



MULTIPLE MIRROR TELESCOPE OBSERVATORY

Smithsonian Astrophysical Observatory and Steward Observatory, University of Arizona

Reply to: MMT Observatory
University of Arizona
Tucson, Arizona 85721
(602) 626-1558

MMTO Technical Memorandum 83-1

From: B.L. Ulich

Subject: Image Stacking and Guiding Accuracy

Date: January 22, 1983

The Telescope Coalignment System now in use at the MMT has the capability of measuring star image positions, and of tilting the secondary mirrors to put the individual images in the desired locations. For some time, however, it has been apparent that the accuracy of image stacking was not as good as expected. For instance, single images of about 0.7 arc second FWHM are stacked to produce a composite image of about 1.0 arc second FWHM. Further, the images begin to separate with time, so that an effective FWHM of about 1.5 arc seconds is actually achieved for periods of about twenty minutes. Several things can be done to improve this situation, and this memo reports on some of the work carried out recently to understand and to eliminate known problems.

Six sets of open-loop flexure data have been taken since the Optics Support Structure tuning was completed in early 1982. These data are used to predict how the images from each of the six telescopes will move in the focal plane, as the elevation angle of the telescope changes. It was immediately apparent that hysteresis in the optics mounts was important, since the flexure curves for rising stars were different than for setting stars. Thus, two sets of equations are programmed into the TCS computer (EAST and WEST). Some work (such as rebuilding the tertiary mirror mounts) has been done to reduce this hysteresis, and to improve repeatability. We now have enough data to show that the largest effect on the flexure curves is due to mechanical changes in the telescope, such as the addition of an X-Y stage to the beam combiner. Temperature effects may be present at a lower level, but this interpretation is not yet certain. We will continue to regularly acquire data, which may allow the prediction of changes in the flexure curves. However, it is clear that the open-loop flexure coefficients should immediately be determined following any mechanical work on the telescope which might affect the flexure of any of the optics.

Tests of the closed-loop TCS have shown significant broadening of the combined image. If one spreads the six images out into a line after point stacking, one can easily see that the images are not accurately superimposed. Further, tests of the closed-loop autoguiding accuracy showed a strange problem, which seemed to be related to the quantization of pixels in the digitized TV picture. Figure 1 shows the EL centroid position of a star image for a single telescope as a function of time. We took 512 samples spaced by about one second of time. The upper curve is the star position with no corrections being applied to the secondary mirror. Here we see just the tracking accuracy of the mount, which happened to be rather poor during these tests, because the encoder periodic error corrections had not yet been updated, after a long period of bad weather. The lower curve is the star EL position, when the software servo loop was closed, and corrections were applied which are proportional to the position error and its derivative and integral. Clearly visible in both curves is a non-random sequence of values, which looks somewhat oscillatory, with a peak-to-peak range of about two pixels. Further tests by John Montgomery located the source of this problem as a sign error in the software fitting routine, which applied the fractional pixel value in the wrong direction. This was verified by the results shown in Figures 2 and 3. J.T. Williams devised an artificial star in the focal plane beneath the Top Box, using a light bulb to illuminate a pinhole, and a tilting micrometer-driven wedge prism located above the pinhole, to translate the image. During a single scan of 100 position samples, we moved the artificial star image manually in an approximately triangular wave fashion. As shown in Figure 2, the centroids were discontinuous as a result of the sign error. After correcting this problem, the measured positions were continuous, as shown in Figure 3. Similar results were obtained in both the horizontal and in the vertical directions (in the Grinnell).

Next, we tested the stability of the whole system, by measuring the artificial star position with everything fixed and motionless. Figure 4 shows a 512 second record for the horizontal direction, and Figure 5 shows for the vertical direction. In both cases, we used the old (incorrect) software, and one does see jumps in both axes of an amplitude of about 1.5 pixels. With the new (correct) centroiding software, we repeated the same stability test, which resulted in Figures 6 and 7. Now, periodic variations are apparent, which are about two pixels peak-to-peak horizontally (in X), and about 0.5 pixel peak-to-peak vertically (in Y). The period is the same for both directions, about 76 seconds. The amplitudes, frequencies, and shapes of these curves are consistent with the initial stability tests performed in 1981 (see MMTO Technical Memorandum 81-4), which identified a beat frequency between the intensified vidicon electronics and the 60 Hz power line as the culprit. Since no changes have been made to that camera, we should and do see the same effect. Of course, the CCD camera will be different, and probably somewhat better, but it seems prudent to synchronize all cameras to the line frequency.

A slow drift in the mean X position in Figure 6 is due to temperature variations of the voltage controlled oscillator (VCO) which clocks the Grinnell video digitizer. Figures 8 and 9 show the horizontal and vertical positions of a dot generated by a test pattern generator and applied to the Grinnell input. A slow horizontal drift similar to that of Figure 6 can be seen in Figure 8, but the vertical drift in Figure 9 is nil. Thus, the Grinnell is good in the vertical direction, but needs improvement in the horizontal direction. Figure 10 shows what happens to the horizontal position of the test dot, when the VCO chip was cooled (at 75 seconds) and heated (at 160 seconds). A solution to this problem has been found by the manufacturer, and will be installed in our Grinnell in the next few months.

In summary, we have identified one software and two hardware problems which affect the accuracy of image alignment. The software error has been fixed, and will be tested on the sky at the first opportunity on an Engineering night at the MMT. The VCO drift problem in the Grinnell is well understood, and modifications will be installed as soon as some parts are delivered. Synchronizing the TV cameras to the power line frequency is being investigated, but it is not yet known how long it will take to complete this task. The benefits of the software fix can be evaluated during the next Engineering night at the MMT, and should include better image stacking and autoguiding accuracy. However, the full potential of the TCS will not be realized until the two hardware changes are also completed.

FIGURE 1

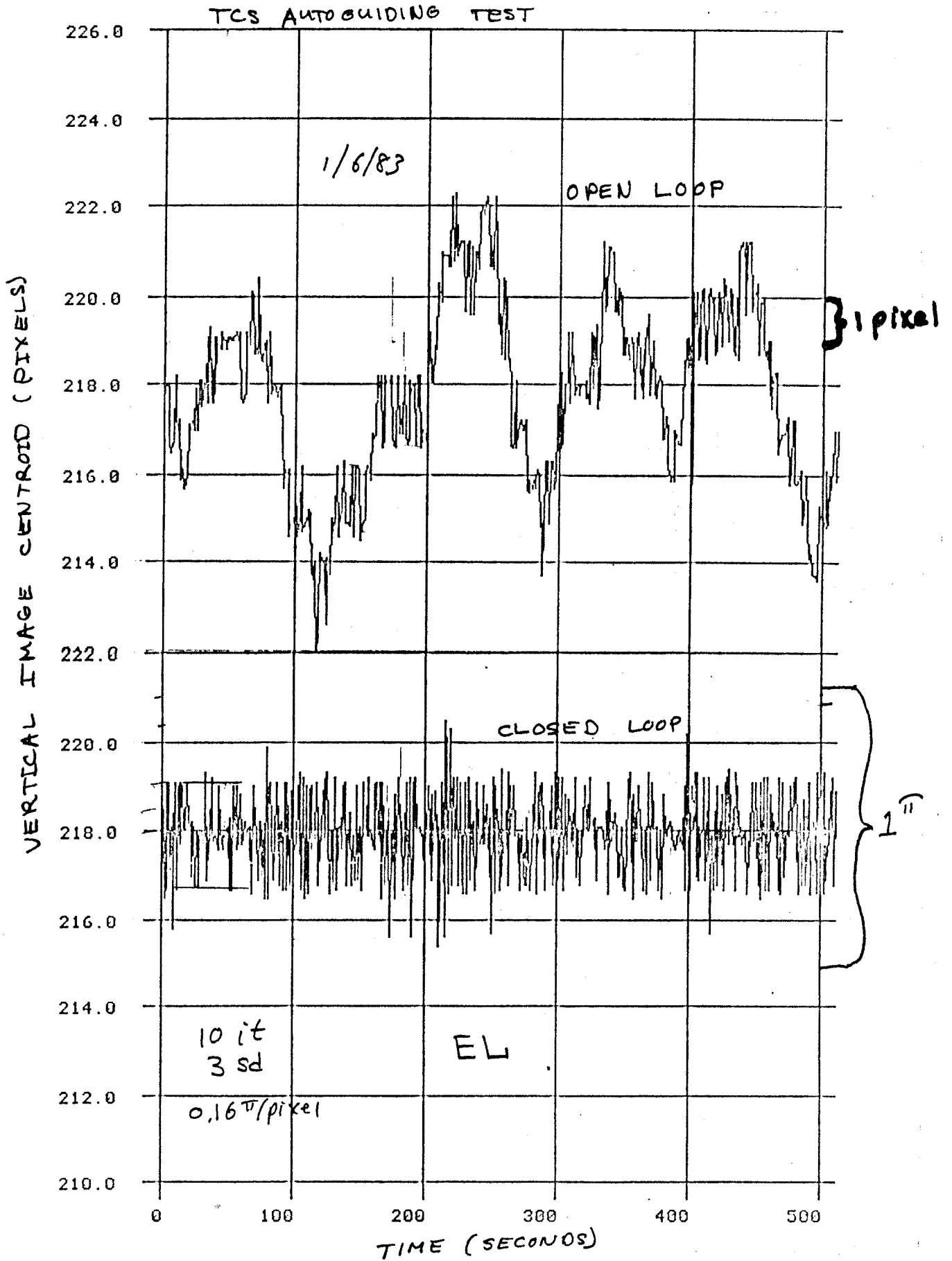
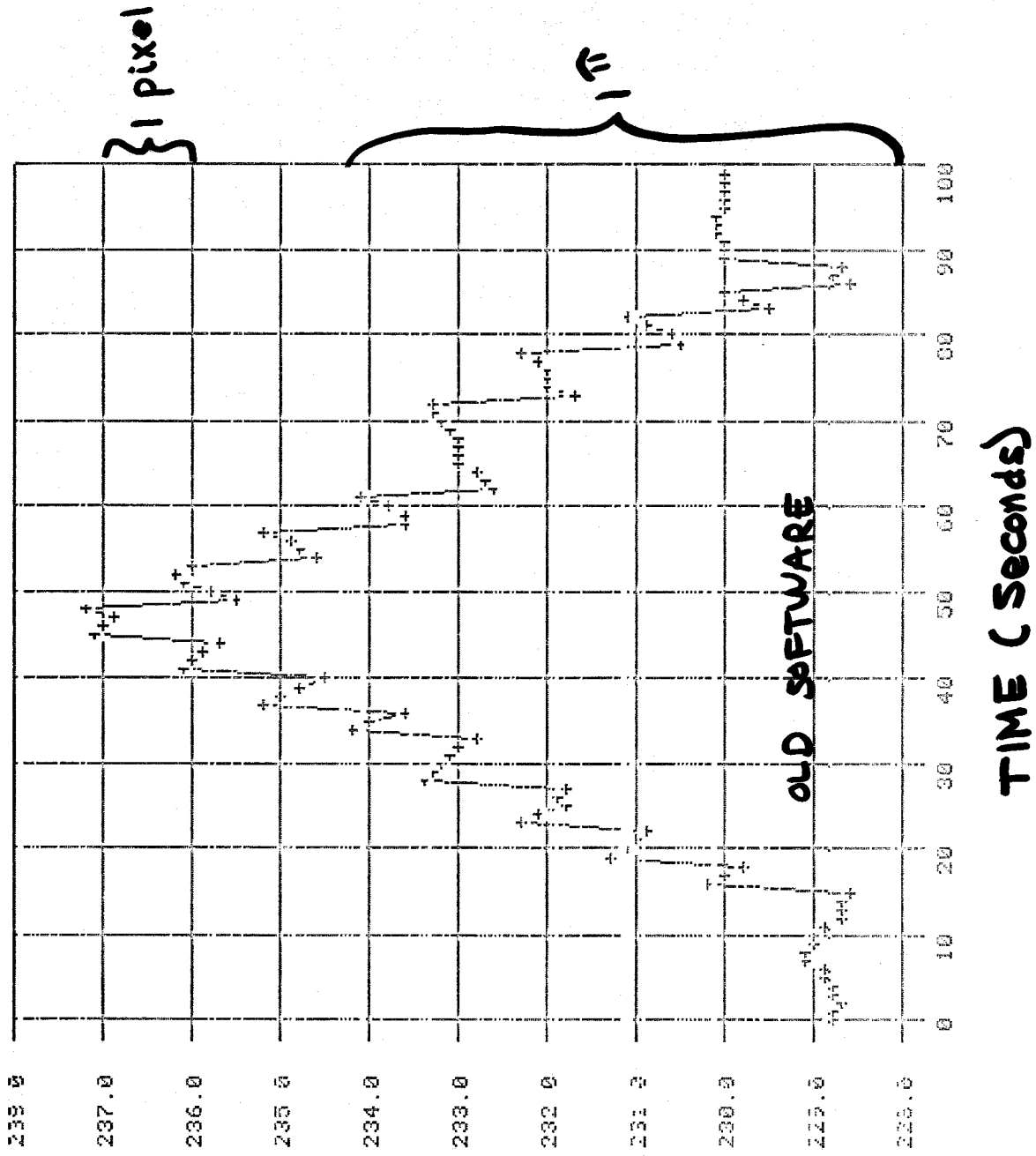


FIGURE 2

5-Vert.



1/21/83
Vertical
Scan #5

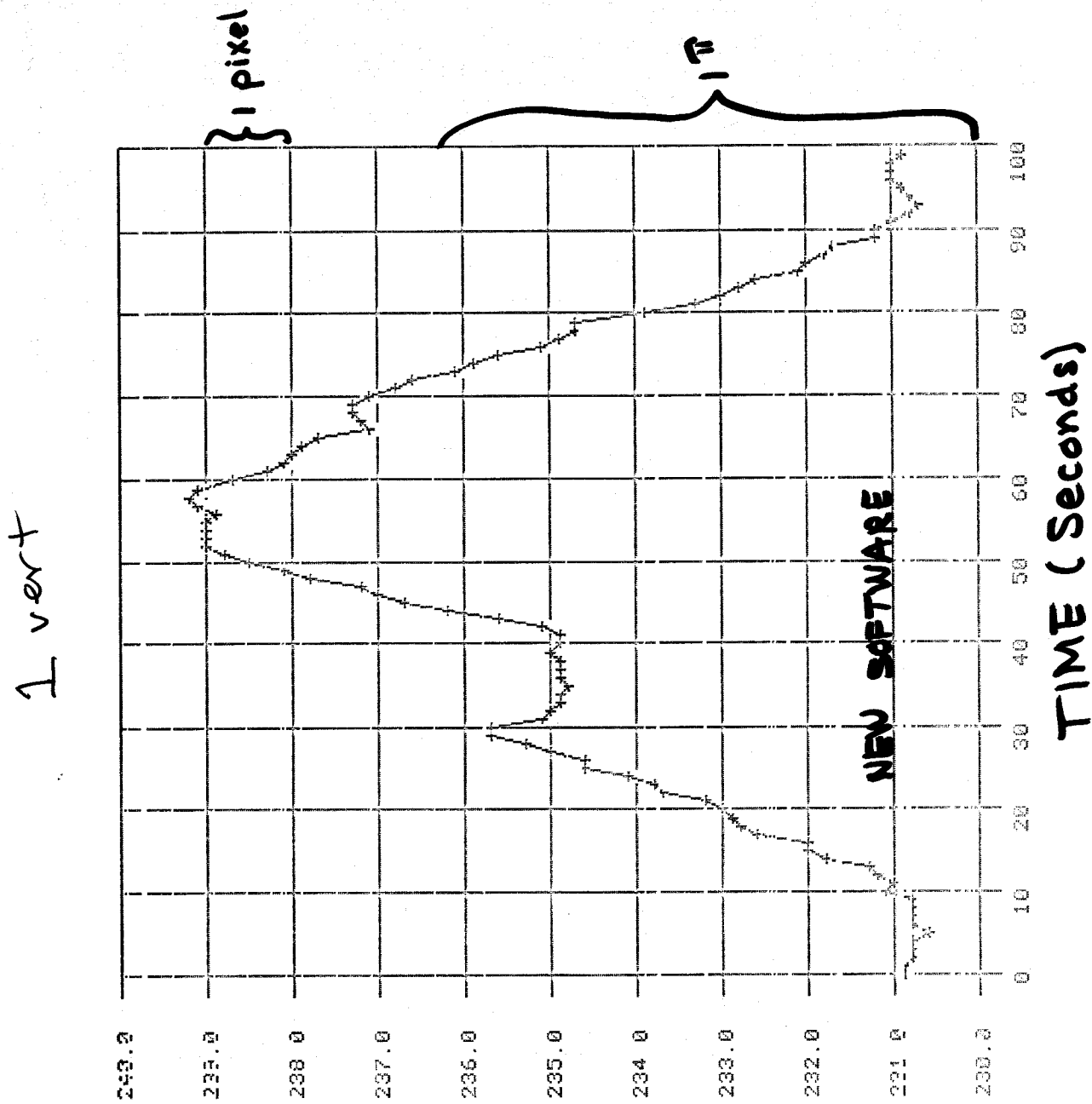
10 it
3 sd
AD Lens

Y' Position (Pixels)

TIME (Seconds)

OLD SOFTWARE

FIGURE 3



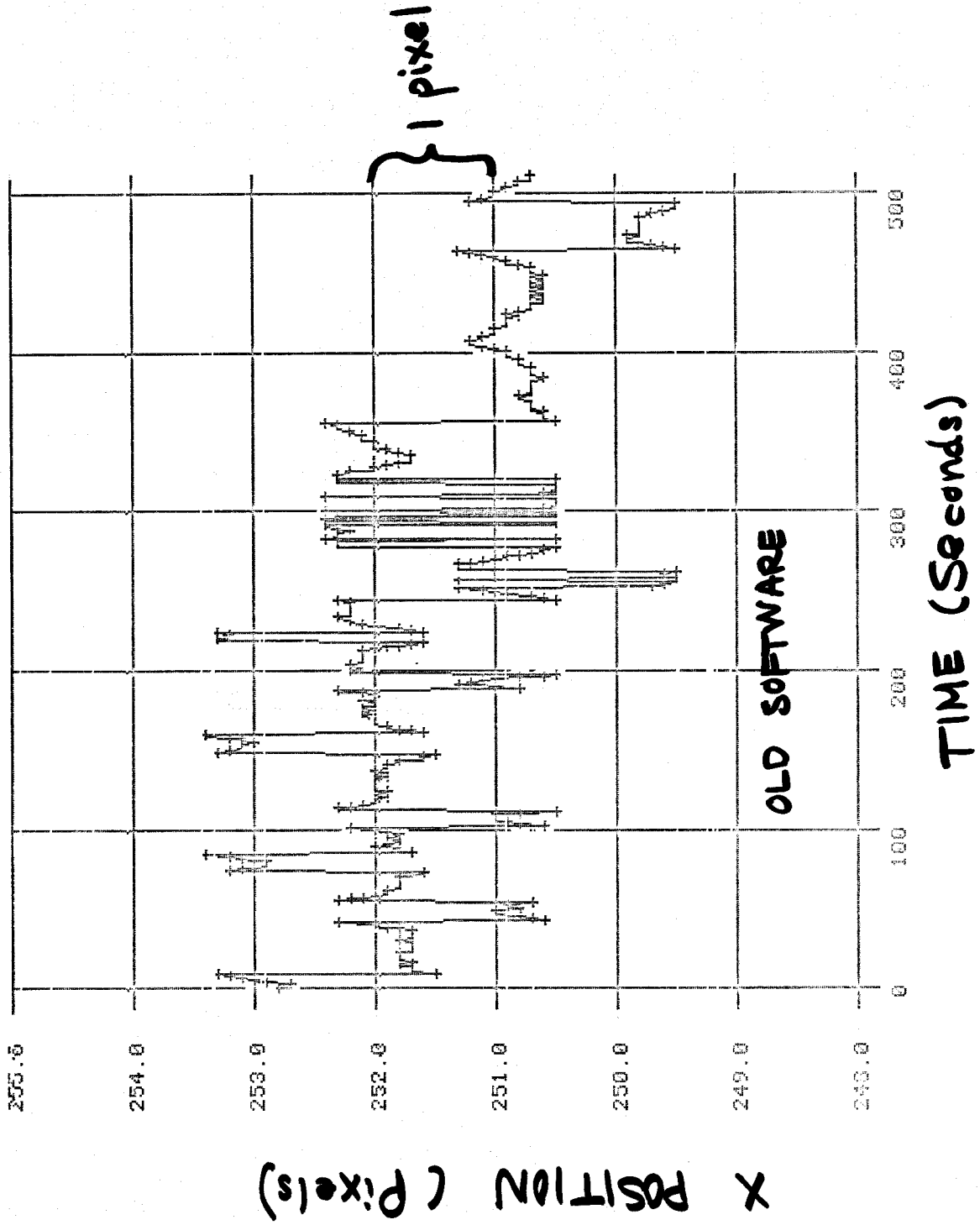
1/21/83
Vertical
Scan #1

10 it
3 sd
AO Lens

Y POSITION (Pixels)

FIGURE 4

4 HORIZ



OLD SOFTWARE

FIGURE 5

4-Vert

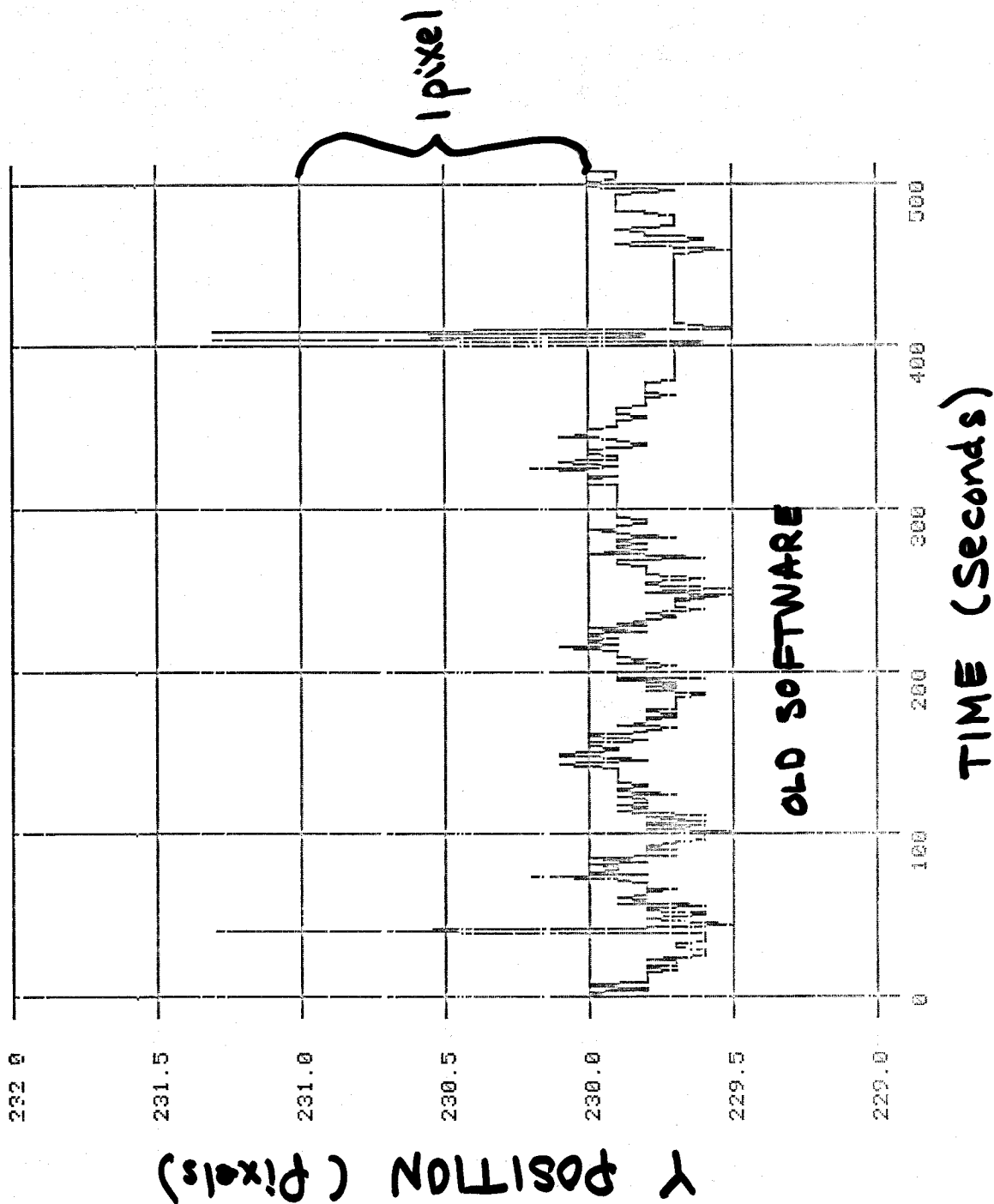


FIGURE 6

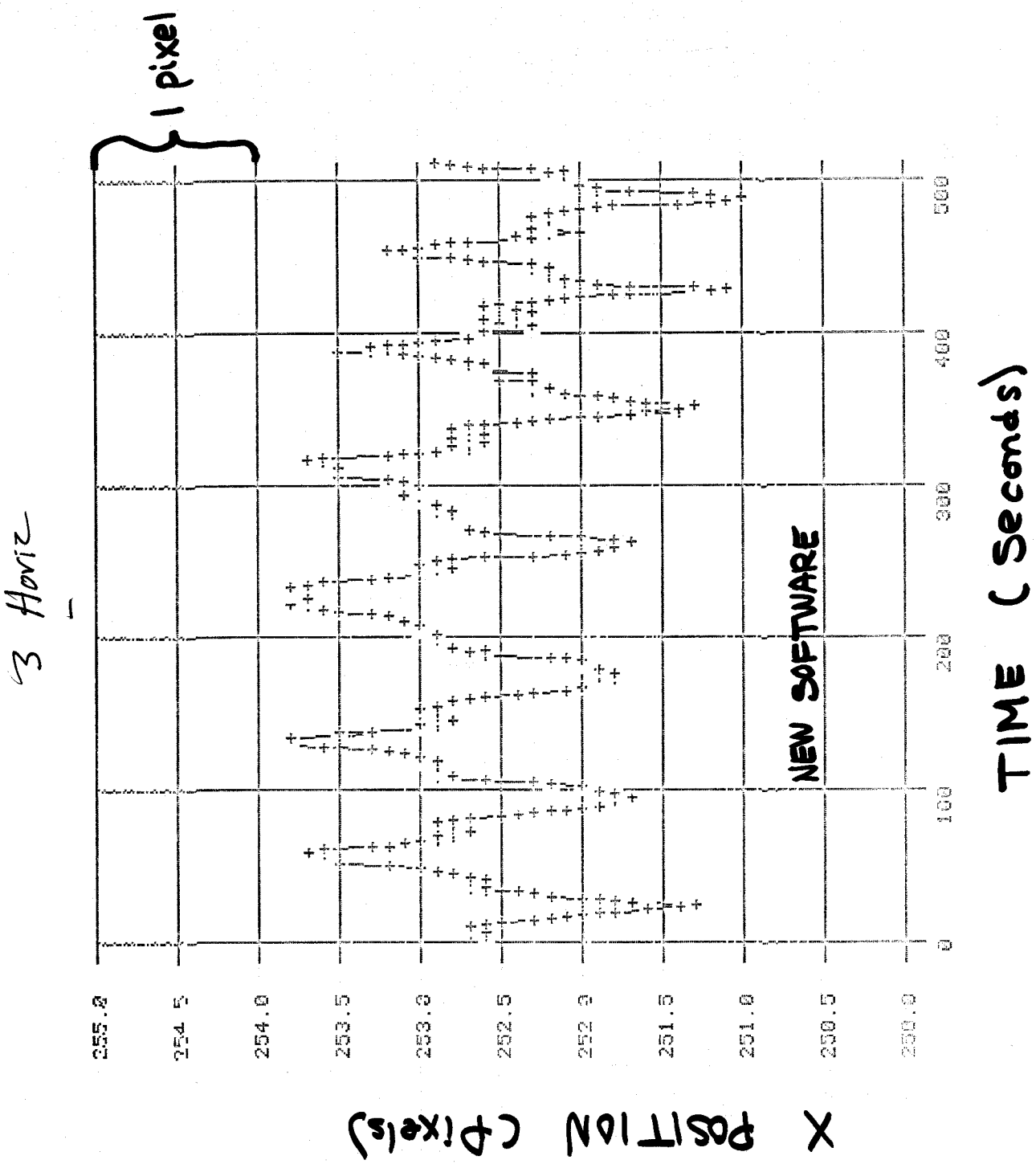


FIGURE 7

3 vert

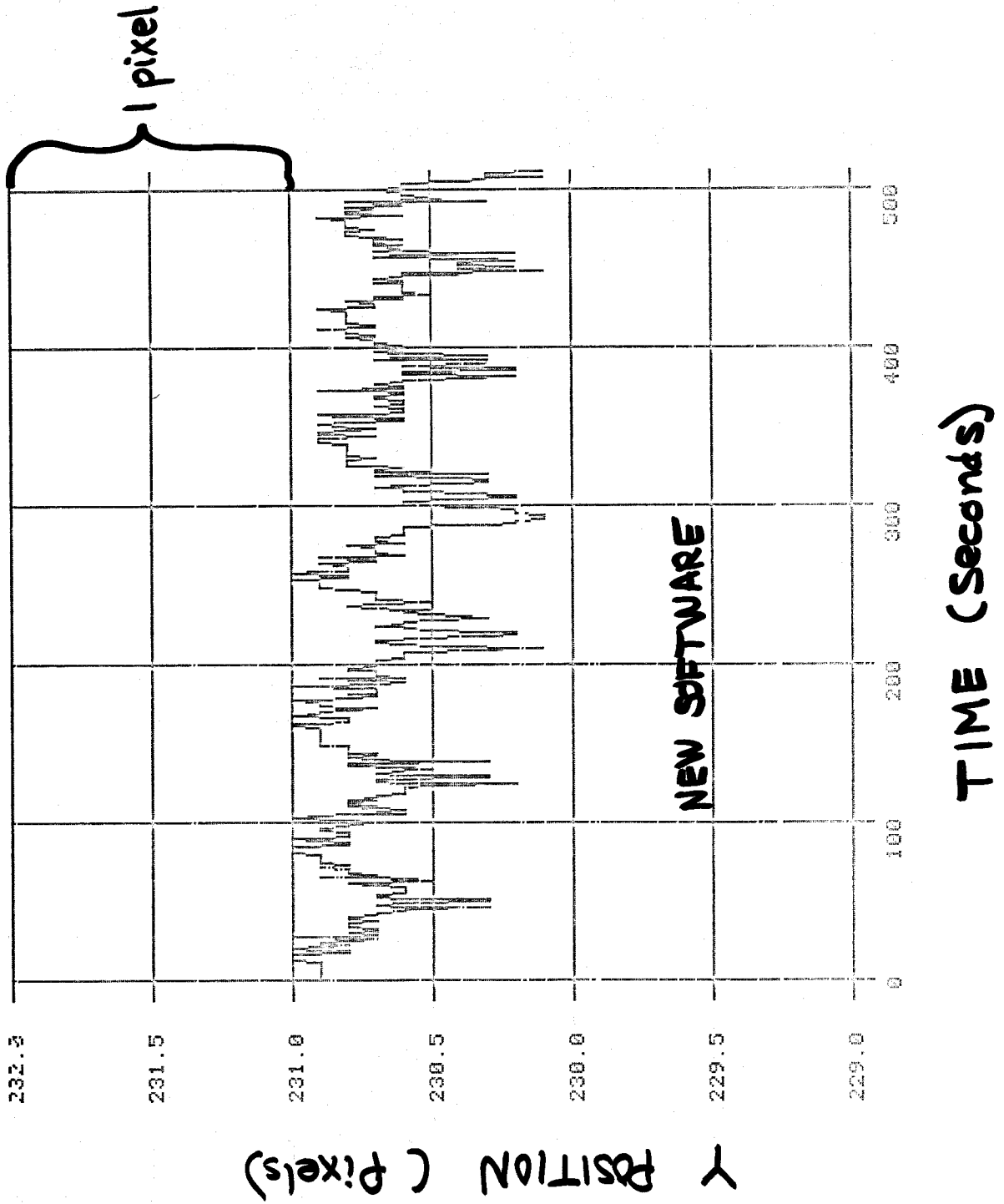
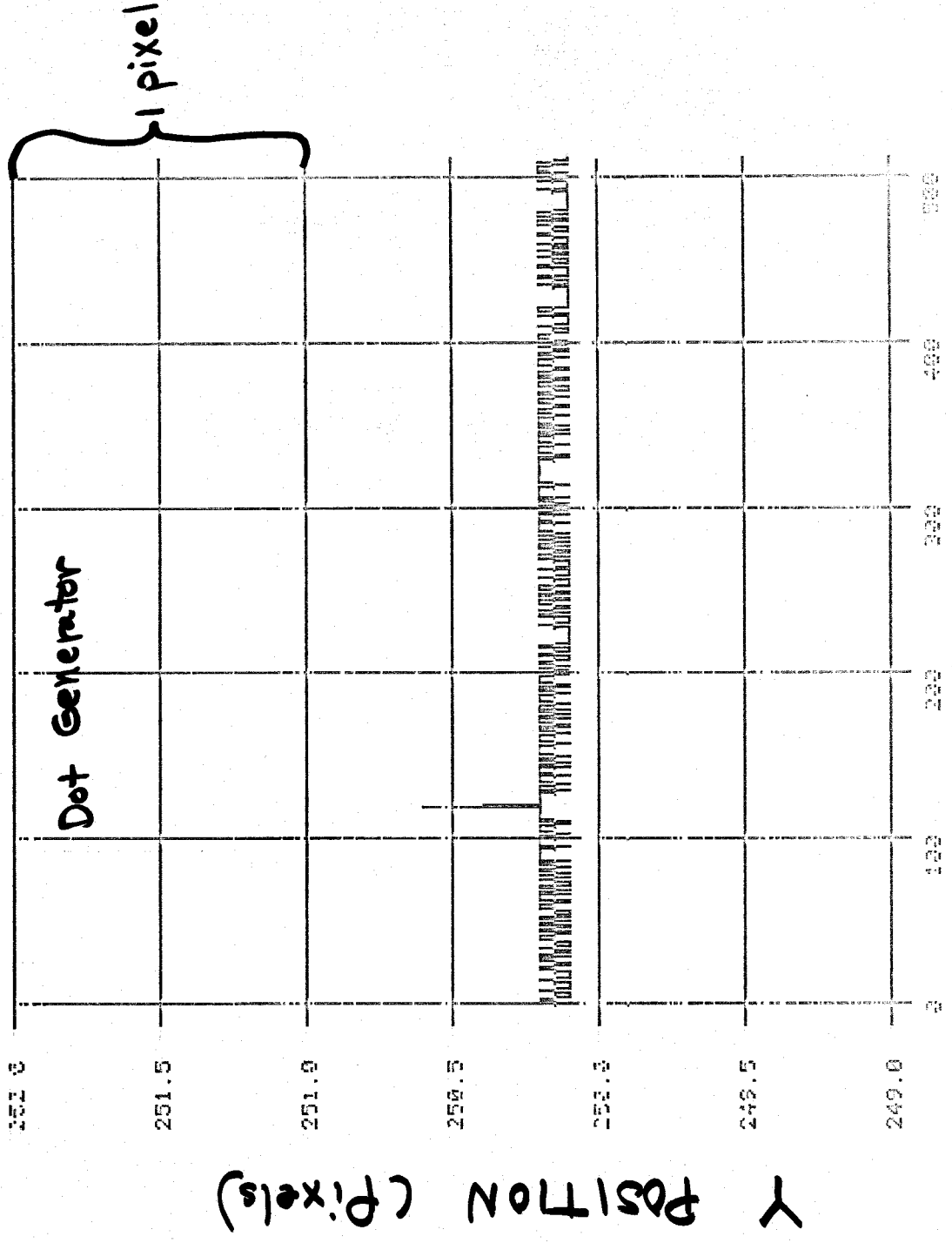


FIGURE 9

6 vert



TIME (Seconds)

Y POSITION (Pixels)

FIGURE 10

7 April

