Automated X-ray Inspection
Understanding and Configuring the 5DX Selftest and Black/White Level tests

This document will explain in detail how the Selftest and Black/White Level test actually work and how to configure your 5DX's Selftest/Black/White Level test for optimum performance monitoring and Drift compensation. First, we will start out with a brief theory of operation on how the Selftest and Black/White Level tools work. We will then discuss ways to optimize the configuration to monitor parameters that are important to the 5DX.

Theory of Operation

Selftest is meant to run multiple times a day (usually every 30 minutes) and verify that the 5DX Plane of Focus has not drifted substantially over time.

Selftest helps determine whether changes in measurements are due to variations in the circuit boards or to system drift.

Selftest checks consistency of several different measurements, including:
- Laser reading of stage at 400 FOV
- Plane of Focus stage height
- Gray level measurement of selftest coupon
- Measured thickness of selftest coupon

- Resolution of selftest coupon horizontal edge

SELFTEST SETUP makes initial measurements of these parameters and stores them as initial/nominal values in SELFTEST.CFG. This information includes coordinates, nominal parameter values, threshold limits, and Plane of Focus (POF) Z height used by the system. Running Selftest Setup establishes the "stake in the ground" for all future drift measurements of the 5DX system. It should only be run when the system is functional and stable. Future selftest results are compared to these initial values. The Selftest setup process logs a message in the selftest.log file indicating that selftest has been initialized/setup at the indicated date/time.

Laser Test

Laser readings of the stage at the 400 FOV.

Laser test will move the XYZ stage to position the vertical Z-axis support under the Front laser at the current 400FOV and then acquire several laser readings. If the average laser reading is greater than the tolerance in the Laser.cfg file, it will fail the test. In any case, the average value is logged into the Selftest.log file.

Gray Level Test

Gray level measurement of the upper section of the selftest coupon

The Gray Level test will move the XYZ stage to position the Selftest coupon under the X-ray Source at the current 400FOV and then takes a foreground and background reading from a 30 X 30 pixel sample area on the selftest coupon and just off of the coupon (hole).

Thickness Test

Measures the thickness of the selftest coupon at the upper section

Based on the Gray Level measurements obtained from the previous test, the program will calculate the thickness of the coupon using the current thickness tables (Backwards Compatible or Universal panels)

POF Test

Measures and records where the Plane of Focus is in Z height units (Mils)

The Plane of Focus test will move the XYZ stage to the Selftest coupon 5-hole pattern under the X-ray Source at the current 400FOV. It takes a snap of the 5-hole image and centers the pattern in the view. The program also analyzes the edge sharpness by utilizing a subprogram called "Find sharpest Z". This utility will move the z-axis a slight distance, snap and analyze the image for edge sharpness and then move again. The test starts out below the POF, and then travels through it in small steps to find the Z height that provides the sharpest image. This is the

only test that makes an adjustment in the selftest program. The POF Z height value obtained by this test is used to shift **_all_** laser measurements to track the POF

Resolution Test

Runs a resolution MTF test at the diagonal edge of the Selftest coupon.

The resolution test will move the XYZ stage to the Selftest coupons upper horizontal edge under the X-ray source at the current 400FOV. The program will take a snap of the edge and apply a MTF algorithm across the imaged edge to determine the slope of the transitioning gray level values, the steeper the slope, the higher the resolution. The program then calculates a quasi-Modulation Transfer Function. The results are listed in percentage (%) modulation.

Black/White Level Test

Runs the Black Level test to compensate for drift.

The Black Level test is an independent test program from the Selftest program and is imbedded into an executable called "Driftaverage". It was designed to compensate for offset drift in the X-ray image camera (Dark Current) caused by temperature variation. First the test moves the XYZ stage to the Black/White Level Test area (MXB area) on the fixed rail and take an image snap. This image snap is collected with the X-ray current turned off and the e-beam parked on the dump ring of the X-ray tube target, so as to represents the darkest image that the camera will ever see. The program then

compares this gray level average value with the average value recorded during photometric adjustment (static value). If the differences in these two values are greater than the threshold specified in the glcor.cfg file, (GLCOR_2X2_BlackThresh & GLCOR_4X4_BlackThresh) the program will go back, take multiple snaps and calculate an average of the new black level value. The number of averages is dependent on the glcor.cfg file threshold (GLCOR_CalcNsnap). The program then calculates this dynamic value as the pixel offsets multiplier to dynamically correct the original values loaded from the "B" part of the Mbtable1.dat or Mbtable2.dat files. These dynamic values are specifically not saved in any file; they are only useful for the current temperature of the camera. As the temperature drifts, these values need to change to compensate for the difference in dark current. In fact, if the camera's temperature drifts, without rerunning the black level test, these outdated dynamic "B" values will more than likely cause false calls.

A second part to the Black level test has recently been added. With the new Series 3 camera, the CCD design was changed. Now the CCD is read with four analog amplifiers instead of just one. This allows the date to be read out at a much faster rate. With this new design, the four amplifier outputs or quadrants must be adjusted independently. This is accomplished with the White level adjustment, imbedded in the Black Level program (7.X and greater software rev).

After running the Black Level adjustment, the program takes another set of snaps at the MXB area with the X-ray current at 100%. It then compares the gray level averages of each of the four quadrants to the total average (2X2_NomBright or 2X2_NomBright from the GLCOR configuration file). If the gray level values are beyond the threshold (2X2_BrightThreshold or 4X4_BrightThreshold from the GLCOR configuration file), the program will calculate a multiplier value and apply it to all of the gain values in the MXB table dynamically. Again, these new values are not recoded and are dynamically changed every time the Black/White level test runs. It is therefore imperative that the Black/White level test be allowed to run as scheduled to maintain solder thickness calibration.

Selftest Log

Below is a brief explanation of the data recorded in the selftest.log file:

Laser Z

LaserZ - Laser 1 reading on the *stability point* located on the Fixed Rail vertical support bracket Values are in Laser unit (Mils)

GL

GL - Gray level measurement of the selftest coupon

Thick

Thick - Thickness measurement of the selftest coupon derived from the gray level measurement

Delta

Delta - Delta Gray level foreground/background on the selftest coupon

DotX

DotX - X-axis pixel location of the selftest coupon 5-hole pattern center in the X-ray image (512 max)

DotY

DotY - Y-axis pixel location of the selftest coupon 5-hole pattern center in the X-ray image (512 max)

POF

Pof - Plane of focus Z-axis stage height where the selftest POF pattern is sharpest

Res

Res - Resolution of the horizontal edge on the selftest coupon in percent (%) modulation

LsrFcs

LsrFcs - Laser reading at the POF spot (LsrFcs + POF Z Height = Laser Home Distance)

AnodeV

AnodeV - This is the DC Anode voltage of the X-ray tube (times 1,000)

CathodeA

CathodeA - This is the DC Cathode current of the X-ray tube (Micro Amps) from the X-ray gun

FocusV

FocusV - This is the DC voltage of the internal focus element in the X-ray gun (Volts)

GridV

GridV - This is the DC voltage of the grid element in the X-ray gun (Volts)

Gtemp

Gtemp - The internal X-ray tube temperature in degrees C

TubePSI

TubePSI - The pressure of the diaeletric gas inside the x-ray tube (PSIG)

Selftest Quick Diagnostics

Gray Level problems

- Check LOG\HVXRAY.LOG for corresponding shifts in Anode Current
- Reload X-ray Scan Controller banks (**LOADSYNC**)
- Check LOG\PHOTOCAL.LOG for gain variations over time
  - A large gain change can indicate that Photocal was run with an obstruction in the path of the X-ray source (to the detector).

- A large offset change in multiple Photocals can indicate a temperature sensitive camera.
- Verify that the position of the MXB open area for Photocal is correct (off the panel or centered in the hole on the rail)
- Verify that the Black Level test is running every 15 minutes (\5dx\%releaseroot%\calib\glcor.cfg)

Laser Test problems

- Verify laser measurements & calibration
- Manually verify laser measurements using **LSRCHECK**
- Check that LASER1.DAT and LASER2.DAT files increase normally
- Run **AXISINIT -r** & **AXISINIT**
- Run **LOCLASER** or Laser Spot Region setup from the C&Amenu
- Run laser calibration (**LASERCAL**).

POF Test problems

- If X-ray calibration was run recently, run Self-test Setup (**STSETUP**) to adjust Plane of Focus value in SELFTEST.CFG (@POF_INITIAL_Z)
- Check LOG\HVXRAY.LOG for corresponding shifts in Cathode Voltage
- Reset Z-Stage axis (**AXISINIT -R**)
- Run **LSMZTEST** or Z Stage Test from the C&A menu

- Verify laser measurements & calibration

Resolution problems

- Verify XYZ coordinates are accurate for the Resolution test on the Selftest coupon
- Check if resolution is visibly better in STATIC mode. (**Rotate -s; Sync -e; Live**)
- Run **AXISINIT -r** & **AXISINIT**
- Verify the XYZ position of the knife edge for the Resolution test with **GOTOCAL - RES**
- Run the 5DX Confirmation & Diagnostics RESOLUTION program

Thickness Test problems

- Re-load the X-ray Scan Controller banks (**LOADSYNC**)
- If the Gray Level is normal, verify FGCAL Camera Index settings (FG400.DAT and NFG400.DAT)
- If the Gray level has shifted, verify Dump Bank and Photometric calibration
- Re-run Photometric Adjustment

Selftest Configuration File

@LOGFILE_SIZE	2500	Maximum number of log entries.
@LT_THRESHHOLD	**5.00**	Laser test threshold.
@MAP_POINT1_X	0.00	X location of first map point.
@MAP_POINT1_Y	9540.00	Y location of first map point.
@MAP_POINT2_X	200.00	X location of second map point.
@MAP_POINT2_Y	9525.00	Y location of second map point.
@MAP_POINT3_X	125.00	X location of third map point.
@MAP_POINT3_Y	9200.00	Y location of third map point.
@STABLE_X	1120.00	X location of stability test.
@STABLE_Y	9475.00	Y location of stability test.
@STABLE_Z	350.00	Tracks laser Z of stability test.
@DOT_X	**285.00**	X location of solder dot.
@DOT_Y	**8770.00**	Y location of solder dot.
@Z_OFFSET	0.00	Z offset of wire from surface map.
@DOT_SHAPE	1	Square = 0, Circle = 1.
@DOT_DIMENSION	40	Square: length of side, Circle: diameter.
@4MIL_WIRE_X	330	X Coordinates of resolution edge.
@4MIL_WIRE_Y	9680	Y Coordinates of resolution edge.
@4MIL_WIRE_Z	1550	Z Coordinates of resolution edge.
@4MIL_WIDTH	3.00	Minimum Edge Resolution.
@DELTA_G_ZERO	0.00	Initial delta gray value.
@GLA_NUM_IMAGES	3	Number of images to average.
@GLA_X_OFFSET	-60	X offset from solder dot to gla test area.
@GLA_Y_OFFSET	0	Y offset from solder dot to gla test area.
@GLA_AREA_DX	30	Length of a side of gla test area.
@GLA_THRESH	**7.00**	Maximum change in measured gray level.
@GLA_NOMINAL_GL	0.00	Nominal gray value.
@TT_NOMINAL	4.00	Nominal Thickness.
@TT_THRESH	**1.00**	Maximum change in measured thickness.
@POF_THRESH	**5.00**	Maximum change in plane of focus.
@POF_DOT_X	120.00	X location of plane of focus dot.
@POF_DOT_Y	9300.00	Y location of plane of focus dot.
@POF_INITIAL_Z	1550.00	Initial plane of focus height.
@POF_DOT_TO_DIAG_EDGE_X_OFFSET	-5.00	X offset POF Dot to diag edge. (Default -5.0)
@POF_DOT_TO_DIAG_EDGE_Y_OFFSET	-744.00	Y offset POF Dot to diag edge. (Default -744.0)
@POF_DOT_TO_DIAG_EDGE_Z_OFFSET	0.00	Z offset POF Dot to diag edge. (Default 0.0)
@BKWD_COMPAT	1	Use pre-6.0 confirmation and adjustment tables

Selftest Optimization

Note: For best results, insure that the system is freshly calibrated when setting up Selftest.

With the Configuration file, the User can control certain aspects of the Selftest information to better monitor the stability of the 5DX measurements. After a close examination of the Config file, it becomes obvious that most of the parameters are set wide to prevent the selftest from failing. This span in the parameters is intentional. We prefer that the customers decide which aspects of selftest they want to monitor closely.   For example, the TT_thresh parameter is set for an allowable drift on 0.001" of solder thickness on the selftest coupon (which measures approx. 0.004"). This means that a solder thickness measurement drift of 24.9% would be allowed.

A close review of the selftest log is required to determine which thresholds need to be adjusted.

These four different parameters should be adjusted to monitor a stable 5DX production system. The actual value of the threshold will vary from system-to-system and customer preference.

- LT_THRESHOLD
- TT_THRESH
- GLA_THRESH
- POF_THRESH

LT_THRESHOLD - A threshold for monitoring the **LaserZ** results

The LT_THRESHOLD value is a control over how much the Laser measurement over the vertical Z-axis support stability point can drift before a warning is issued. This value can be used to verify the stability of the front Surface Map laser (laser 1). If the LaserZ measurement value changes abruptly, this is an indication that the front laser camera has moved or been bumped. If a major change is detected, see if it coincides with a system C&A. This may be and indication of an improper adjustment or a mechanical problem with the Surface Map Laser.

TT_THRESH - A threshold for monitoring the **Thick** results

The TT_THRESH value controls how much variation in solder thickness measurement will be allowed before a warning is issued. Use this threshold to monitor the corrected solder thickness over time. Shifts in the Thickness measurements of the selftest log can indicate that the photometeric adjustment needs to be re-run. The Thickness measurement in the log file should be stable over time.

GLA_THRESH - A threshold for monitoring the **GLA** results

The GLA_THRESH value controls how much variation in gray level will be allowed before a warning is issued. Use this value to monitor the stability and

repeatability of the X-ray image camera. Shifts in the GLA values in the selftest log can indicate that the photometric adjustment is not re-setting the camera gray levels back to their original values obtained in the full C&A. Inconsistent GLA values on a known reference are an indication that the solder thickness measurements will be off as well. This can be a further indication of a problem in the image chain with the X-ray tube, the scintillator or the camera.

POF_THRESH - A threshold for monitoring the **POF** results

The POF_THRESH value is a control over how much the Plane of Focus Z Height can drift before a warning is issued. Use this value to monitor the stability of the stage hardware. The POF height should not change much over time due to the basic geometry of the system. Slight variations in the POV value in the selftest log can be expected and are attributed to thermal growth of the stage and the x-ray tube. Again, abrupt changes of this value in the selftest log can indicate a problem with the z-axis motors or the laser mapper assembly(s).

DOT_X &DOT_Y

Even though there is currently no threshold value for these two data points, there soon may be. The DOT_X and DOT_Y values in the selftest log are an excellent indicator of the mechanical

stability of the fixed Z-axis rail, a real portability concern. Abrupt changes in these two values can indicate that the fixed rail has moved. This could lead to panel handling problems, as well as an increased false call rate.

Black Level Quick Diagnostics
Problems with the Black Level test.

If the Black Level test adjustment runs every time the Black Level test checks the offset, this is not necessarily an indication of a problem. With the gray level threshold set to 0.5, there is not much of a margin for drift in the measurement. Decreasing the frequency of the Black Level test will only increase the drift in all of the gray level measurements made by the 5DX. Some X-ray image cameras require more compensation than others do. Review the Photocal.log file to determine if there is a problem with the X-ray image camera. This can be detected by a progressive increase in the scale value (Camera Gain). Also, monitor the "Out of Range" value. These indicate pixels in the camera that can't be corrected.

Black Level configuration (Glcor.cfg)

@**GLCOR_TestNMinutes**	15	Test frequency in minutes (0..1440) 0=never
@**GLCOR_2x2_BlackThresh**	0.5	Black level 2x2 correction threshold
@**GLCOR_4x4_BlackThresh**	0.5	Black level 4x4 correction threshold
@GLCOR_TestNSnaps	1	Number of Snaps to do when doing test
@GLCOR_CalcNSnaps	10	Number of Snaps to do during correction calculation
@GLCOR_2x2_NomBlack	220.00	2x2 black nominal Gray Level
@GLCOR_4x4_NomBlack	220.00	4x4 black nominal Gray Level
@GLCOR_2x2_LastTestTime	12/23/2000	Last 2x2 date/time test occurred
@GLCOR_4x4_LastTestTime	12/23/2000	Last 4x4 date/time test occurred
@**GLCOR_X**	200.00	X location of Gray Level correction Not used!
@**GLCOR_Y**	7000.00	Y location of Gray Level correction Not used!
@**GLCOR_Z**	1550.00	Z location of Gray Level correction Not used!
@GLCOR_2x2_NomBright	70.00	2x2 bright nominal Gray Level
@GLCOR_4x4_NomBright	70.00	4x4 bright nominal Gray Level
@**GLCOR_2x2_BrightThreshold**	2.00	2x2 bright Gray Level threshold
@**GLCOR_4x4_BrightThreshold**	2.00	4x4 bright Gray Level threshold

Black Level test Optimization

GLCOR_TestNMinutes

GLCOR_TestNMinutes - Set this value to determine the frequency to run Black Level Test. The default value of 15 minutes has been recommended by the division and should not be changed. **<u>Changing this value can adversely affect your call effectiveness!</u>**

GLCOR_2x2_BlackThresh

GLCOR_2X2_BlackThresh - Set this threshold to trigger the Black Level adjustment. The default value of 0.5 gray level's is recommended by the division.

GLCOR_4x4_BlackThresh

GLCOR_4X4_BlackThresh - Set this threshold to trigger the Black Level adjustment. The default value of 0.5 gray levels has been recommended by the division and should not be changed.

GLCOR_X

GLCOR_X - This value is the X-axis position of the hole in the Z-axis fixed rail where the Black Level test and the photometric adjustment take their measurements. This value will change from system to system and is determined manually. These values no long read from this file!

GLCOR_Y

GLCOR_Y - This value is the Y-axis position of the hole in the Z-axis fixed rail where the Black Level test and the photometric adjustment take their measurements. This value will change from system to system and is determined manually. These values no long read from this file!

GLCOR_Z

GLCOR_Z - This value is the Z-axis position of the hole in the Z-axis fixed rail where the Black Level test and the photometric adjustment take their measurements. This value will change from system to system and is determined manually. These values no long read from this file!

GLCOR_2x2_BrightThreshold

GLCOR_2x2_BrightThreshold - This value is the amount of gray level drift allowed before the White Level adjustment modifies the MXB table. The default value of two gray levels has been recommended by the division and should not be changed.

GLCOR_4x4_BrightThreshold

GLCOR_4x4_BrightThreshold - This value is the amount of gray level drift allowed before the White Level adjustment modifies the MXB table. The default value of two gray levels has been recommended by the division and should not be changed.

Note: Please consult with the Division before making any changes to the Selftest or Black Level test configurations.