FIRMWARE TARGET ACQUISITION

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ABSTRACT

The firmware target acquisition (TA) maps out a portion of the $4''.3 \times 4''.3$ aperture, filters the data, finds a peak within a given brightness window, and locates the center in X and Y of the peak. The data acquisition, filtering, and finding of peaks is described in detail. Firmware acquisition has been designed to be flexible, with both user determined parameters and internal parameters. The user determined parameters are in Table 1 and 2; the internal parameters, which can be changed but are not in general meant to be changed, are in Table 3. Defaults for these parameters are given. The serial engineering data returned by the firmware can be seen in Table 4.

One very efficient way to use the firmware target acquisition is to first perform a coarse grid in Y and locate the target, then perform a fine grid in the area around the target. This mode of operation is sketched out at the end and parameter values are suggested.

I. DATA ACQUISITION

There are two very different ways to initiate firmware target acquisition. The first is by setting the target acquisition bit in the onboard FOS microprocessor with the YACQMODE command. This sets a flag which causes the TA algorithms to be performed automatically on the data as a part of the normal data acquisition process. The second way to initiate TA is to send a YTA command, which presupposes that data has already been taken and performs the TA algorithms on that data. These are described further below.

Since firmware target acquisition uses ordinary science data, setup for data collection is done in the normal fashion but using parameters and values as appropriate for the TA situation. A description of the setup for data collection can be seen in Section 3.4 of the Faint Object Spectrograph Instrument Handbook. The exposure time is determined by the nested parameters

$$XSTEPS \times OVERSCAN \times YSTEPS \times SLICES \times PATTERNS$$

.

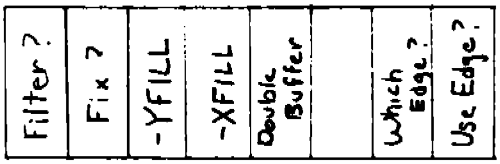
XSTEPS determines how many steps in X are made per diode and is typically defaulted to 4. Overscan is designed to correct for the effects of any diode- to-diode non-uniformity, including dead channels, and is typically defaulted to 5. In TA, 20 diodes are typically used, which is sufficient to cover the TA aperture in X. Using 20 diodes with an overscan of 5 and XSTEP of 4 leads to an X dimension in the acquired data of 96 ($(20+OVERSCAN-1)\times XSTEP$). The dimension in Y is simply given by the number of Y steps (YSTEPS).

The user can control the fineness with which the aperture is mapped in Y through the parameter YSTEPS in conjunction with YRANGE. YRANGE sets the range in YBASE units (scaled by 32 to fit in an 8 bit command field) over which the aperture will be mapped. Then the step size in YBASE units (see Section IV below) is given by

$$YSIZE = \frac{32 \times YRANGE}{YSTEPS}.$$

SLICES determines the number of times the Xsteps×overscan×Ysteps sequence is carried out and is defaulted to 1. Each subsequent SLICE goes into a new set of memory locations. When the TA ACQMODE bit is set the target acquisition analysis is done directly after each SLICE on the data in that SLICE. For TA, SLICE should always be set to 1. If, however, target acquisition processing is initiated by sending the YTA command, the TA analysis is performed on data that has already been taken.

The mode of TA is set in the YTAMODE command, which is illustrated here.



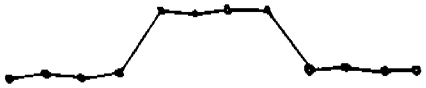
YTAMODE

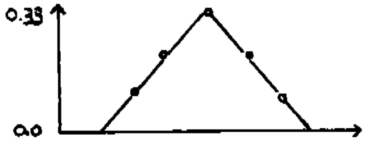
To use the Y edge of the diode for TA, as described in Section II, the first bit in YTAMODE is set, while the second bit tells which edge to use. There is a bit to denote usage of a double buffer. This allows the original data to remain unchanged, if desired, so that it can be refiltered. By leaving the -XFILL and -YFILL bits equal to zero in YTAMODE, the default filters tables, YFTBL and XFTBL, are filled with default filter shapes with widths determined by YXFILWID and YYFILWID. By setting the -XFILL and -YFILL bits (16 and 32 respectively) the filter tables can be filled with other customized shapes and not be overstruck by default initialization. Finally, one can set the Fix and Filter bits (64 and 128 respectively). Fixing will correct for bad channels, which is not so important because we are only using about 20 channels and can hopefully choose well behaved ones. Filtering on the other hand is highly desirable, as discussed in Section II.

Initiating TA on data that has already been taken, by sending the YTA command, is used when no targets were found in the count window after an ordinary firmware TA. Then the NSSC-1 Applications Processor (AP 28) that is driving the firmware can broaden the window and the TA algroithms can be performed on the original set of data. When acquisition is initiated through YTA, the filter bit can be turned off so that the procedure does not re-filter the data.

II. FILTERING

After the data is taken it is filtered. Using the standard XSTEP of 4, a point source appears in 4 consecutive data elements in the X direction. The default filter for X is simply a 5 point triangular filter.


COUNTS IN X



FILTER

Convolving the filter with the data produces an unambiguous peak. To filter optimally, the FWHM of the data should be about the same as the FWHM of the filter.

In the Y direction a point source appears in many consecutive data elements, since the diode is extended in that direction.

The default filter shape for Y is therefore more complex since it must find the center of a very broad plateau. It is the convolution of a piecewise parabolic smoothing function and a differentiating function and has a default width of 7. The idea is that we want to simultaneously filter the data to reduce noise problems and look for the maximum derivative in the Y direction. These two operations commute so that they can be done at the same time with a sawtooth convolution filter.

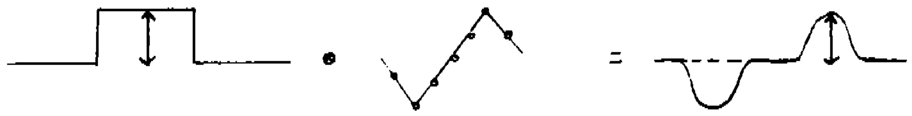
SMOOTH DIFFERENTIATE SAWTOOTH

This filter converts the flat topped peak of a source to a narrow peak on one edge and a narrow negative peak on the other edge as selected in YTAMODE. Any negative values are actually truncated at zero. This effectively locates the point of maximum derivative in the Y direction.

Thus the sawtooth filter uses the edge of the diode to locate the target, rather than the center. A simple triangular filter shape in Y is also selectable in YTAMODE but generally produces less sensitive results due to the height of the diodes.

Does filtering significantly affect the peak counts, and thus affect the setting of the window of allowable values to be accepted as a peak? The extent to which the filtering reduces the peak height in the data being smoothed is dependent on a number of factors; the width of the filter functions (XFILWID, YFILWID), the size of the steps between data points (XSTEP, YSTEPS, and YRANGE), the size of the target object image, and the relative brightness of the object and sky background.

The low pass filtering itself will have only a small flattening effect on a peak as long as the width of the peak in the raw data is large compared to the width of the filter. This is likely to be the case in the X direction (and in Y if edge detection is not chosen) since the real data peak can be no narrower than the width (height) of the diodes. However, in the case of edge detection in Y the sawtooth is normalized to account for the filtering such that, after the combined filtering and differentiation operation, the maximum height of the smoothed peak resulting from an ideal step function in the data is equal to the size of the original step discontinuity as illustrated here.



A reduced output peak height would result from a softer transition in the raw data. There is a softer transition when the "size" of the edge in the data due to optical/electron-optical image size and diode edge response is not small compared to YSTEP size (e.g. a fine scan). Additionally it must be remembered that the size of the peak resulting from differentiation will be related to the difference in brightness between the object plus sky and the sky, rather than the absolute brightness of both together. This needs to be considered especially when acquiring very faint targets.

The net reduction in counts is a combination of these effects, and can be significant. For example, during August, 1985 firmware testing, cases were run with a target of 1500 peak counts and with YSTEP sizes of both 40μ and 16μ. The filtered data showed peak counts of 1180 for Y stepping of 40μ but only 810 counts for the finer Y stepping of 16μ. This must be taken into account when setting values for the windows in YTARACQ (see

Table 1).

III. FINDING PEAKS

Once the data is filtered, it is searched for peaks. In X, a peak corresponds to the point where the target is in the center of the diode. For the sawtooth filter in Y, a peak corresponds to the point where the target is on the appropriate edge of the diode array.

When a count falls within the acceptable range (TAL < N < TAU), the algorithm looks to see if it is a relative maximum. It looks at the counts in a region ± XSKIRT from the peak for X and in a region ± YSKIRT for Y. If it is a relative maximum, a centroid position is calculated for the peak, using the adjacent pixels in X and Y. If a peak isn't found, the window limits can be changed from the program that calls the firmware (AP 28) and the firmware algorithm can be run again without acquiring new data by sending a YTA command. A parameter can be set in AP 28 (YTALM) that limits the number of times that the windows can be changed.

The algorithm continues looking for peaks and, if a second peak is found that is also a relative maximum, it asks if the peak is close enough to the first peak to be considered as the same peak. This parameter, XPCLOSE, is a default distance of 32 in XBASE units, or the width of a diode. In Y, this parameter is YECLOSE if using the edge and is set to a default value of 64 in YBASE units, which represents the same physical distance as XPCLOSE. If the center is used to locate the target in Y, the parameter is YPCLOSE, and is set by default to 256, or the height of a diode.

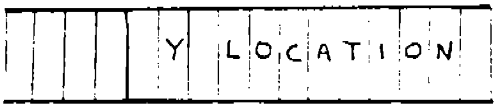
If a second relative maximum is part of a first maximum, the centroid positions are averaged and the search continues. If it is not part of the same maximum, the firmware quits. The number of peaks which are averaged together is stored in the upper 4 bits of

YTARYCTR. Up to 15 relative maxima can be considered to be part of the same peak, and averaged together in this way. With over 15 peaks, the maxima still get averaged but with the incorrect weight because of the 4 bit limit on the number of peaks. This large number accomodates the very flat topped plateau in the Y direction, when the Y edge is not used.

Finally, when the final peak has been found, there is a parameter, CDIODE, that designates which diode the offset X and Y values will deflect the target to. This value is set by default to 256, roughly the middle of the diode array. There are a number of internal parameters, not normally changed by the user, which can be changed by the YKEY command. It is possible to change XSKIRT, YSKIRT, XECLOSE, YECLOSE, YPCLOSE, and CDIODE parameters with the YKEY command. These parameters are summarized in Table 2.

The results of the firmware TA are sent down with the serial engineering data as YTARXCTR and YTARYCTR. This is a 16 bit word that has 12 bits for the X or Y base values which would directly place the target on the center, upper edge, or lower edge of diode number CDIODE. The remaining four bits tell if all the data was too faint, if any peaks too bright were found, if the field was too crowded, and if the TA was valid.

YTARXCTR



YTARYCTR

IV. UNITS

In units of microns, one diode is 40 μ wide and 200 μ high, spaced at 50 μ. An arcsecond subtends 140 μ at the photocathode, so that a diode is $0\farcs358$ wide and $1\farcs434$

high. There are units that the user interfaces with the instrument in, YBASE and XBASE units. The scaling between microns and YBASE units is set by XPITCH and YPITCH. For TA, XPITCH and YPITCH will always be set such that 256 YBASE units represents 200 μ and 32 XBASE units represents 50μ. XPCLOSE, YPCLOSE, and YECLOSE are expressed in these units, along with YBASE and XBASE.

V. EXAMPLE: COARSE AND THEN FINE

A time efficient and generally reasonable way to use the firmware target acquisition is to first locate a target in the $4''.3 \times 4''.3$ aperture by doing a coarse and quick map of the aperture. This position of the target, which should be good to 3 - 4 μ, is then used for the center position of a fine mapping of the same target. This will probably be done by actually repointing the telescope, since it is important to have the target near the center of the $4''.3 \times 4''.3$ aperture to avoid edge effects. Also, the NSSC-1 cannot loop new YBASE values directly into the firmware. They must be linked from the ground and therefore the values for YBASE for a series of observations must be set in most cases weeks in advance.

Typical values for the coarse mapping would be YRANGE=26, YSTEP=16. This results in a YSIZE of

$$YSIZE = (\frac{32 \times 26}{16}) = 52.$$

This roughly covers the large $4''.3 \times 4''.3$ aperture. After finding the target in this position, and recentering, it can be rerun with YRANGE=8, YSTEP=16 so that YSIZE=16. This is roughly the same sample spacing as in the X direction with the default XSTEP of 4 and should result in a Y accuracy of better than 1 micron, or $0''.007$. These would be run with all the default values as recommended in the tables.

Table 1

Firmware Target Acquisition Parameters

Name	Description	Default
YACQMODE	Choose firmware mode of data acquisition. For example time tagged mode, reject mode, and/or target acquisition mode.	16 plus other options if desired
YTA	Perform target acquisition on data. already in microprocessor memory.	
YTAMODE	Fix and filter science data as needed. 1 = Use edge instead of peak for Y position. 2 = Leading edge. 0 = trailing edge. 8 = Use double buffer to save both raw and filtered data. 16 = Don't use default filter table in Y. -YFILL 32 = Don't use default filter table in X. -XFILL 64 = Fix data; replace bad diodes, end effects, rejects. 128 = Filter data.	131 filter data, use single buffer and leading edge
YXFILWID	If default filters are used, specify X filter width.	5
YYFILWID	If default filters are used, specify Y filter width.	7
YTARACQ	Sets window levels for comparison with data intensity.	
	TAU = upper window	$2^{16} - 1$
	TAL = lower window	10

Note: Values here are quoted in decimal but in the procedures are quoted in octal.

Table 2

Firmware Target Acquisition Parameters

Name	Description	Default
YBASE	Inital deflection value in Y in YBASE units.	
XBASE	Inital deflection value in X in XBASE units.	
YRANGE	Range in Y over which the diodes will scan. In YBASE units.	20-6
YSTEPS	Number of steps used to scan Y-RANGE. Note that Y-RANGE and Y-STEP determine Y-SIZE; $YSIZE = 32 \times YRANGE \div YSTEP$ Region is scanned in Y from Y-BASE to YBASE+(n-1)÷n×32×YRANGE.	16
XSTEPS	Number of steps used to scan 1 diode width (50μ) in X.	4
1STCHN	First channel of diode array to be read.	
NUMCHNLS	Number of channels of diode array to be read.	20
OVERSCAN	Number of times to repeat the XSTEP sequence. Each subsequent sequence starts at a new diode.	5
SLICE	Number of times to repeat XSTEP, OVERSCAN sequence	1

Note: Values for YBASE and YRANGE are in YBASE units.

Table 3

Firmware Target Acquisition; Internal Parameters

Parameter	Description	Default
XFTBL	Filter table for X.	Triangular filter
YFTBL	Filter table for Y.	Sawtooth filter
XSKIRT	Range in X to look for relative maxima.	1 diode
YSKIRT	Range in Y to look for relative maxima.	1 diode
CDIODE	Diode number where the results of TA "put" the target.	256^{th} diode
XPCLOSE	If a second relative maximum is found, this parameter sets how close it must be to be considered part of the same peak.	32 XBASE units
YPCLOSE	When using the peak to find the Y position, how close must a second maximum be to be considered part of the same peak.	256 YBASE units
YECLOSE	When using the edge to find the Y position, how close must a second maximum be to be considered part of the same peak.	64 YBASE units

Table 4

Serial Engineering Data

Parameter	Description
YTAMODE	The mode that firmware TA was run in.
YXFILW	The filter width in the X direction.
YYFILW	The filter width in the Y direction.
YTAMIN	Minimum number of counts to be considered a peak.
YTAMAX	Maximum number of counts to be considered a peak.
YTARXCTR	X location. Distance in X-Base units between current X position of target and middle of diode CDIODE.
YTARYCTR	Y location. Distance in Y-Base units between current Y position of target and specified portion (middle, upper edge, or lower edge) of diode array.

Note: YTARXCTR and YTARYCTR store the position in 12 bits and have four additional bits for other information. In YTARXCTR, these 4 bits keep track of whether a peak was found, if a peak of too great a brightness was found, if the field was too crowded, and whether the data was valid. In YTARYCTR, these bits indicate the number of separate maxima that were averaged together to get the final result.