STATUS REPORT ON THE SURVEY AND ALIGNMENT EFFORTS AT FERMILAB

Terry M. Sager
Fermi National Accelerator Laboratory, Batavia, Illinois, USA

1. INTRODUCTION

With the successful completion of the fixed target run on September 15, 1997, the Main Ring was shut down for the last time. This event marked the beginning of the final stage in the construction of its replacement ring, the Fermilab Main Injector (FMI). An added burden to an already ambitious schedule is the addition of a second beamline that will share the FMI tunnel. This new beamline is called the Recycler Ring which will use permanent magnet technology to store anti-protons. It will be installed and commissioned concurrently with the FMI. This paper presents an overview of the schedule, the progress of the alignment of the FMI, and near term projects.

2. FERMILAB SCHEDULE

The current schedule is as follows: [1]

October 1997	Start F0 construction (demolition) to link the FMI with the Tevatron.
March 1998	Start half turn commissioning of the Main Injector.
June 1998	Main Injector under vacuum, start full turn commissioning.
Summer 1998	Recycler under vacuum, start commissioning.
July 1998	Start F0 beamline reinstallation and installation of FMI/TeV transfer lines.
September 1998	Start Tevatron cooldown.
November 1998	Complete F0 construction. Start delivery of beam to the Tevatron. Parasitic commissioning of the remaining beamlines.
January 1999	Complete Recycler installation and commissioning.
March 1999	Project complete.

3. FERMILAB MAIN INJECTOR AND RECYCLER RING

As a prerequisite for all other FMI alignment activity, a double stereographic mapping projection was defined across the expanse of the project. The earth parameters for the projection were supplied by our geodesists to the College of London, where, under contract, a program was developed to allow beamline lattices to be translated into the several coordinate systems necessary. We invite you to visit our web site at http://www-rd.fnal.gov/~alignweb/align.html to see the documentation on the Fermilab Coordinate Systems [2] and the Lattice Program [3] developed by the College of London.

In November of 1996, what we hope is the last external horizontal control network was completed. This of course will depend on what we see as we continue to monitor the vertical deformation around the ring. One internal laser tracker network around the ring was completed in August 1996. All indications from this network adjustment show that with minor modifications to our procedures, we can achieve the required alignment tolerances. My colleagues will be presenting a more in-depth look at these accomplishments later in this workshop.

At this time, nearly all of the 344 dipoles have been installed and pre-aligned with optical tooling techniques. The pre-alignment became an unscheduled necessity when it was learned that the bypass buss could not be installed if later final alignment moved the magnets more than +/- 3mm. In hindsight, I would opt to do this anyway. It provides us with one iteration of redundant measurements. We now know that during laser tracker final alignment, we should not have to move the magnets by more than the final adjusted control moved. It gives us a very good envelope for error control. The 80 new quadrupoles are being installed and pre-aligned and 128 quadrupoles that are required from the main ring are now being removed and reworked for their new home in the FMI. Testing of our magnet alignment software and procedure is now complete. We have successfully aligned a string of 30 dipoles and quads in the MI30 region using the laser tracker, the One Fixed - Four Random (1F4R) fiducialization system, and a modified procedure from that presented in Japan in 1995. [4] It was found during testing that attempting a nine magnet string measurement (~40m volume) from one tracker setup was not efficient and did not yield any useful precision outside of the three magnets directly adjacent to the tracker (~20m volume). We have now redefined our procedure and can at this time declare ourselves ready for the final alignment process. This change in procedure will require another laser tracker internal network, coming on the heels of the final alignment, incorporating the center ‘E’ lug of each magnet in the bundle adjustment. By this method, we will be able to perform a smoothing survey.

The 8GeV line is now 80% installed and aligned. This line utilizes permanent magnets, chosen to gain experience with the technology under consideration for the Recycler Ring. On February 20, 1997 beam was observed at the entrance to a temporary dump situated two-thirds of the way down the beamline after two hours of tuning. [1]

The success of the 8GeV line prompted the approval to construct the 3319m 8GeV Recycler Ring just above the conventional magnets of the FMI using the same tunnel. The Recycler Ring will be aligned conventionally using the same control as the FMI. Once commissioning is complete, a laser tracker as-found of the ring will be performed.

The transfer line region now under construction between the Tevatron and the FMI remains our biggest challenge. The limited space, beamlines that must spiral like roller coasters to interact with other beamlines and the time constraints, will make alignment very difficult.

3. COLLIDER UPGRADES

During the next two years, both of the Fermilab Colliders (CDF and D0) will undergo major upgrades in order to take advantage of the increased performance (luminosity) that the FMI will provide. Just now underway, each project has elevated its demand for precision to the very threshold of our in-house instrumentation capabilities. Much effort has poured into a new facility at Fermilab called the Silicon Detector Facility. It houses several CMM machines that will have the responsibility for referencing all the components that can be contained within there limited measurement area and transfer that information to the alignment fiducials. The problem however becomes logistical when you have huge components being machined around the world. One cannot easily move a big CMM efficiently to QC a machined part, and big CMM machines are not readily available. The solution seems to be to request that the alignment group go to the part and measure it to within 50 microns or better with whatever tools are available to us. For this reason, we are exploring every instrument that can achieve these accuracies and yet be mobile and efficient. Systems such as videogrammetry, multiple axis laser alignment devices, and laser tracker technology seem to hold the greatest promise.

In addition to these upgrades, a new collider detector facility will be constructed during this shutdown at C0 TeV. Our alignment involvement for this project will take shape over the next several months.

4. NEAR TERM PROJECTS

During the next three to five years, several major projects will impact our alignment resources.

4.1 NUMI

The long baseline neutrino experiments (NUMI) emanating from the FMI will have both close (COSMOS) and far (MINOS) detectors. The MINOS detector is 730km distant. To hit the target will require the equivalent of pointing a rifle 7km and hitting a target within a 15m area.

4.2 CMS

The Compact Muon Solenoid for the LHC project at CERN will require tolerances that are routinely in the 50 micron range. We are only now beginning to enjoy these challenges.

4.3 Pierre Auger

The Pierre Auger experiment will be the largest detector ever built. The northern hemisphere site in Utah will cover an area bigger than the state of Rhode Island to collect cosmic rays. The southern hemisphere site will be equally as large. Some 1600 detectors measuring 3m will be placed in a designed pattern. The ~1m alignment tolerance for placement of the detectors is very achievable, however the shear size of this project and its remoteness makes it especially time consuming and logistically difficult. GPS will certainly be the instrument of choice here.

REFERENCES

[1] Stephen D. Holmes, Status of the Fermilab Main Injector and Recycler. FERMILAB-conf-97/298, August 1997.

[2] Babatunde O'Sheg Oshinowo, et al., Fermilab Coordinate Systems.

[3] Mark Jones, John Iliff, et al., Lattice Program.

[4] Virgil Bocean, Babatunde O'Sheg Oshinowo, Terry M. Sager, Survey and Alignment Overview: Fermilab Main Injector Ring. Proceedings of the 5th International Workshop on Accelerator Alignment, 1995.