Chapter 8

HXDS Translation Stages and Related Calculations

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8.1 Introduction

This chapter describes the HXDS translation stage equipment, what each stage moves, and how to compute useful information from the raw numbers given in the stage log files.

8.2 Hardware Description: Focal Plane Stack

In Figure 8.1 we diagram the logical structure of the focal plane HXDS equipment and translation stages. The entire HXDS detector set at the focal point (the HRMA X-Ray Detector Assembly, or HXDA) is mounted on a pair of translation stages, which move in the x and y directions. These stages are known, respectively, as `primex` and `primey`.

On top of this moving platform, there are two stacks of equipment. The first consists of the `hsiz` stage, which moves in z and supports both the `hsi` and `ssd_x` detectors.

The second stack of equipment on the platform is the `fpc_x1`, the `fpc_x2` and their supporting translation stages. The two detectors can be moved in y and z with the `pcy` and `pcz` stages. This set of equipment in turn sits on another pair of translation stages, the `pcay` and `pcaz`, which also support the aperture screen for the two `fpc_x` detectors. Each z stage stits upon the corresponding y stage.

In order to position the `hsi` or `ssd_x` at a desired position in space, one uses the `primex`, `primey`, and `hsiz` stages. Aperture selection for the `ssd_x` is by way of the `ssda` stage, described below.

The motion of the two `fpc_x` detectors is more complex. Their aperture screen is a flat screen roughly 30 ×60 cm, with apertures placed in a diamond pattern spaced approximately 5 cm apart. To select an aperture, one uses the `pcy` and `pcz` stages to move the desired detector into position behind the selected aperture. Then the whole assembly can be put into position in space using the `primex`, `primey` or `pcay`, and `pcaz` stages. Since the accuracy specifications are more stringent for the `primey` stage than the `pcay`, standard procedure calls for using the `primey` for precise positioning.

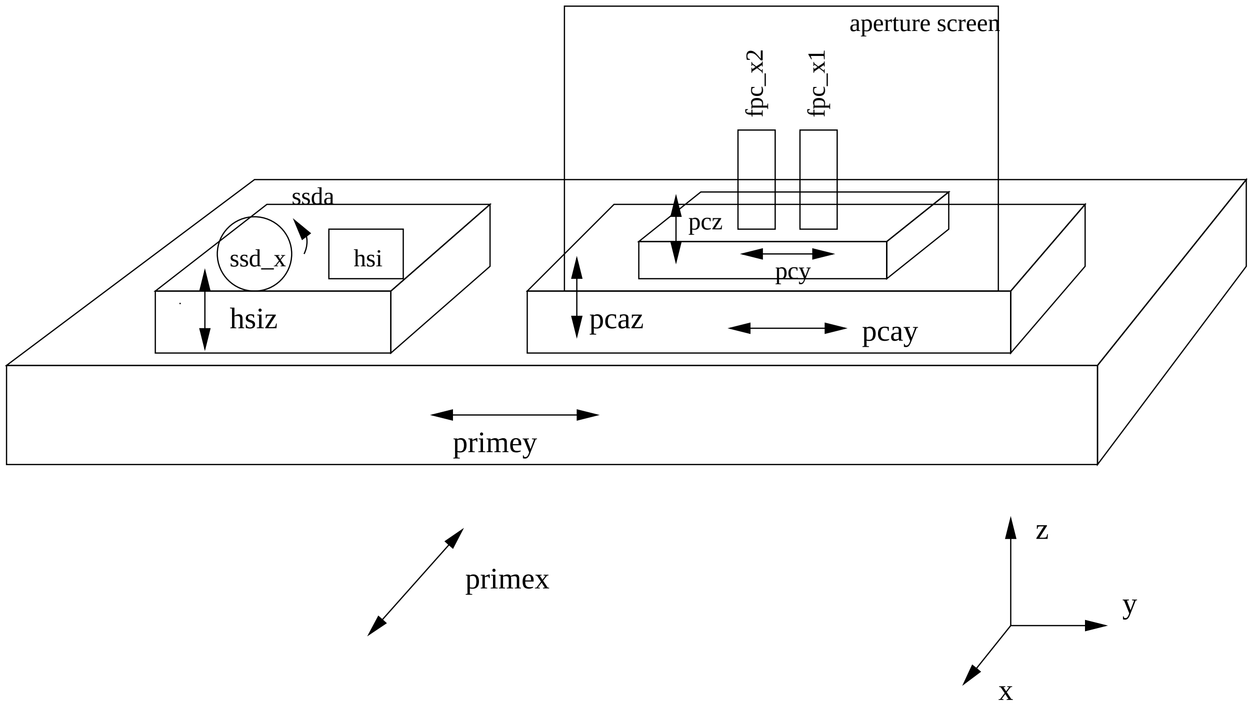

Figure 8.1: A diagram of the focal plane HXDA translation stages and detectors. Coordinates are XRCF coordinates; the HRMA is in the $+x$ direction from the detectors. Top refers to the $+z$ direction, and South to the $+y$ direction.

8.3 Hardware Description: BND

The `fpc_hn` detector can be moved about in two dimensions in a plane just in front of the HRMA entrance. This is accomplished with the `hy` and `hz` stages. In a similar way, the `fpc_5` detector can be moved in two dimensions in building 500, roughly 38 meters from the x-ray source. This motion is by way of the `5y` and `5z` stages. These two pairs of translation stages were used primarily for making beam maps, during tests known as Beam Uniformity tests.

8.4 Hardware Description: Apertures for SSD and BND Detectors

The two `ssd_` detectors each had an integral aperture wheel, operated by a rotary stage motor. These two stages are known as the `ssda` and `5ssda`, for the `ssd_x` and `ssd_5` respectively.

The `fpc_5` apertures are on a sliding plate, which could be put into place by moving the `5fpca` stage. This detector also has a blocking plate with a 36 mm diameter circular hole in it. Only one aperture at a time can be placed in front of the hole.

The `fpc_hn` has a circular aperture which can be moved in front of the detector using the `ha` stage, or it can be left open, exposing the full detector area. This stage, unlike the others mentioned in this chapter, has no encoder on it, and so cannot be read back to determine the status of this aperture. Standard procedure calls for running the stage until it trips limit switches, and counting steps. The resulting number in the `stglog` files thus varies somewhat from instance to instance, but it seems to be the case that `ha` values less than -2000 indicate the 35 mm aperture was in place,

irig	runid	caller	hsiz	ssda	primex	primey	pcaz
015193056000	108975	collect	−3411.75	144124.00	−46652.34	431655.41	−38280.75

pcz	pcay	pcy	hy	hz	ha	5y	5z
35431.00	−17297.00	−21031.00	−72563.87	−83537.02	0.00	120600.45	−89341.00

5fpca	5ssda
19999.50	32997.00

Table 8.1: Sample stage log entry, split into several lines for the reader's convenience

while those greater than -2000 indicate an open detector collecting area.

8.5 Stage Log File Formats

Entries in the stage logs were recorded by the HXDS computers for each "test," *e.g.* commanded stage motion, data collection etc. These logs, split into short files by time, are rdb tables (tab delimited ASCII files with headers identifying the columns). They contain three identifying columns plus the readouts of all HXDS stages. The columns are the irig time (in format DDDHHMMSSsss; a 3 digit day, 2 digits each of hours, minutes, and seconds, plus 3 digits of decimal seconds. Then follows the HXDS runid, a unique identifier which increments with each test, and a field called "caller" which identifies what operation was in progress following the move. Examples of this include "collect" (*i.e.* collecting x-rays; a single exposure), "beamcen" (finding the beam in the $y-z$ plane), and "acis_collect," a procedure for taking numerous short exposures for later coadding. The remaining columns are the values from the translation stage readouts, in units of microns. A sample entry (split into several lines to facilitate reading by humans) is presented in Table 8.1.

8.6 Computations with the Stage Log information: `fpc_x` Detectors

The basic maneuver with the HXDA equipment is a `focusmove` command. This causes the selected aperture to be put into the position of the last known best focus for a given mirror combination. The software must rely on a number of tables of information in order to accomplish this. These tables are as follows:

- The facility optical axis (FOA) table `foa.rdb`, which contains the 3-dimensional position of the best focus for each supported mirror combination (each shell, the full HRMA, and the outer and inner pairs of shells). The best focus is actually the stage readings of the `fpc_x2 P` aperture (*i.e.* the 20 μm diameter aperture). The mirror identifier, and the irig time at which the focus was updated are also included in this table. A sample of this table is shown in Table 8.2.
- The master table for the focal point instrument in question. This contains the hardware coordinates for the necessary stages to move each of this instrument's apertures to the focal point. It stores the geometry of the aperture screen or wheel. In the case of the `hsi`, various aim-points on the chip were established as pseudo-apertures, and these are listed with their

irig	mirror	primex	primey	pcaz
015132723000	all	−32882	−307149	10650
015132724000	1	−33115	−307149	10650
015132724000	3	−32764	−307149	10650
015132725000	4	−32495	−307149	10650
015132726000	6	−32867	−307149	10650
015132727000	13	−32968	−307149	10650
015132728000	46	−32634	−307149	10650
015132728000	leg	−32882	−307149	10650
015132729000	meg	−32968	−307149	10650
015132730000	heg	−32634	−307149	10650

Table 8.2: Sample section from the FOA table

hardware coordinates in the `master.hsi` file. These tables were updated from time to time as the geometry became better understood, and so the final version of the table is to be used in each case.

- A table of aperture sizes. Each aperture has a name, which is what is given in the master table. To convert the name into a size (diameter in microns, if a circular aperture, or dimensions in microns with a tilt for rotated slit apertures), this table is used. The master tables and aperture sizes for the detectors are listed in Tables 8.3 – 8.5.

These tables are found in the `$DB` directory at XRCF. A copy of this directory as it existed at the end of Phase E of the calibration was made at SAO and is the default location for these tables. As of this writing, it is kept in `/proj/axaf/simul/databases/hxds`.

What follows is an English description of the computation of the aperture in use, and its position, which is implemented in the perl script known as `calcstage4`.

- Read the FOA table and the master table for the fpc_x2. Compare the numbers from the last FOA table entry prior to the measurement for the mirrors used, to the entry in the fpc_x2 master table for aperture P. Differences in the 3 coordinates ($FOA - master$) are the offset between the original and the contemporary facility optical axis ("FOA offsets").

- Search the master table for the fpc_x for `pcy` and `pcz` values that match those from the stage log, within a given tolerance (5000 μm works well). This identifies the aperture in use.

- Look up the aperture size in the aperture size table.

- Compute the location of the aperture center:

$$X = stglog_{\texttt{primex}} - master_{\texttt{primex}} \quad (8.1)$$
$$Y = stglog_{\texttt{primey}} - master_{\texttt{primey}} + stglog_{\texttt{pcay}} - master_{\texttt{pcay}} \quad (8.2)$$
$$Z = stglog_{\texttt{pcaz}} - master_{\texttt{pcaz}} \quad (8.3)$$

- Subtract the FOA offsets from all 3 coordinates.

8.7 Computations with the Stage Log information: Other Detectors

The computations with `ssd_x` and `hsi` detectors are not very different from the above, except for the method for obtaining the aperture in use. For the `ssd_x`, one compares the entries in the master table for the `ssd_x` to the stage log `ssda` stage, within tolerance, to obtain the aperture ID. For the `hsi`, which has no native apertures, the name of the pseudo-aperture (*i.e.* aim point on the chip) is obtained from a parameter (*i.e.* supplied by the user). In this case the aperture size is not applicable.

The Y and Z position computations are also slightly different, since the `ssd_x` and `hsi` detectors are not sitting on the `pcay` and `pcaz` stages:

$$Y = stglog_{\texttt{primey}} - master_{\texttt{primey}} \quad (8.4)$$

$$Z = stglog_{\texttt{hsiz}} - master_{\texttt{hsiz}} \quad (8.5)$$

The remainder of the computation proceeds as above for the `fpc_x` detectors.

8.8 Known Shortcomings of this Method

During Phase E of the XRCF testing, tests were performed with nonzero values of the HRMA pitch. Because of a stuck actuator, the HRMA was rotated not about its node, but about a line through the stuck actuator. This results in a motion of the focal point by approximately -317.7 μm for each arcminute of pitch. This offset was made manually by the HXDS operators for each test, and not in general incorporated into the FOA table. Thus the `calcstage4` script outlined above cannot include this offset, and the offset must be applied after the fact to the results of the calculation. Details are in §14.2.

Brad Wargelin's Analysis of the focus tests with the `hsi` and the `fpc_x2` shows a systematic offset along the facility axis direction (x), in the sense that the `hsi` is 2744 μm from the `fpc_x2` in the x direction, which is 291 μm less than the the assumed value of 2975 μm. This could be fixed for analysis purposes by adjusting the `primex` values in the `hsi` master table.

It also appears, from Brad Wargelin's analysis of the non-zero-order grating focus check tests, that the `primey` stage is rotated slightly about its vertical axis, so that `primex` (along the FOA) changes slightly as `primey` is varied. The amount of rotation is approximately 0.0058 ± 0.0004 radians (1/3 of one degree) in the sense that the focal plane detector moves slightly away from the HRMA ($-x$) as `primey` is increased ($+y$, to the south).

Details for these last two effects may be found, for now, on the web at

`http://hea-www.harvard.edu/MST/simul/xrcf/HRMA/focus/hsi_offset`.

Another shortcoming has come to our attention: The FOA table was often not updated to reflect beam centering tests. Often prior to a test the `beamcen` procedure was run with a small aperture to find the beam for the subsequent test. The test was then run not at the recorded FOA position but at the location of the beam found by the `beamcen`. We are therefore analyzing the `sum` files from the `beamcen` runs, and will produce an FOA table which can be read by the `calcstage` script which will reflect their results.

aper	primex	primey	pcaz	pcz	pcay	pcy
A	−43381	−325402	7244	11600	50614	−86871
B	−43440	−325402	11932	6912	10357	−48614
C	−43500	−325402	7939	10905	−29140	−9117
D	−43501	−325402	−40573	59417	−82683	44426
E	−43461	−325402	−40284	59128	−56716	18459
F	−43461	−325402	−40471	59315	−30373	−7884
G	−43430	−325402	−40411	59255	−3775	−34482
H	−43361	−325402	−21405	40249	19880	−58137
I	−43470	−325402	−16635	35479	−17284	−20973
J	−43469	−325402	−16681	35525	−43485	5228
K	−43499	−325402	−16756	35600	−69645	31388
L	−43510	−325402	7804	11040	−82766	44509
M	−43480	−325402	7835	11009	−56570	18313
N	−43450	−325402	32554	−13710	−17292	−20965
O	−43500	−325402	32466	−13622	−43505	5248
P	−43500	−325402	32416	−13572	−69634	31377
Q	−43530	−325402	56229	−37385	−82746	44489
R	−43531	−325402	56292	−37448	−56528	18271
S	−43500	−325402	56326	−37482	−30399	−7858
T	−43440	−325402	56412	−37568	−3793	−34464
U	−43440	−325402	44511	−25667	19898	−58155
V	−43502	−325402	80136	−61292	−69678	31421
W	−43500	−325402	80152	−61308	−43468	5211
X	−43461	−325402	80188	−61344	−17304	−20953
Y	−43499	−325402	80234	−61390	8950	−47207
Z	−43441	−325402	80239	−61395	35134	−73391
AA	−43500	−325402	−65107	83951	−69621	31364
AB	−43450	−325402	−65171	84015	−43531	5274
AC	−43350	−325402	−65105	83949	−17212	−21045
AD	−43301	−325402	−69843	88687	9015	−47272
AE	−43251	−325402	−48294	67138	23489	−61746
AF	−43170	−325402	−64957	83801	50642	−86899
AG	−43301	−325402	−32714	51558	50574	−86831
AH	−43300	−325402	49043	−30199	50530	−86787

aper	size
A	35000
B	20000
C	10000
D	4000
E	2000
F	1000
G	500
H	300
I	200
J	150
K	100
L	70
M	50
N	40
O	30
P	20
Q	15
R	10
S	7.5
T	5_40
U	3
V	5x100v
W	5x100v−5
X	5x100v+5
Y	5x100h−15
Z	5x100v−15
AA	10x200v
AB	10x200v−5
AC	10x200v+5
AD	10x200h
AE	80x500v
AF	500x10v
AG	500x10v+5
AH	500x10v−5

Table 8.3: Master table (left), and aperture size table (right) for the HXDA FPC detectors

aper	primex	primey	hsiz
ap1	−57039	413484	18482
ap2	−57039	413464	18380
ap3	−57039	413464	18380
ap4	−57039	413464	18380
ap5	−57039	413296	18410
ap6	−57039	413354	18408
ap7	−57039	413384	18387
ap8	−57039	413372	18393
ap9	−57039	413395	18407
ap10	−57039	413478	18426
ap11	−57039	413481	18428
ap12	−57039	413596	18472
ap13	−57039	413405	18453
ap14	−57039	413331	18534
ap15	−57039	413584	18540
ap16	−57039	413498	18546
ap18	−57039	413609	18529
ap17	−57039	413484	18482
ap19	−57039	413484	18482
ap20	−57039	413484	18482

aper	size
ap4	5000al25
ap3	5000al125
ap2	5000
ap5	2000
ap6	500
ap7	200
ap8	100
ap9	70
ap10	50
ap11	40
ap12	30
ap13	20
ap14	15
ap15	10
ap16	7
ap18	5_40
ap1	Fe_LK
ap17	5_12
ap20	200x2v+5
ap19	200x2v−5

aper	size
ssd5_12	5_12
ssd5_40	5_40
ssd7	7
ssd10	10
ssd15	15
ssd20	20
ssd30	30
ssd40	40
ssd50	50
ssd70	70
ssd100	100
ssd200	200
ssd500	500
ssd2000	2000
ssd5000	5000
ssd5000al25	5000al25
ssd5000al125	5000al125
ssd2spos	2spos
ssd2sneg	2sneg
ssd244cm	244cm

Table 8.4: Master table (left) and aperture size table (center) for ssd_x, and aperture size table for ssd_5 (right)

aper	primex	primey	hsiz
CEN	−46475	64863	17134
CA1	−46475	64958	17894
CA2	−46475	64547	17898
CA3	−46475	64136	17902
CA4	−46475	64954	17483
CA5	−46475	64543	17487
CA6	−46475	64132	17491
CA7	−46475	64950	17072
CA8	−46475	64539	17076
CA9	−46475	64128	17080
CAL1	−46475	68188	22291
CAL2	−46475	67398	22729
LL90	−46475	68018	22879
LL95	−46475	68039	22919
LL99	−46475	68210	23227
CAR1	−46475	59451	12749
CAR2	−46475	60104	12238
UR90	−46475	59521	12291
UR95	−46475	59493	12264
UR99	−46475	59236	11997

Table 8.5: Master table for hsi