MIDAS
Co-ordinate Systems

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Change Record Sheet

Issue	Issue Date	Sections	Description of Changes
Draft 0	12.04.1999	All	Initial issue
Draft 1	07.05.1999	3.3	Origin of TRF system
1.0	28.10.2008	All	Revised version

This document contains information that is as complete as possible. Where final numerical values or specification references are not available, best estimates are given and noted To Be Reviewed (TBR). Items which are not yet defined are noted To Be Determined (TBD). The following table summarizes the TBD/TBR items in this revision of the document, and supplements the revision notice above.

Section	Description

1 Introduction

1.1 Purpose of Document

The purpose of this document is to define the co-ordinate systems to be used for the instrument MIDAS/Rosetta, and to establish the nominal relations between positions in the Unit Reference Frame and the readings of position sensors in the instrument, for both the mechanical dimensions and electrical signals.

1.2 Applicable Documents

	Title of Document	Identifier	Issue.Rev.	Date
[AD-1]	MIDAS EID-B	RO-EST-RS-3010/EID B	1.0	15-01-1999
[AD-2]	Rosetta EID-A	RO-EST-RS-3002/EID A	1.1	15-06-1998

1.3 Reference Documents

	Title of Document	Identifier	Issue.Rev.	Date
[RD-1]	Target Wheel for MIDAS	wheeldes.doc	1	12-07-1998

1.4 Abbreviations

AFM	Atomic Force Microscope
ARF	AFM Reference Frame
LVDT	Linear Variable Differential Transducer
URF	Unit Reference Frame
TBC	To Be Confirmed
TBD	To Be Defined
TRF	Target Reference Frame

2   Configuration of the Instrument

2.1   Mechanical and Structural Concept

The MIDAS instrument consists of one mechanical unit, the main instrument box. The box itself consists of a "top" part, called AFM Box (Fig. 1), housing the elements of the atomic force microscope (AFM) including the scanner and the dust manipulation system, and a lower part, the electronics box or E-Box (Fig. 2), which carries the main part of the electronics. The boxes are connected by means of 8 screws.
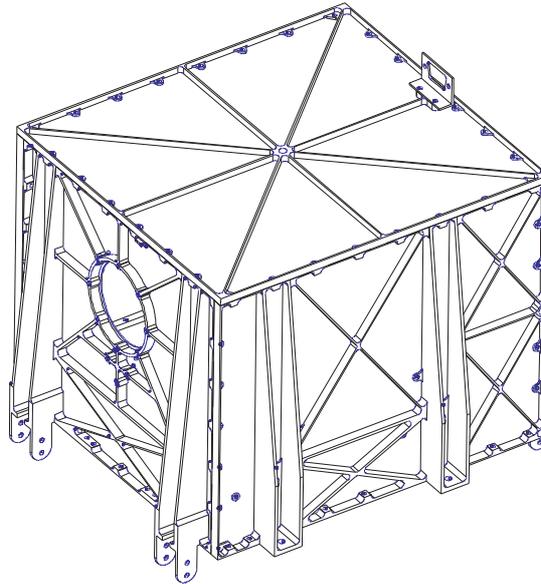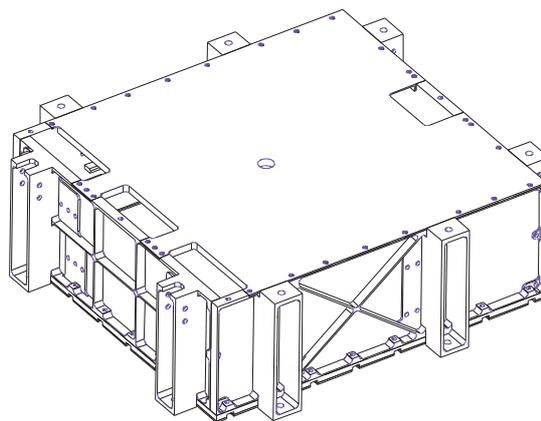

Figure 1: AFM Box

Figure 2: E-Box

Provisions for mechanical decoupling of the AFM from the box have been made in order to reduce the effect of microvibrations on the AFM. The dust collector and the scanner system are mounted inside the AFM Box on a mechanically decoupled "AFM

Baseplate", which is held in position by four studs of silicon damping material. During ground operations and launch the AFM platform will be locked in zero position by means of four spring-loaded clamps. Zero position means the silicon dampers will not be loaded. After launch the clamps will be released by a mechanism involving two paraffin actuators.

2.2 Mechanisms Concept

2.2.1 Robotics system

The task of the robotics system is to ensure that dust particles are collected on a predetermined surface area and transported in a controlled manner to the scanner head of the AFM. It requires three motions:

- a rotation to bring the exposed area of the dust collector wheel (a facet) in front of the scanner head, and to select one of the available rows within the facet

- a translation of 32.8 mm to select another tip from the scanner head, and for coarse positioning within a row

- a translation of about 1 mm, perpendicular to the previous translation, to move the tip of the scanner to the scanning area on the dust collector wheel.

2.2.2 Collector wheel

In order to select one of the 64 facets on the collector (or target) wheel and one individual row within a facet the collector wheel has to be rotated by a piezo-motor. An attached encoder with 1024 positions per rotation and a reference position determines the position of the wheel. A schematic view is given in Fig. 3.
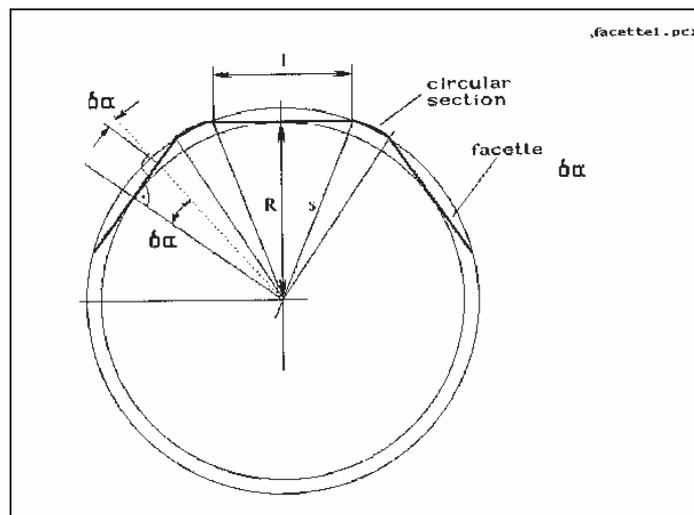

Figure 3: Schematic view of facet arrangement on collector wheel

The facets are numbered consecutively. The reference pulse of the encoder coincides with the center position of facet #1.

Not all facets have the same structure. On certain positions there are calibration gratings and other special purpose facets.

2.2.3 Linear translation

The need for a translational movement of 32.8 mm ensues from the need to select one of the available tips, and for coarse positioning within a row. The longitudinal movement is measured by a transducer (LVDT). The linear translation stage has a launch lock position.

2.2.4 Approach mechanism

Whereas the "Z-Piezo" varies the distance between the needle and the facet on the target wheel in the range of micrometers, the approach mechanism is used to achieve a coarse positioning in the order of one millimeter. The approach is achieved by widening a wedge system with a shaft with bearings. The linear translation of this shaft is done by a fine threaded shaft which is coupled to a DC motor with a gearbox.

By design the plane of the scanner table is normally not exactly perpendicular to the AFM Baseplate, but tilted "away" from the collector wheel by a small angle. At the same time the point of contact between the needle and the wheel moves downward by the same angle.

The approach mechanism has a launch lock position. In this case the plane of the scanner table is exactly perpendicular to the AFM Baseplate, and the distance to the wheel is a minimum (in fact, the position is even within the radius of the wheel. The wheel must have been moved sidewards using the linear translation stage in this situation).

2.2.5 Scanner

The scanner is fixed by an intermediate plate to the top plate of the sample approach. The scanner contains a piezoelectric scanner table moving in a plane, another piezo actuator moving in perpendicular direction, and a scanner head on which an array of 16 tips is mounted. The typical scanning ranges are 100 µm in the plane parallel to the target surfaces and 7 µm perpendicular to the surface.

2.2.6 Shutter

The shutter is a movable system to control the exposure of the collector to the ambient dust flux, based on a piezo motor rotating a cylinder which contains two opposite slits.

2.2.7 Other mechanisms

The instrument contains additional mechanisms to release launch locks and the cover. These mechanisms are not directly addressed in this document, as no position sensors other than end switches are involved.

3 Co-ordinate Systems

3.1 Unit Reference Frame

The basic co-ordinate system to be used for MIDAS at instrument level is the

Unit Reference Frame (URF) [Xu, Yu, Zu]

as specified in [AD-1]. The origin of the URF system is located in the centre of the reference hole of MIDAS, on the interface plane. The subscript "u" shall be used for the URF. The orientation and location are shown in Fig. 4, which is the top view of the instrument as an excerpt from the Mechanical Interface Control Drawing in the EID-B [AD-1]. For more detail see [AD-1].
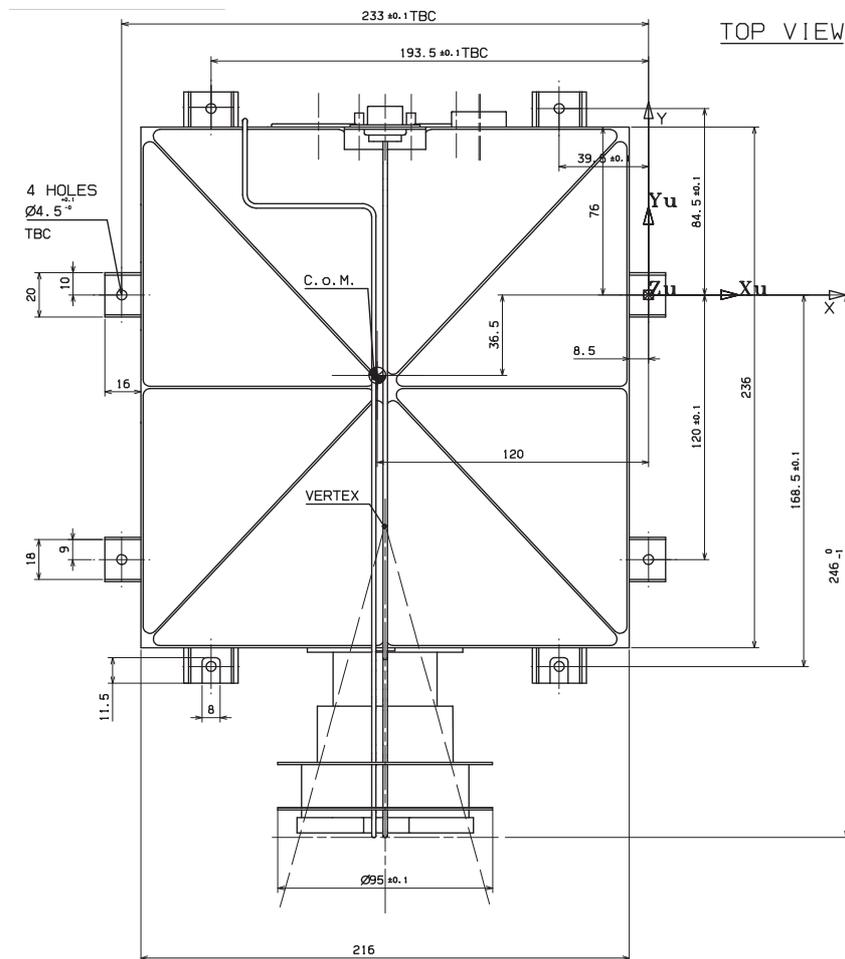

Figure 4: MIDAS with URF system shown at the reference hole

The co-ordinates of the AFM Box in the URF system refer to the nominal mounting position on top of the E-Box.

The co-ordinates of the AFM Baseplate and the AFM in the URF system refer to the locked position of the clamping system.

3.2   AFM Co-ordinate System

The AFM co-ordinate system is the

AFM Reference Frame (ARF) [Xa, Ya, Za]

The ARF system should be used in the context of scanner operations. The ARF system is fixed to the frame of the scanner table. The origin of the ARF system is located at a TBD location at the scanner frame, i.e. the XY stage. The subscript "a" shall be used for the ARF. As the scanner can be moved with respect to the AFM Baseplate by the approach mechanism, the relation between the URF and AFM systems is not fixed. In addition, the relation between the AFM Baseplate and the URF is only defined for the AFM Baseplate clamping mechanism in clamped state.
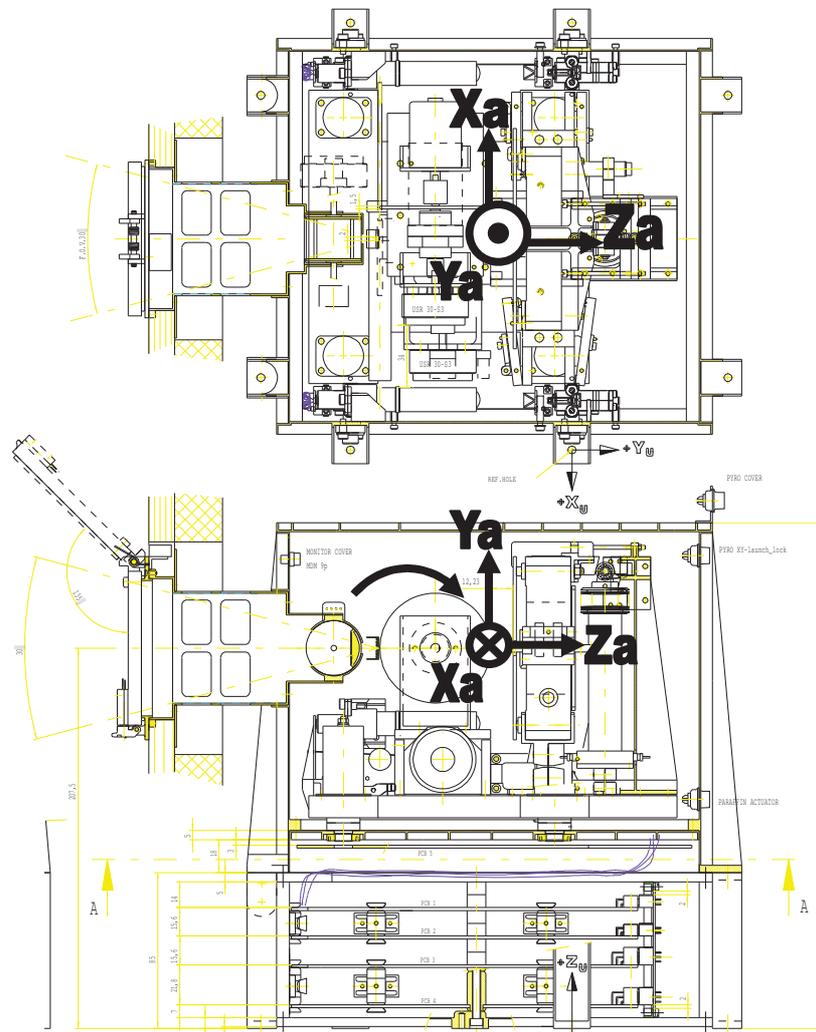

Figure 5: Top and side views of MIDAS with ARF system

The orientation of the scanner frame within the instrument box is shown in Fig. 5, which contains the top and side views of the instrument with some mechanisms being indicated. Note that the details of the figure do not reflect the latest status of the mechanical design.

3.3 Target Co-ordinates

The co-ordinate system on any individual target area (or facet) on the collector wheel is the TRF

Target Reference Frame (TRF) [Xt, Yt, Zt]

The TRF system is fixed to the nominal position of one target area on the collector wheel. The subscript "t" shall be used for the TRF.
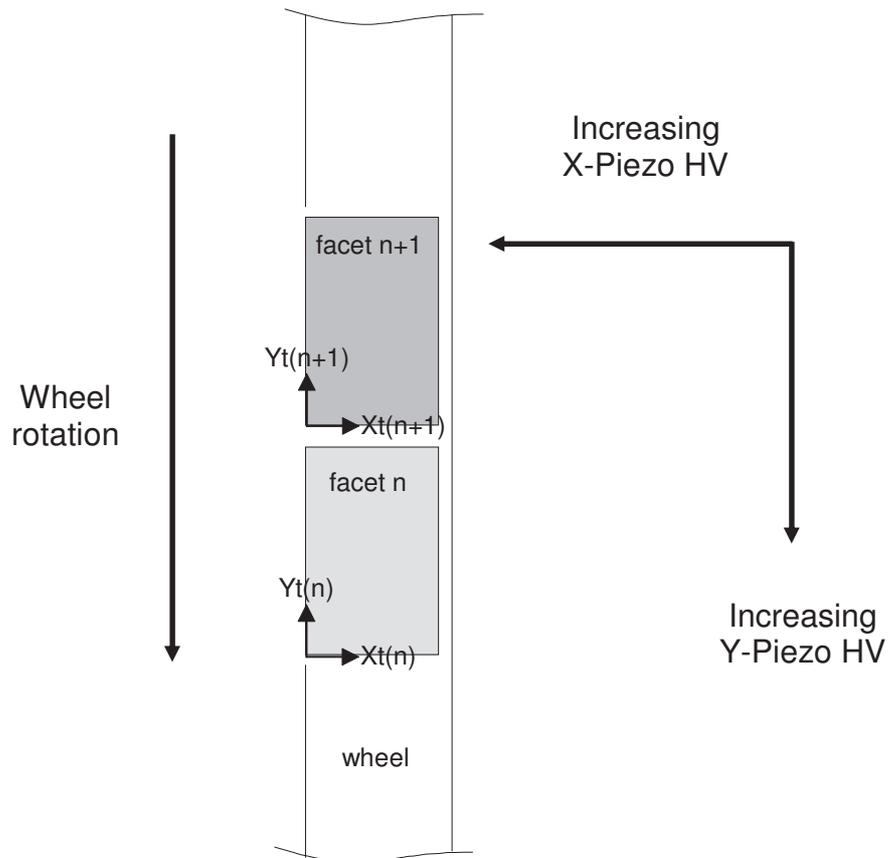

Figure 6: TRF co-ordinates on a target area (facet)

The origin of the TRF system is located at the lower left [Xt, Yt] corner of the mounting area of a target facet, as illustrated in Fig. 6 (TBC). The mounting areas have the size xt=1500 µm, yt=2500 µm. Because of the crystalline structure of the facet material the edges cannot be manufactured to high accuracy. A tolerance of ±50 µm has to be granted at each edge. As the facets have to fit into the available mounting space, the nominal size of the facets is 1400 x 2400 µm. The origin of the TRF system is fixed to the mounting area, rather than to the facet material glued onto it.

The TRF system should be used in the context of images produced by the AFM. E.g., offsets of individual image co-ordinates should be defined in the TRF.

3.4 Relation between the URF and ARF Systems

As the ARF system is fixed to the moving scanner frame, no unique relation can be given.

When the approach mechanism is in launch lock position, the Ya axis is parallel to the Zu axis (TBC). In all other positions of the approach mechanism the Ya axis is tilted towards the +Yu direction and therefore only approximately parallel to the Zu axis. The origin of the ARF system is TBD.

The following transformations apply:

$$Xu = -Xa$$
$$Yu \approx Za$$
$$Zu \approx Ya$$

$$Xa = -Xu$$
$$Ya \approx Zu$$
$$Za \approx Yu$$

3.5 Relation between the TRF and ARF Systems

When a facet is located in scanning position and parallel to the scanner table, then the TRF and ARF co-ordinate systems only differ by their origins. Normally, the facet and the scanner table would not be exactly parallel due to the rotation angle of the collector wheel and the tilt of the scanner table due to the approach mechanism.

The origin of the ARF system in the URF system depends on the position of the approach mechanism. There is a fixed relation between Xa and Xu, but the Ya/Za plane rotates with respect to the Yu/Zu plane.

The position of an individual needle on a target surface is determined by the position of the linear translation stage (in Xu and Xt) and the X-coordinate of the individual needle at the scanner head. The contact point at Yt is mainly determined by the rotation of the collector wheel and the position of the selected facet at the wheel, but also slightly by the tilt of the approach mechanism and the alignment errors of the needles in Ya-direction.

Both the ARF and TRF systems are right-handed co-ordinate systems. If the TRF is used to describe an image acquired by the AFM, the +Zt dimension is equivalent to the "height" of an imaged structure. At the same time, the piezo moving in +Za direction, which is approximately parallel to the +Zt direction, has to retract with increasing height of a structure.

3.6 Direction of rotation

A positive rotation of the collector wheel is defined as a clockwise rotation, if viewed along the Xa axis. For clarification see the side view of Fig. 5. A positive rotation corresponds to a "downward" movement (to -Ya) of the wheel in front of the needles.

4 Operational Aspects of Mechanisms and Co-ordinate Systems

4.1 Overview

The electric voltages as output of various position sensors and input to various actuators do not necessarily coincide with the directions in any of the co-ordinate systems. However, the polarity of sensor and actuator voltages is always the same.

Directions of increasingly positive voltages of sensors (linear stage and approach LVDTs) and actuators (X, Y and Z piezo high voltage set values) are shown in Fig. 7.
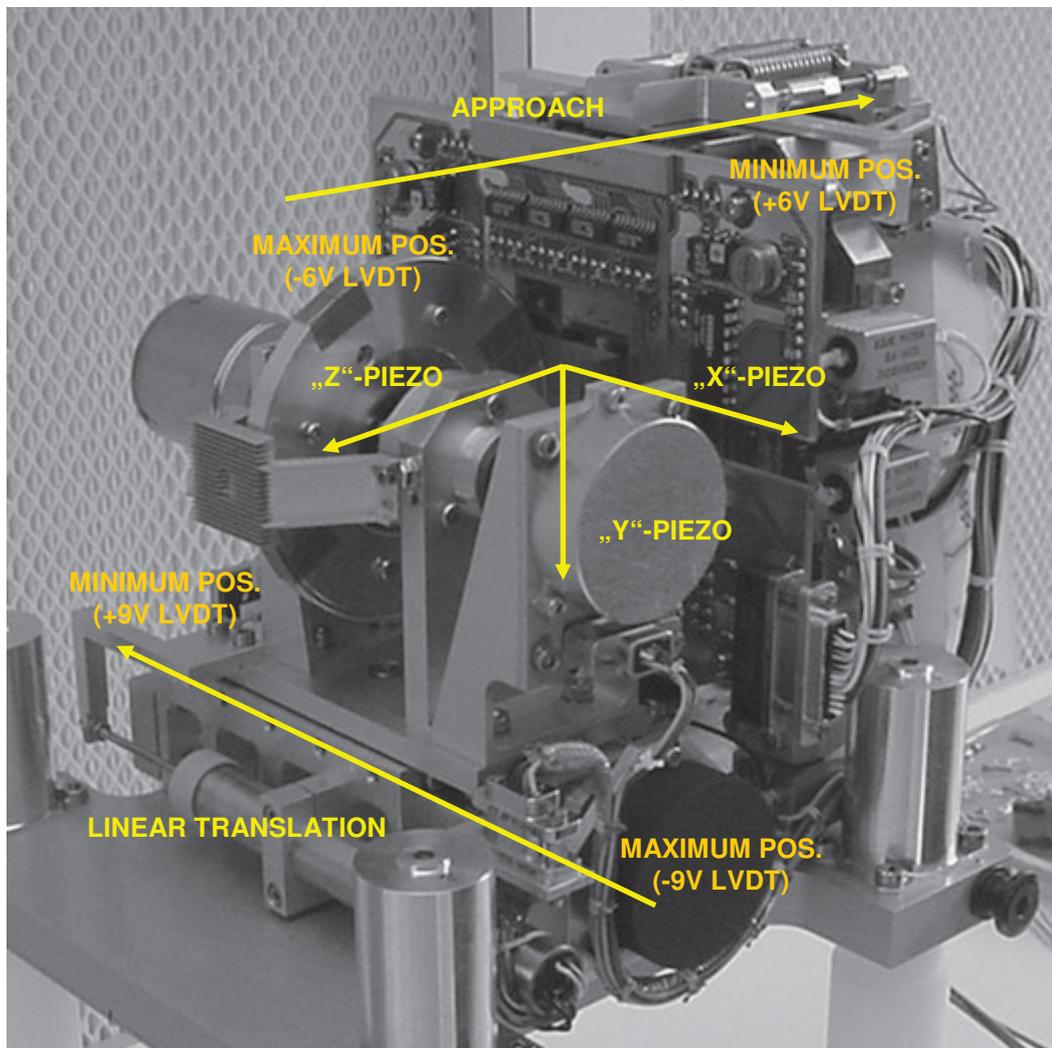

Figure 7: Directions of increasing voltages of sensors and actuators

Note that the tripod shown in Fig. 7 does NOT represent a co-ordinate system, but rather the direction of movement of the scanner table when increasingly positive voltages are applied to the X-, Y-, and Z-stages, respectively. Positive voltages move the scanner in the directions -Xa, -Ya, and -Za.

Positive voltages at the approach mechanism (i.e. at the LVDT which measures the movement) move the scanner table in +Za direction.

Positive voltages at the linear translation stage (i.e. at the LVDT which measures the movement) move the translation stage in +Xa direction.

4.2   Range of movement and special positions

4.2.1   Collector wheel

The facets at the collector wheel are numbered consecutively from 1 to 64.

The reference position of the encoder corresponds to the center position of facet number 1.

The zero position of the wheel corresponds to the position when the reference mark at the wheel points into reference position. Facet number 1 is the first complete facet encountered by the needle array when the wheel is moved in positive direction from its reference location.

Individual facets have the extensions $Xt=1400$ μm and $Yt=2400$ μm.

4.2.2   Linear translation

The linear translation stage has a launch lock position at the minimum linear translation stage position, corresponding to +9.1 Volt of the linear LVDT signal.

The full mechanical range of 32.8 mm corresponds to an electrical range of the linear LVDT signal of 18.0 Volt.

The safe position for the needle array is at the minimum linear translation stage location with an electrical value of +9.0 Volt.

Note that the position of a needle on a target area of the wheel is determined by several dimensions:

- position of the linear translation in Xa direction

- position of the selected needle in Xa direction

- rotation of the collector wheel (corresponds to a movement in Ya direction)

Additional corrections in other directions may be necessary due to imperfect alignment of needle arrays at the scanner head, facets at the wheel, etc..

Table 1 shows the linear LVDT set values for selecting a needle and setting different positions on the target area:

Cantilever	LVDT Position [V]			Geometric Position [mm]		
	Target left edge	Target centre	Target right edge	Target left edge	Target centre	Target right edge
Minimum		9,00			0,00	
1	6,97	**6,59**	6,21	3,70	**4,39**	5,08
2	6,10	**5,72**	5,34	5,29	**5,98**	6,67
3	5,23	**4,85**	4,47	6,88	**7,57**	8,26
4	4,35	**3,97**	3,59	8,47	**9,16**	9,85
5	3,47	**3,09**	2,71	10,07	**10,77**	11,46
6	2,58	**2,20**	1,82	11,70	**12,39**	13,08
7	1,69	**1,31**	0,93	13,32	**14,01**	14,71
8	0,80	**0,42**	0,04	14,95	**15,64**	16,33
9	-0,10	**-0,48**	-0,86	16,58	**17,27**	17,96
10	-0,99	**-1,37**	-1,75	18,19	**18,89**	19,58
11	-1,87	**-2,25**	-2,63	19,81	**20,50**	21,19
12	-2,76	**-3,14**	-3,52	21,43	**22,12**	22,81
13	-3,63	**-4,01**	-4,39	23,02	**23,71**	24,41
14	-4,50	**-4,88**	-5,26	24,60	**25,29**	25,99
15	-5,37	**-5,75**	-6,13	26,19	**26,88**	27,57
16	-6,24	**-6,62**	-7,00	27,77	**28,46**	29,15
Maximum		-9,00			32,80	

Table 1: Linear translation stage positions for cantilever selection (FM)

4.2.3   Approach mechanism

The approach mechanism has a launch lock position at the closest position to the collection wheel, in which case the scanner table is exactly perpendicular to the AFM Baseplate, i.e. Ya is parallel to Zu, Za is parallel to Yu.

This lock position corresponds to -9.0 (TBC) Volt of the approach LVDT signal.

The full mechanical range of ±0.5 mm which includes the launch lock position corresponds to an electrical range of the approach LVDT signal of 18.0 Volt.

The full mechanical range of the approach mechanism corresponds to a full mechanical range of the needle movement in Za-direction of TBD mm. In other words, the transfer function is Za(needle) = TBD * Za(approach).

The full electrical range of the approach position sensor (LVDT) is ±0.7 mm (TBC).

After the launch lock has been released the mechanical range of the approach mechanism is shortened to TBD mm, corresponding to TBD V.

4.2.4   Scanner

In Xa and Ya-direction the full nominal range of the piezo actuators in closed loop is 0 ... 100 μm, which corresponds to an electrical signal of -5.0 to +5.0 V.

In Za-direction the full nominal range of the piezo actuator in closed loop is 0 ... 7 μm, which corresponds to an electrical signal of -5.0 to +5.0 V.