Construction Schedule Estimate for ILC
Peter H. Garbincius – 15feb06 – after speaking w/ Tom Lackowski & Elaine McCluskey
prelim_construction_schedule_15feb06.doc – rev 27feb06

This is intended to give a brief indication of when the first beam enclosures, service tunnels, and service buildings would be available for the installation of components. This would indicate the lead times for gearing up production, testing, etc. for the technical components including when the first components should be ready for installation. This is a "brief" indication, not based on detailed (site-dependent) scheduling considerations, but is intended only to give an estimate to allow the Area, Technical, and Global System groups to properly size the production plants and delivery schedules for technical components.

The intention is to complete the construction phase in 7 years or so. That would mean all components would have to be installed by then (maybe ready for installation 6 months to a year before then) to give the time window for production, testing, and delivery. It is assumed that after the first stage Area Systems are installed, they will begin checkout

This is based on a technically-limited and not a funding-limited schedule. Once we know the costs, we can iterate to find more realistic timescales for the conventional construction, the production and installation of components, and the initial check-out operations of individual Area System accelerators.

27march06 – added in response to Nobu Toge's question on what we mean by a technically-limited, not funding-limited schedule:

> The implicit assumption was that we would have 6 (or possibly 7) tunnel boring machines working in parallel in US, Japan, and Switzerland, and maybe double that number (!?!?!) in Hamburg to preserve schedule. Six would be one each for:
>
> > e- straight beam tunnel (part of RTML, ML, one leg of BDS)
> > e- straight service tunnel
> > e+ straight beam tunnel (part of RTML, ML, one leg of BDS)
> > e+ straight service tunnel
> > e- DR
> > e+ DR
> > and possibly one additional doing 2nd legs of BDS for 2nd IR
>
> In talking to consultants years ago for VLHC, hat would be a conceivable number of TBM achines to have available and operating. Doubling that number might not be resonable, and would cost more per year during a shorter civil construction period. Chris Laughton just mentioned that there were 3 TBMs on the 26 km LEP tunnel and that was about as much as they could manage.
>
> The other consideration was that we should try to achieve a balance between the rate of civil construction and the rate of delivery of cryomodules and RF systems for ML. The production schedules of CM and RF will drive their cost. If we request the first components earlier and that the last components also be delivered

earlier, that will mean the manufacturers will have to build BIGGER production plants QUICKER, both driving up costs.

By Technically Driven Schedule, what we meant to say was that we could begin both the civil construction and the fabrication of components at a natural, not accelerated (and more costly) pace. There was concern that we would have to invest so much funding to get the civil construction started early, that we would not be able to let contracts for CM and RF for many years. We did NOT mean that we would expect to have enough funding for a crash program, such as pushing for a completion substantially shorter than 7 years.

The choice or compromise that was shown here was to assume both construction and component fabrication (plant mobilization) to begin in parallel from the beginning. This would have the first CM and RF components ready for installation about when then first section of ML tunnel will be ready to accept them.

Summary: The approximate times (after authorization to spend funds) at which tunnels will be ready for the first installation of technical components are estimated to be:

~ 30 months for	e- Source, keep-alive e+ Source, and arcs for RTML
~ 33 months for	Damping Rings
~ 41 months for	Main Linac
~ 65 months for	Beam Delivery System (started tunneling at DR ends)
no estimate yet for	Experimental Halls or positron bypass around IPs

These are some important concepts:

0. Personnel safety, including egress, is of paramount concern!

1. Construction front-end load: after project approval and availability of funding, an external contractor is anticipated to be needed to perform the final Construction Document Preparation. This has been called Title II activities in the U.S. This period will also include the bidding process, contract award, and contractor mobilization. The length of the construction front-end load period is thought to be about 1 year before the actual linear feet per day of tunnel boring gets started.

2. It will not be possible to start on the tunnel finishing (including shotcrete or grouting and installation of invert floor) in a given tunnel section while the tunnel spoils (fractured rock) are being transported through that section. Installation of standard utilities, including electrical power, fire protection, and ventilation, cannot start until the tunnel finishing is completed. Unless the attached service buildings on the surface have at least their shell completed, there will be humidity and condensation problems in the tunnels, at least during summers. Given assumed tunnel boring machine speeds and top-of-the-head estimates based on the NuMI tunnel experience, this would indicate that it

would require approximately 3 years from start of actual construction to beneficial occupancy (when technical components can start to be installed) for a section of tunnels approximately 5 km long (the distance between cryogenic plants). This includes the beam tunnel and service tunnel and all RF waveguide and personnel cross-overs between the two parallel tunnels.

3. As a first assumption, in competent rock strata as at Fermilab, there will be at least 8 tunnel boring machines working simultaneously at the electron DR, positron DR, upstream electron ML tunnel, upstream electron service tunnel, downstream electron ML tunnel, downstream electron service tunnel, upstream positron ML tunnel, upstream positron service tunnel, downstream positron ML tunnel, and downstream positron service tunnel, and maybe also one for the positron bypass tunnel around the IPs. Since the TBM advance rates are approximately a factor of two slower in the Hamburg area, twice as many TBMs would be needed to keep up the pace for the DESY site.
(**How do you go through IP's to dumps? Does it make sense to start at dump halls and work back toward sources?**)

4. Tunnels for Electron Source and (keep-alive) Positron source will begin as soon as possible. The hair-pin turn-arounds of the RTMLs and the tunnels for the electron and keep-alive positron sources will likely be drill-and-blast, rather than TBM due to the short and complicated interface geometries.

5. There are complications for interfaces TBM sections, specifically between the tangent to the DR circular and the RTML/ML linear sections, that still need to be worked out.

6. Isolation of tunnel segments with installation work and tunneling: need blast wall (atmospheric shock wave), dust wall, and flooding barriers. Also, will installation and alignment of sensitive items survive the seismic shock of blasting maybe 5 km away? We will have to understand this.

7. The **TESLA TDR** expects no more than one year between financial approval and beginning of construction for public planning approval procedure and bidding and the awarding of contracts. It doesn't say when civil construction starts. (**There doesn't seem to be any lead time for contractor mobilization.**) The total civil construction will take 3.5 years (4 TBMs – one tunnel), and installation can begin installation (utilities?) can begin in the tunnel 2 years after start of civil construction (or 3 years + mobilization from availability of funding). The installation of first cryoplant, water, etc in the DESY service hall can begin after 2.5 years after start of construction. So 3 years (plus mobilization) before 1st installation of technical elements – complete civil in 4.5 years.

8. The **USLCTOS** study required 15-18 months of A&E firm construction design (including bidding) after availability of funding before construction could start. The installation of technical elements could begin after approximately 24 months for BDS, 27 months for Injectors and DRs, and 36 months for ML, with construction completed 27 months (BDS), 33 months (Injectors & DRs), and 45 months (MLs) respectively.

9. **Fermilab FESS** (Tom Lackowski), based on NUMI experience, estimated 3 years for tunnels (15 km both sides for two tunnels), including boring, finishing, and standard utilities, after launching the TBM. This would occur after 9 months A&E design (includes bidding), site preparation providing construction power, driving the first shaft, procuring the TBMs (6-8 months) + setup TBM (3 months) (mobilization). So that would require 9 + (6-8) + 3 = 18-20 months before TBM launch. Installation of technical components could begin maybe 2/3 * 3 years = 2 years = 24 months after that, or 42-44 months after start funds become available for construction. Completion of civil construction would be another 12 months or 54-56 months total. Initial installation of technical components for the Damping Rings, Injectors, and RTML arcs could likely begin 6 months sooner or 36-38 months after availability of funding, with civil construction completion after 48-50 months.

10. The schedule outlined in **play_schedule_20feb06.xls** is intended merely to show when the tunnels will be available for installation of technical components after the tunneling, the tunnel finishing, and the conventional utilities (AC power, HVAC, fire protection, etc.) are installed. This also assumes that a service building is complete (weather protection/humidity regulation and crane) to accept the components. It assumes that the construction contractor cannot be using a single shaft simultaneously for both spoil removal and access for installing conventional utilities. Finally, it is assumed that the digging, finishing, and utilities for any additional alcoves, side caverns, or widening of the standard tunnels, and the digging and finishing of the waveguide crossovers and personnel crossovers between beam and service tunnels can be accomplished within these timescales.

There is still a question of waveguide cross-overs: can they be drilled or will they need to blasted? What is their location in tunnels? Impact on radiation safety and beam-on accessibility to service tunnel. Similar questions for geometry of personnel labyrinths between service and beam tunnels.

11. The approximate times (after authorization to spend funds) at which tunnels will be ready for the first installation of technical components are estimated to be:

~ 30 months for	e- Source, keep-alive e+ Source, and arcs for RTML
~ 33 months for	Damping Rings
~ 41 months for	Main Linac
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12. Comments on the estimate in **play_schedule_20feb06.xls**

We start $t = t_0$ at the point at which the ILC project is approved and we can begin spending money externally to the institutional labor. This would include hiring an Architectural Engineering firm (A&E) to do the preparation of the detailed construction design. This assumes that the site has already been selected, the land and easements have been procured, and any environmental or legal permits have been settled.

$t = t_0$ authorization to begin spending construction money,
hire A&E firm for detailed civil construction design,
bidding process

$t = t_0 + 9$ mo. Award contracts
prepare site, provide construction power, mobilize contractor
drive first shaft (6-8 months) (call it 8 months)
procure tunnel boring machines (TBMs) (6-8 months in parallel)

$t = t_0 + 17$ months
assemble TBM (3 months), prepare to begin boring

$t = t_1 = t_0 + 20$ months
begin 15 km TBM drives (at least 4 in parallel for e- linac & BDS,
e- service tunnel, e+ linac & BDS, e+ service tunnel)
this is estimated to take ~ 3 years in competent rock as at Fermilab, it might take 2x as long in Hamburg, or require twice as many TBMs to maintain a 3 year tunneling schedule.
Each 15 km tunnel will be broken into 3 segments corresponding to
service buildings designated A(one end), B, C, D(other end)

$t = t_1 = t_0 + 20$ months
TBM drilling between A and B – spoil removal through shaft at A

$t = t_1 + 12$ months $= t_0 + 32$ months
TBM drilling between B and C – spoil removal through shaft at B
Incrementally completing finishing tunnel and installing utilities
Clean-up surface at A and build Service Building at A (9 months)

$t = t_1 + 21$ months $= t_0 + 41$ months
Start technical component installation between A & B from building at A

$t = t_1 + 24$ months $= t_0 + 44$ months
TBM drilling between C and D – spoil removal through shaft at C
Incrementally completing finishing tunnel and installing utilities
Clean-up surface at B and build Service Building at B (9 months)

$t = t_1 + 33$ months $= t_0 + 53$ months
Start technical component installation between B & C from building at B

$t = t_1 + 36$ months $= t_0 + 56$ months
Complete tunneling for linacs, service tunnels, and BDS
Remove TBM from shaft at Service Building D (3 months)

$t = t_1 + 39$ months $= t_0 + 59$ months
Incrementally completing finishing tunnel and installing utilities
Clean-up surface at C and build Service Building at C (9 months)
Clean-up surface at D and build Service Building at D (9 months)

$t = t_1 + 45$ months $= t_0 + 65$ months

Start technical component installation between C & D from building at C

$t = t_1 + 48$ months $= t_0 + 68$ months

all tunnels and all service buildings complete,
including finishing and conventional utilities
tunnels & service buildings ready for installation of technical components