DØ Schedule and Contingency Plan

The DØ Collaboration

March 30, 2000

We describe the current schedules and contingency plans for the DØ detector. We describe the Silicon Detector construction in some detail, since this is the critical path item and is an area where viable descope options remain. The installation and commissioning plan for DØ forms the second part of this document. We remain fully committed to installing the complete DØ detector ready for beam on March 1, 2001 and do not intend to exercise any of these fallbacks or contingency plans, but we feel that having such plans in place forms part of a strategy that will maximize our chances of achieving this goal.

1. Overview

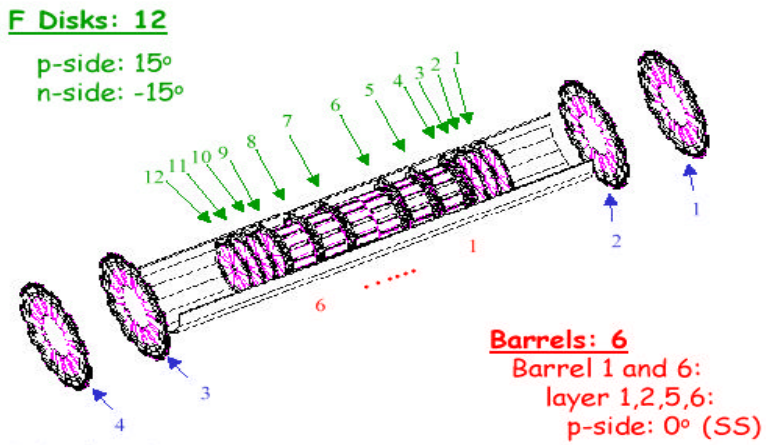
In January 2000 we submitted the document: "Fallback Options for the DØ Upgrade" (DØ note 3724) to Fermilab. In that document we laid out all the possible fallback and schedule contingency planning options for the DØ upgrade project. This document (DØ note 3741) is a follow up to D0note 3724 and describes the dates at which decisions have to be made to implement the fallback options or use schedule contingency.

The primary goal over the last few months has been to create schedule contingency, especially in the installation part of the project. We have succeeded in this by rearranging the installation sequence and by splitting the support cylinder for the silicon microstrip tracker (SMT) in half, so that the SMT can be installed as two independent halves. These decisions have lead to much more flexibility in the schedule and in an extreme case the SMT could be installed in the collision hall. The details of this are described in the silicon installation section of this document.

The construction of the Central Fiber Tracker and the Muon System detectors is largely complete and the remaining fallback issues for these detectors relate to their installation. The Fiber Tracker will be installed as a unit in June of this year and the installation of the forward muon detectors is described in more detail in the installation part of this document. The Preshower, Inter-Cryostat and Luminosity detectors are also very close to completion. They will be installed in the near future, as indicated on the time line graph in the installation section. For the remaining parts of the upgrade project: tracking, calorimeter and muon electronics, trigger, DAQ and online system we refer back to D0note 3724. The fallback options for those systems require no clear decision dates, because we will simply complete them as installation progresses and in extreme cases will complete their installation when the detector is in the collision hall. In all cases it is clear that enough functionality will be available by March 2001 to start Run II. For these reasons the remainder of this document concentrates on the SMT and installation milestones.

2. Silicon Detector

The layout of the silicon detector is shown below. The fallback plan follows discussions of the impact of different scenarios on the DØ physics program. It weights the possibilities with the current understanding of the status and projections of the assembly process. Importantly it assumes the current baseline plan to install the north and south halves of the silicon modules separately. The installation of the H-disks is separate from the two central half-cylinder assemblies and follows after installation of the corresponding half-cylinder.



	Barrels	F-Disks	H-Disks
Channels	387120	258048	147456
Modules	432	144	96
Inner R	2.7 cm	2.6 cm	9.5 cm
Outer R	9.4 cm	10.5 cm	26 cm

The baseline installation schedule shows the arrival of the first half-cylinder at DAB on August 1, 2000 and the second on November 1, 2000. There is contingency in the installation schedule of approximately one month. Therefore if the completion date of the first half-cylinder slips by more than 1 month serious consideration must be given to reducing the complement of detectors in that half-cylinder. Similarly subsequent slippage of greater than one month of the second half-cylinder will lead to a serious discussion of deferring the installation of that half-cylinder until after the main detector platform has been rolled into the collision hall. The date, which triggers the relevant discussion of any of these options, should adequately precede the critical date.

The above dictates that, in the event of limited resources, the detector assembly should emphasize completion of the complement of modules for the first half-cylinder before giving emphasis to the second.

Emphasis should be given to the half-cylinder components over the corresponding H-disk assembly if necessary.

Sensor and Module Quality

A modest relaxation of the quality of sensors and detector modules increases the schedule contingency and was shown to have a modest physics impact. The following guidelines are therefore being followed.

- Having understood the impact of single p-stop defects in the Double Sided Double Metal (DSDM) large-angle stereo detectors we will proceed to use selected sensors with this defect for detector production.
- DSDM large-angle stereo detectors will be deployed in such a manner as to maximize the radiation hardness by choosing detectors for Layer 1 with higher depletion voltages provided the **nominal schedule** is not jeopardized by any delays that this engenders.
- Small-angle stereo detectors will be deployed in such a manner as to maximize the radiation hardness by choosing detectors for Layer 2 with higher depletion voltages provided the **nominal schedule** is not jeopardized by any delays that this engenders.
- Single sided and small-angle stereo detectors will undergo remedial work only if their mechanical characteristics would lead to a significant degradation of the SMT performance, in particular in its influence on the STT trigger rejection and not jeopardize the **nominal schedule**.

Barrel Modules

The first barrel module assembled will be an end barrel module with single sided detectors. This assembly will be a learning experience and since the outer modules are the least critical we choose to do an outer (in |z|) barrel first even though it is inconsistent with the emphasis on the most critical components.

If detector or module assembly endangers the completion of the six barrel modules, emphasis, after assembly of the first barrel which is currently underway, will be given to the inner barrels with large-angle (DSDM) stereo detectors, as opposed to the remaining outer module

F Disks

Present studies indicate that the loss of one or two of the end F disks has slightly less impact on the physics capability than the loss of all the interior disks. The support for disks 2 & 11 is structural. Therefore the likely order in which F disks would be omitted is (3 & 10) followed by (1 & 12). We continue efforts to understand the physics impact of these choices, and may refine this ordering in the light of simulation results. We also note that disks (1 & 12) carry radiation monitors and some modest re-engineering would be needed if they were to be omitted.

H Disks

The H disks are only a minor schedule risk nevertheless, if there is a conflict, they will be assigned the least importance of all the detector species.

Readout Testing & Commissioning

The nominal schedule provides significant time for readout and testing of each completed module, barrel, F-Disk and H-disk. As experience is gained and in the light of schedule evolution, the extent of this testing will be reviewed and minimized. It cannot be reduced to zero: there is likely a minimal functionality test below which the risk becomes excessive of installing elements which would endanger the functionality of the detector.

Critical Dates for Silicon

- **June 1, 2000.** Review the status of the production so as to project the likelihood of completion of the first half-cylinder (SMT-S) by August 1. Consider whether both detector and module assembly status is satisfactory. If so, defer discussion until July 1. If less than three F-disks are complete, we will discuss and decide whether or not to use the 1 month contingency deferring arrival at DAB until September 1. At the same time consider whether it is necessary to reduce the F disk complement in order to satisfy September 1 arrival at DAB. If it is already clear that the F-disk complement cannot be satisfied, we will reduce the number to ten.

- **July 1, 2000**. Again review the status of the production so as to project the likelihood of completion of SMT-S by August 1. Consider whether both detector and module assembly status is satisfactory. If less than two barrels, and/or less than 3 F-disks are complete, we will decide whether or not to defer arrival at DAB until October 1. If three F-disks are not yet complete, we will reduce the F-disk complement to ten.

- **August 1, 2000 (If necessary).** Review the status of the production so as to project the likelihood of completion of SMT-S by October 1, 2000. Consider whether the detector and module assembly status is satisfactory for an October 1 delivery to DAB. If a disk assembly rate of two disks per month is not being maintained, consider further reductions in the complement of F-disks.

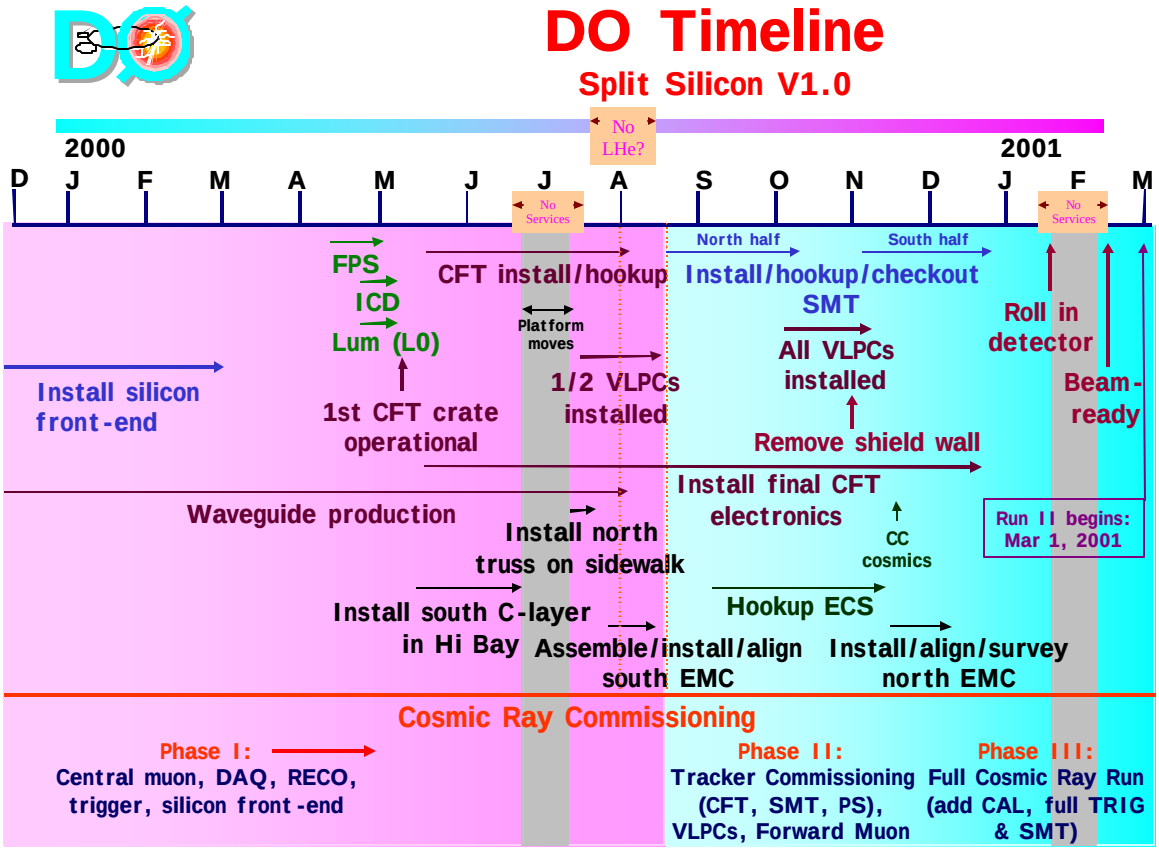
- **September 1, 2000.** If the first half-cylinder is not yet complete, we will reconsider the layout of the complete SMT and reconfigure it, so that SMT-S will be available for installation no later than November 1, 2000, and so that SMT-S and SMT-N will be symmetric. If less than seven F-disks are complete, we will again consider a reduction in the complement of F-disks.

- **October 1, 2000.** Review the status of the production so as to project the likelihood of completion of the second half-cylinder (SMT-N) by November 1. Consider whether both detector and module assembly status is satisfactory. If not, decide whether to use the 1 month contingency deferring arrival at DAB until December 1, 2000.

- **November 1, 2000 (If necessary).** Review the status of the production. If less than five barrels and/or seven disks are complete, consider whether to defer the installation of the second half-cylinder until January 2001, or after the detector platform has been rolled into the collision hall. Consider whether it is necessary to further reduce the F disk complement, beyond that required to symmetrize the detector based on the contents of the first half-cylinder, in order to meet January installation.

The above information is also presented in table form at the end of this document. In that table we also indicate what the silicon schedule predicts in terms of production at each of these dates and what the conditions are for triggering the above described actions.

3. Installation



Our current baseline installation schedule is shown above. It incorporates the split-silicon design, which we are pursuing as our primary option. Most of the technical hurdles associated with this design have been looked at in some depth, and we are currently finalizing and fully fleshing out the engineering details. Nothing we have seen to date - related to its internal construction or alignment, the installation constraints, or associated installation fall-back schemes - leads us to believe that there are any serious impediments to splitting the silicon detector.

The current date for delivery of the first (north) half of the silicon detector (SMT-S) to D0 for installation is **August 1, 2000**. We believe it would be imprudent to bring this highly sensitive (and expensive) item into the assembly area and install it during the time that the south EMC truss is being rolled into the Collision Hall for placement prior to the commissioning run. We are therefore planning to install SMT-S after the south truss installation in the Collision Hall is complete and the Collision Hall wall is back up (currently August 21, 2000). The completion date for the SMT-S remains August 1, however, and we intend to use the additional time for further testing of the detector at SiDet or, if needed, schedule contingency for detector comp letion.

In general, our scheduling has taken into account the boundary condition that neither half of the silicon detector be installed concurrently with the movement of any nearby large detector elements or infrastructure parts (muon shielding elements, concrete shielding blocks, forward muon detector planes, etc.). Arrival of SMT-S at D0 after **September 1** would require that installation of the south B-layer forward muon MDTs, now scheduled to begin September 6, be delayed until after the silicon is installed (September 15). This one week we feel we could absorb without any overall penalty but, if at all possible, we do not want to interrupt the installation of the B-layer once it has begun. Moreover, the arrival of the second half-cylinder (SMT-N) is scheduled for **November 1, 2000**. If late arrival of SMT-S requires

delaying installation of the B-layer muon detectors, the tail end of this muon installation would then coincide in time with the arrival and installation of SMT-N. Assuming that installation of the silicon would have priority under these circumstances, this would push the final installation of the B-layer detectors to the end of the installation cycle, and would leave us uncomfortably little contingency to complete their installation prior to roll in. This cascading effect, therefore, provides us with very strong motivation to deliver SMT-S no later than September 1.

Installation of the south muon truss in the collision hall

Movement of the platform is necessary in order to pick up the EF irons, which are currently on the north and south sidewalks. Such motion requires that all services be disconnected, and no work can be done on the platform itself or the remainder of the assembly pit area. In order to move the south truss into the Collision Hall by August 1, the following steps must be taken:

1. Fiber tracker is installed.
2. The south calorimeter is moved onto the platform.
3. Platform moves west to pick up both EF irons.
4. Platform returns east.
5. South truss, with detectors, is brought from the Hi Bay down to the (now cleared) south sidewalk and reassembled.
6. South truss is rolled on sidewalk into the Collision Hall.

Two conditions, therefore, must be met in order to realize this scenario in time for the 2-3 week window for truss installation, which begins **August 1**: the Fiber Tracker must have been installed (step 1), and the C-layer MDTs and pixels must have been installed on the south truss (condition for step 5). In order to meet this August 1 deadline for installation of the south muon truss, the duration of the related tasks then dictates that: (1) the CFT arrive at D0 for installation no later than **June 15**, and (2) both layers of detector planes, and the attendant shielding, be installed on the south truss in the Hi Bay by **July 1**. If either of these conditions are not met, we will not install the south truss during August, and will instead put it in the Collision Hall nearer the end of the installation cycle. The options for this are discussed in more detail later in this document. The decision about whether to move the truss in during August must be made before **June 1**. This date gives us ample time to prepare for the platform move, along with the other time- and manpower-intensive activities that would follow. We have consulted with the Beams Division about this decision date, and they have assured us that none of their constraints demand that this decision be made any earlier. Of course, should the construction rate of either the CFT or Forward Muon sub-projects falter between now and then in a manner that allows us to decide that going in early would not be appropriate, we will do so as early as possible. However, we are currently on track to meet these deadlines in both sub-projects, and are proceeding with this as our primary scenario for the June-August time period.

Fallbacks for early truss installation

If circumstances unfold in such a way that early truss installation in the collision hall is not a viable alternative, there are two options depending on the arrival date of SMT-S:

1. Move platform west to pick up EF irons before arrival of SMT-S
2. Move platform west to pick up EF irons after the arrival of the SMT-S

The decision date for this is around **July 1** and the advantages and disadvantages are discussed next.

The major remaining motivation for moving the platform would be the installation of the north truss (and perhaps the south truss – see below) onto the sidewalk from the Hi Bay. There are substantive gains (accesses, fixes, etc.) to installing the G-layer detectors while the trusses are on the sidewalk in the Assembly Pit. Also, the sidewalk is the only place in the Assembly Hall where there is enough vertical

height for the full trusses to be assembled (only half-truss elements can be assembled in the Hi Bay).

Although both of these objects have already been fully assembled and surveyed at Lab G, it would clearly to be to our advantage to put both objects together as soon as possible in DAB, confronting any potential problems as quickly as possible.

At the moment, the north C-layer detectors will be ready for installation in mid-July, which motivates our intention to have the north truss on the sidewalk by this time. However, should the design or fabrication of detector mounting hardware or construction of the C-layer MDTs become delayed, it would be to our advantage to wait the month or so for SMT-S to be installed before bringing the north truss down to the sidewalk. This wait would eliminate an additional move of the platform if the fall-back SMT-S installation scheme needs to be implemented. In fact, it might be to our advantage to wait in any case, as the silicon could be installed earlier (immediately after its arrival on August 1) in this case, because there is no need to wait until mid-August when the truss is installed. We feel that, should we opt not to install the south truss early, the decision to move the platform and install the north truss on the sidewalk prior to, or after, the north silicon half-cylinder arrives needs to be made by **July 1**. This leaves us 4 weeks to prepare for the platform move, disassemble the north truss in the Hi Bay, and reassemble it on the north sidewalk.

Forward Muon Installation

The optimization of our installation schedule has dictated a specific installation sequence for the Forward Muon detectors: the A-layer is installed first, followed by the C-layer, with the B-layer being installed last. There are a number of reasons for this choice:

1. The A-layer detectors have been completed for some time, and are ready for installation at DAB.
2. The A layer faces of the north and south end irons, as they are perched on the sidewalk, are as accessible as they will ever be in any other configuration. Once it becomes advantageous to move one or both of the irons onto the platform, this open configuration will disappear. The A-layer can still be installed under these circumstances, but the tighter space constraints complicate the operation enough that we feel it sensible to try to do it earlier rather than later.
3. We believe that, unlike the other layers, the B-layer detectors can be installed in the Collision Hall using a specially designed installation cart and supporting the lifting off of the EF iron. We therefore have opted to install the B-layer last with the understanding that, should we fail to complete it, we would roll in to the Collision Hall and install the B-layer detectors during a scheduled shutdown.
4. Independent of whether the C-layer detectors are mounted, the trusses support the low-beta quadrupoles and an extensive amount of the forward muon shielding that is needed for the associated Run 2 physics program. We therefore must install the trusses, and have placed the C-layer installation ahead of the B-layer installation for this reason as well.

We can see no sensible evolution of the schedule that would prompt us to reconsider this order. That is, if the A-layer installation is delayed, we cannot foresee any set of circumstances that would make redirecting the engineering and technical resources toward either the C-layer or the B-layer instead. Much of the engineering and technical considerations for installation in the Forward Muon system is common to the three layers; we feel that concentrating on solving the problems of the A-layer will help us with the subsequent C- and B-layer mounting. Diverting the resources to subsequent layers if difficulties are faced in a precursor layer will only delay the total time of the operation, and is destined to be very inefficient. Moreover, as has already been mentioned, the installation ordering of these layers has been chosen in order to interleave properly with our overall installation plan, the global dynamics of which we do not expect to change.

Installation of the silicon detector

The flexibility of the split-silicon detector offers truly palpable advantages. Should we install the south truss early, we would end up after this move with the shield wall up and the detector in its east-most position. Both end irons and both calorimeters would be on the platform. The silicon would be ready to install on **August 21**, after the truss is moved into the Collision Hall (see above). Unlike the CFT and the previous full-cylinder silicon design, which both require(d) that the south calorimeter be off the platform in order that a large (~ 18') gap be made available for their installation into the bore, the silicon half-cylinders have been designed to fit in the maximum gap of 39" that is available between the cryostats while they are on the platform. This means that no additional move of the platform is needed after the truss is installed, which previously would have been required in order to remove the south iron onto the south sidewalk, and remove the south calorimeter to create the additional space. The platform will then have to move only once after this period: when it is ready to move into the Collision Hall. We mention that all associated commissioning of the experiment can continue uninterrupted between August and the December/January time frame as well – no disruption of services to the platform occurs until near the end of the installation cycle, which is the optimum time for this to happen.

Final placement of the end irons onto the platform will occur during the first half of August. This allows the B-layer forward muon detectors – MDTs and pixels – to be installed in the most accessible configuration available. The space to the rear of each of the end irons is not restricted in any way, and crane access is open. The split silicon option allows us to be in this configuration, without interruption, for 5-6 months prior to roll-in. In the previous version, where the silicon was being installed in one piece, the south end iron was on the platform only briefly (Scheme I) or not at all (Scheme II). In this case, the installation of the south B-layer detectors would have had to be done while the south end iron was on the platform. Because of interferences with the catwalk overhead, additional engineering and construction would have been required in order to create additional space between the rear of the south iron and the south wall of the Assembly Pit. The split-silicon option obviates the need for such additional work.

We point out here that our decision to pick up both end irons during the installation of the south truss is the result of a collective, carefully weighed cost/benefit assessment. We have considered the viability of silicon half-cylinder installation and feel that the gains, some of which we've already discussed, are well worth any risk that will be incurred.

Fall-backs for Silicon Installation

As mentioned above, the half-cylinders of silicon must be installed through a fairly tight gap, between the central and endcap calorimeters, that is populated by delicate fiber waveguides and detectors mounted on the end calorimeters during installation. In the unlikely event that we do not complete both halves of the silicon in time for roll-in, the same 39" gap between the calorimeters is available for silicon installation in the Collision Hall. We are designing a rail system for support and guidance of the half-cylinder as it is brought in between the central muon irons and calorimeters and put in place within the bore of the CFT. Setting up this rail system will be somewhat more difficult in the Collision Hall, but there are no likely insurmountable hurdles.

The current schedule has SMT-N arriving to DAB for installation on **November 1.** In order to ensure that we have enough time for final hook-up and getting the detector ready for running and physics, the latest date that we will move the detector into the Collision Hall is **mid-January**. In order to prevent impeding the roll-in, and taking into account other activities in the Assembly Hall that will have to cease during arrival and installation of SMT-N, the latest we feel that the full chain of installation, hookup, and checkout of SMT-N could be accommodated is **December 1**. This would leave approximately one month for

hookup of SMT-N (SMT-S will already have been hooked up and read out), as well as the readout of both halves of the silicon in concert.

We are leaving open the option of installing SMT-N into the barrel of the CFT without hooking it up, if time grows too short. The latest date at which this might occur is **December 15**. Allowing contingency for unforeseen problems, this is the latest date at which we could install it without any danger of affecting the roll-in.

We could provide more contingency for the installation of SMT-N by installing the detector into the Collision Hall early (say, mid-December), and opting to install the silicon last while the platform is being hooked up in the Collision Hall. The date to decide on whether to roll in early would be **December 1**. We feel, however, that we are better off using the amount of flexibility that the split silicon provides by optimizing the installation and hookup of the detectors that are in place by that time, and installing the second half-cylinder of silicon during an appropriately scheduled shutdown. We feel that a shutdown of 2 months would offer us enough time to install and hookup the silicon while in the Collision Hall.

Summary of important dates for SMT production

Date	Schedule	Action Trigger	Actions
By 6/1	*Schedule: 2 Barrels, 4 F disks complete*		Review likelihood of SMT-S installation by 8/1/00. Consider early reduction of F disk complement if 3 disks are not complete
By 7/1	*Schedule: 3 Barrels, 5 F disks complete*	<2 barrels <3 F disks	If two barrels are not complete: Delay SMT-S installation date to ~10/1/00. If 3 F disks are not complete reduce F disk complement by two to 10.
By 8/1	*Schedule: 4 barrels, 7 F disks complete, SMT South ready for delivery*		Review SMT-S installation date. Consider further F disk reductions if an assembly rate of two disks/month is not achieved.
By 9/1	*Schedule: 5 barrels, 10 F disks complete*	SMT-S incomplete <7 F disks	If SMT-S is not complete: Reduce detector complement to ensure that SMT-S will be installed by 11/1/00 and SMT-N and S are symmetric. Consider F disk reduction.
By 10/1	*Schedule: 6 Barrels, 11 F disks complete*		Review date for SMT-N installation. If necessary delay arrival at DAB until 12/1/00
By 11/1	*Schedule: 6 Barrels, 12 F disks complete, SMT North ready for delivery*	<5 barrels <10 F disks	Delay SMT-N arrival at DAB until January 2001 or after roll-in.

Summary of important dates for installation

June 1, 2000	Decision on whether to install south muon truss in collision hall during August.
June 15	Latest date for CFT to DØ (consistent with August truss installation)
July 1	Muon detector planes and shielding must be installed on south truss (for August installation). If south muon truss will not be installed in collision hall, decide whether to move platform before or after SMT-S arrival at DØ.
August 1	Baseline date for north half silicon detector (SMT-S) to DØ; start south muon truss installation in collision hall.
August 21	South truss installation in collision hall completed.
September 1	Fallback date for delivery of SMT-S to DØ. Attempt to install from north end; if not possible, install from south end.
November 1	Baseline date for north half silicon detector (SMT-N) to DØ. Latest possible date for SMT-S at DØ. Install north truss in collision hall.
December 1	Decide whether to move into collision hall by December 15 or remain with default schedule.
December 15	Latest date for SMT-N to DØ (consistent with installation before roll-in).
January 15, 2001	Latest date for detector to roll into collision hall.
March 1, 2001	Run II begins.

Conclusion

We believe that the above plan provides for a rational approach to fabrication, assembly and installation of the DØ detector for March 1, 2001.