SPACE TELESCOPE SCIENCE INSTITUTE

INSTRUMENT SCIENCE REPORT

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TITLE: Mode 2 Target Acquisition: Binary Search Parameters

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ABSTRACT

Introduction:

The idea of binary search target aquisition is to identify a given target in the $4''.3 \times 4''.3$ aperture, calculate a centroid in the direction along the diode array (x), and place it on the edge of the diode array to accurately determine its y position. The target is identified by specifying the range of counts that stars in the field are expected to have, and then specifying which star, in order of brightness, is the target. The target is driven to the edge of the diode array, the position of the star is found, and a slew request to place the target in the center of the aperture is made to the telescope.

Finding the target and placing it on the edge of the diode array is a two step process. First, the aperture is mapped in three y strips, typically with 4 x steps per diode and with a multiplicity (or overscan) of 5. The target is located in one of the three strips, and the total counts are calculated. Now the target will be driven to the lower edge of the diode array if it is in the middle y strip or the lower y strip, and will be driven to the upper edge if it is in the top y strip. The diode array is now moved in a sequence of y steps, each one being half the size of the preceding y step. After each y step a check is made to see if the counts correspond to the star being on the array, on the edge of the array, or off the array. If the star is on the array, the array is moved so as to get it off. If the star is off the array, the array is moved so as to get it on. If the star is on the edge of the array, the sequence stops and the position is calculated.

Description and Implementation of Parameters:

There are a number of parameters that control this process. First, there are the parameters used to find the sources in the field and to identify the star. These include: the count window for stars in the field, NMAX, and NMIN; the order of brightness of the target, YNBRT; the number of sigma above the noise to count as a peak, SMOTSV; the width of a peak, YHWHM; and an option to stop after the first peak is found, YNPEAK. There are two parameters that are used to set the windows for determining when a star is on the edge of the diode array, YSTAT, and YTOLER. There are two parameters that tell the program what to do in case the target is not found, YPPB, and YRSINV. Finally, the offsets from the center of the large aperture to the science aperture plus the offsets to the object of interest in the case when TA is done on a reference star, are given by YXOFST, and YOFFST.

These parameters are summarized in Table 1. Their default values are also given along with the names of the procedures in which they are implemented. The recommended values for the parameters are outlined in Table 2.

To locate a given star, the $4''.3 \times 4''.3$ aperture is mapped by the diode array in three y strips. When a y strip has been mapped it is searched for peaks in the procedure YFPKFD. In the search for peaks, the parameter SMOTSV sets the multiple of the sky variance that defines a peak. The width of a peak is set by YHWHM, which depends on the number of x steps. For a peak to be considered a field star, it must lie within the range NMIN and NMAX. Finally, to identify the target from the field stars, YNBRT specifies which star, in order of brightness, is the target star. If fewer than YNBRT stars are found in the field, the faintest star is selected for the binary search. The peak number that is actually chosen is returned in the standard header packet (SHP).

If a field is known to contain only one star, YNPEAK can be set to 1 to stop the aperture map when the first peak lying within NMIN and NMAX is found. If YNPEAK is set to greater than 1, the entire aperture is mapped. The binary search processor can not handle more than four stars per y strip. If more than four stars are found, an error message is written and the processor exits.

How does the processor determine when a star is on the edge of a diode? The processor checks to see if the target counts are within a window around half of the maximum number of counts in the star. Two factors come into determining the window. The first is the edge response, or the rate at which counts decrease as the star moves across the edge of the diode. The edge response is given in the parameter YTOLER, which scales half the total counts in the star, NMAX/2. The second factor is the $\sqrt{N}$ noise. YSTAT scales the $\sqrt{n}$ noise. Both YTOLER and YSTAT are expressed in percentage.

The star is considered on the edge of the diode if

$$NMAX/2 - f_- < N < NMAX/2 + f_+ \tag{1}$$

where

$$f_+ = YTOLER \times NMAX/2 + YSTAT \times \sqrt{NMAX/2(1 + YTOLER)} \tag{2}$$

$$f_- = YTOLER \times NMAX/2 + YSTAT \times \sqrt{NMAX/2(1 - YTOLER)}. \tag{3}$$

To give an example of how the two factors come into play, we can look at the extreme examples. For zero edge response, which would be a perfect step function, the window for the target on the edge of the diode array is given by

$$NMAX/2 - YSTAT\sqrt{NMAX/2} < N < NMAX/2 + YSTAT\sqrt{NMAX/2}. \tag{4}$$

This means simply that the window is dominated by the $\sqrt{N}$ noise. In the other extreme, if there are infinite counts the $\sqrt{N}$ noise effectively goes to zero and the window is given by

$$NMAX/2 - YTOLER(NMAX/2) < N < NMAX/2 + YTOLER(NMAX/2). \tag{5}$$

In this case the window is dominated by the edge response.

If the field does not yield a target, there are several options. A pre-planned branch (such as choosing another target) can be made available by setting YPPB to 1. For YPPB greater than 1, no branch is available. A raster scan can be requested for YRSINV of 1. For YRSINV set to 2, no scan is requested, and for YRSINV of 3, a raster scan is forbidden.

When a target's position has been determined in the binary search, a slew request is made to the telescope and a slew is done. This slew includes only the slew from the target position to the center of the $4''.3 \times 4''.3$ aperture. Although there are several offsets involved in getting the desired target into the science aperture, the only offset included in the TA slew is the offset to put the reference target in the center of the large aperture. The additional offsets needed to go from the reference target to the target of interest, when applicable, and to go from the center of the large aperture to the science aperture are included in the parameters YXOFST and YOFFST and appear in an explicit slew request to HST.

Table 1

Parameters for Mode 2 Target Aquisition: Binary Search

Parameter	Description	Default Value	Procedure
NMAX	Upper count limit for star field window.	65535	YFPKFD
NMIN	Lower count limit for star field window.	50	YFPKFD
SMOTSV	Number of sigma above noise to count a peak.	2	YFPKFD
YHWHM	Width for merging peaks. YHWHM depends on X-step value. Default assumes X-step = 4	4	YFPKFD
YNBRT	Choose the Nth brightest peak. N is 1 to 12.	1	YFBSC1
YNPEAK	For YNPEAK = 1, stop map at first peak. For YNPEAK > 1, map entire aperture.	2	YFBSC1
YPPB	If target is not found, pre-planned branch is available for YPPB = 1. YPPB = 2, no branch.	2	YLKELS
YRSINV	Options if no peak is found. For YRSINV = 1, raster scan requested, for = 2, raster scan not requested, for = 3, raster scan forbidden.	3	YLKELS
YSTAT	Scales the square root statistical fluctuation to set tolerance for edge centering.	100	YFETST
YTOLER	Scales the edge response to set tolerance for edge centering.	35	YFETST
YOFFST	Offset in Y.	0	YFBSC2
YXOFST	Offset in X.	0	YFBSC2

See text for detailed explanation of parameters.

Table 2

Parameters for Mode 2 Target Aquisition; Recommended Values

Parameter	Units	Recommended Value
NMAX	Counts per diode for one x-step	65535
NMIN	Counts per diode for one x-step	50
SMOTSV	Number of sigma	2
YHWHM	Integer x steps	4
YNBRT	Integer	N
YNPEAK	Integer	2
YPPB	Integer	2
YRSINV	Integer	3
YSTAT	Percentage	100
YTOLER	Percentage	35
YOFFST	32^{nds} of a micron at the photocathode	0
YXOFST	32^{nds} of a micron at the photocathode	0