GHCO Measurement

Matthew Jones
February 10, 2025

The Gantry Head Camera Offset (GHCO) is the vector representing the displacement between the focal point of the gantry camera and the axis of the pickup tool, which is used to move sensors or readout chips on the gantry. We need to know this displacement when performing rotations of surveyed parts to place them in the desired location and orientation. The approach used to determine the GHCO is to measure the position of a fiducial marker on a test structure using the camera, pick up the structure using the picker tool, rotate it about the gantry head z-axis, and then re-measure the location of the fiducial marker once the calibration part has been put down and is held in place under vacuum.

If the assumed location of the axis of rotation is $\vec{x}_i$ then we can express this in terms of the true location of a point on the gantry head axis of rotation, $\vec{x}_r$ and displacements relative to this axis:

$$\vec{x}_i = \vec{x}_r + \vec{\Delta x}.$$

After rotation by an angle θ about the axis that intersects the point $\vec{x}_r$, the new location of the assumed axis of rotation is

$$\vec{x}_f = \vec{x}_r + R(\theta)\,\vec{\Delta x}$$

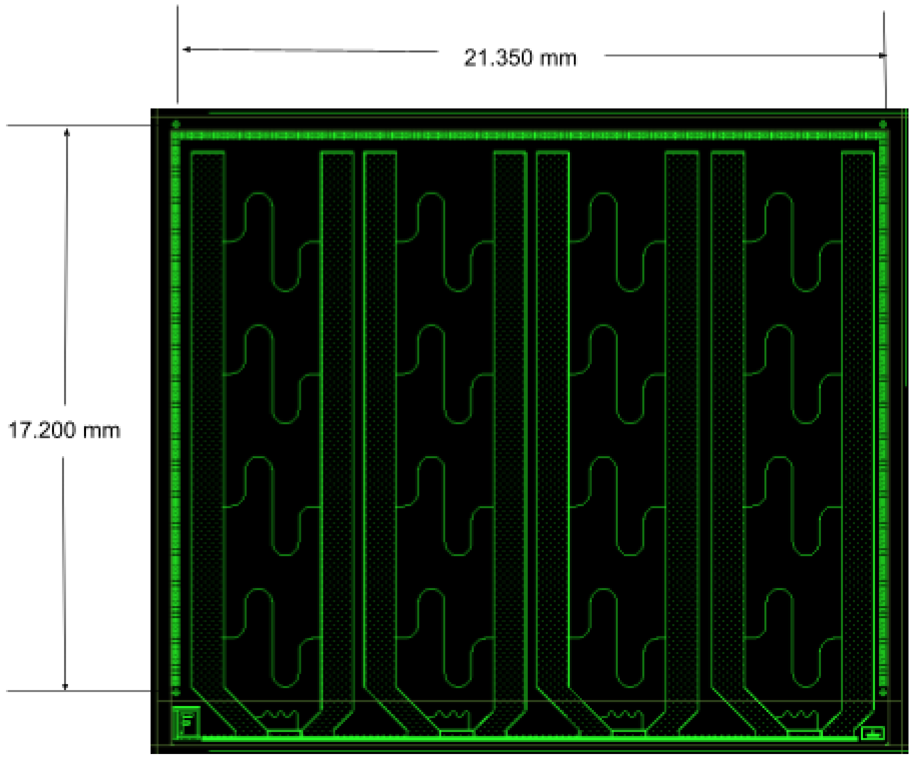
and the displacement $\vec{\Delta x}$ between the actual and assumed axes is calculated using

$$\vec{\Delta x} = (R(\theta) - 1)^{-1}(\vec{x}_f - \vec{x}_i).$$

If significant, the corrections $\vec{\Delta x}$ can be added to the assumed GHCO displacement to provide a more accurate GHCO measurement.

This procedure defines the x and y components of the GHCO vector, while the z component can be defined as the difference in gantry z of the focal plane of the camera and the point where the suction cups on the picker tool touch down on the object.

The single-chip thermal mockups are well suited for measuring the GHCO displacement because they have well-defined fiducial markers that are easily aligned with the gantry camera. There are four crosshair fiducials located at the corners of the pixel array with dimensions as shown below.



The procedure, described below, surveys the locations of the four markers, calculates the coordinates of the center of the pixel array, and attempts to rotate the part about this point. If the GHCO displacement is determined accurately, then the location of this point will not change significantly after rotation; otherwise, a correction to the GHCO displacement can be calculated.

Script Installation

There are two site-specific changes to make before running this script for the first time. The first is to specify the initial position and rotation of the 1x1 calibration part on the chip launch pad and is only necessary to facilitate finding the fiducials. At Purdue, we push a chip or sensor against a stop made from Kapton tape on the chip launch pad to constrain its initial location. The coordinates of the center of the part, relative to the top pin on the HDI launch pad are set by the $initial_rot and $initial_loc parameters. These can be initially set to the following nominal values:

```
COPY $initial_rot 0.000
COPY $initial_loc {-49.000,17.000,-0.500}
```

The z-component of the $initial_loc vector accounts for the nominal thickness of the calibration part. After the initial survey of the fiducials, new values for $initial_rot and $initial_loc will be suggested, and can be used to update these parameters to facilitate future measurements.

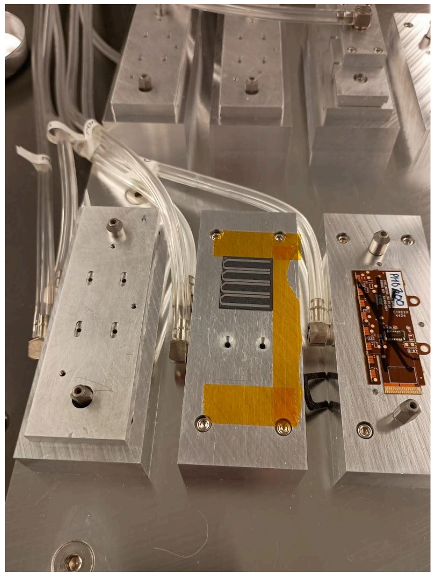
Furthermore, the first step is to measure the drop correction parameters for the calibration part, so these should initially be set to zero:

```
COPY $drop_correction {0.000,0.000,0.000}
COPY $drop_rotation 0.000
```

Procedure

The following procedure takes about 5 minutes to perform, not including any initial setup.

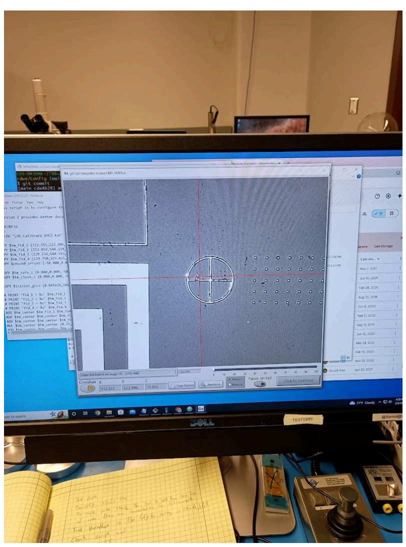
1. Ensure that the site-specific modifications have been made to the script. In particular, make sure the $top_pin_1x2_hdi_launch and all the $focus… parameters have been updated from the Initial_Gantry_Survey script. Also, check that the initial location of the calibration part has been specified as described above, and that the drop correction parameters are initially set to zero.
2. Verify that the gantry is in the assumed initial state:
    - The picker tool is mounted in the tool rack
    - Vacuum is turned on, compressed air to the vacuum manifold is on, vacuum manifold is powered by 24V.
    - Place a 1x2 assembly module carrier on chuck 0 as shown below.
3. Place the single-chip thermal mockup on the upper vacuum holes of chuck 1. The bond pads should face to the left, as shown:

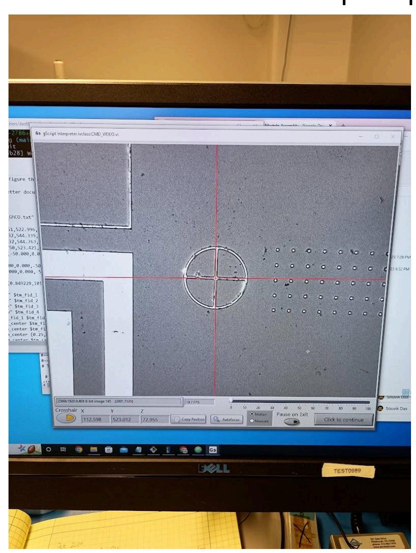


4. Load the script (GHCO_Calibration_new.gscript) and run it.

5. The script prompts with the pop-up: “Place 1x1 Thermal mockup on Chuck 1 top”. Select ‘Yes’ to continue, or ‘No’ to abort the script.

6. The gantry will move the camera to the four fiducial locations. Align the crosshairs with the fiducials in the video as shown, and proceed to the next fiducial when prompted.





7. Once all four fiducials have been surveyed, the script pops up the prompt: “Ready to pick up part?”. Select ‘Yes’ to continue or ‘No’ to abort the script.

8. The gantry will then load the picker tool, move it over the part, and prompt: “Measure GHCO z displacement?”. Select ‘Yes’ to continue or ‘No’ to abort the script. This is where the script measures the height of the suction cups relative to the focal point of the camera. If you select ‘Yes’, you will then be asked to adjust the z-coordinate of the

gantry head until the suction cups touch down on the surface of the calibration piece. Use the A3200 Motion Composer to move the gantry head down until the suction cups just barely touch the surface. The additional overtravel needed to compress the suction cups will be added later, so do not compress the suction cups significantly at this point. Once the suction cups are just barely touching, select ‘Yes, continue’ from the prompt.

9. After the z-height of the suction cups has been measured, the gantry can pick up the part and place on assembly chuck 0. It prompts for an angle to rotate the part, but the first step is to measure the drop correction parameters, so we initially enter ‘0’ for the rotation angle. The calibration part is then placed on chuck 0 without any additional rotation. The picker tool will then be returned to the tool rack.

10. Follow the prompts to measure the positions of the four fiducials again. The camera moves to their expected positions and uses the surveyed positions to calculate the parameters of the drop correction. For example, at Purdue we obtain

    New drop correction = {-0.002119,0.002131,0.000000} mm
    New drop rotation angle = -0.015853 deg

    which should then be updated in the script.

11. This process can be repeated to determine that the drop correction has been determined accurately. The process should converge after only one or two iterations but you should track the convergence in a spreadsheet. These are the parameters determined at Purdue from several iterations:

	DC.x (mm)	DC.y (mm)	DC.r (deg)	Δx (mm)	Δy (mm)	Δr (deg)
1	0.000000	0.000000	0.000000	-0.006102	0.009853	-0.025531
2	-0.006102	0.009853	-0.025531	-0.002657	0.001332	0.005643
3	-0.008759	0.011185	-0.019888	-0.001854	-0.000269	-0.000084
4	-0.010613	0.010916	-0.019972	0.000529	-0.000003	-0.001700
5	-0.010084	0.010913	-0.021672			

You can see that the changes in the drop correction parameters become dominated by the statistical uncertainty after two iterations and can only be improved by averaging the results of several measurements.

12. After the drop correction parameters have been measured, the part can be placed with a rotation angle to measure the GHCO displacement vector. Repeat the process but this time select a rotation angle of 30 degrees. Larger angles will give better precision (180

degrees is optimal) but these will tangle up the vacuum lines to the gantry head, so only try larger angles with extreme caution. In practice, 30 degrees seems to be fine. After the angle is specified, the part will be moved to assembly chuck 0 and rotated into position before being placed and held under vacuum.

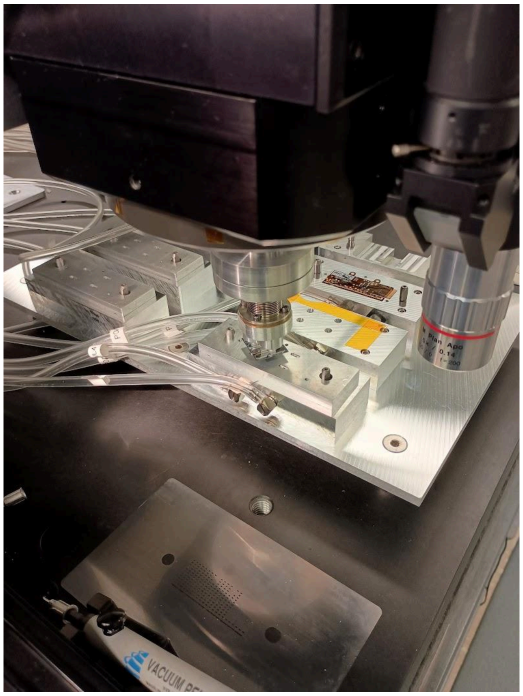
13. The four fiducials are then surveyed again with the camera initially moved to their expected locations. If the camera is initially centered on a fiducial, then no correction is required. Otherwise, the difference between the expected and observed fiducial location is used to calculate the new GHCO displacement vector which is reported by messages like this:

    GHCO correction dx = 0.003054, dy = -0.009110
    New GHCO offset = {0.849228,101.906706,-3.950}

    This process converges after only a few iterations. At Purdue, the corrections become incrementally smaller until they are dominated by statistical uncertainties:

	GHCO.x (mm)	GHCO.y (mm)	Δx (mm)	Δy (mm)
1	0.841257	101.916871	-0.010079	-0.021713
2	0.831178	101.895158	0.007890	0.009558
3	0.839068	101.904716	-0.002290	0.005397
4	0.836778	101.910113	0.000037	0.002101
5	0.836815	101.912214		

14. The new GHCO offset, if significantly different from the initially assumed displacement, can be used as the $ghco vector for subsequent measurements and can update the value stored in the site specific flex_config file.


Plan Apo
0.14
VACUUM