Surveying the Construction of Super Module 1

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Abstract

The survey of the far detector planes, to give a seed for locating the scintillator strip positions, used the Vulcan system. Related survey data provided continuing feedback on the erection of detector planes. Cumulative results from the surveys during SM1 construction will be presented, illustrating the drift of the planes east-west and up-down, the plane pitch and the warping of planes.

Introduction

The survey of the far detector was originally envisioned to determine the position of the scintillator module alignment holes in the detector frame of reference. This, along with the module mapping data, would provide an initial value for the scintillator strip positions, which will later be finalized with cosmic ray muon data. Markers on the planes were also surveyed, that could later be re surveyed with higher precision by FNAL to provide a comparison and perhaps calibration of the Vulcan survey measurements.

After erecting the first few planes, it become apparent that the Vulcan could also be used to provide feedback on plane to plane movements. In particular information was sought on the lateral drifts and warping of the planes. The eight bolts/holes of the collar and the eight axial bolts, (at the edge of the plane), were then included in the plane surveys. The collar points provided information on both the plane drift and pitch, whilst the axial bolt data was used for pitch only. Comparing the axial bolt and collar data also garners detail of plane warping. Later it was decided to survey a point on the support ears, from which each plane was hung, to give further detail on the warping of planes.

Feedback was provided weekly in the form of collar and axial bolt position plots which allowed the mine crew to successfully shim and grind the collar and axial bolts to keep the detector growing straightly. The cumulative plots for all the planes surveyed in SM1 will be presented in the memo.

The data presented in this memo has no implications for event reconstruction.

Coordinates and Conventions

The coordinate system that was used has already been documented (NuMI-NOTE-GEN-784). In this system +x is west, +y is up and +z is perpendicular to the planes in the approximate direction of the beam. Due to the location of the Vulcan transmitters and the plane being surveyed the measurements are most reliable in x and y and least in z. The coordinate system NuMI-NOTE-GEN-784 presents is based off FNAL survey data

collected in July 2001. The numbering system of the axial bolts and collar holes is the same. Both were numbered 1-8 increasing in the clockwise direction, with 1 closest to 1 o'clock all when facing south.

Recalibration

The Vulcan system was calibrated and then transformed to the coordinate system presented in NuMI-NOTE-GEN-784. The Vulcan occasionally needed to be recalibrated. This was done as infrequently as possible as recalibration introduces offsets in the calibrated coordinate system. The Vulcan would not be recalibrated until it stopped working when the detector became too close to the two laser transmitters. The transition from working normally to failing was abrupt ~ 0-3 planes of lower quality data before failure. This has been partially corrected for in the collar data. However, since the purpose of the construction data was to give feedback over the detector as it was built and not over the entire detector, these corrections are only needed to see detector wide trends. It was not until the latter stage of construction of SM1 that all the mine crew who surveyed were experienced on the procedure of recalibration, meaning that several planes might go un-surveyed until a proper recalibration could be done. The net effect of this is that correcting for offsets is more difficult then expected as surveys around the recalibration are unreliable.

Uncertainties and Errors

The uncertainty due to the survey in the module data is investigated in NuMI-NOTE-GEN-828. A 3-4 mm error in the x-y plane per point was estimated. Since the module points are similar in position to the axial bolts, survey lugs and to a lesser extent the ears a similar error for these points should be expected. The collar is in the middle of the plane and should do better then the other data sets. The error estimate in NuMI-NOTE-GEN-828 is based off the sigma from a gaussian fit to the data. In this note, only statistical errors from combining the survey data are plotted. The eight collar points are combined to give the x, y and z position of the center of the collar as follows:

- The error estimates involved 8 points
- These 8 points were paired off into 4 pairs of opposing points
- An average of the two points in the pair was determined
- From the 4 averages a standard deviation was calculated
- This standard deviation is stated to be the error

The eight axial bolt measurements for each plane are combined to give a single average z position of the axial bolts. An estimation of the error on these measurements was made by comparing the standard deviation of axial bolts positions with the average position of the plane they are on. When averaged over all 8 axial bolts over all planes a value of 5.5 mm was obtained.

Axial Bolt Data

The axial bolt measurements were used for a variety of tests. The average position was used to determine the pitch of the detector in the z-axis. The rods of axial bolts were also tested to verify that all eight rods were growing in z at the same rate. The mean rod z position was also compared with the mean collar position to verify the center of detector was growing at the same rate as the edge of the detector.

Results:
Plot 1 shows the growth of the detector in z. The pitch is 59.49 mm/plane. Plot 2 shows the variation of the 8 axial bolts when compared with the average of the 8 axial bolts. The few outlying points are due to surveyor/Vulcan error.

Collar Data

The collar measurements are unique in this data set as they are sensitive to movements of the center of the plane. All the other measurements are sensitive to movements at the outer fringe of the plane. The collar is also surveyed to verify that the tube, which holds the coil and cooling system, will fit in the bore.

Results:
Plot 3, Plot 4 and Plot 5 show the collar position in x, y and z versus plane respectively. The pitch is found to be 59.49 mm/plane (Plot 5), the same pitch as the axial bolts. Plot 3 and Plot 4 show the movement of the collar in x-y space. An attempt to correct for recalibration has been made in Plot 6 and Plot 7, by adding an offset to the plane surveys such that the points immediately before and after the recalibration agree. The adjustments were made for all recalibrations recorded in the survey log, although large jumps in these plots (e.g. at plane 22) indicate not all recalibrations were recorded. One could chose to recalibrate at these points, however since these are in the early plane surveys before all the quality control features were in place, it is best just to view the data prior to plane ~60 with caution.

In the x axis, the drift westward shown in Plot 6 of ~ 6 mm from plane 140 to 175 is real. This drift was first observed in the survey data and then by the mine crew. The y axis measurements after the offset is added are shown in Plot 7, revealing a variation that is ~ 17 mm in y over the detector. Again this is a real effect, with the collar being continuously shimmed, as once the collar had started rising it was best to keep it on this slope than bend it back down, else the cooling tube would not fit. The cooling tube fitted well in the end.

Plot 10 shows the difference between a linear fit to, and the measured value of, the z coordinate as a function of plane number. The error bars show the error in the measured position and do not include the small error in the fit.

Survey Lug Data

The survey lug data set is the smallest of the four data sets. The survey lugs are only on every fifth plane. Furthermore, only the z measurement is used as the survey lugs are not

always put in the same (xy) place each plane. The purpose of the survey lugs was to allow a FNAL survey team to compare the positions obtained with the Vulcan system to the positions obtained with the higher precision survey equipment. This now seems unlikely to occur, or be needed.

Results:
The survey lug data plot is shown in Plot 8. This plot shows the average z position of the 8 lugs as a function of plane number. The average pitch from the fit is 59.51 mm/plane, which is consistent with the axial bolt and collar measured pitch, within expected errors.

Ear Data

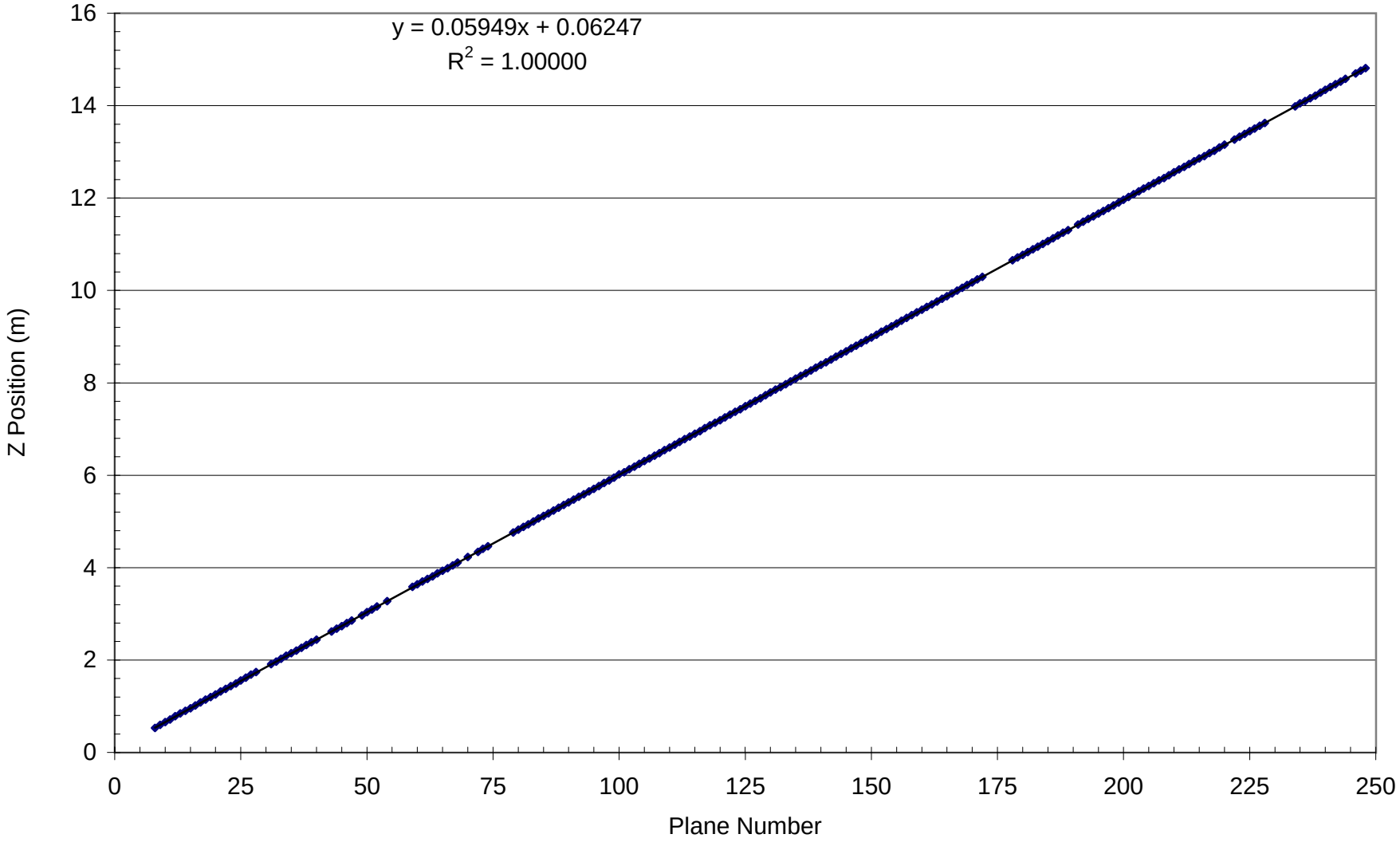
The ear data set is for identifying warp in the planes. The ear data was only taken for z information as the location of the x-y measured point was never exactly the same. The ears were compared to the two closest axial bolts. The east ear was compared to axial bolt 7 and the west ear was compared to axial bolt 8. The ideal situation is that the differences between the ears and axial bolts on each side are equal.

Results:
Plot 9 shows the ear data set. The data is for the most part has the east and west sides consistent with each other. The only exception being a few points where there is a large (unphysical) variation due to surveyor/Vulcan error. The lines are drawn to aid the eye.

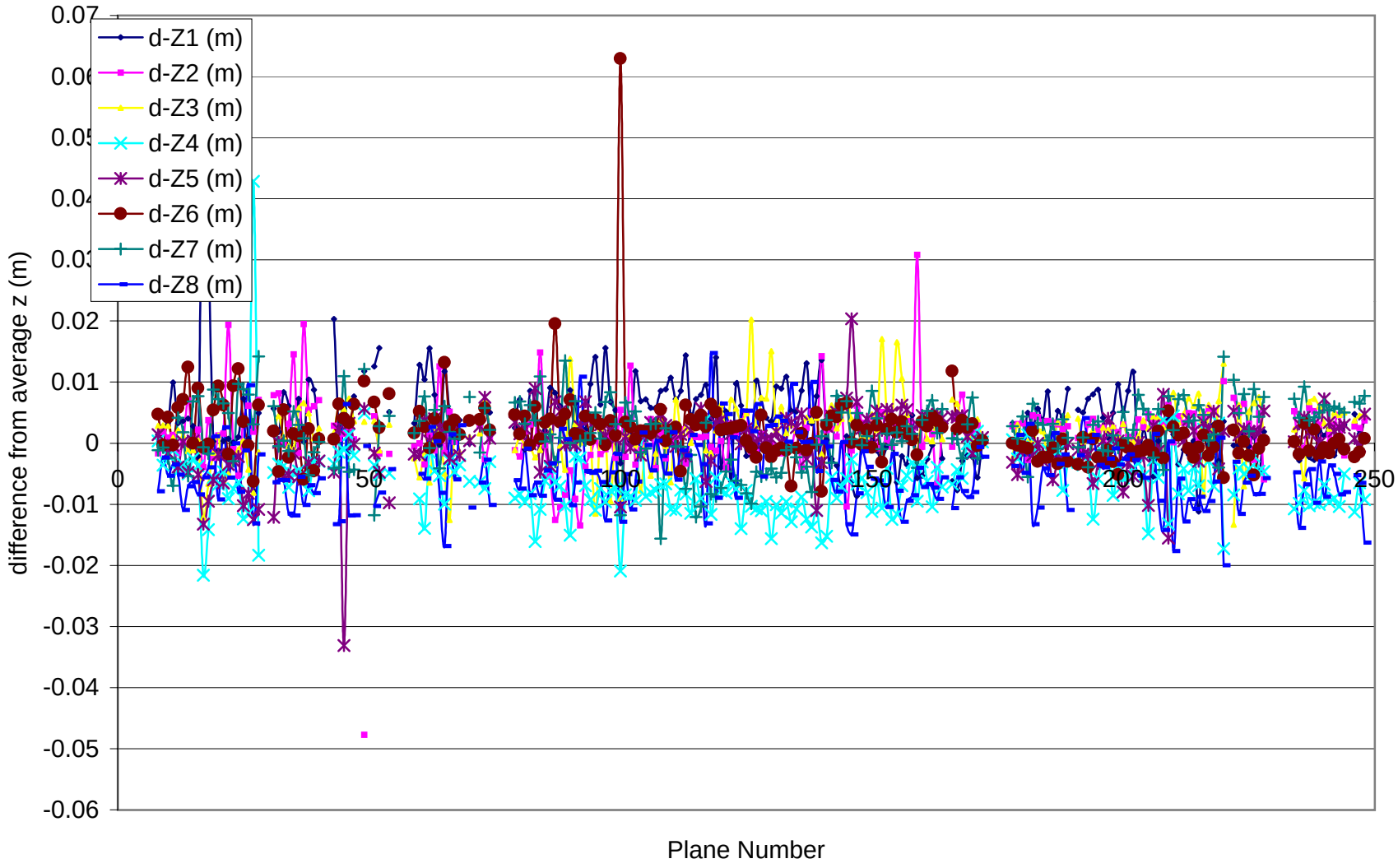
Conclusions

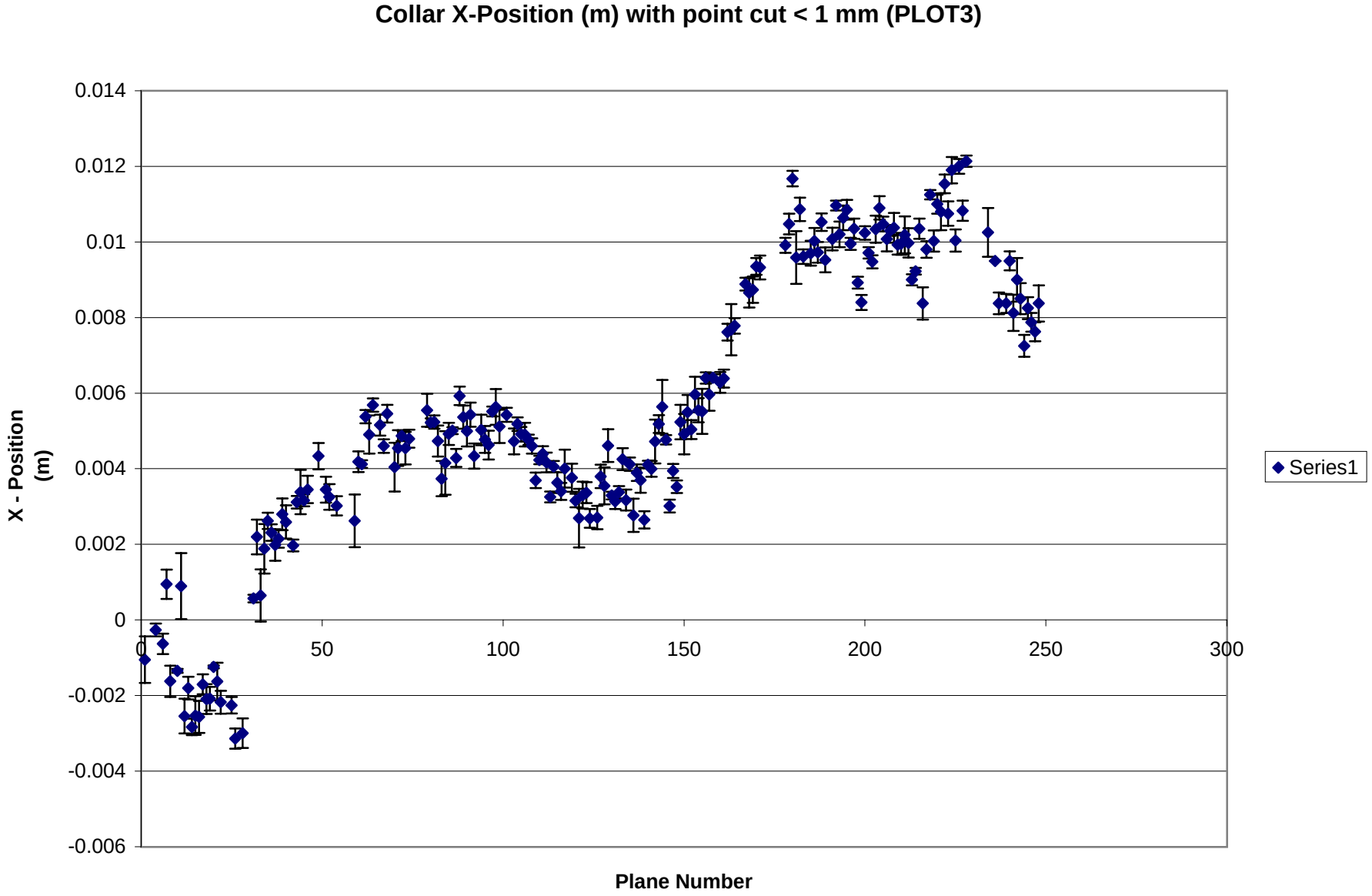
The survey data proved useful in the construction of SM1. The data set was sufficiently powerful to allow for corrections to be made as SM1 was erected. Quality control steps have been implemented and mine crew experience with the survey procedure should mean SM2 surveys will realize construction problems quickly.

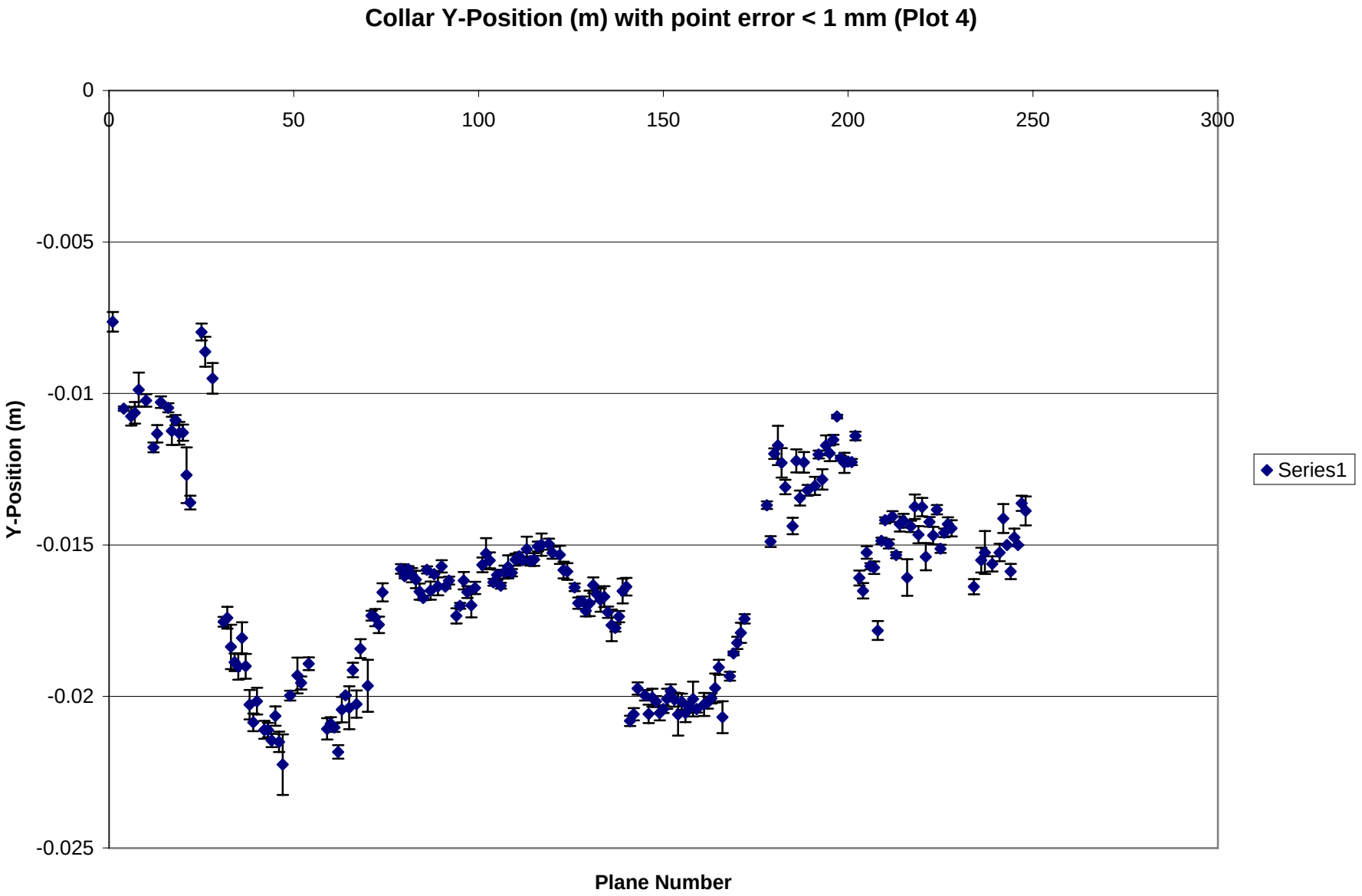
Average Axial Bolt Location in Z Direction (PLOT 1)

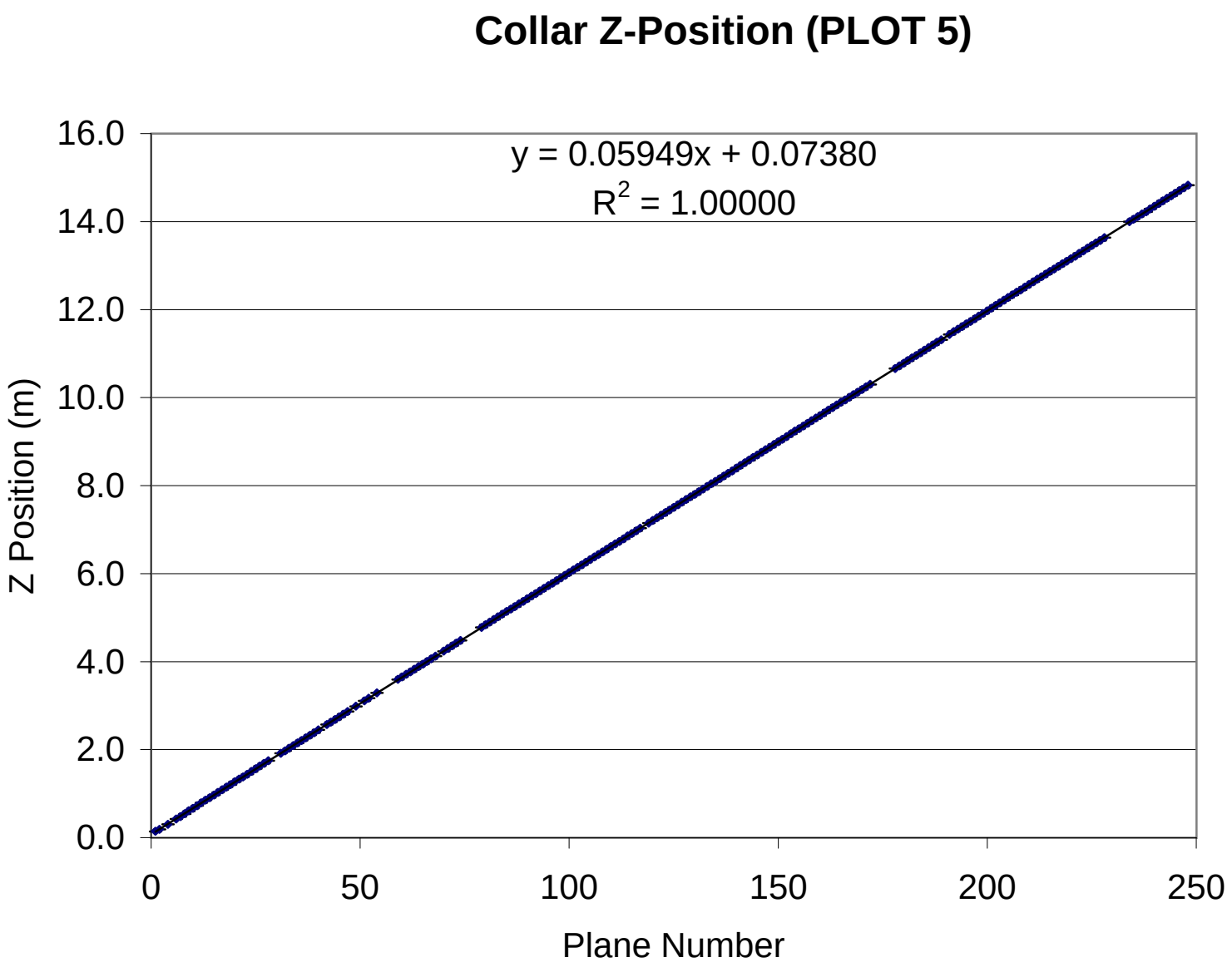


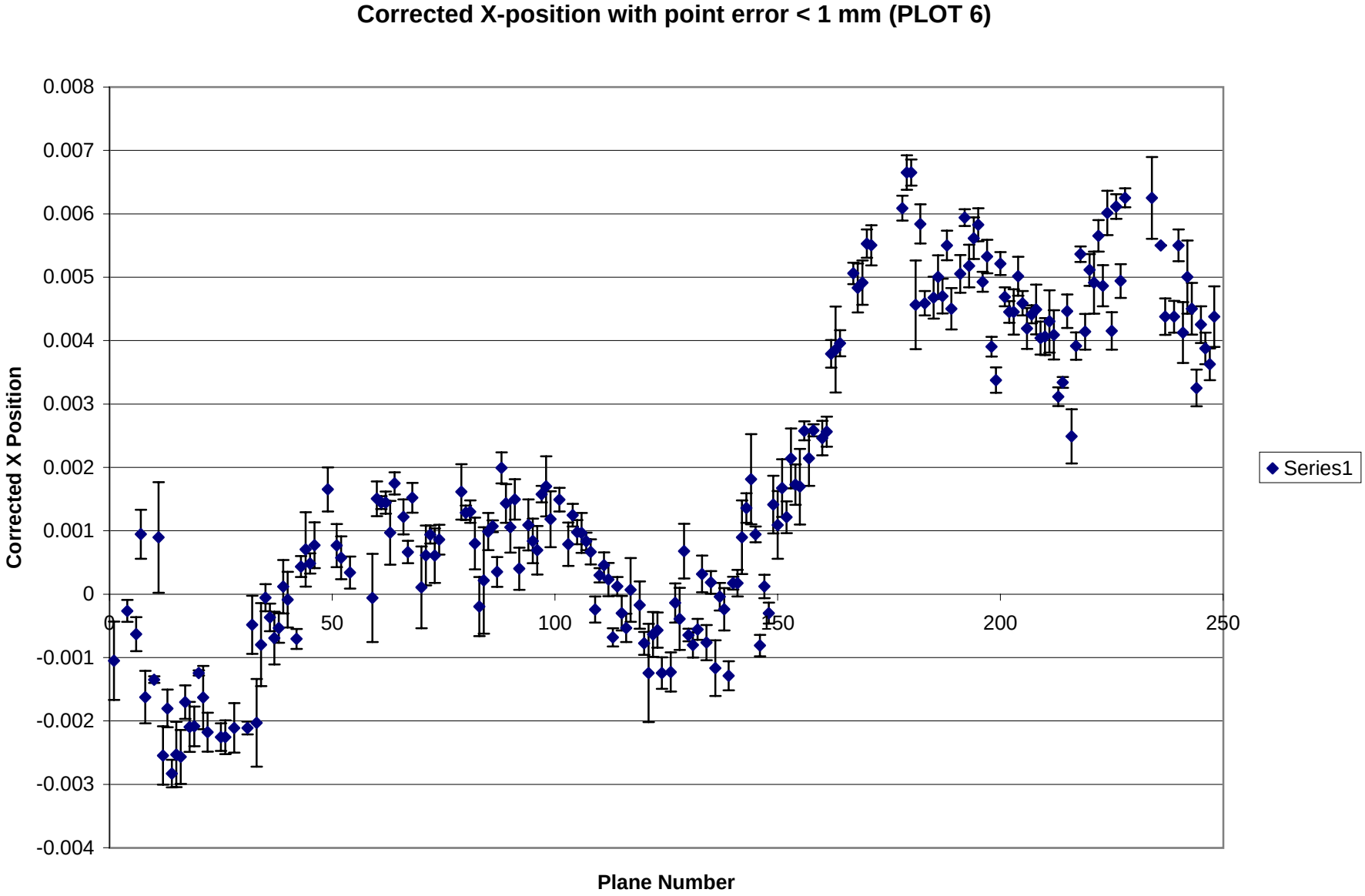
Axial Bolt Delta Z (PLOT 2)

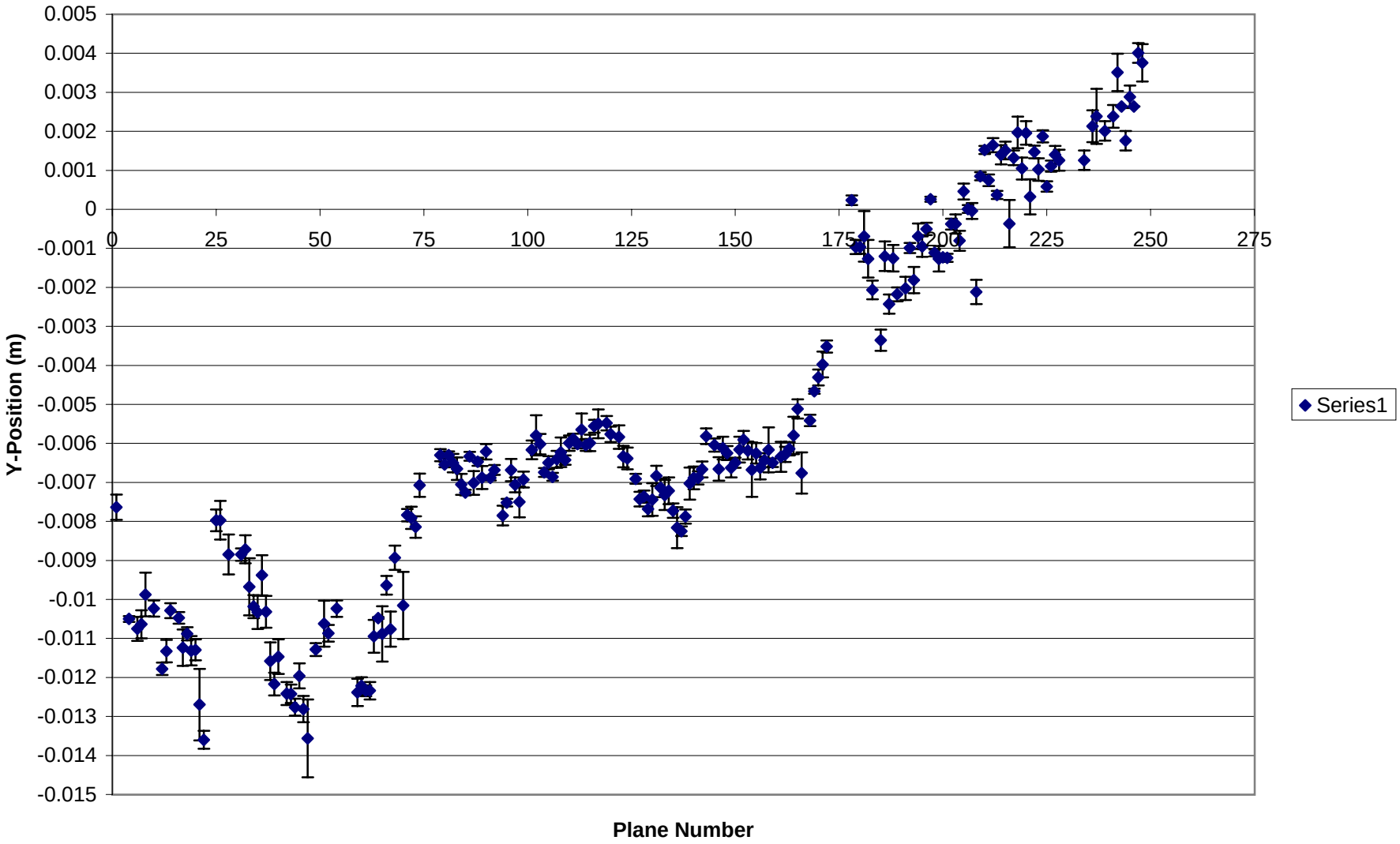


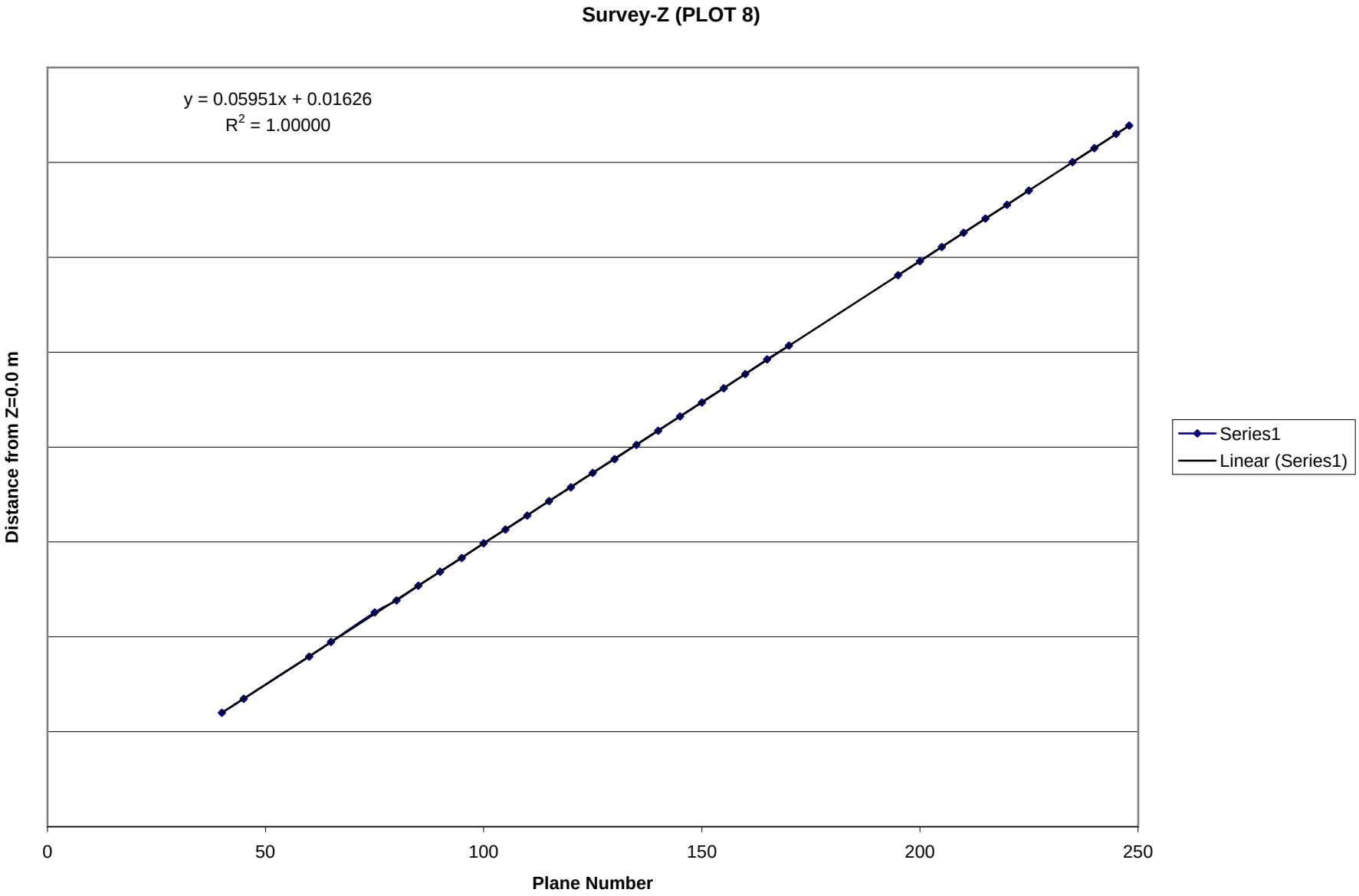

Collar X-Position (m) with point cut < 1 mm (PLOT3)
X - Position (m)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
0
50
100
150
200
250
300
Plane Number
Series1

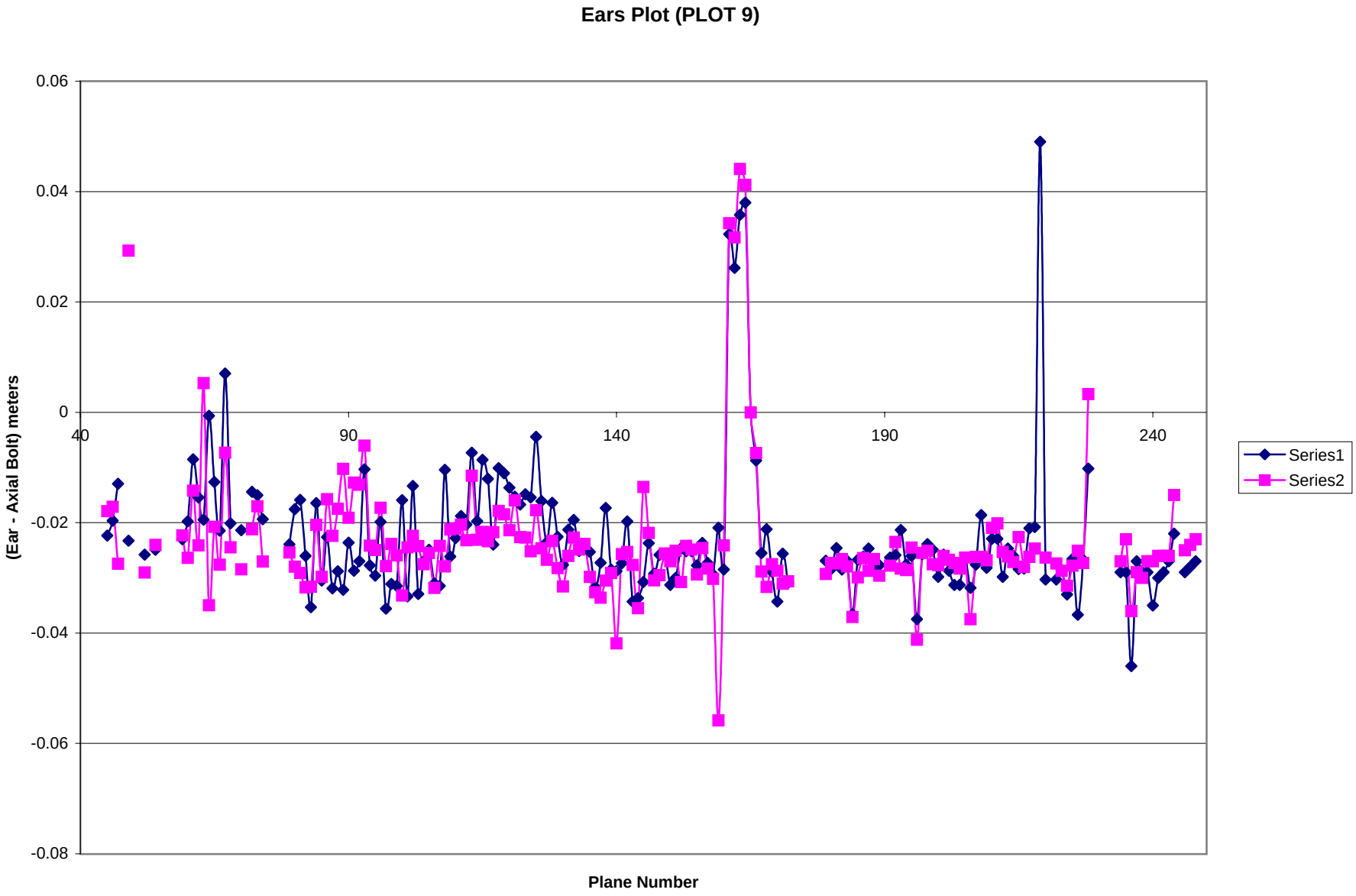

Collar Y-Position (m) with point error < 1 mm (Plot 4)
0
0
50
100
150
200
250
300
-0.005
-0.01
-0.015
-0.02
-0.025
Y-Position (m)
Plane Number
Series1

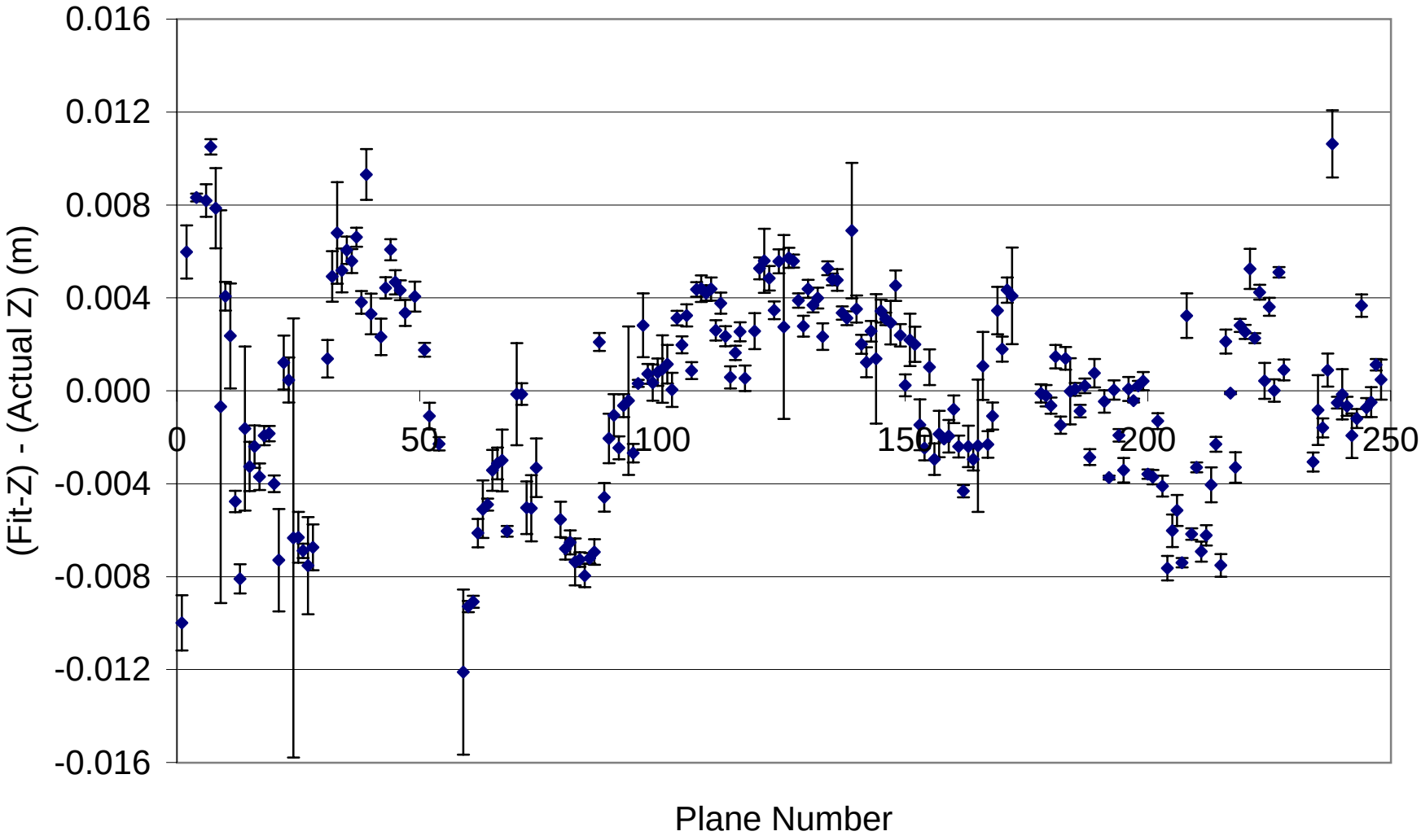

Collar Z-Position (PLOT 5)
y = 0.05949x + 0.07380
R2 = 1.00000
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Z Position (m)
0
50
100
150
200
250
Plane Number


Corrected X-position with point error < 1 mm (PLOT 6)
Corrected X Position
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
0
50
100
150
200
250
Plane Number
Series1


Corrected Y-Position with point error < 1mm cut (PLOT 7)
Y-Position (m)
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.01
-0.011
-0.012
-0.013
-0.014
-0.015
0
25
50
75
100
125
150
175
200
225
250
275
Plane Number
Series1


Survey-Z (PLOT 8)
y = 0.05951x + 0.01626
R2 = 1.00000
Distance from Z=0.0 m
0
50
100
150
200
250
Plane Number
Series1
Linear (Series1)


Ears Plot (PLOT 9)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
40
90
140
190
240
(Ear - Axial Bolt) meters
Plane Number
Series1
Series2


Delta-Collar-Z (PLOT 10)
0.016
0.012
0.008
0.004
0.000
-0.004
-0.008
-0.012
-0.016
(Fit-Z) - (Actual Z) (m)
0
50
100
150
200
250
Plane Number