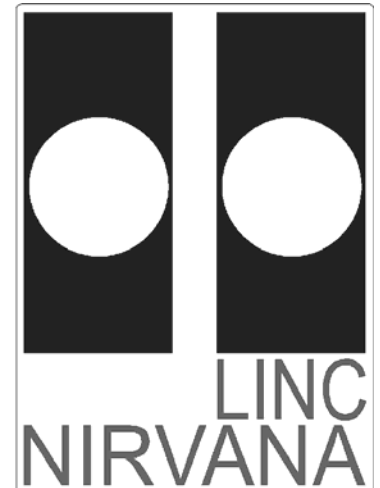


# LINC-NIRVANA

The **L**BT **I**nterferometric **C**amera and  
**N**ear-**I**nfra**R**ed / **V**isible **A**daptive  
**i**nterferometer for **A**stronomy

A collaborative project of the MPIA Heidelberg, INAF-Arcetri,  
Universität zu Köln, and MPIfR Bonn

<http://www.mpia.de/LINC>



## LINC-NIRVANA

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### Test on the Differential Tip-Tilt Unit

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# 1 Scope

This document describes and presents the results of the test made to determine how accurate the Differential Tip-Tilt Unit of LINC-NIRVANA is.

## 2 Applicable documents

No.	Title	Number & Issue
	MoCon Programmer's Guide	

## 3 Acronyms and abbreviations

DM	Deformable Mirror
FoV	Field of View
MoCon	Motion Controller Board

## 4 Introduction

The purpose of the Differential Tip-Tilt Unit is to minimize the difference between the images from each arm in order to reach the full interferometric performance over the complete FoV. For this reason it is important to test its accuracy, and observe its behavior by the different allowed tilt positions.

## 5 Settings

The Tip-Tilt Unit was controlled using the MoCon Board. The following table shows the most important motor's settings (Motor 1 & Motor 5) used for the test:

Table 1. Motor's Settings

Command	Parameter	Description	Value
110	1	Profile	0 (trapeze)
	2	Steps per revolution	200
	3	Velocity (rev/min)	200
	5	Acceleration (rev/min <sup>2</sup> )	7200
111	1	Limit switch	0 (disable)
	3	Reference switch	0 (disable)
	7	Auto Power Off / Break	1 (enable)
112	1	Micro steps	8
	2	Micro steps adaption	0 (disable)

## 6 Method of Measurement

The tilt of the Tip-Tilt Unit was measured using the ELCOMAT 3000 Auto Collimation Telescope. Using an unplugged Deformable Mirror as a normal mirror, and pointing to it to the auto collimation telescope, the variation of the angle between the mirror and the auto collimation telescope was measured. This variation represents the tilt of the Tip-Tilt Unit.

There were a series of tests done. First of all the repeatability. This means, to test if the mirror comes back to the same position after turning the Tip-Tilt Unit one whole turn. Then there was the question of how many steps are required to move the Tip-Tilt Unit in one absolute encoder step, and how many arc seconds correspond to this movement.

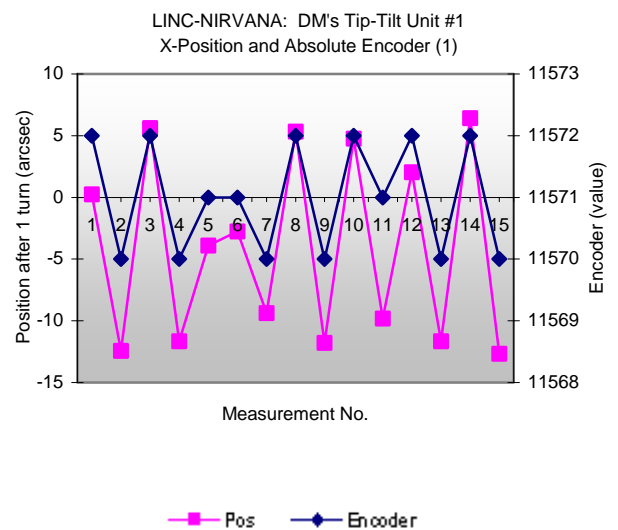
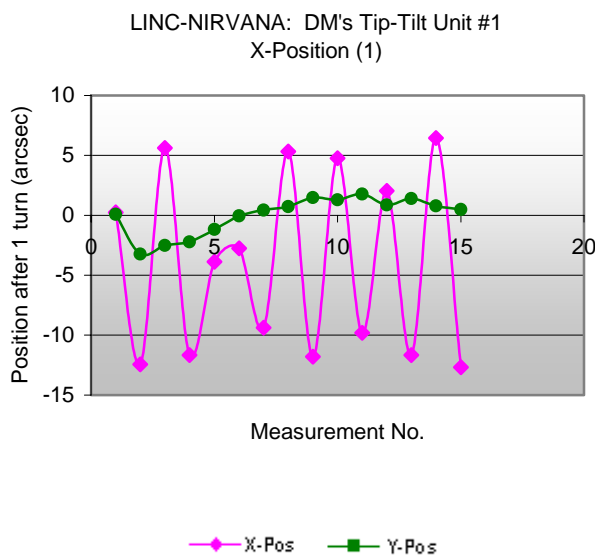
### 6.1 Repeatability

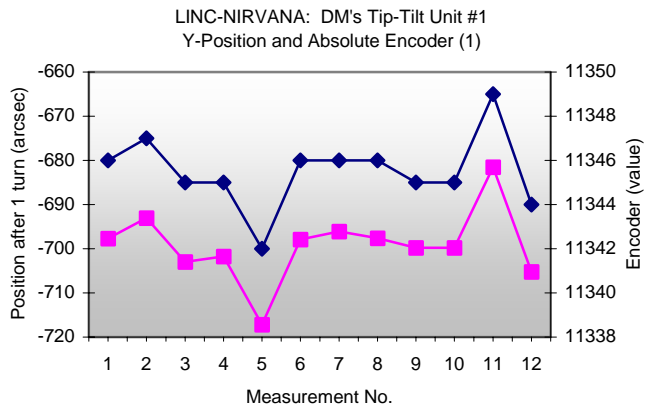
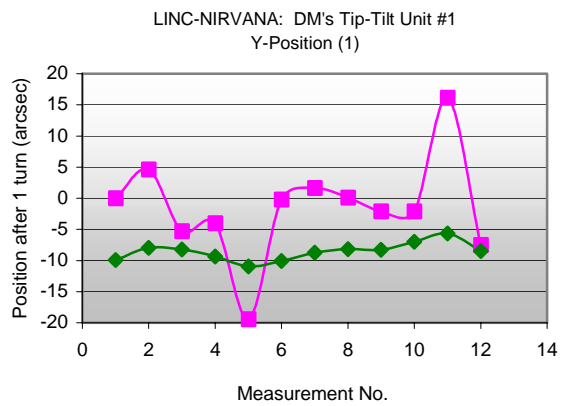
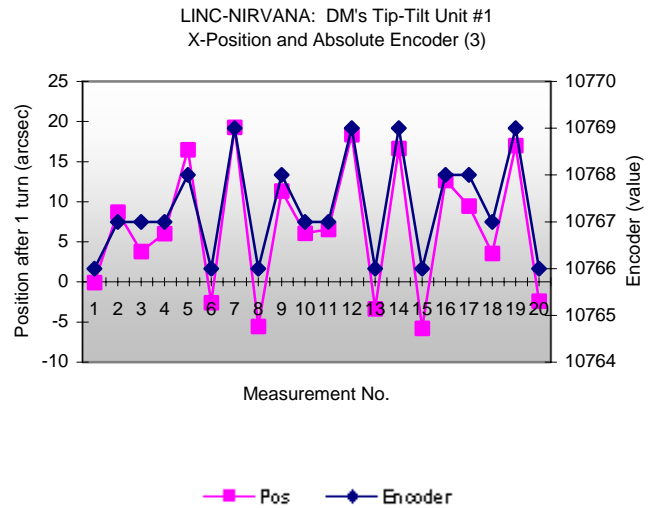
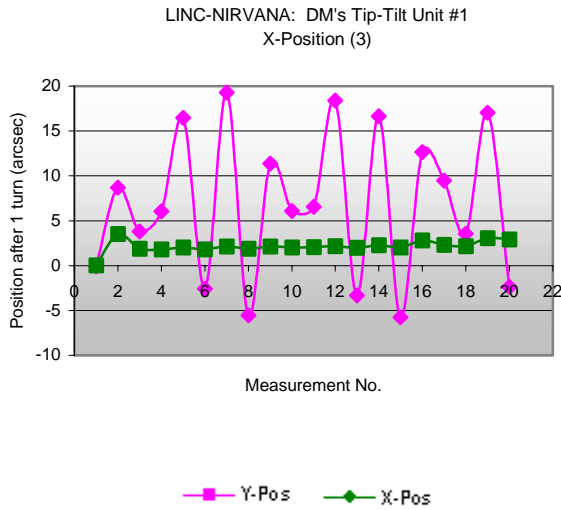
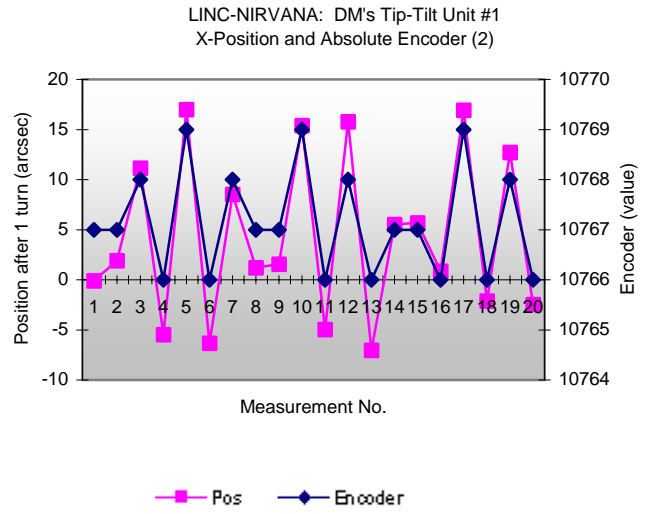
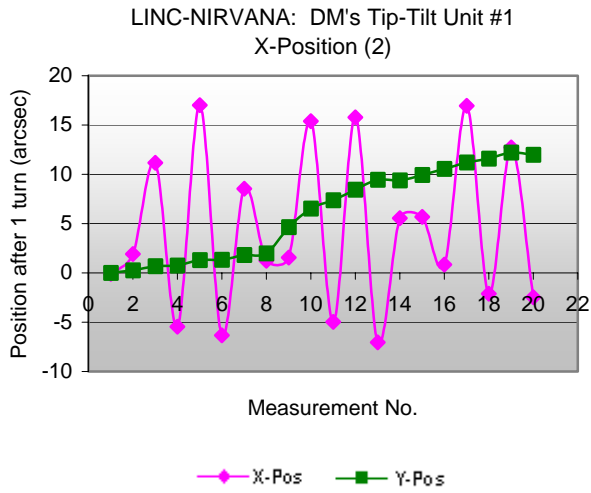
This test consisted in rotating the Tip-Tilt Unit one whole turn and checking if the mirror came back to the same position every time. The procedure was repeated 3 times with 20 measurements for each direction (x,y), with exception of Unit 4 that was tested just 1 time. The results show that the mirror didn't always come back to the start position, and that the behavior is random for every test and every unit. In order to understand this phenomenon, the measured position and the absolute encoder values were plotted against one another. The information revealed that the motor loses steps in a random way.

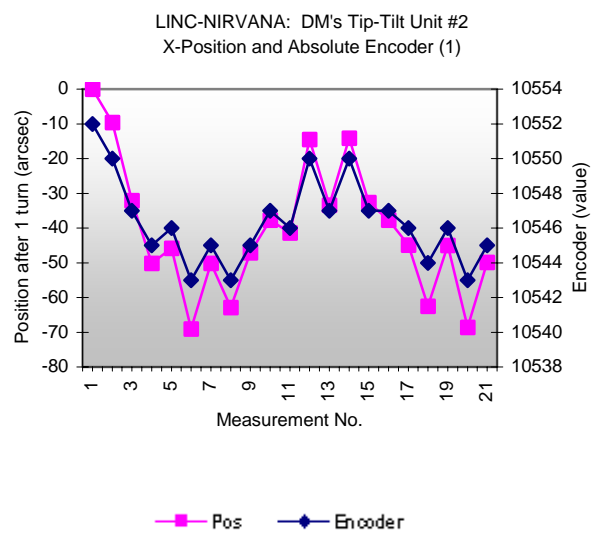
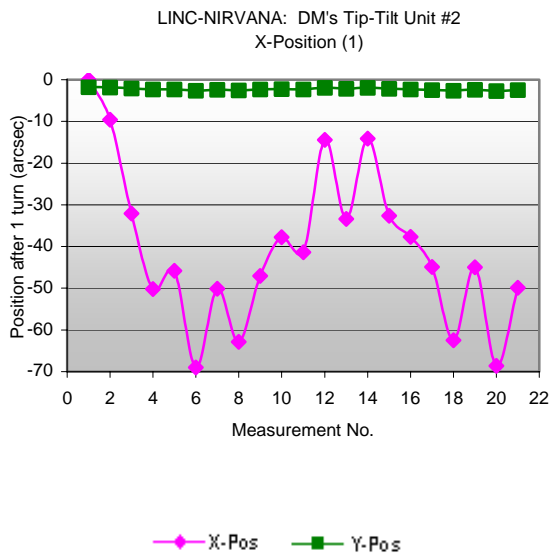
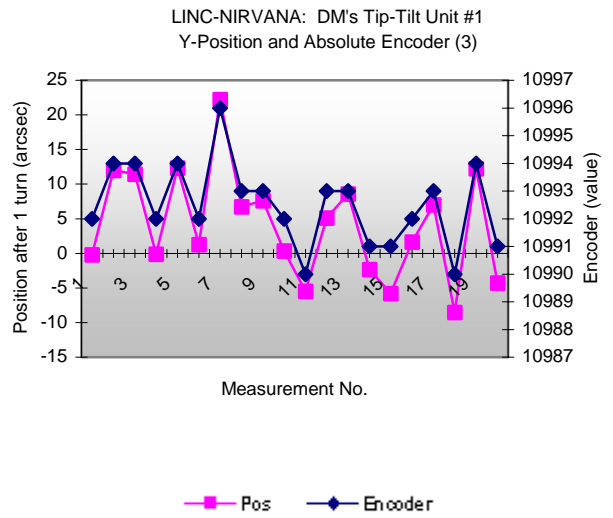
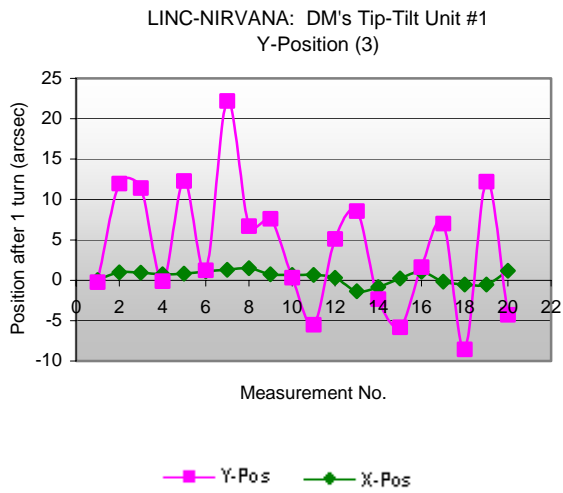
The following diagrams show the results of the measurements described above. The first column of graphs corresponds to the position of the mirror after every turn; the second column shows the measured position and the absolute encoder values plotted against each other.

Figure 1.1 – 1.19: Positions of the mirror after 1 turn

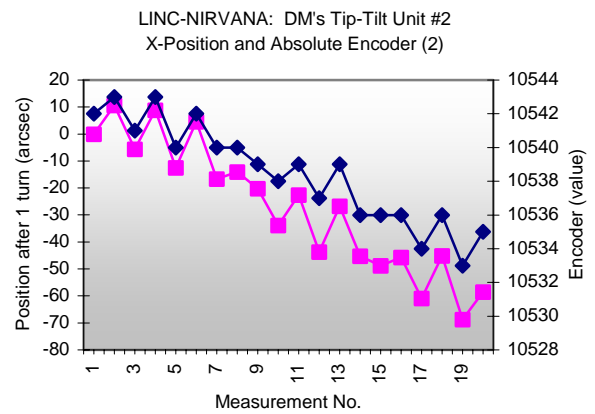
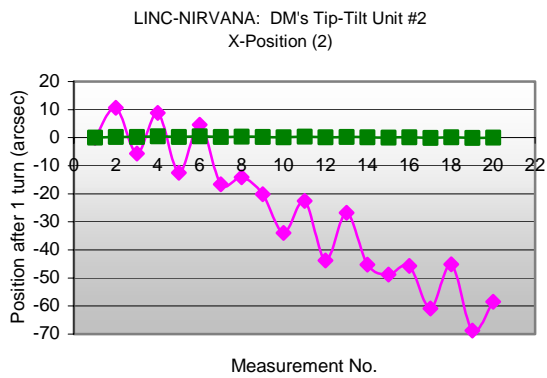
Figure 2.1 – 2.19: Position and absolute encoder

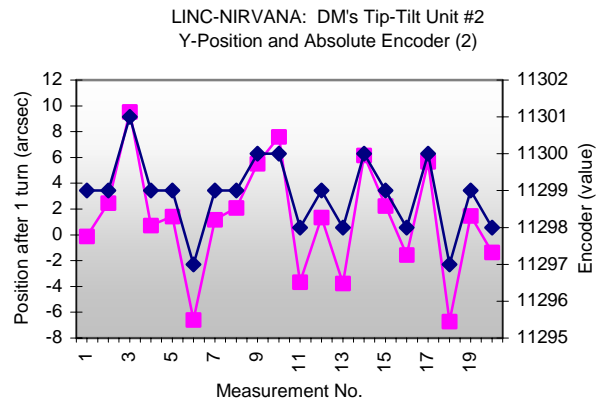
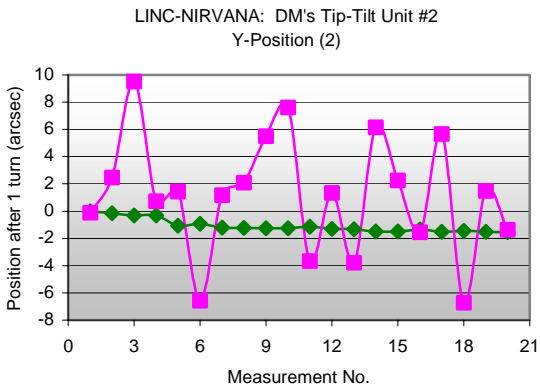
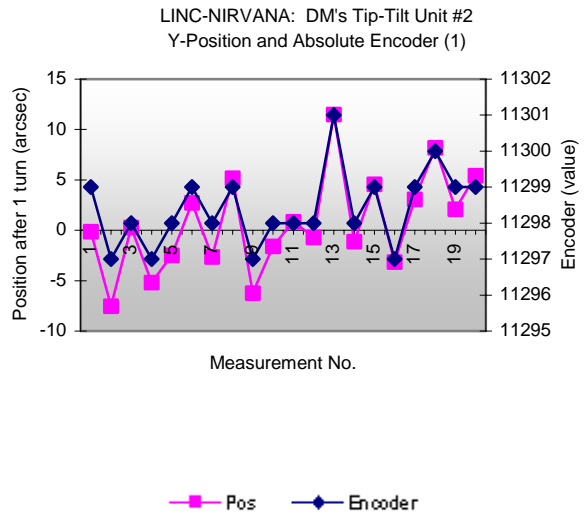
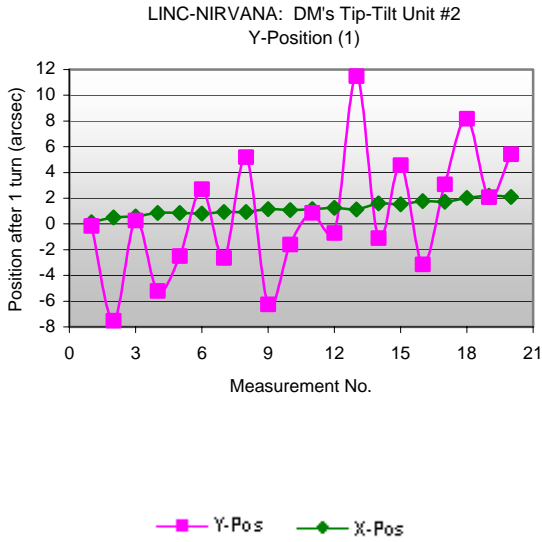
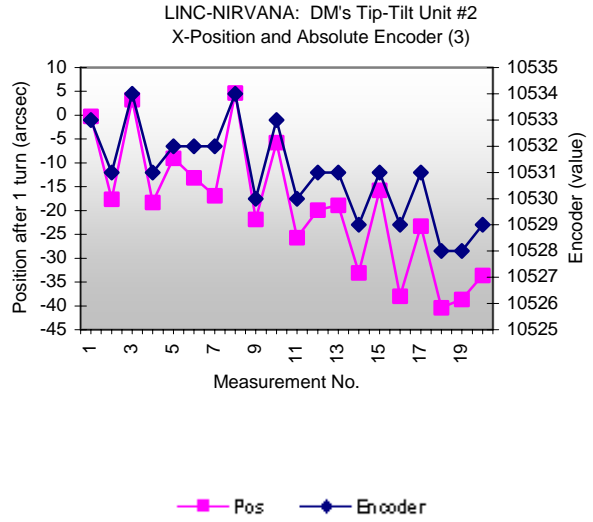
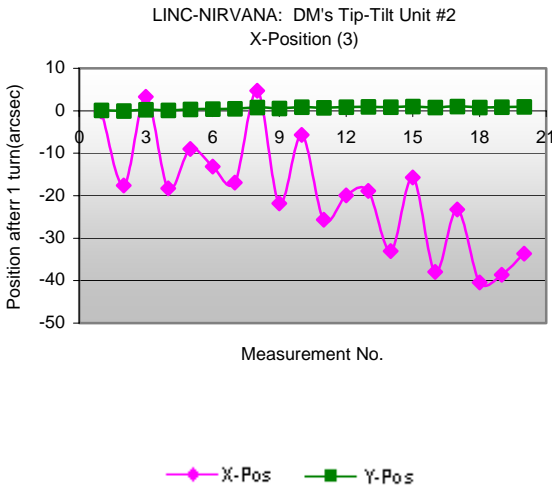


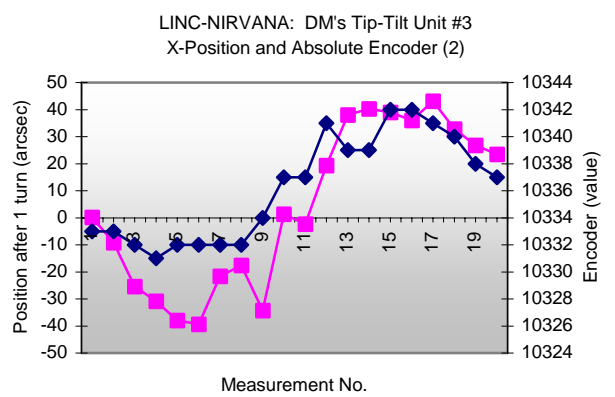
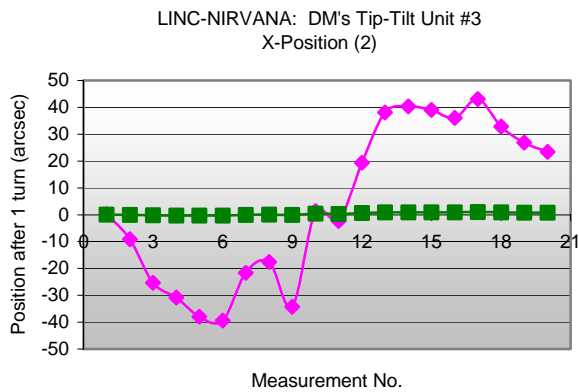
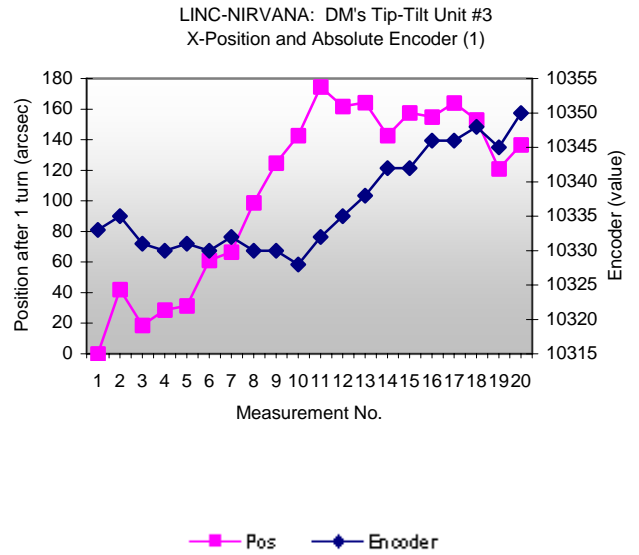
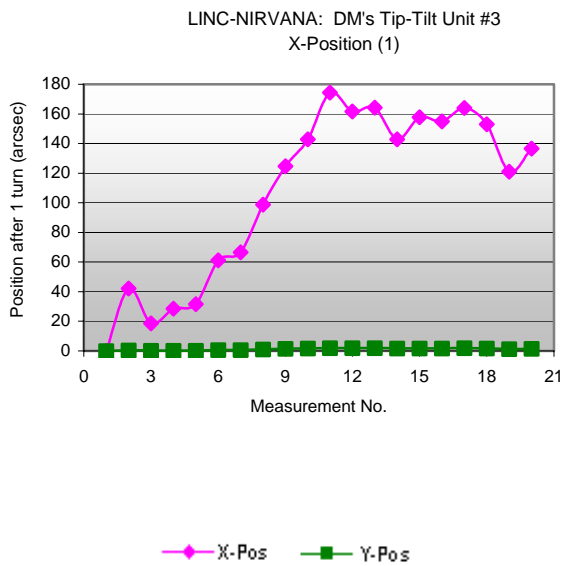
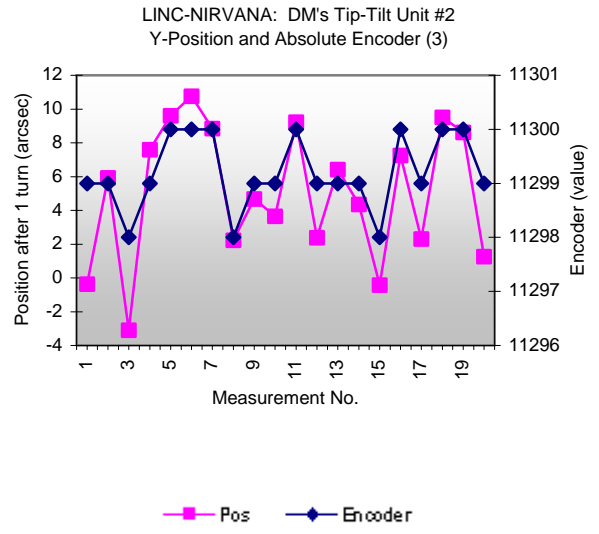
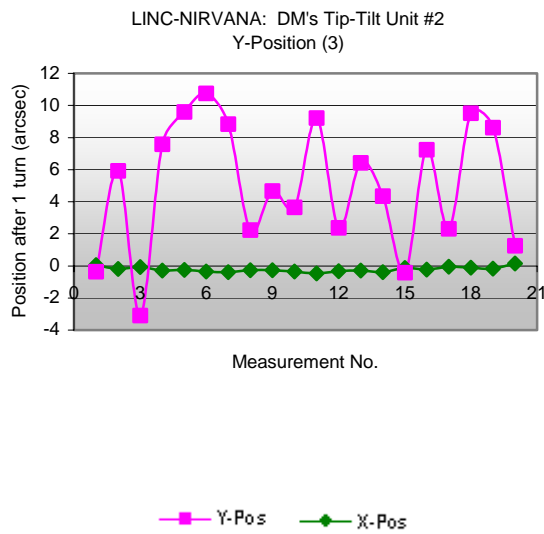


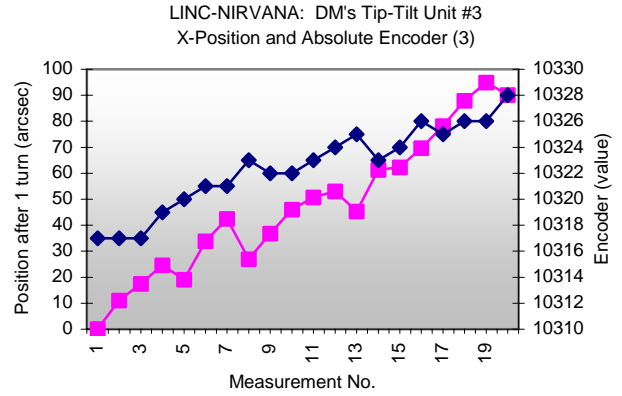
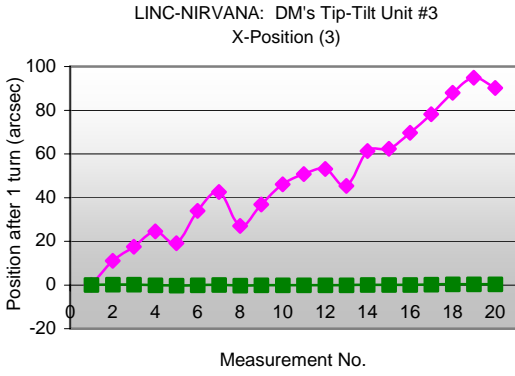


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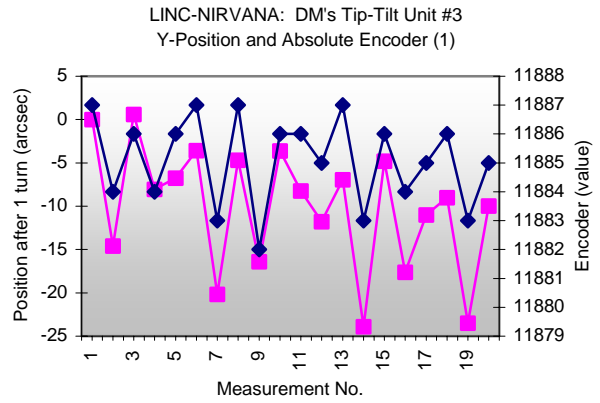
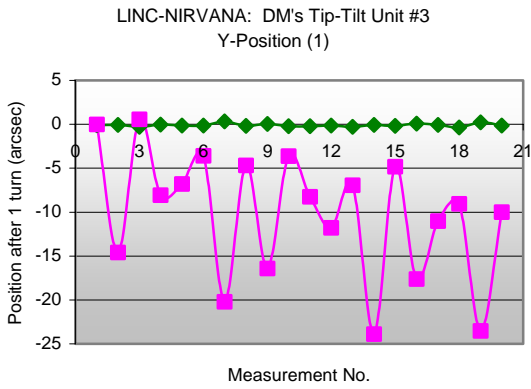






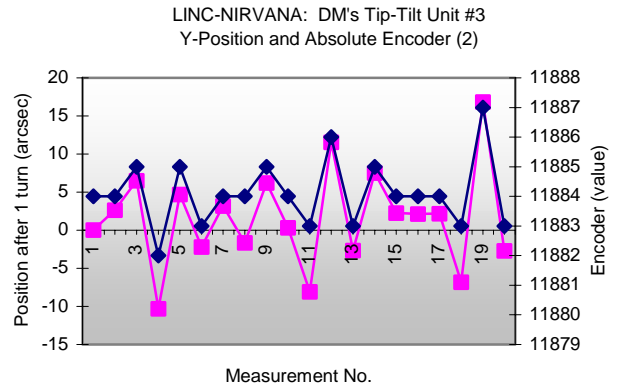
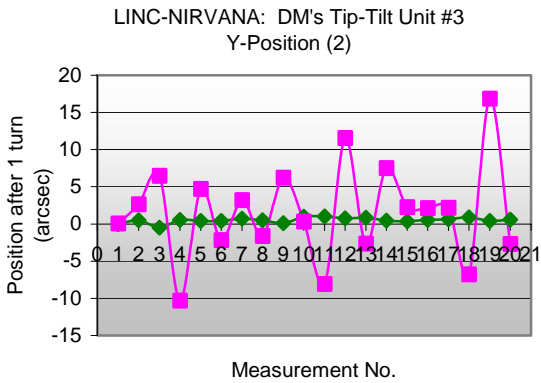
X-Pos Y-Pos

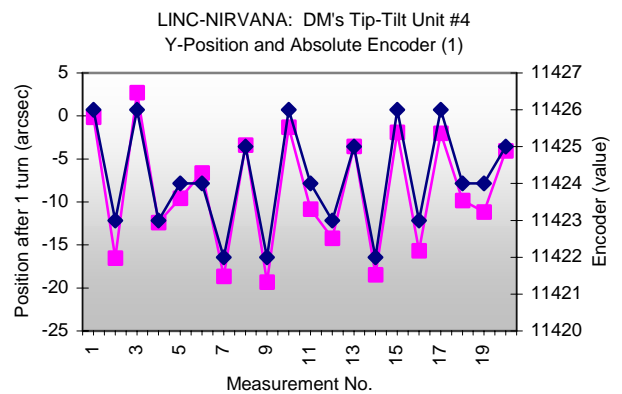
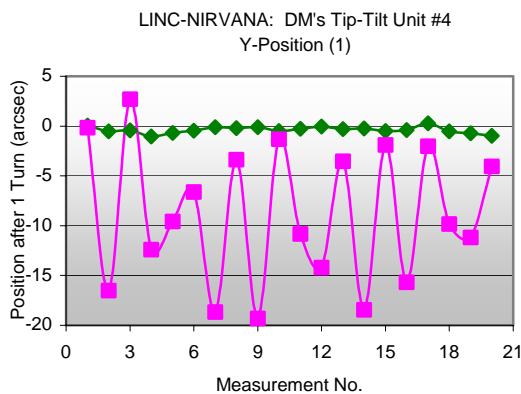
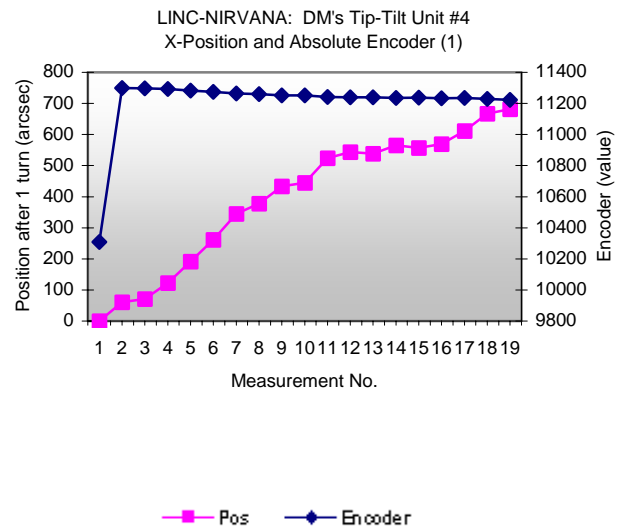
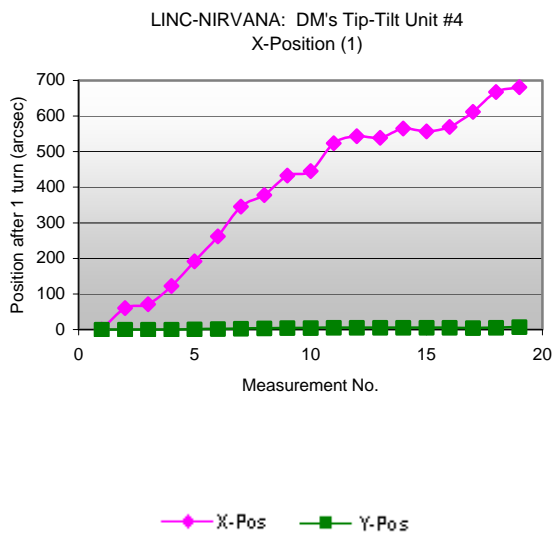
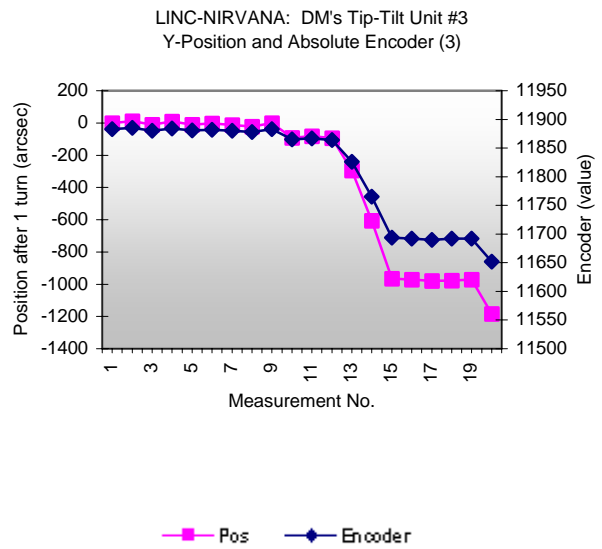
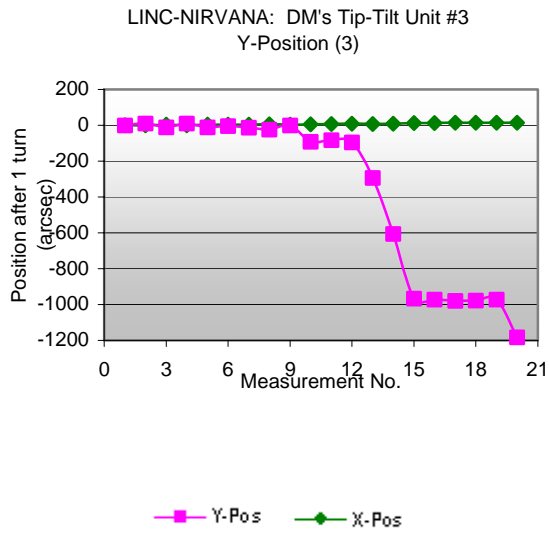
Pos Encoder



Y-Pos X-Pos

Pos Encoder





The following tables show a summary of the standard deviation of each measurement:

Table 2. Standard deviation of the measured position and the absolute encoder values

Test	Unit 1			
	Pos Y (arcsec)	Encoder (value)	Pos X (arcsec)	Encoder (value)
Y1	7,88	1,61	1,43	-
Y2	7,45	-	1,24	0,36
Y3	7,59	1,46	0,75	0,43
X1	1,51	-	7,34	0,89
X2	4,49	-	7,99	1,06
X3	0,65	0,43	8,07	1,10

Test	Unit 2			
	Pos Y (arcsec)	Encoder (value)	Pos X (arcsec)	Encoder (value)
Y1	4,68	1,01	0,55	0,49
Y2	4,27	0,99	0,47	0,22
Y3	3,85	0,67	0,15	0,00
X1	0,25	0,29	18,44	2,39
X2	0,15	0,30	23,59	2,90
X3	0,33	0,00	13,08	1,74

Test	Unit 3			
	Pos Y (arcsec)	Encoder (value)	Pos X (arcsec)	Encoder (value)
Y1	6,99	1,50	0,16	0,00
Y2	6,30	1,13	0,34	0,48
Y3	446,08	87,29	4,91	0,47
X1	0,66	0,47	56,63	7,03
X2	0,46	0,00	28,94	3,80
X3	38,32	7,49	26,59	3,15

Test	Unit 4			
	Pos Y (arcsec)	Encoder (value)	Pos X (arcsec)	Encoder (value)
Y1	6,70	1,38	0,32	0,00
X1	2,25	0,45	212,82	212,69

## 6.2 Encoder Steps

This test consisted in moving the Tip-Tilt Unit a known amount of steps (10, 100, etc.) at different positions of the range of the Tip-Tilt Unit to determine the relationship between steps, absolute encoder units, and arcseconds.

The tests show, that the result is different depending on the position of the mirror in respect to the auto collimation telescope, that is, on the actual absolute position within the movement range. There were 3 main mirror's positions chosen; this correspond to the diagrams below:

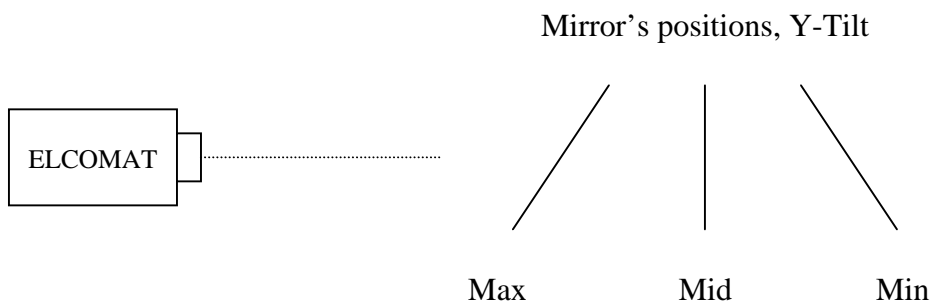


Figure 3. Alignment of the mirror for the different y-tilt positions (side view)

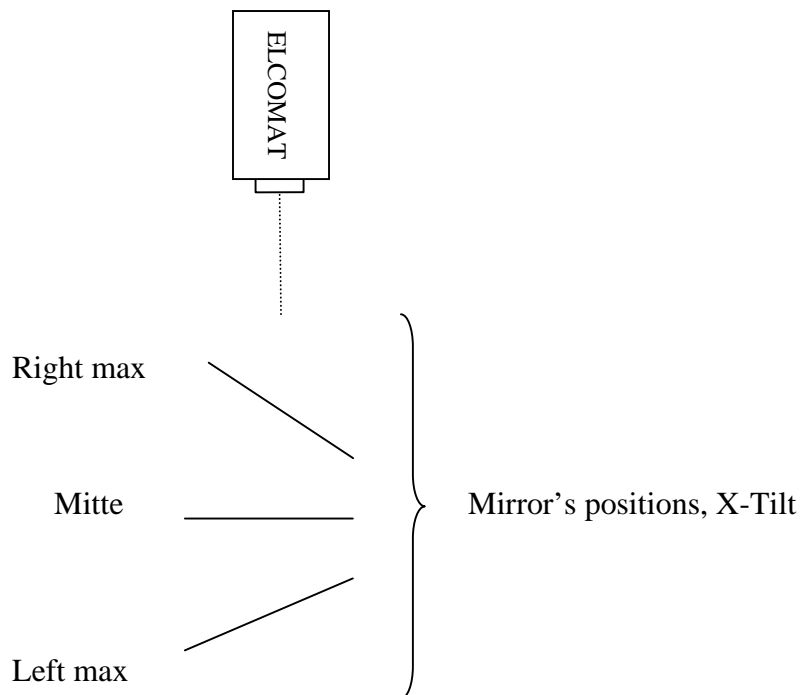


Figure 4. Alignment of the mirror for the different x-tilt positions (top view)

It was also observed, that at the limits (Max, Min, Right max, Left max) the number of steps needed to increase the encoder in one unit was more than at points far from the limit. A similar phenomena occurs to the middle positions, where depending on the unit (there are 4 units) it is impossible to determine a relation between this values (encoder steps and arcseconds). This awkward situations could be caused by relaxation of the spring while in the middle position and too much stress at the limit positions.

For Unit #1, the most representative positions are positions located between the main positions shown in the figures above. Those are between Max and Mid (mid max), and between Mid and Min (mid min) for the y-tilt positions, and between Right max and Mitte (mid right max), and between Mitte and Left max (mid left max) for the x-tilt positions. The following tables show the relationship between the steps moved, encoder steps, and corresponding arcseconds for the positions named above.

Table 3. Y-Tilt Positions, Tip-Tilt Unit #1

<b>Position</b>	<b>Steps moved</b>	<b>Encoder counts</b>	<b>Arcsec</b>
Min (far from limit)	10	1	4,084
Min (at limit)	10	1	2,504
Min (far from limit)	100	10	43,283
mid min	10	1	4,367
mid min	100	12	60,81
mid max	10	1	5,560
mid max	100	10	53,879
Max (at limit)	10	0,5	1,536
Max (at limit)	100	3 – 4	17,028

Table 4. X-Tilt Positions, Tip-Tilt Unit #1

<b>Position</b>	<b>Steps moved</b>	<b>Encoder counts</b>	<b>Arcsec</b>
mid right max	10	< 1	3,523
mid right max	30	1	9,812
mid right max	100	4 – 3	30,959
Mitte	10	1	5,0179
Mitte	100	10 – 12	69,058
Left max (at limit)	10	0	0,100
Left max (at limit)	100	0	0,412

From the last 2 values of Table 4 it is possible to observe, that even if the encoder steps don't change, the angle does. This means that the encoder is less sensitive than the precision of the Tip-Tilt Unit.

Table 5. Y-Tilt Positions, Tip-Tilt Unit #2

Position	Steps moved	Encoder counts	Arcsec	Backlash correction
Mitte	8 - 10	1	~ 5	10
mid min	10	1	~ 5	10
Min (at limit)	130 - 150	1	3,5	~ 50

Table 6. X-Tilt Positions, Tip-Tilt Unit #2

Position	Steps moved	Encoder counts	Arcsec	Backlash steps
Mitte	10	1	7	10
mid left max	10	1	~ 7	10
Left max (at limit)	35	1	data lost	30 - 35

Table 7. Y-Tilt Positions, Tip-Tilt Unit #4

Position	Steps moved	Encoder counts	Arcsec	Backlash correction
Min (at limit)	70 - 80	1	5,02 – 7,99	100
Mitte	8	1	4 - 5	8
mid min	10	1	5	9
mid max	8 - 10	1	~ 4	8 - 10
Max (at limit)	40	1	5,2	20

Table 8. X-Tilt Positions, Tip-Tilt Unit #4

Position	Steps moved	Encoder counts	Arcsec	Backlash steps
Mitte	10	1	6	70
mid left max *	20	1	4,7	?
mid left max *	40	1	7	?
Left max (at limit) *	125	1	5,54	200

\* Makes funny things

### 6.3 Absolute Encoder Correction

The previous sections reveal 2 important things: the motor loses steps, and that it is possible to determine how many steps are needed to increase the absolute encoder in 1 unit. That is, it is possible to correct the error introduced by the motor using the information provided by the absolute encoder.

The following diagrams show the behaviour of Tip-Tilt Unit #3 as the motor loses steps, and the results obtained after the absolute encoder correction. The correction was made using the information provided in tables 3 and 4.

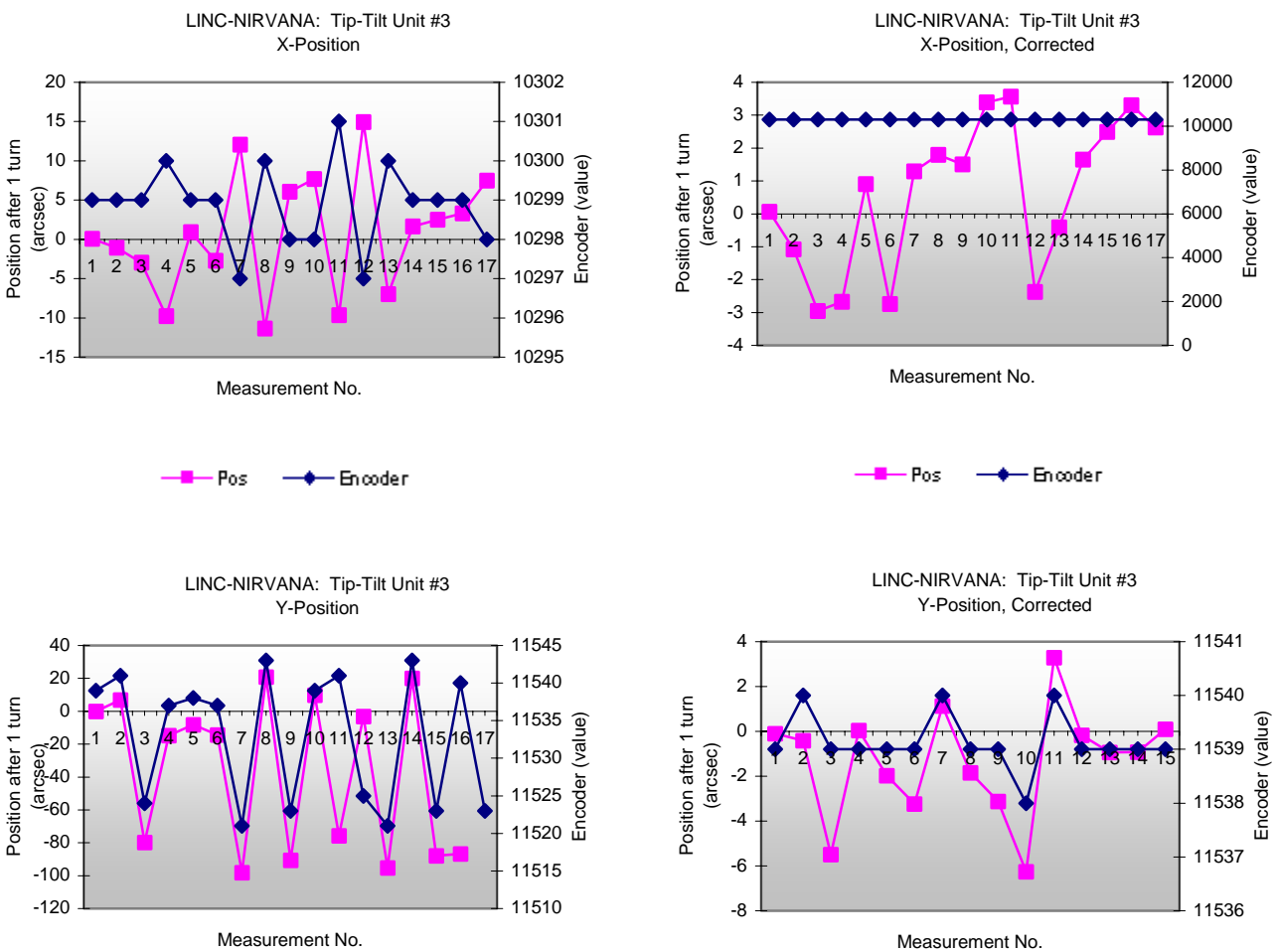


Figure 5. Position after 1 turn and absolute encoder correction

The following table shows the standard deviation obtained from the diagrams above:

Table 9. Standard deviation of original data and corrected value

Test	Unit 3			
	Pos X (arcsec)	Encoder (value)	Pos Y (arcsec)	Encoder (value)
X	7,34	1,02	0,14	0,38
X corrected	2,20	0	0,13	0,38
Y	0,86	0	46,14	8,65
Y corrected	0,78	0,25	2,37	0,49

The information provided in the previous diagrams shows that the error introduced by the lost steps of the motor was able to be corrected. This is reflected in the results of the standard deviation (Table 9), where the values improved from 7,34" to 2,20" in the x-direction, and from 46,14" to 2,37" in the y-direction. Both values are within the specification of 10".

## 7 Conclusion

The tests verify that either the motor loses steps, or the relaxation and stress of the springs play a significant role in the positioning of the DM's. However, the absolute encoder can be used to correct the error introduced, allowing the tip-tilt unit to be within the specifications, i.e., 10".