Finalize PM choices by 4/1/00 Complete revised cost models by 7/1/00	MacNair Lipari Nesterov Rodriguez
Electromagnet monitoring	124	Magnet Systems	Review proposed design for thermal monitoring by 3/1/00 Down-select vs. other methods Estimate costs by 4/1/00	MacNair et al

3. Modulators	**Reference**	**Resp TSETs**	**Major Milestones**	**Resources**
Modulators	15,80	SS Modulator	Complete full power stack by 6/1/00 Test to 500 kV 3 usec by 8/1/00 Revised cost estimate by 8/1/00	Cassel Nguyen De Lamare Pappas LLNL-Bechtel
Modulators	--	SS Modulator Baseline Modulator	Simulate load fault models & protection by 6/1/00 Load arc tests by 9/1/00	Cassel et al Gold et al
4. Global Systems	**Reference**	**Resp TSETs**	**Major Milestones**	**Resources**
Controls Architecture	91,92,93,94,95,126	Architecture	Complete requirements outline by 2/15/00 Complete requirements document by 5/1/00 Complete preliminary specification by 9/1/00	Clark et al FNAL
Timing	--	Timing, LLRF	Complete phase stability tests by 5/1/00	Cisneros Frisch Brown FNAL
Personnel Protection (PPS)	96,127	PPS TTF SP RP OPS	Complete preliminary PLC evaluations by 4/1/00 Complete entryway requirements & concepts document by 8/1/00 Revised cost estimate by 9/1/00	Kroutil Bong Dimaggio TTF SP CF
MPS	97	MPS, Architecture RP OPS	Complete requirements document by 5/1/00 Complete concept & spec. document by 8/1/00 Revised cost estimate by 9/1/00	Tilghman Crane Architecture SP
BCS	98	BCS Architecture RP	Complete requirements document by 3/1/00 Complete concept & spec. document by 6/1/00 Revised cost estimate by 8/1/00	Zdarko Bennett Architecture RP SP

1. TUNNEL ELECTRONICS STUDY/ R&D

General Concept: Highly integrated electronics for BPMs, Movers, Vacuum and LLRf placed entirely in the main linacs and other tunnels will greatly reduce or in some cases eliminate the following:

- Long haul cables
- Cable trays
- Racks to house crates and modules
- Special buildings to house racks, crates or modules

Features (See Figure 1):

1. It may be feasible to protect standard off the shelf electronics sufficiently well from gamma and neutron dose that non-radiation-hardened (COTS) electronics can be used in the tunnels.
2. Highly integrated electronics will reduce power and cooling demands dramatically and make feasible very modest water cooling of sealed, electrically shielded modules.
3. A low voltage (e.g. 28V) rail system, with power supplies on each end, can be used to distribute power to small front-end modules throughout a sector.
4. Signal jumpers from sensors or controls; power and cooling lines to electronics very short
5. Multiple devices might be contained on separate cards in a single plug-in.
6. Wireless LAN and other communications might eliminate communication network/timing cables in tunnels.
7. Tunnel electronics together with extensive use of permanent magnets to eliminate power cables could eliminate associated cable trays in the tunnels.
8. Robotic maintenance units, if required, could swap out plug-in modules, eliminating need for human entry into the radiation environment.

Work Groups/ Tasks/Milestones/Resources:

Tunnel Electronics	**Reference**	**Resp TSETs**	**Major Milestones**	**Resources**
Baseline R&D	46,99,100,101,112 -- 70,103,113,114,122 102,123	BPM LLRF Movers Vacuum	Proof of principle prototypes (end FY01)	Smith, Corredoura, Browne, Porter et al
Tunnel Radiation Modeling	120	Radiation Physics (RP) Tunnel Task Force (TTF)	Evaluate models for gamma, neutron dose in ML/DR/BD Down-select COTS vs. RH 6/5/00	Rokni et al TTF (RP, CF) LLNL
Tunnel Structures		TTF	Down select model by 6/5/00	TTF
Tunnel Electronics Pkg/ Architectures	120	TTF, RP, CF	Requirements & specs by 6/5/00	TSETS, TTF, FNAL
Robotics Remote Servicing System	120	TTF, LLNL, Others TBD	Specify by 6/1/00 Cost by 8/1/00	ME Depts. LLNL
Wireless Communications	121	TTF, Others TBD	Specify requirements all areas by 7/1/00	TBD
CD 0.4 System costs		TTF & TSETS	Complete Preliminaries: 8/1/00	TBD

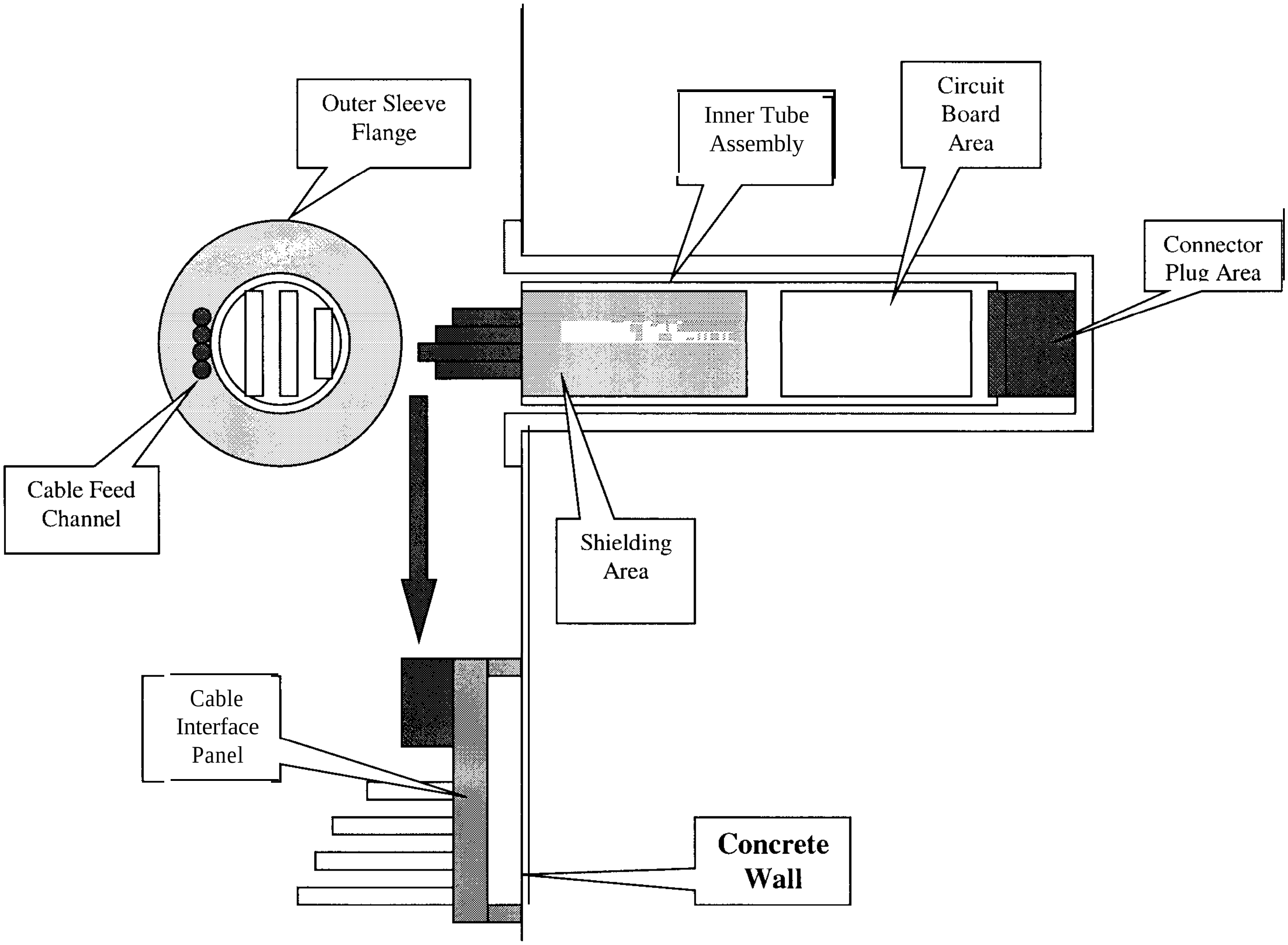

Figure 1 – Tunnel Electronics Packaging Concept

Descriptions:

1. *Baseline R&D:* BPMs, LLRF, Movers and Vacuum already are embarked on proof-of-principle R&D programs. These will continue under the new work groups except priorities may shift to put earlier emphasis on evaluating the new tunnel models.

- The BPM program has a circuit development using commercial digitizers as well as a custom chip development aimed at simplification and economy of the final implementation.
- The LLRF program has a similar program, including simulations and experimental measurements of phase stability and noise through a closed loop RF system around an existing klystron. Since the new model will be based on a 3 μsec RF pulse and eight phase flips instead of 1.5 μsec and four, and only half the number of klystrons, the technical model and costs need to be revised.
- Movers are using a prototype stepper motor test system that has achieved the required mover specifications. Servo-motors are claimed to have economic advantages and will be investigated. The mover work will also have to be greatly expanded to address the adjustable permanent magnet model that is being adopted for CD 0.4.
- Vacuum pump electronics R&D consists of investigating miniaturized electronics that could be mounted directly on small pumps with short jumpers. A new multi-channel concept' that would minimize the rad-hard components required at the pump, will be investigated.

2. *Tunnel Radiation Modeling:* Preliminary studies by Rokni and Roesler, after a suggestion of Breidenbach, suggest that it may be possible to suitable protect COTS electronics in small diameter (6-inch) backward angled holes (Ratholes) in the concrete tunnel walls. In short, gamma radiation is well contained in this model, but neutrons, the principle source of damage in silicon, are less well investigated. Work is continuing, and further expertise[2] will be sought. If neutron damage cannot be suitably contained, it will be necessary to design significant amounts of the various subsystems in a rad-hard silicon or GaAs process. In either case the model to be investigated appears to offer significant advantages in eliminating costly support structures, including extra tunnels and building floor space.

- Radiation environment models need to be completed for all major electronics areas (Main Linac, Injection and Beam Delivery) in order to determine the feasibility of operation of COTS electronics in these areas.
- If *not feasible*, then a second determination is needed, case by case, to determine if *custom radiation hardened circuits* can offer a practical alternative.
- If neither proves practical, then locating electronics further away from the beam, outside the tunnels or behind substantially more shielding, will be mandatory.

3. *Tunnel Structures:* A large number of electronics housing options have been identified. They range from electronics completely in the tunnels, to parallel structures sufficiently shielded from the main tunnels to house the radiation sensitive COTS electronics in small, distributed water cooled modules that use serial communications in and out, power from a low voltage DC rail, and no crates or backplanes. Minimizing cable lengths by either approach is estimated to save roughly $50M in cabling alone. Niches in the main tunnels that will allow non rad-hard electronics to

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[1] Proposed by M. Breidenbach, SLD. This is interesting if COTS electronics can be used for the bulk of the circuitry, or if a rad hard circuit cannot survive near the pump.
[2] LLNL, Boeing, CERN

survive, will be much cheaper than an additional parallel tunnel. Drawbacks are the possible complexity of shielding, access for repair, and extra cost if radiation hard electronics becomes mandatory. There are many housing options between these extremes that involve moving electronics into shielded areas with somewhat longer than minimal cable runs. Special areas are costly and preferably avoided. For CD 0.4, it is proposed that the Rathole model described above be adopted for study so that evaluation of compatible circuit designs can proceed in parallel with continuing radiation studies. Work on other options will be undertaken in situations where the Rathole model cannot work for technical or cost reasons.

4. *Tunnel Electronics Packaging/Architectures:* The goal of this work package is to develop a standard packaging system that will serve all tunnel subsystems. The packaging concept will have to be developed in parallel with an evaluation of requirements for each of the individual subsystems (BPMs, LLRF, Movers and Vacuum), all of which have system-specific needs in the areas of circuit design, connectors, calibration, programmability and power dissipation. The board space requirements for each subsystem, and the possibility of combining subsystems in one module, will determine overall numbers of Ratholes. Reliability will be a major concern:
   - Ideally sufficient reliability and/ or redundancy can be built into the electronics to enable a full mission time run without having to provide servicing that would require human access. There is inherent redundancy along the linacs, for example, such that isolated failures could be tolerated. If several co-located devices fail at once, however, intervention and loss of beam time is inevitable.
   - An alternative is to have less reliable or redundant electronics packaged in modules that can be replaced by a robot. This adds the cost of the robotics, and imposes additional design constraints on the precision of mechanics and especially on connectors. The connectors are the least reliable part of any system, so a well engineered hermetically sealed multi-connector containing coax, power and possibly communication connectors is likely to be less reliable and more expensive than COTS mil spec connectors that might normally be used.
   - Water connections are also required but it is proposed that these be made to an outer metal casing that serves as the cold plate for the internal module that is in close thermal contact, thus avoiding having to break the connections when a module is replaced.
   - Power supplied by a DC bus will minimize board space for AC-DC conversion. DC-DC converters in small packages are envisaged on the modules. For some applications, such as vacuum, the bus might also provide a control communications path. A general study of supply and communications schemes is needed.

5. *Robotics Module Replacement System:* This option, if deemed justifiable by reliability limitations, is to robotically replace modules that fail more often than tolerable. If a robot is to be effective it ideally must be able to hot-swap modules without beam interruption. If the robot will receive excessive radiation exposure for a typical “mission time”, then beam must be interrupted to make the entry. In this case the time and cost of robotics intervention should be compared with a manned entry. Manned entry will ease some difficult requirements in areas such as high performance slide-on RF connectors. The robot would normally reside at the top of a shaft such that it is out of the radiation area and can be loaded, unloaded and sent on its mission without breaking personnel radiation barriers. This alone would save time. There would be no personal driving time involved to the repair site, only the robot’s travel time to reach and return from the device along the tunnel. The many issues in the design and operation of such a system over 30 km

of beamline housing include reliability, radiation tolerance, capital, operational and maintenance costs.

6. *Wireless Communications:* Wireless communications in the tunnels offers potential advantages of flexible placement of components without the clutter and expense of communication cables. Since the installation cost of a cable often outweighs the hardware cost, eliminating cables is generally desirable. The kinds of data to be carried, and availability, survivability and cost of COTS electronics to provide wireless links, will ultimately determine what can and cannot be done. In addition to a wideband data channel, we also need to include the transmission of timing fiducials to BPMs and LLRF, the accuracy of which depends on how data are being sampled and processed. This work package intends a broad look at the entire problem and derivation of a feasible model or models for the applications described. Wireless communication models can extend to other systems that require sector to sector communications in the tunnels. Security and reliability required depend on the application, with Protection Systems posing the highest levels. MPS and Timing must also meet guaranteed response times that may preclude the use of wireless.

7. *CD 0.4 System Cost Estimate:* The ultimate goal is a WBS System Cost Estimate based on our best assessment of a feasible tunnel electronics model by approximately 9/1/00, which means completing preliminaries by 8/1/00 or sooner. The engineering estimate will be produced with the common tools already in use (Excel, Project) and will be transferred into a WBS structure with a toolset to be determined by the Planning Group. A few group coordinators will oversee this work together with the Planning Group. The WBS will be structured to achieve traceability to the original engineering worksheets, so engineers can verify that their estimates have been transferred correctly.

2. DC MAGNET POWER

Description: In the original Baseline Model for Lehman, DC Magnet Power was estimated for all electromagnets including quads, sextupoles, bends, correctors etc. The linac assumed individually powered quadrupoles with a standard redundant configuration for reliability, and oversize cable for minimum heat loss in the tunnel, to help maintain stability to 1 degree C. In the later (current) working models, the sizes of magnets have been optimized, and the standard individually powered magnets with redundant supplies have been in many cases replaced with strings of power supplies with individual trims for energy adjustment and beam based alignment. These models are generally considerably more economic in power supply and cable costs. Work on these models is incomplete, so the first Work Package is to complete these as reference points for further power supply and cable models. While this is in progress, the Area Groups will specify the set of candidates for permanent magnets and DC power systems will be re-estimated to cover only the remainder. The Mechanical Engineering group will estimate the magnet and associated cooling, monitoring and installation costs. A second Work Package is to evaluate a proposed electromagnet monitoring circuit[3] in comparison with alternative approaches using thermocouples or similar approaches.

[3] Described in a brief internal note by G. Haller, D. Nelson and M. Beidenbach.

Work Groups/ Task: Milestones/Resources:

DC Magnet Power	Reference	Resp TSETs	Major Milestones	Resources
DC Magnet Power Systems	7,17,18,19,20,34,51	Magnet Systems	Complete ML, Inj & BD conventional models by 3/1/00 Finalize PM choices by 4/1/00 Complete revised cost models by 7/1/00	MacNair Lipari Nesterov Rodriguez
Electromagnet monitoring	124	Magnet Systems	Review proposed design for thermal monitoring by 3/1/00 Down-select vs. other methods Estimate costs by 4/1/00	MacNair et al, SP

3. MODULATORS

Description: The Modulator program is to develop a solid state unit that can drive eight klystrons in parallel. The main advantages to be gained are economy, reliability, energy efficiency, flexibility in pulse width and smaller size. The major problem to be solved is to assure that a load can accidentally arc without becoming destroyed by the large stored energy of the modulator. Unlike line-type modulators, there is no limitation of the pulse width by fixed components so this modulator design can easily adapt to a varying width, within the limits of the energy storage capacitors and the induction magnetic cores. The major Work Package is to complete a demonstration of full voltage and current into a dummy load by 6/1/00, along with a revised cost estimate by 8/1/00. A second Work Package is to continue simulations and experiments to determine behavior of tandem klystron tubes under fault conditions and report results by 9/1/00.

Work Groups/ Tasks/Milestones/Resources:

3. Modulators	Reference	Resp TSETs	Major Milestones	Resources
Modulators	15,80	SS Modulator	Complete full power stack by 6/1/00 Test to 500 kV 3 usec by 8/1/00 Revised cost estimate by 8/1/00	Cassel Nguyen De Lamare Pappas LLNL-Bechtel
Modulators	--	SS Modulator Baseline Modulator	Simulate load fault models & protection by 6/1/00 Load arc tests by 9/1/00	Cassel et al Gold et al

4. GLOBAL SYSTEMS

Description: A number of suggestions have been made to reduce the costs of Global Controls. Some of these costs, such as Equipment Racks, are impacted by costs of other systems already discussed under Tunnel Electronics and Magnet Power. Other costs are specific to subsystems such as the central computers, Timing and Protection Systems. Suggestions made for various systems will be examined. Credit will be taken in the CD 0.4 estimate for cost reductions already identified since Lehman. Further near term reductions are not likely to be large since the estimates are software labor dominated. The main Work Package is to continue developing more comprehensive descriptions of system requirements to generate more complete specifications and more accurate estimates over the next couple of years as the model improves. A second Work Package is to study the problem of accelerator operation from a remote user site. A third package is to complete a requirements document for the Machine Protection System (MPS). A fourth package is to investigate the impact of a higher level of integration and extended use of non-mechanical sensors at PPS entry doors. Note that we have already greatly reduced the number of entries from the Lehman Model.

4. Global Systems	**Reference**	**Resp TSETs**	**Major Milestones**	**Resources**
Controls Architecture	91,92,93,94,95,126	Architecture	Complete requirements outline by 2/15/00 Complete requirements document by 5/1/00 Complete preliminary specification by 9/1/00	Clark et al FNAL
Timing	--	Timing, LLRF	Complete phase stability tests by 5/1/00	Cisneros Frisch Brown FNAL
Personnel Protection (PPS)	96,127	PPS TTF SP RP OPS	Complete preliminary PLC evaluations by 4/1/00 Complete entryway requirements & concepts document by 8/1/00 Revised cost estimate by 9/1/00	Kroutil Bong Dimaggio TTF Architecture SP CF
MPS	**97**	MPS, Architecture RP OPS	Complete requirements document by 5/1/00 Complete concept & spec. document by 8/1/00 Revised cost estimate by 9/1/00	Tilghman Crane Architecture SP
BCS	**98**	BCS Architecture RP	Complete requirements document by 3/1/00 Complete concept & spec. document by 6/1/00 Revised cost estimate by 8/1/00	Zdarko Bennett Architecture RP SP