

Motivation

Satellites rely on precise sensor arrays to capture high resolution images of Earth, requiring very tight mechanical tolerances. Small angular deviations during assembly can result in severe distortion of images. In addition, sensor assemblies are extremely delicate, containing components that cannot be interfaced with. As a result, precise, fast and repeatable alignment of sensors is a challenging, time-consuming, and frustrating undertaking.

Overview

Our goal is to develop an automated system to angularly align multiple sensor chip assemblies with a tolerance smaller than 0.01° .

- Replace traditional manual alignment procedures with a high-precision motorized alignment process.
- Allow users to input initial sensor fiducial coordinates into a Raspberry Pi controller.
- Use the Raspberry Pi to calculate the required motor movements based on fiducial coordinate data.
- Control stepper-driven linear actuators via the CANopen communication protocol.
- Execute precise actuator movements to achieve the desired sensor alignment automatically.

Operational Flow Chart

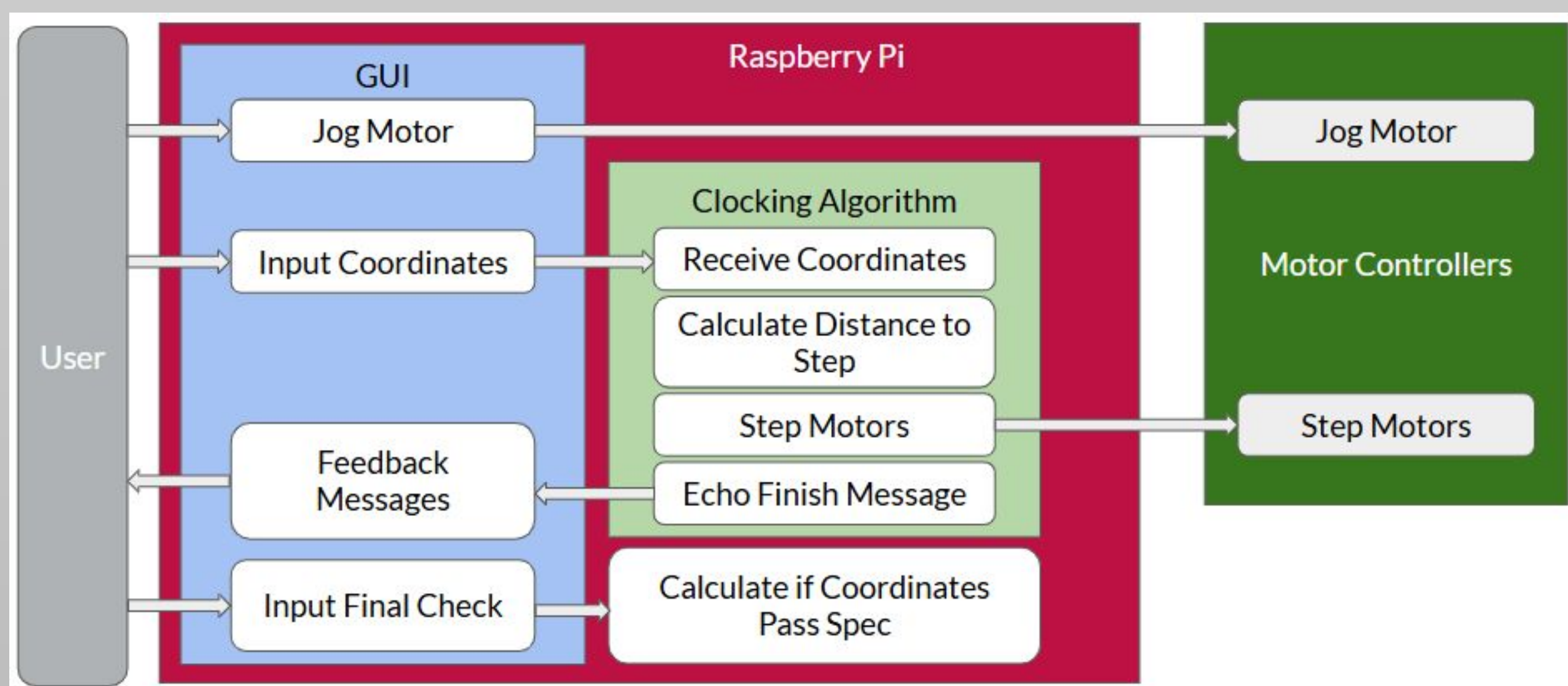


Figure 1: Operational Flow Chart of Final Prototype

Final Design

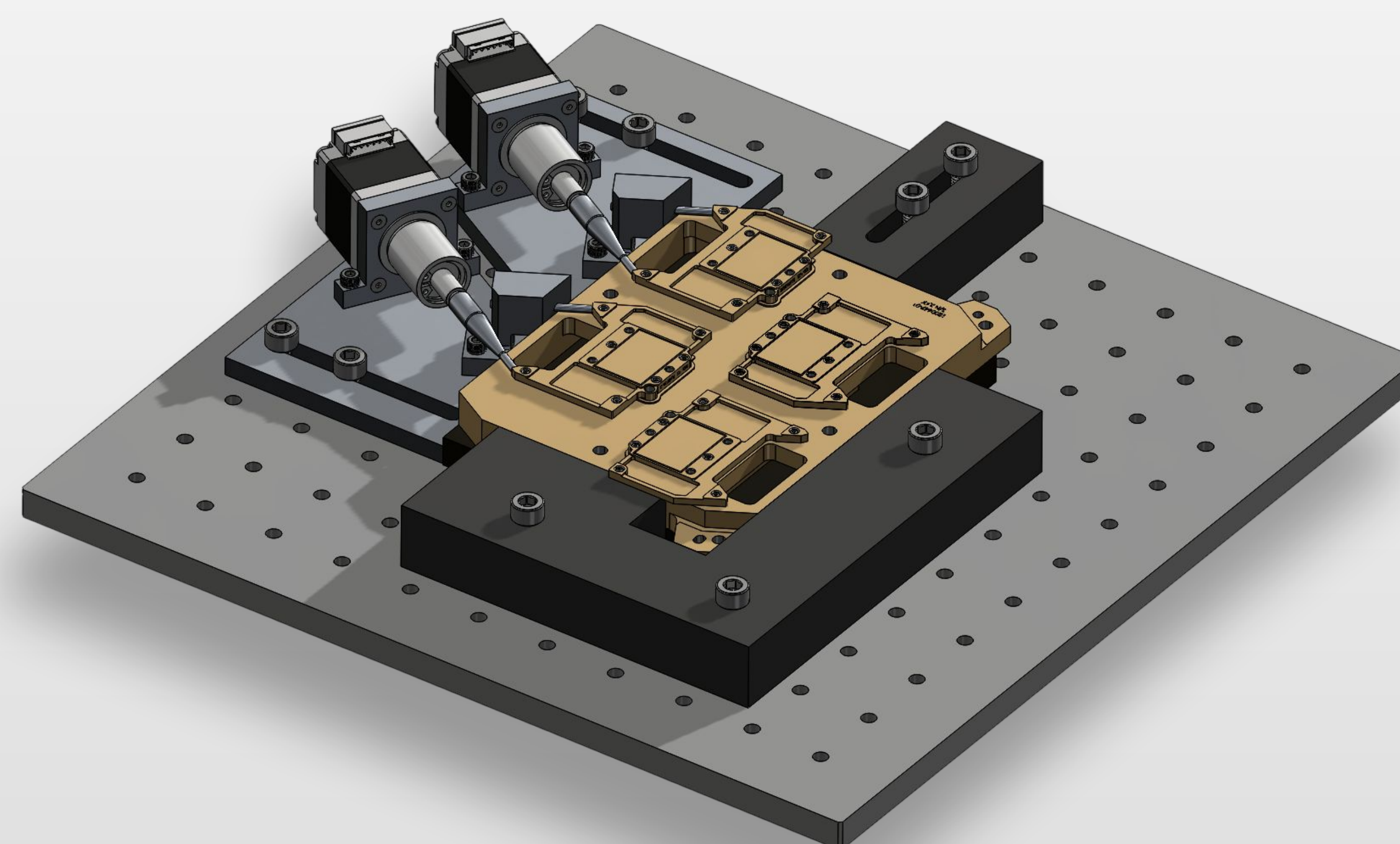
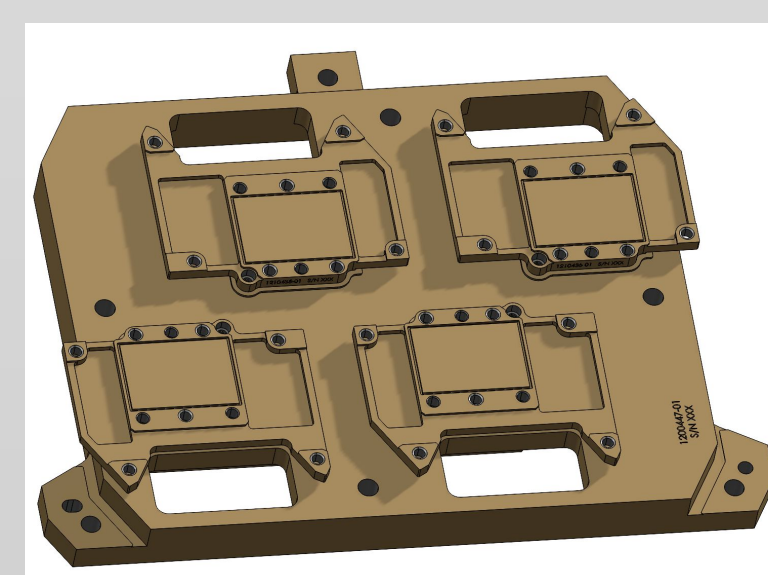


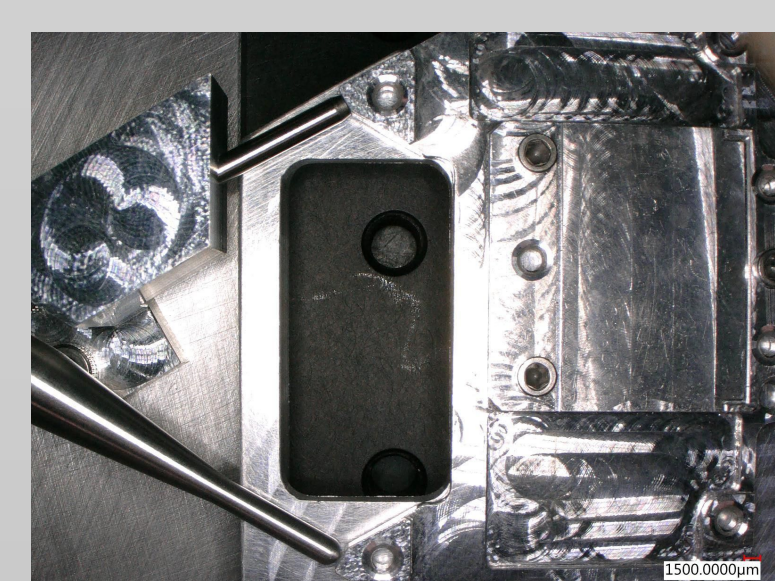
Figure 2: Above is a 3D CAD Model of the Left and Right Alignment tools as they interface with the four sensor Mosaic on our fixture.

Designing the Solution



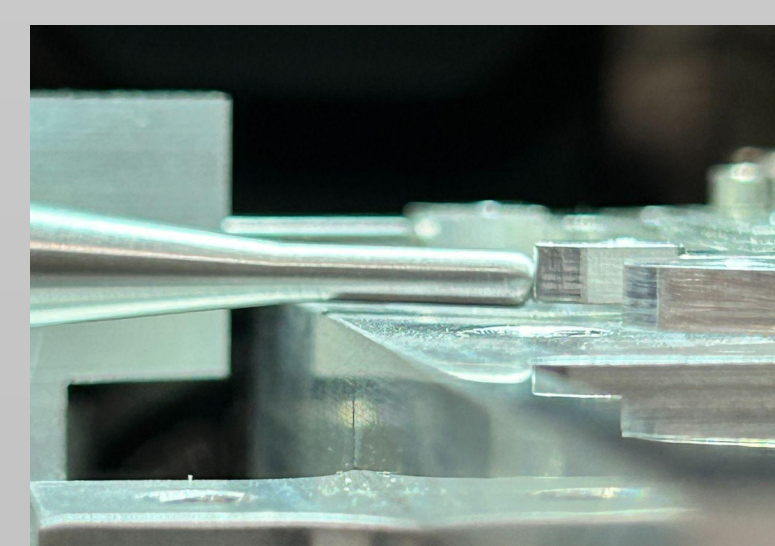
Alignment

- Four sensors on this assembly must be aligned rotationally until no sensor is more than a few tenths of a degree from the other three
- Equivalent to shifting tens of microns.



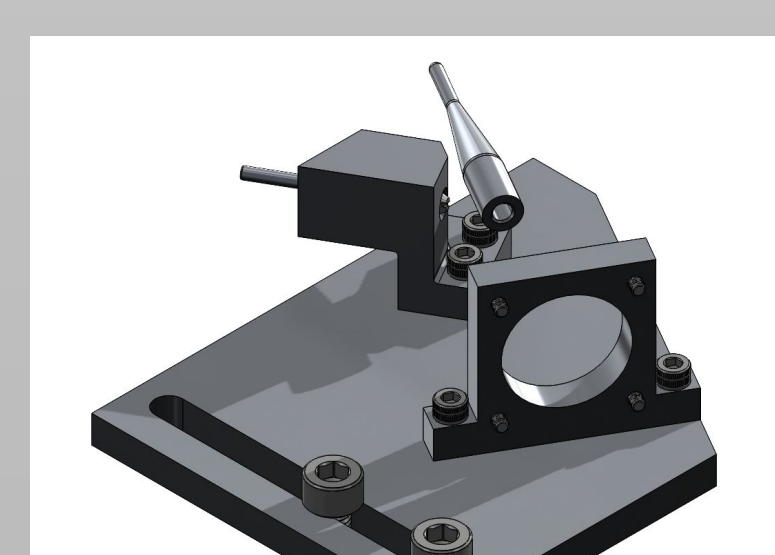
Optics

- Alignment of the sensors can only be checked by an advanced measuring microscope.
- Closed loop system—capture coordinates of the sensor and repeatedly correct the alignment until the aligned.



Tolerance Stackup

- Every part in the assembly is slightly off from its intended dimension.
- Stack these small errors end-to-end and the final part's position will be far off even if the individual parts seemed fine on their own.



Keep it Simple

- The less parts you have in your assembly, the better.
- Although attractive complexity will result in increased tolerance stackup, lead time, manufacturing costs, and more.

Angular Clocking Test

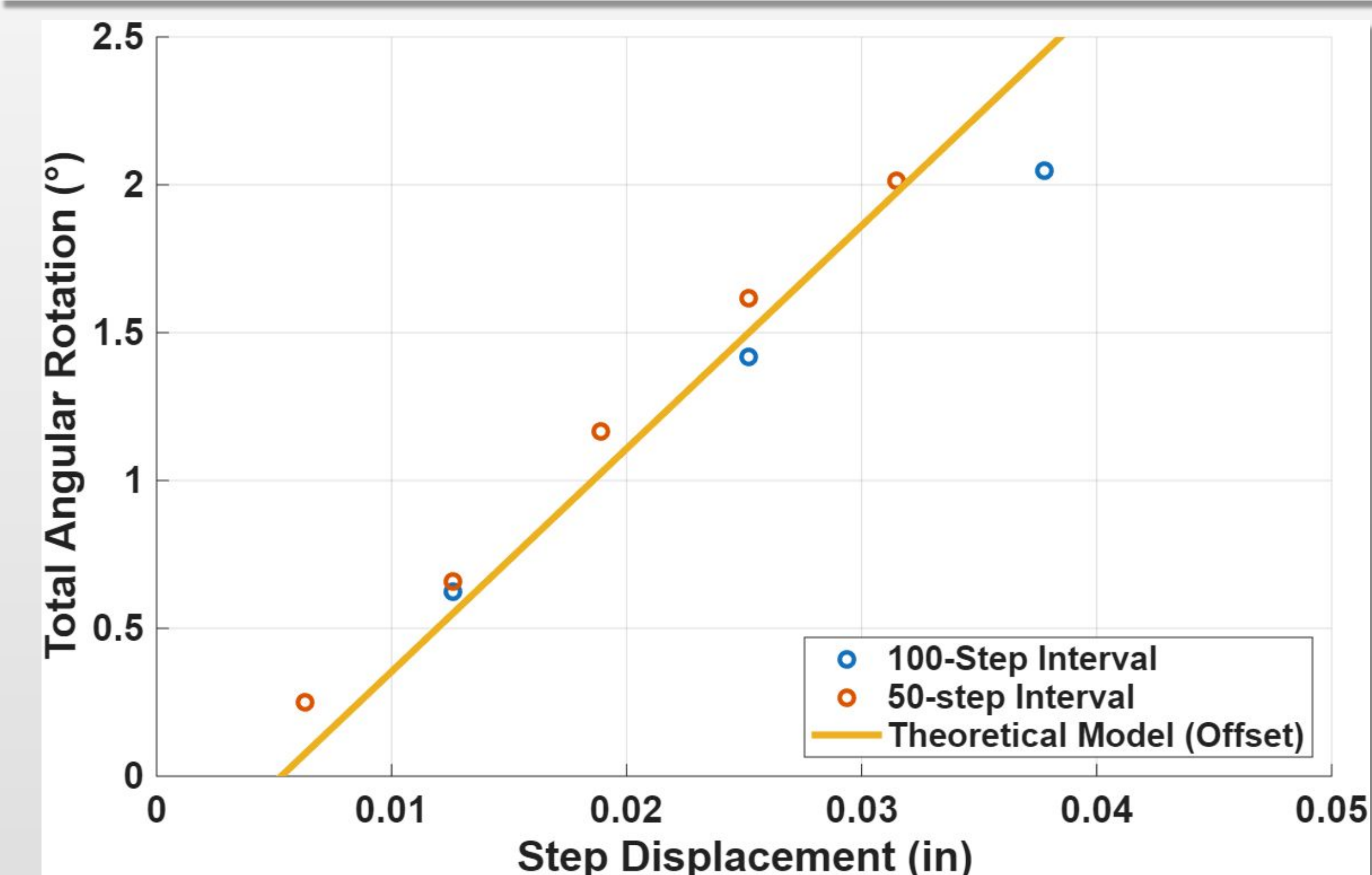


Figure 3: Chart of Measured Sensor Rotation based on Step Interval of Motor. A theoretical model based on the unloaded motor specification is also presented for comparison.

Motor Step Increment	Angular Displacement per Increment ($^\circ$ /increment)	Angular Displacement per Motor Step ($^\circ$ /step)
100-Step (0.013 in) Interval	0.68 ± 0.10	0.007
50-Step (0.006 in) Interval	0.40 ± 0.10	0.008
Theoretical	-----	0.008

Table 1: Table of the average angular displacement per each motor increment and the calculated angular displacement for an individual motor step.

- Conducted motorized angular testing using 100-step and 50-step actuator intervals to evaluate system alignment performance.
- Smaller step intervals are achievable but difficult to verify without specialized optical measurement equipment.
- System can align sensors within the required tolerance of $< 0.01^\circ$ if using smaller motor step intervals.