The Accelerated Installation and Commissioning Plan for the DZero Run IIb Upgrade

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1. Introduction

The DZero Run IIb Silicon and Trigger Installation Schedule, developed in preparation for project base lining at the Lehman and External Independent Reviews (September and November 2003, respectively), described all activities related to removal of the old detector and trigger elements, the associated infrastructure preparation, installation and electronic hookup of the Run IIb counterparts, and adequate verification of the electrical continuity and integrity of these connections prior to delivery of beam. (We call this last phase "technical commissioning".) The schedule corresponded to suspension of Tevatron operations for a period of 31 weeks. No attempt was made to minimize this interruption because other activities external to DZero required a period of this length.

The schedule assumed a single shift of work and unlimited continuous access to the Collision Hall (CH) until the pacing item (here, the silicon detector) was completely hooked up and checked out, and the end calorimeters and muon irons were closed. The commissioning beyond this point – or the portion of the commissioning more closely related to preparing downstream elements for acquiring physics-quality data or "physics commissioning" – is described in a different MS Project plan in development.

In light of the accelerator plan released in May 2003, and in particular the back-end loading of delivered luminosity, it became clear that a reconsideration of this schedule, employing a more aggressive approach, could yield palpable gains in the physics reach of the experiment. Much work over the past few months has gone into reworking the installation schedule under these new constraints. As before, a fully resource-loaded MS Project file describing the installation plan was developed. In particular, the following items were considered in detail:

- the amount of time required to perform each of the tasks;
- the order in which the tasks are performed;
- the resources required to realize shorter task durations;
- consideration of less labor-intensive technical approaches for a few key tasks, and study of the associated impact to both the detector performance and the schedule;
- the practical limitations associated with space. This included the creation of a separate resource for each of the regions of most concern – the cathedrals, which are the areas between the east and west surfaces of the calorimeter shells and the

innermost plane of the central muon PDTs, and the inter-cryostat gaps – in order to precisely track manpower flow in these areas;

- preparatory work, mock-ups, and staging work that might be done ahead of time in order to streamline the work during the shutdown and relieve the pressure during this period;
- the availability of general technical and physicist manpower, as well as supervisory and other specialized personnel. This consisted in some cases of having developed lists of people by skill type, training, and, in many instances, by name, who we believe we will need to have at our disposal in order to successfully mount this effort.

The reevaluation of the silicon installation and commissioning indicates Tevatron operations will be interrupted for 14 weeks. This is consistent with the duration of the summer shutdown. An additional 14 weeks will be required for commissioning.. The table below contains a summary of the most relevant installation and commissioning milestones from our current schedule.

Milestone Name	**Current Forecast Date**
Tevatron Shutdown Begins	10/28/05
Silicon Ready to Move to DAB	12/05/05
Detector Ready for Resumption of Tevatron	02/09/06
Ready for Physics Commissioning	03/06/06
Accumulation of Physics Data Begins	05/19/06

We have introduced double-shifts wherever possible and sensible, particularly in the silicon portions, remaining cognizant of the scheduling constraints described below. A five day work week has been assumed; we have reserved the weekends in order to provide us with some time contingency during peak periods, to deal with unforeseen difficulties, etc. More details are provided below that describe how the components of the schedule were considered.

2. General Considerations

We outline below the constraints that drive this new schedule, and some of its more relevant underlying features:

- As before, in order to begin the installation of the silicon detector as soon as possible after the silicon is completed, we have assumed that the shutdown begins prior to the silicon completion date at the Silicon Detector Facility (SiDet). **Six weeks are**

required to remove the Run IIa silicon and prepare the other necessary infrastructure in the collision hall (CH) to accept the Run IIb silicon. Preparatory work outside the CH is being done, and will continue to be done, while the Run IIb sub-projects are being prototyped and fabricated.

- **We have sought to limit the amount of downtime for the accelerator associated with our work in the CH**. This was done in order to allow for a commissioning run as soon as possible after the proposed 2-3 month shutdown requested by the Beams Division (BD), under the assumption that the shorter the downtime, the shorter the time required to bring the machine back up to a smoothly running state. We remind the reader that DZero has designed its silicon detector in two halves, which allows for its installation in the inter-calorimeter gaps while the detector proper remains in the CH: **no rollout of the platform is required**. This reduces greatly the time, effort, and technical risk associated with the silicon installation.

- **The installation phase requires a 14 week shutdown.** At this stage, the silicon electrical connections will have been checked using local PCs connected directly to the interface cards in the cathedral area in the CH, and the beryllium beam tube will have been installed, connected, and leak checked. Note that no downstream software is yet required. The detector remains open to allow access to all connections as the beam comes up, should they be needed. This procedure was used to advantage in Run IIa.

- **The installation phase is driven entirely by the silicon activities in the CH**. Since much of the trigger installation is staged and the hardware debugged in independent racks near the Movable Counting House in the DZero Assembly Building prior to the shutdown, and in any case does not require CH access, **the readiness for beam for the trigger elements occurs three weeks into the shutdown.**

- **An additional four weeks after installation is required for the completion of technical commissioning.** While most of the work is software-related and is therefore expected to be outside the CH, we consider this period as providing some contingency for the debugging of detector connections as well. We believe that access time provided from either intended or unintended accelerator downtimes, and those scheduled directly with the BD and CDF, will allow us the necessary integrated access time during early machine commissioning, should it be needed. This, too, is similar to the actual Run IIa scenario.

- For practical reasons, the schedule is constructed in such a way that the technical commissioning continues in an uninterrupted fashion immediately after the installation phase, giving **a total work cycle of 18 weeks to the end of technical commissioning**. This is to be compared to the 31 week shutdown called for in the previous schedule; that is, the state of detector readiness is the same in each case.

- The transition to physics commissioning will likely occur adiabatically after delivery of first beam, melding naturally with the technical commissioning. For reasons similar to those mentioned in the previous bullet, however, it is assumed to follow immediately after the technical commissioning. **The estimated duration of this physics commissioning time is expected to be 10 weeks**, which reflects a more aggressive approach than was assumed in our previous estimate of three months. It is based on a more detailed understanding of the process, including an MS Project plan that is currently under development.

- The above yields a total of 14 weeks installation time, in which the CH is open for access, and 14 weeks total commissioning time (technical + physics), during which increasingly limited access is expected to be required. **This gives a total "physics-to-physics" downtime of 28 weeks**, which is to be compared with our original estimate of 10 months.

- **It is important to note that increasing the total commissioning time from 14 to 21 weeks in the scenario in which the silicon is upgraded, while keeping the non-upgraded commissioning duration at the nominal 14 weeks, results in only a 4% decrease in the integrated, double-b-tag weighted luminosity ratios for both the base and design luminosity profiles**: seven weeks is a small fraction of the total running period, and the accumulation of double-b-tag-weighted luminosity is thus reasonably insensitive to few week dilations in downtime.

- We mention that, independent of whether the silicon upgrades ultimately go forward, the trigger and DAQ/online upgrades have been taken off the table, having been slated for completion. While the installation needs are reduced, we estimate that the 14 week total commissioning time discussed above will be required to establish the physics readiness of the trigger. **Assuming the accelerator needs 14 weeks of downtime for maintenance and its own Run IIb upgrade work, the total physics downtime for DZero will be approximately independent of whether the silicon is upgraded or not**.

- Finally, we emphasize that the silicon installation has been done before by many of the same people who will be devising and executing the current plan. **The approach is also the same as that in Run IIa, and we have designed the silicon detector with an eye toward retaining as much of the infrastructure as possible, limiting the amount of work required**.

The peak labor personnel requirements are 29 (24) for technical personnel (physicists), which should be divided by two to get the per-shift values. These peaks occur during the uncabling and removal of the Run IIa silicon (technical personnel), and during cabling and checkout of the Run IIb detector after it is installed (physicists). The integrated totals are 43 and 45 person-months for technical personnel and physicists, respectively. These numbers are consistent with past estimates and with cross-checks of Run IIa installation work, and respect the spatial constraints that will exist in certain regions. More details on this latter point are discussed in later portions of this document.

3. Two-Shift Schedule

In the original schedule, the detector was opened without removal from the CH, the beryllium beam pipe and Run IIa silicon tracker would be de-cabled and removed, the new Run IIb silicon tracker and beam pipe would be installed and hooked up, the new trigger components installed in parallel, and all elements of the new systems commissioned. At this point, the detector would be closed; work in the CH terminated and physics commissioning with colliding beams begun. This original schedule assumed all work in the D0 collision hall took place on a single-shift, five-day work week basis.

Reformulation of the schedule with a two-shift workday offers a significant reduction of the Tevatron shutdown time. Careful consideration of the instantaneous manpower levels and types, spatial constraints, and other factors must be included as this schedule is being developed in order to avoid serious conflicts. Our studies indicate that the shutdown can be constrained to 14 weeks.

Many of the tasks required to remove the Run IIa silicon and certain portions of the associated silicon infrastructure do not require unusually special care, and assigning two shifts per day is an ideal way to speed up this particular part of the process. Typically, these tasks are the reverse of the Run IIa installation process, and the time and effort required for them is quite well understood. Many do not specifically require experience from Run IIa; providing the necessary personnel and supervisory oversight does not pose a problem.

Certain of the tasks do not require, nor do they benefit from, two-shift work days. Typically, such tasks are those of short duration which do not realistically accelerate with the addition of a second shift or from adding more workers to a single shift. Examples of tasks that do not sensibly benefit from the introduction of a double shift, and remain at a single-shift in the new schedule, are given below:

- creating an opening in the shield wall to permit the silicon to be lowered into the CH by crane;
- performing the radiation and beryllium hazard surveys as the detector is opened;
- preloading the beryllium beampipe in the North end calorimeter;
- debugging the transfer of the trigger decision signals from the Level 1 Calorimeter/Track Match MTM boards to the Trigger Framework;
- debugging the inputs and verifying the outputs of the L1 CTT;
- installation and commissioning the Level 2 Beta trigger;
- installation of the Silicon Track Trigger modules.

Other tasks require specific training and experience, and it is important therefore that before they are scheduled for two-shift work, the availability of appropriate personnel, along with necessary two-shift supervision, be assured. For example, it is necessary to remove the Run IIa silicon carefully, both to preserve some portions for study or potential use elsewhere, and to ensure that the surrounding critical and sensitive equipment is not damaged during the uncabling and removal of the silicon itself. An initial accounting has been made to evaluate whether those persons involved in the same or similar tasks during Run IIa installation, or equivalent replacements, will likely be available during the Run IIb installation phase. We anticipate that a number of these experienced people will in fact be available, and will be assigned to similarly delicate tasks during Run IIb. The remainder of the needed personnel will have to be trained appropriately as the time approaches. This initial tally has increased our confidence that a safe, efficient two-shift workload can be accommodated.

3.1 Spatial Considerations

During the installation, a great deal of work, subdivided into many different tasks, will be required in the "cathedral", the inner regions of the open detector above the platform where many components of the silicon readout electronics are housed, and the gaps between the north and south end calorimeters, a particularly delicate region where the inner silicon connections are made. This raises the concern that the number of scheduled, distinct tasks required by the overall installation effort may result in an unrealistic number of people working simultaneously in congested regions of the detector. Resources have been assigned in MS Project to denote these likely areas of congestion. These resources, called "Cathedral", "N Gap", and "S Gap", have been defined in the new schedule and assigned to all tasks to which they apply. The maximum number of people able to work simultaneously in either gap is two to three, and the maximum elsewhere in the cathedral is approximately eight (two at each quadrant of the silicon readout system). The new schedule enables these "area" resources to be monitored to reduce the potential for schedule slip due to congestion. An accounting of these resources shows that only on a few days are three people required for work in the inter-cryostat gap. This occurs when the uncabling activities in the north gap overlap with the connection of the new cooling and dry gas systems. We believe that, with careful interleaving of this work, the described choreography can be realized. A similar accounting shows that the cathedral occupancy limits are never encountered.

3.2 Streamlined Approaches

There are a number of approaches that have allowed us to accelerate specific tasks in the schedule. Given that the bulk of the silicon cable plant remains in place, most of the new power supply cabling can be completed before the shutdown begins. In addition, both the horseshoe cabling and junction card installation, both fairly complex activities containing some new features, will have been studied thoroughly on mock-ups of these systems. A number of the critical cabling tasks will have therefore been fully staged prior to the actual installation, which will facilitate the process during the shutdown. We have used as both input and, in some instances as a cross-check, the time and effort required for the analogous cabling processes during Run IIa. For the trigger, a L1 Cal trigger test stand has been created adjacent to MCH1 which will enable the full L1 Cal Trig system to be assembled and tested before the Run IIb shutdown with actual BLS signals split from the data flowing to the Run IIa Cal trigger system. Such a test stand greatly increases the likelihood that the new system will be installed and commissioned for Run IIb within the time and effort budged planned. Clearly, the successful implementation of the schedule will depend on proactive and informed management and close daily supervision. Extension of the work week to more than five days will be held in reserve should the flow of the work be delayed for any unforeseen reason.

4. Other Schedule Modifications

The revised schedule also includes a number of new or relocated, omitted or revised tasks. These changes significantly shorten the schedule and provide schedule contingency.

The original schedule included a set of infrastructure tasks for both the silicon and the trigger that occurred before the shutdown. These preliminary infrastructure tasks have increased in number and include:

- the installation of the new high voltage and low voltage systems in the MCH and on the platform, and their associated cables;
- the silicon temperature monitoring cables;
- the L1 CTM and CTT trigger electronics installations in the MCH and on the platform.

It is noteworthy that the new silicon LV system is already substantially designed, prototype power supplies under test and evaluation, and cabling systems finalized.

In addition to explicitly scheduling these tasks to be completed well before the Run IIb shutdown (e.g., during the summer 2004 Tevatron shutdown), the new schedule also takes advantage of new planning which simplifies certain tasks. For example, instead of planning for a two-temperature chilling system for the silicon, it was realized that all layers of the silicon can operate at the single low temperature mandated for the first two layers with no resulting complications to detector performance or operations. This scope reduction greatly simplifies the changes that must be made to the existing chiller, and removes completely from the schedule the time and effort required to install an additional insulated piping run in the Collision Hall.

A number of new tasks added to the infrastructure section explicitly detail the design, fabrication, and testing of the silicon transportation and installation fixtures and for the beryllium beam pipe installation fixture. Preparation of safety documentation and operational readiness clearance documentation plus worker training for critical tasks using mock-ups and expert guidance were also added to the schedule.

Finally, uncabling and removal of the horseshoes has been delayed in the new schedule until the Run IIb silicon is installed. This reordering greatly improves working access in the gaps during the major activities and adds conservatism to the flow of work. In the initial schedule removal of the 80-conductor cables and storage nearby created significant obstruction in the north and south gaps. Delaying the uncabling until after the Run IIa silicon is removed and the Run IIb silicon is installed greatly improves working access in the gaps during these major activities. There is also time and effort allocated for training technicians on a mock-up of the horseshoe itself. This mock-up procedure will be used to reduce the number of unforeseen difficulties encountered during final installation of this critical item.

The original schedule was driven by the silicon installation. The time allotted for the commissioning of the trigger systems was commensurate with the longer schedule. Accordingly, the number of physicists required was limited. The new schedule reduces the trigger commissioning time from 12 weeks to 8 weeks. To accommodate this shorter interval, the number of physicists working on the trigger and their working hours will be increased. The new trigger system test area mentioned above greatly increases our confidence that electronic commissioning can be streamlined in the new schedule. Negotiations are already underway with new institutions that are interested in contributing to the trigger sub-projects at all major phases of the project: fabrication, installation, and commissioning.

Proper testing of the reworked interface boards is critical to the success of the installation. Repeated installation and removal of these boards during preparation for Run IIa was a major cause of delay. In the original Run IIb installation schedule these boards were to be removed quadrant by quadrant, sent to Kansas State University (KSU) for rework and testing, and then returned to FNAL for loading into the IB crates and testing before installation in the cathedral. To maintain momentum, the new schedule assumes two shifts per day will be devoted to these tasks. It happens that a full two shift per day acceleration of this work is not required to avoid dilation of the schedule, but by planning for this additional manpower the risk that this operation will consume more time than anticipated is reduced. Discussions with the principals at KSU indicate that the university resources can and will be made available to realize this more aggressive turn-around time.