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Three-Dimensional Laser Scanner

Field Evaluation Specifications

Metrology Department

Alignment Engineering Group

Introduction

The specifications document[1] describes three tests which will be used to evaluate the proposed laser scanners. This document provides details for carrying out these tests and for the evaluation of the data yielded from these tests.

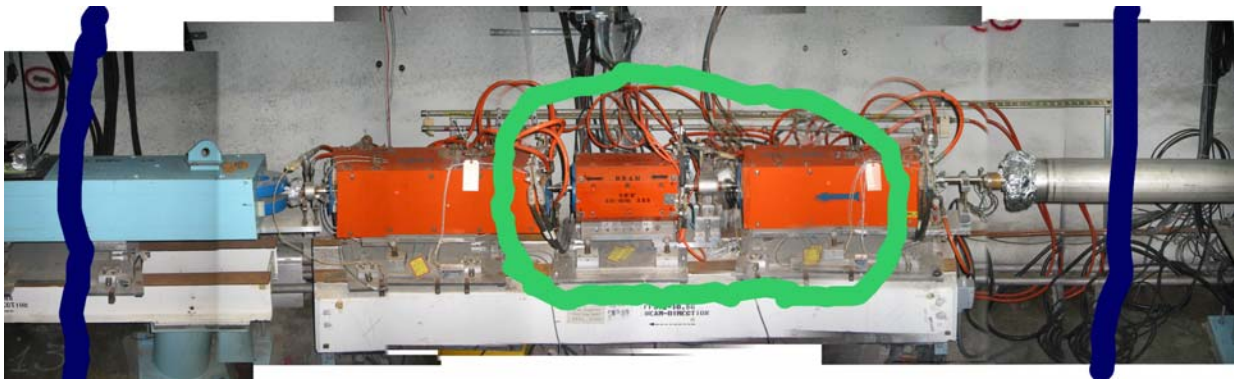
1.0 Test 1: Tunnel Test

The specifications document on page 5 defines Test 1 as follows:
The field testing and evaluation of the laser scanner will include a scan of an area at the Stanford Linear Accelerator Center such as a tunnel in which magnets and other typical components are present. The scan will include measurements of control points that have a common datum with existing Alignment Engineering Group control monuments. This will ensure that the laser scans can be integrated with existing and new surveying control data for a positional tie to an existing network datum. The three-dimensional scans will have the ability to be overlapped and connected due to the unique geometry of the tunnel having a limited width but substantial length.

More specifically, the location of the test will be most likely at a section of the beamline in the South Final Focus of the Stanford Linear Collider. It will be around 10 meters long and comprise at least three unique magnets plus a BPM (Beam Position Monitor) and a collimator. Scanner coverage will also include the existing pipes, wires and hoses as well as the walls in the region.
The classical tooling used at the Stanford Linear Accelerator Center consists of a series of 1½" diameter steel spheres. They are placed on a nest (also known as a Hubbs Cup) that itself fits into a ¼" hole located on a component. With this setting, the center of the sphere is straight over the axis of the ¼" hole at a height offset of exactly 1". For use with the laser scanner, the steel spheres will be painted or preferably plated for optimal scanning reflectivity. The Stanford Linear Accelerator Center will supply these for the test. The steel spheres will be mounted on all accessible ¼" holes for each magnet as well as on the tunnel walls. The tunnel is approximately 3 meters in width and height and the walls are made of shotcrete. The beamline is located closer to one wall and is on a girder approximately 1 meter wide and 1.5 meters high. Testing in this area will ensure that this typical tunnel geometry—including the minimum range requirements describe in Section 2—can be adequately covered with the candidate laser scanner.

1.1 Area to be scanned

The tunnel test will be carried out in the Final Focus section of the now defunct Stanford Linear Collider (SLC). Scanner coverage shall include the girder components as marked in Picture 1 and include any ceiling components, existing pipes, wires, hoses and the walls.



Picture 1: Horizontal demarcation of scanning area and area of special interest

This task should be performed in several scans. SLAC will deliver 3D-coordinates of fiducial points (see table 1), which can be signaled with 1.5" spheres (as described in the specifications).

[1] "*Three Dimensional Laser Scanner – Technical Specifications & Field Evaluation*" written by Brian Fuss and Catherine LeCocq (March, 31, 2004, SLAC).

Control Points

	X (m)	Y (m)	Z (m)
SFF100	-1.04122	3.32052	0.00000
SFF101	0.00000	0.00000	0.00000
SFF110	4.86881	2.92082	1.04662
SFF111	4.91552	0.00000	0.00000
Wall1	0.86664	0.00317	-0.02538
Wall2	0.66190	3.13373	0.54917
Wall3	2.99436	0.03580	-0.02998
Wall4	3.01430	3.18348	0.65448
Girder1	0.41585	1.55212	-0.64174
Girder2	3.50098	1.42697	-0.50846

Test Points

GS48QU1B
GS48QU1C
GS48QU1D

GS48SQ1A
GS48SQ1B
GS48SQ1C
GS48SQ1D
GS48SQ1E

GS48QU2B
GS48QU2D
GS48QU21
GS48QU22
GS48QU2G

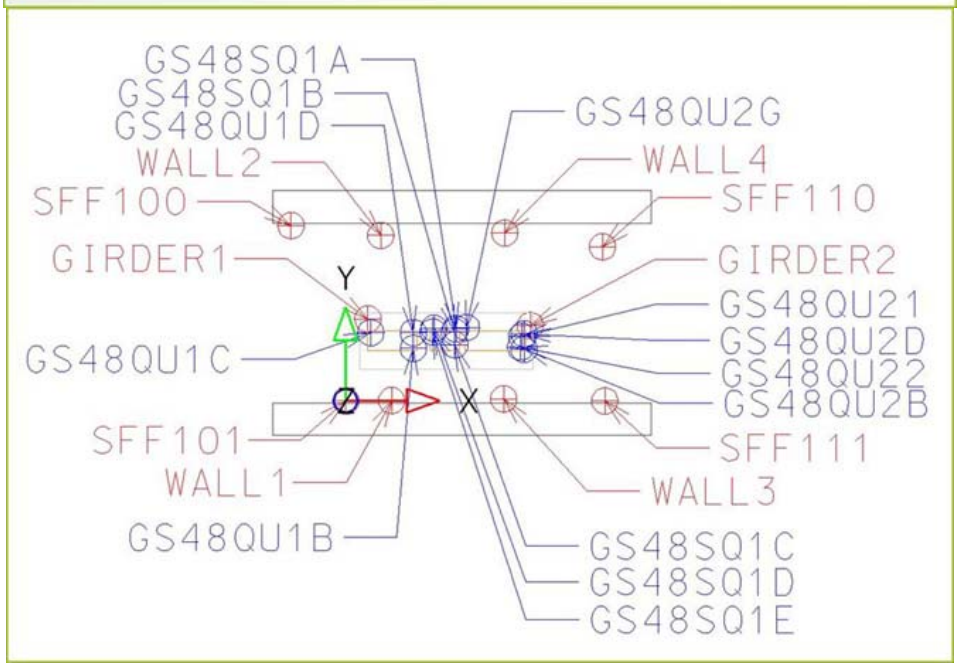


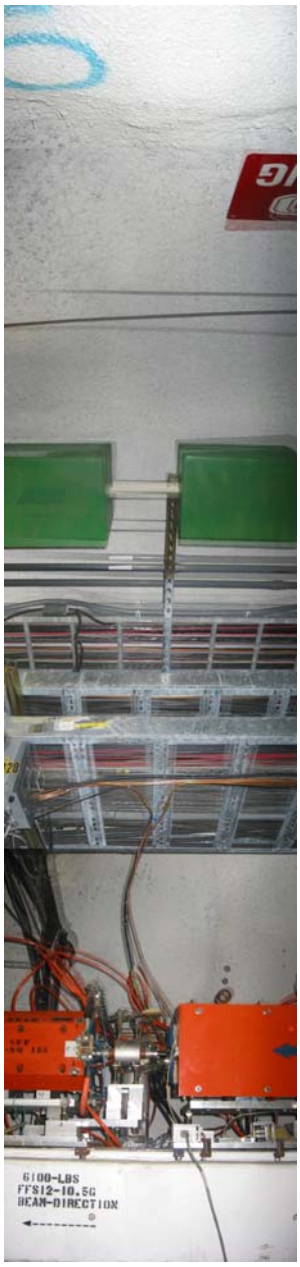
Table 1 Fiducial Point Coordinates and Lay-out

The vendor shall carry out the registration of the individual scans and the analysis of the data. As part of the test, the vendor shall demonstrate the "Ease-of-use" and functionality of the proposed software for data acquisition, data handling (simultaneous loading of multiple scans into memory for registration) and data modeling. Additionally, the vendor shall deliver the whole model (all scans brought to the global system, as defined by the control points) in ASCII-format for independent analysis.

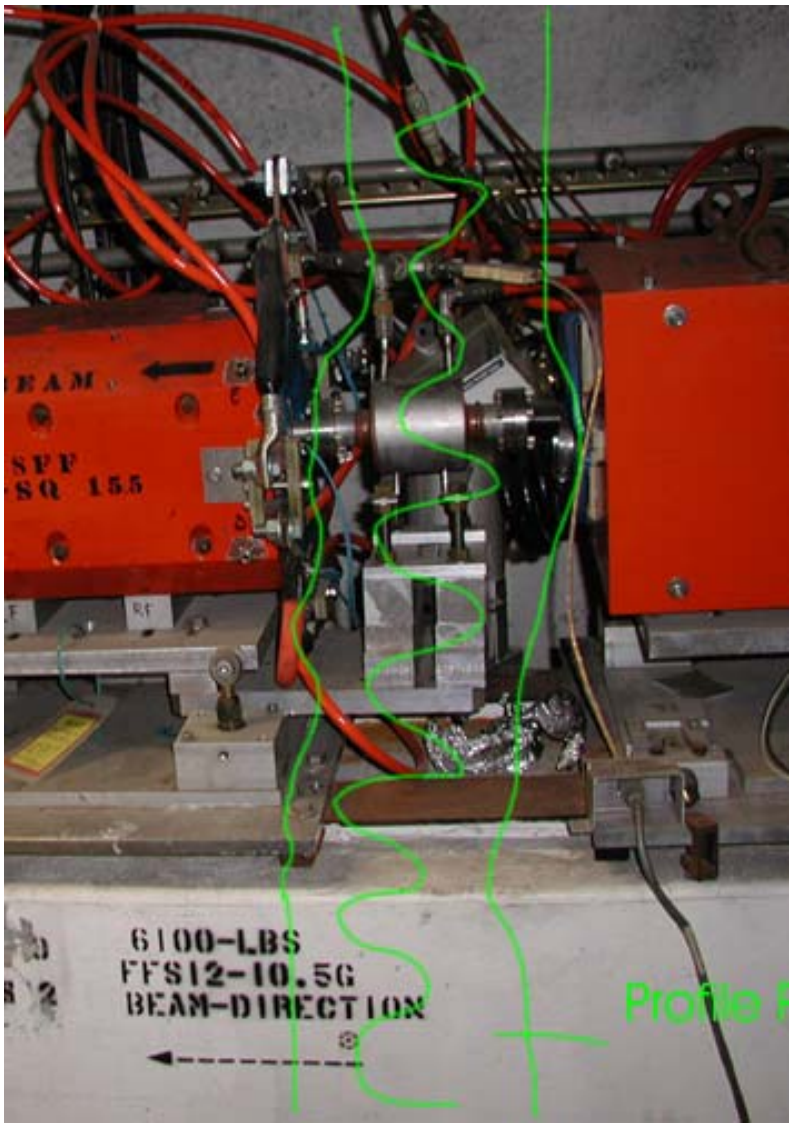
The evaluation of the measurement results will focus on the Completeness, the Level-of-Detail (LOD) and the Geometrical Trueness. To evaluate the laser scanner data against these criteria, but at the same time keep the data analysis manageable, the measurements shall emphasize on the areas of specific interest as described below.

1.2 Areas of specific interest

From the point cloud, three areas of specific interest will be selected and treated according to the above mentioned criteria. The areas selected are two vertical profiles (P1 and P2), perpendicular to the tunnel axis, and the area A indicated by the green boundary line in Picture 1. The profiles will be marked by spray paint to facilitate the easy identification of the profiles in the point cloud. Pictures 2 and 3 show the Profile 1 area in more detail.



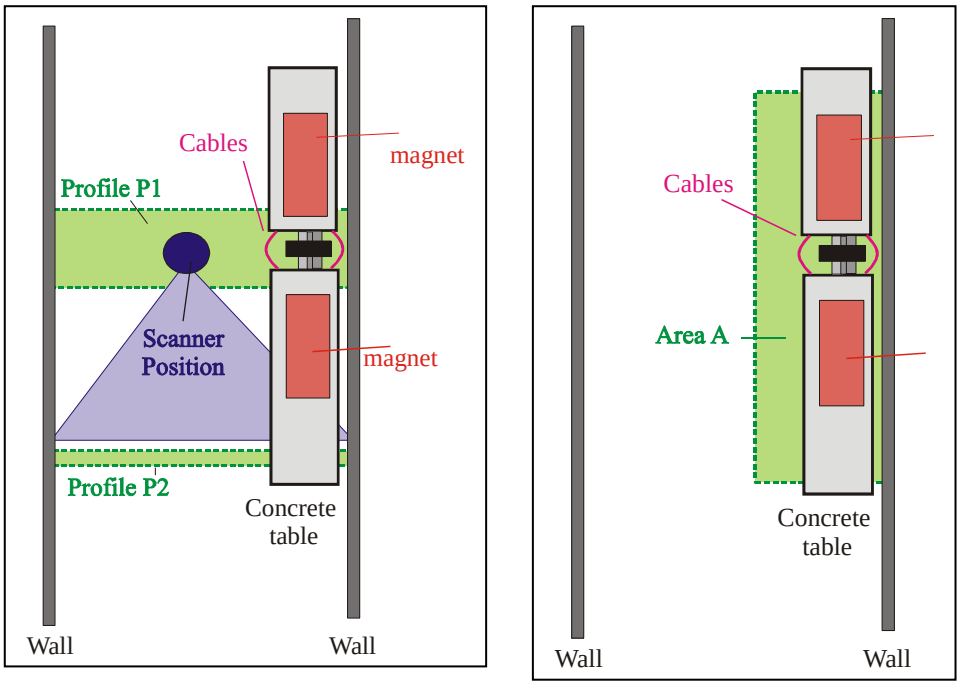
Picture 2: 270º View of Profile 1 Area



Picture 3 Collimator between two magnets

P1 is approx. 30-50 cm wide. Inside the shown area the LOD and the Completeness will be investigated. In the rest of the complete Profile P1, the geometrical deviations from the true geometry of the tunnel and ceiling mounted components (there are two magnets suspended from the ceiling) will be analyzed. In order to acquire all the relevant details (Pic. 3) the scanner has to be positioned in the vertical profile. If the tested scanner is restricted in the vertical measurement range, the vendor should propose solutions for digitizing the “space” between the magnets and overhead.

A second vertical Profile P2 will be selected. P2 is small (compared to P1) and 3 to 4 m away from P1. The analysis of P2 will be done with the point cloud acquired from the position “in” P1. In this configuration a profile from an “off-the-profile-scan-position” will be evaluated which is the standard case in long-tunnel objects like accelerator tunnels.



1.2 Data Evaluation

1.2.1 General Data Analysis

Geometrical trueness is evaluated by comparing the local (global) scanner coordinates with their nominal values. A set of well distributed known points (see table 1) is to be used as “identical points” for the local-to-global transformation of the point cloud(s). The coordinates of these points are given and based on these coordinates a transformation into the beam-line-coordinate-system is to be performed. The unknown fiducial points (as listed in Table 1, test points) signaled with 1.5” spheres should be scanned and determined. In order to investigate the quality of the registration, some of the test points will be signaled only for the first scan and others only for the subsequent ones.

The following information should be extracted from the point cloud:

- Coordinates of fiducial
- Diameter of spheres signaling the fiducial points

1.2.2 Area A

In Area A several objects are selected and calculated to check for repeatability, i.e. consistency within the point cloud and resulting geometrical trueness. These tests will be performed using Magnet M, which is the red object on the very right in Picture 3. The top, side and end plane should be intersected to determine the coordinates of the visible corners. Additionally, the diameter and the length of the collimator (the stainless steel cylinder to the left of Magnet M) should be determined.

1.2.3 Profile P1

In P1 the Level of Detail (LOD) will be investigated. The criteria are:

- completeness
- resolution (density of the point cloud)
- perturbations in the point cloud by total reflections and other optical deviations
- geometry (position, size, orientation) of some objects.

The comparison will be done by visual inspection and by different extractions from the point cloud (section, cross sections, etc…)

1.2.4 Profile P2

P2 is a small profile (compared to P1). The main criteria here are the deviation of the point cloud from the real tunnel (wall or inventory), i.e. geometrical trueness and the completeness of the entire profile. The evaluation will be done by comparing to the known profile, by visual inspection, and by different extractions from the point cloud (section, cross sections, etc…)

2.0 Test 2: Building Test

This test is designed to test and evaluate the range of the scanner and the flexibility of the whole measurement equipment.

Test Location

For part one of this test, the left two sections of the north facade of Bldg 26 (see Pic. 4) shall be scanned with the roll-up door leading into the alignment laboratory opened. Subsequently, the interior of the alignment lab (see Pic. 5) is to be scanned such that the exterior and interior scans can be registered. The interior scan should yield a floor plan of the laboratory. No control points are provided.

Picture 4 Building 26 Facade

Picture 5 Interior Room Scan Area

3.0 Test 3: Accuracy Test

3.1 Test Location

All tests will be carried out in the “Sector 10” Calibration Laboratory.

3.2 Tests to be performed

Eleven sphere mounts with 1.5” spheres are attached to the East facing wall of the laboratory at about 1.8 m height. This test field will be scanned from different positions. Additionally, a resolution target is to be scanned at three different distances.

3.2.1 Horizontal relative distance test

The scanner will be placed in the “prolongation” of the line of spheres (Pos. 3.2.1). From this position all targets are to be measured in one scan.

3.2.2 Horizontal absolute distance test

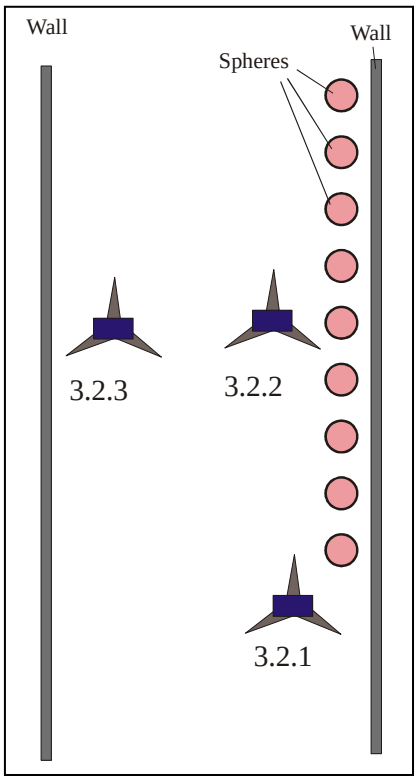
The scanner will be placed in the middle of the test field, very close to the line of spheres (Pos. 3.2.2). From this position all targets are to be measured in one scan.

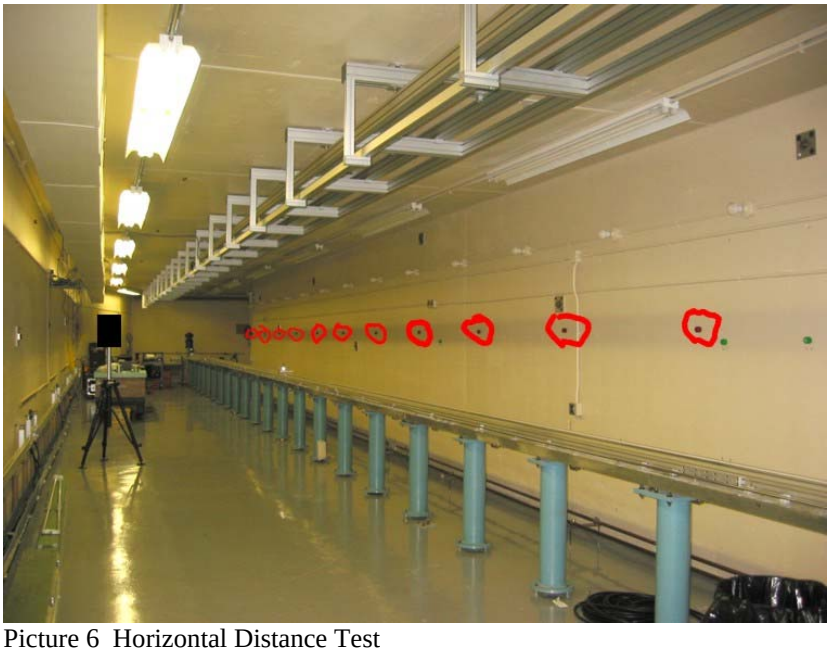
3.2.3 Horizontal Angle test

The scanner will be placed in the middle of the test field, as far away as possible from the line of spheres (Pos. 3.2.3). From this position all targets are to be measured in one scan.

3.2.4 Vertical Angle test

Seven sphere mounts have been mounted to the wall about equally spaced along a vertical line. The scanner shall be set-up with an instrument height of about 1.5 m close to the opposite wall. From this position, the instrument should scan all seven spheres.





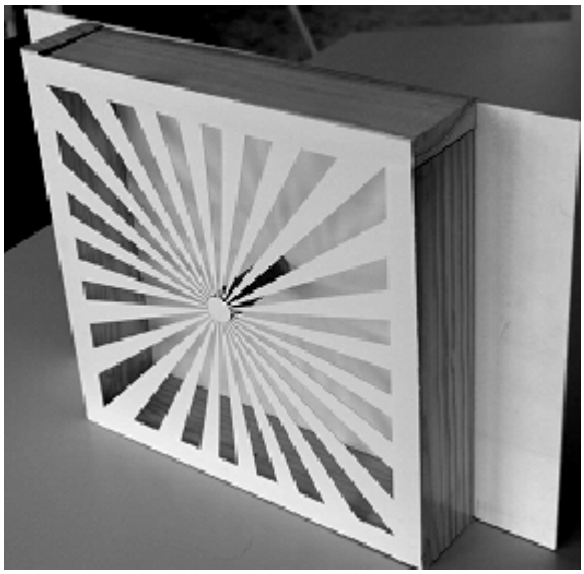
Picture 6 Horizontal Distance Test

Picture 7 Vert. Distance Test

3.3 Resolution

The resolution test uses a target as proposed by Dr. Boehler from the i3mainz group. The front panel has slots which are about 30 mm wide at the outside becoming smaller towards the center. If a scanner has a high resolution (small angular increments and a small laser spot) there should be reflections not only from the front panel but also from the bottom of the box which is about 60 mm behind the front panel. If the resolution is very good, these reflections from the bottom should not

only be present in the outer regions but also near the center. This target shall be scanned to detect resolution information from three different distances, 3 m, 12 m, and 25 m.



3.4 Data evaluation

From each point cloud the position of each sphere should be determined in the local scanner coordinate system. Each determination has to be calculated with nominal and unknown radius. In the latter case the radius is also part of the result.