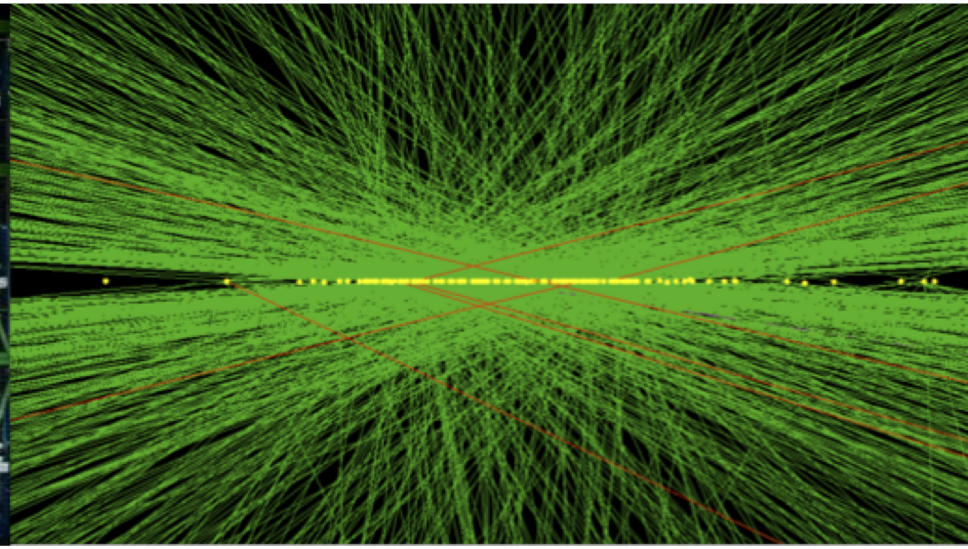
OT B02: Progress on Automation

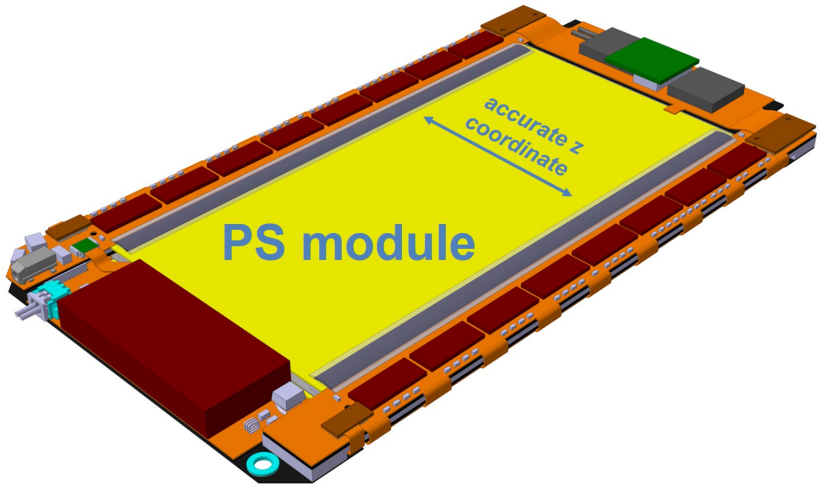
Lenny Spiegel (FNAL), Meenakshi Narain (Brown)

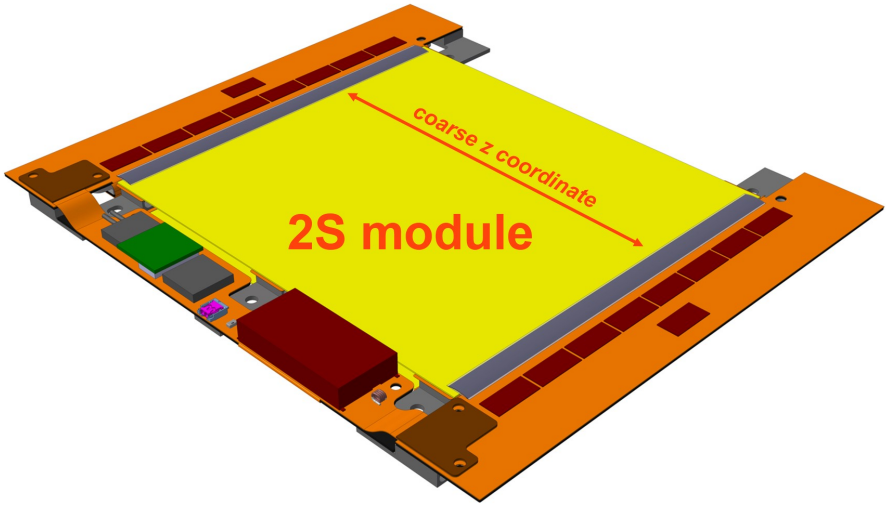
CD1 Director's Review

March 20, 2019

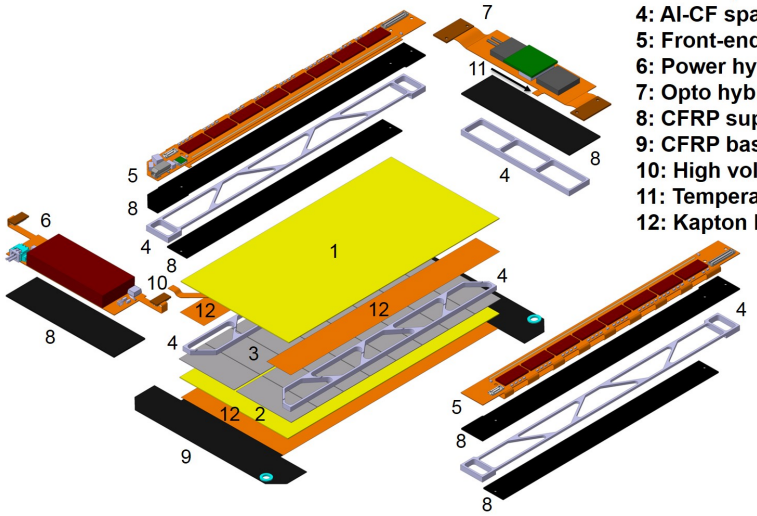


Outer Tracker modules

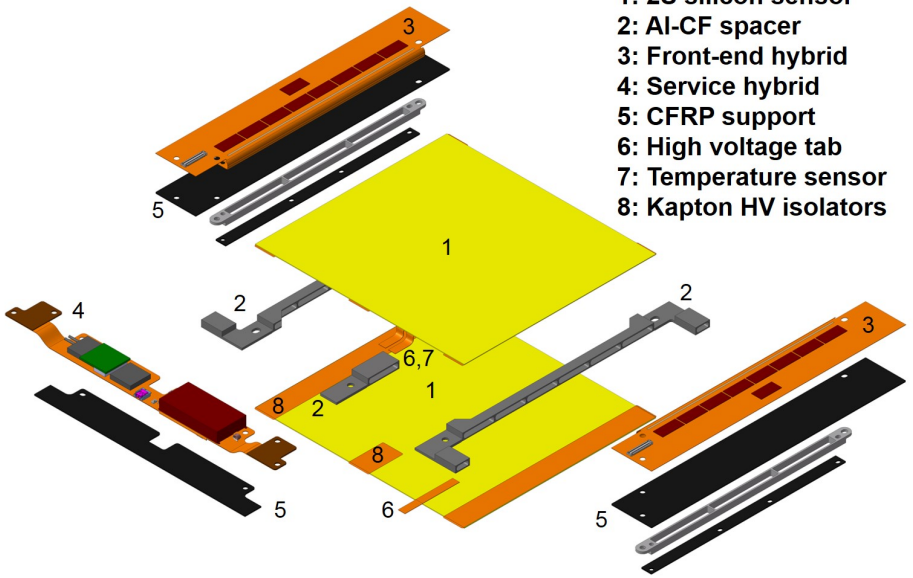




1: PS-s sensor
2: PS-p sensor
3: Macro-pixel ASICs
4: Al-CF spacer
5: Front-end hybrid
6: Power hybrid
7: Opto hybrid
8: CFRP support
9: CFRP baseplate
10: High voltage tab
11: Temperature sensor
12: Kapton HV isolators



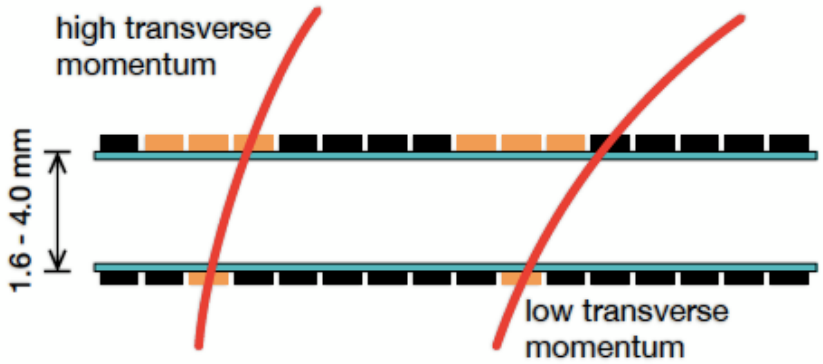
1: 2S silicon sensor
2: Al-CF spacer
3: Front-end hybrid
4: Service hybrid
5: CFRP support
6: High voltage tab
7: Temperature sensor
8: Kapton HV isolators



Plan A is to use fixtures for the manual assembly of PS and 2S modules.

Alignment specifications

- Critical assembly specification
  - PS modules
    - The strips on the PS-s sensor and the macro pixels on the PS-p sensor have to aligned to 800 μrad
  - 2S modules
    - The strips on the two 2S sensors have to aligned to 400 μrad

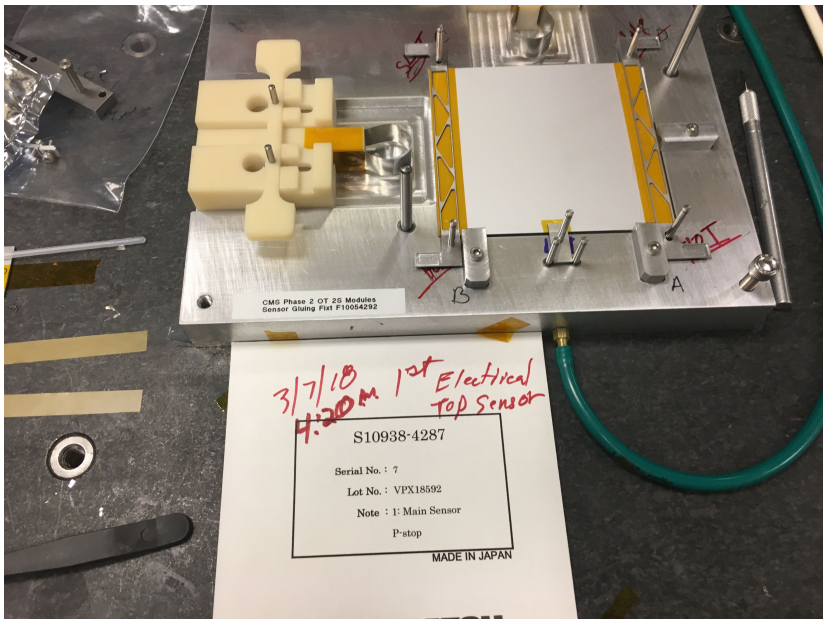


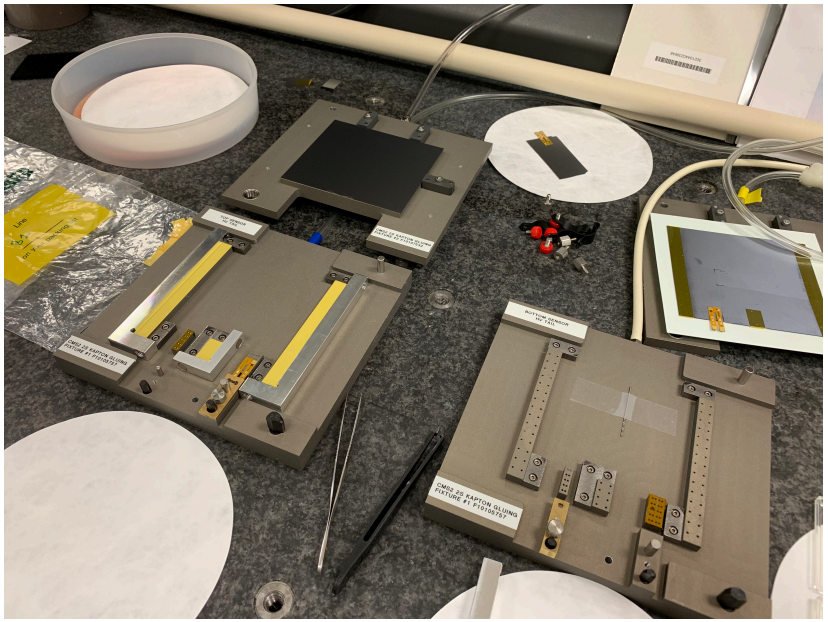
- We assume that *every* sensor-sensor combination will need to be checked for the alignment specs.

Motivation for automation

- Replace some technician effort with less costly undergraduate and graduate student effort
  - Opportunity within Risk Register
- Was a strong recommendation from the June 2018 IPR.
- Provide opportunities that would not be possible in manual assembly for students to participate in the development.
  - LabView programming including instrumentation
- Take advantage of experience gained from past projects in the US.
  - FNAL and UCSB in Tracker Outer Barrel
  - Purdue and Nebraska in the FPix Phase 1 upgrade
- More uniformity across US institutes in final products.
- Help strengthen the infrastructure at the host facilities for future projects.

Challenge imposed by double sensor design



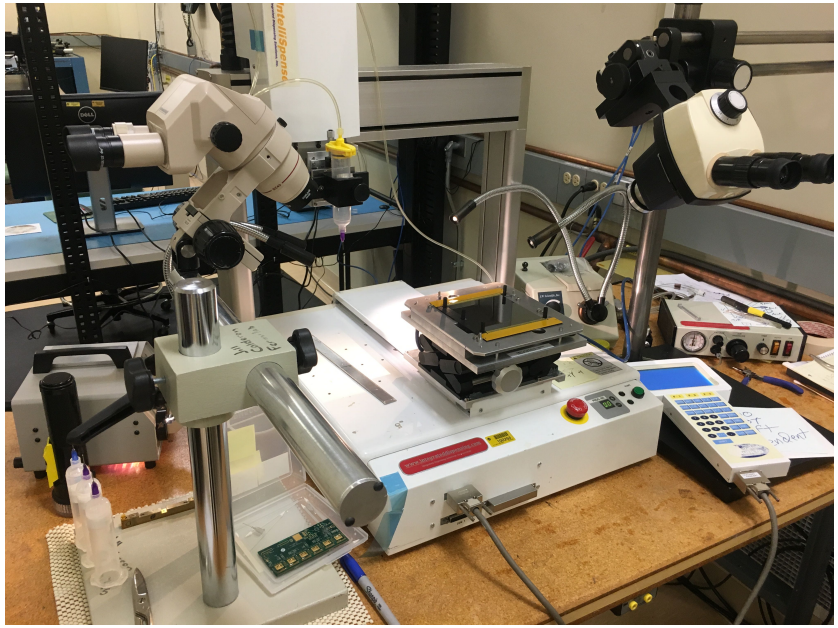


- Both the PS and 2S modules have pairs of sensors separated by Al-CF spacers or bridges. The spacers/bridges are not easy to lift by vacuum.
- Adding kapton strips to isolate the sensors from the spacers/bridges and baseplates, and tabs for biasing sensors is a manual process.
- Top and bottom 2S sensors are identical in size and the bottom sensor does not have icons on the aluminumized side.

Multi-prong approach

- Concede that 2S sensor-sensor combinations are likely to be done manually.
- Explore the use of a combination of LANG GmbH & Co. stages at Brown for assembling individual PS modules.
  - GT9-NSMA XY-Stage
  - LT8-LBMA Linear Stage
  - RT5-xxxx High Precision Rotary Stage
- Explore the use of an Aerotech gantry robot at FNAL for the metrology of PS/2S sensor-sensor combinations and for gluing readout and service hybrids
  - AGS10000
  - Working area can accommodate up to 8 modules

Wire bond encapsulation



- The gantry robot could be used for encapsulating wire bonds.
  - Dow Corning Sylgard 186
- However, the encapsulation takes place after wire bonding and it would be better not break the work flow.
- Fermilab has an older IDS glue dispensing robot and there are many similar units on the market for 10-20k$.

PS module assembly

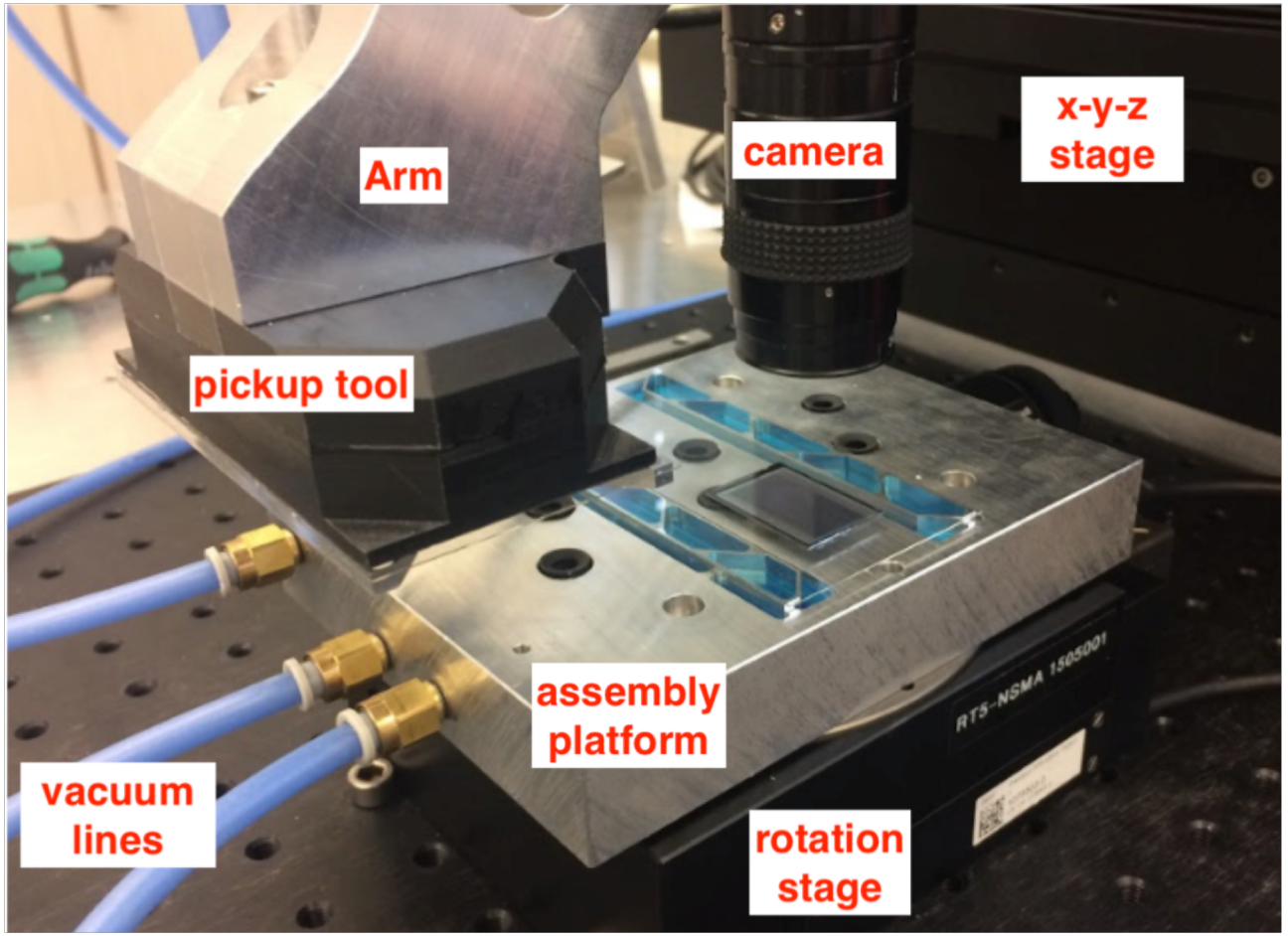
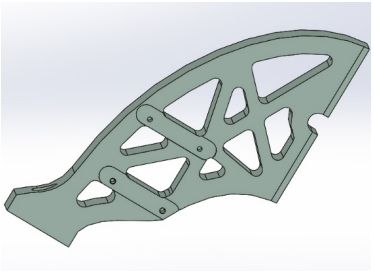
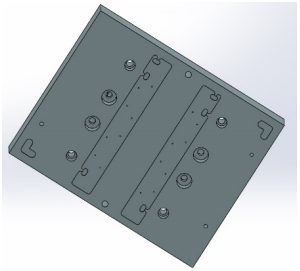
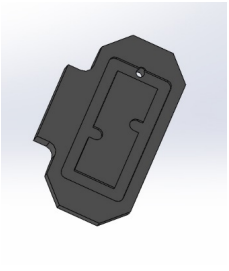


Image from presentation by James Keveaney (DESY)

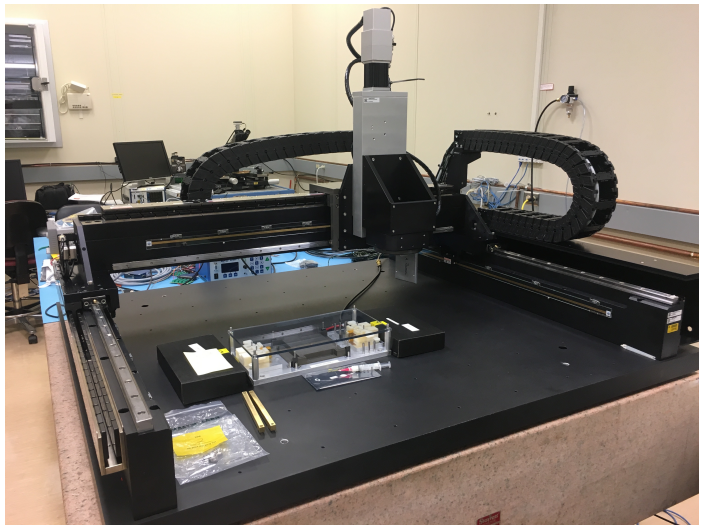
PS module assembly Brown approach

- Similar to DESY concept
  - Take advantage of the ability to see fiducial icons on PS sensors even in a stacked configuration
  - Off-the-shelf stages, now on order from Lang GmbH
  - Custom designed components currently being machined at Brown.

- Evaluate whether similar assembly could be done on a gantry.
  - Would allow multiple modules to be assembled in parallel.

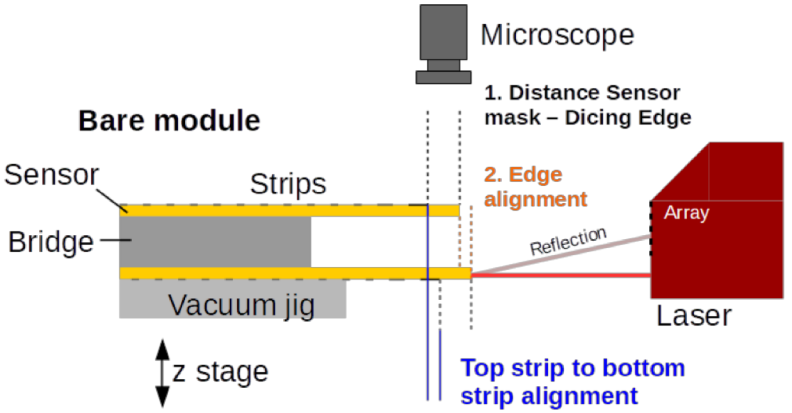
Aerotech AGS10000 gantry robot



- New Aerotech system received at FNAL/SiDet last September.
  - Larger working area than Phase 0 system
    - 75cm x 75cm compared to 50cm x 50cm
- All of the ancillary equipment – Nordson glue dispenser, NI compact DAQ, Festo values – was already in place and some programming had started using the original gantry robot.
- Modified a manual fixture for attaching readout hybrids to 2S sensor-sensor combinations.
  - Will need to be expanded in include the 2S service hybrid and eventually a fixture will be needed for PS readout and service hybrids.

Keyence triangulation laser

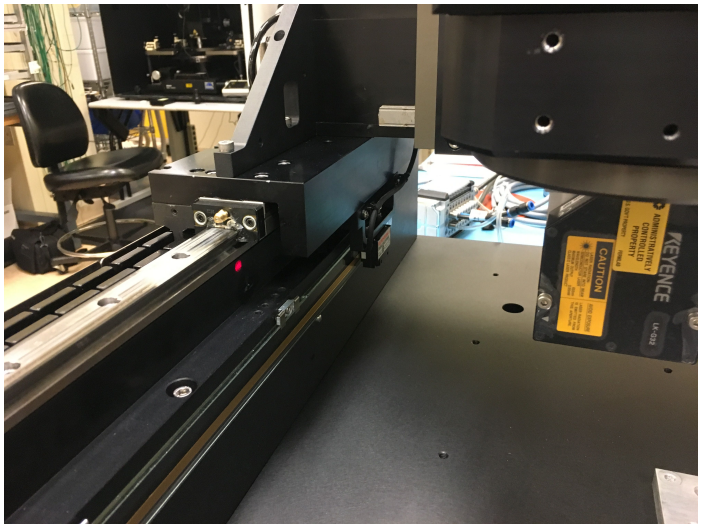
- The edges of diced sensors are sufficiently reflective so that a red light triangulation laser can measure the distance to the edge very accurately.
- Based on studies pioneered by the KIT group we have purchased a Keyence laser for mounting on the Aerotech rotation axis.
- Relative angles can be measured by edge scanning for both PS and 2S modules.
  - For PS it is possible to determine the relative angle by looking from above with a camera microscope.

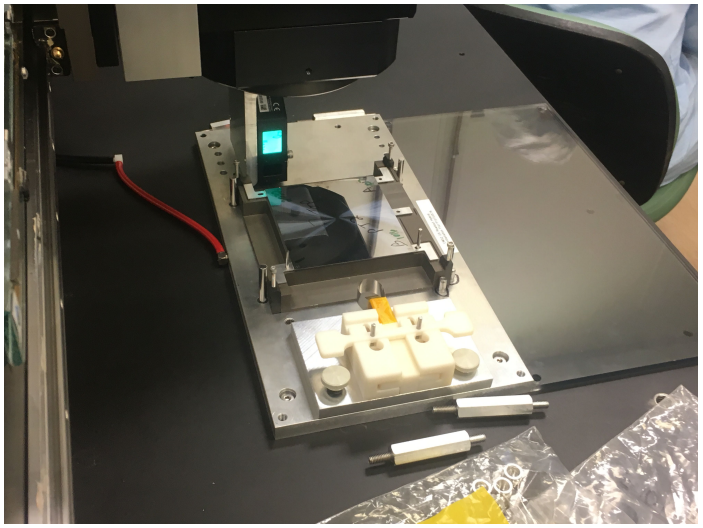


From KIT presentation

Keyence laser purchased by FNAL group

Keyence triangulation laser

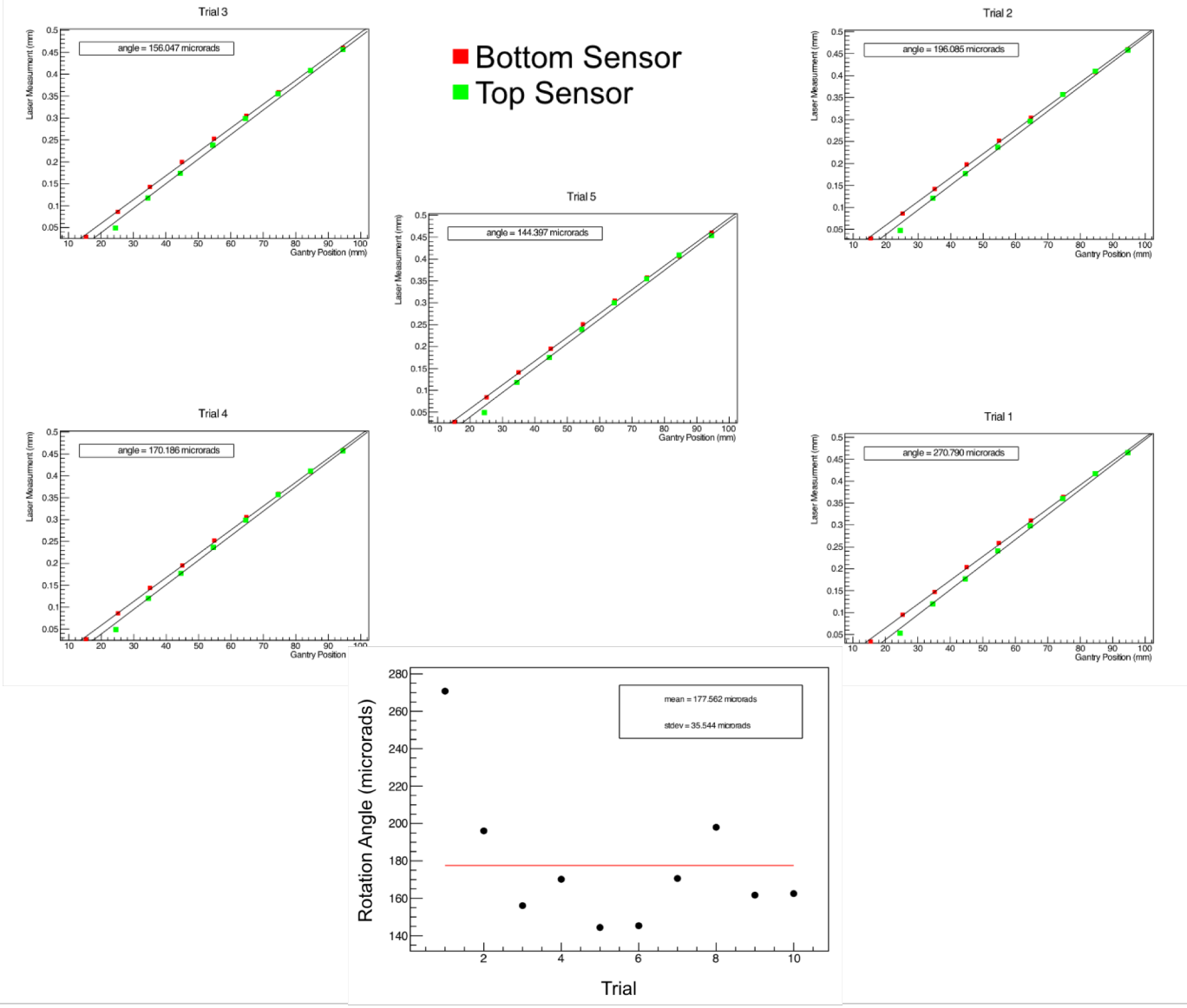




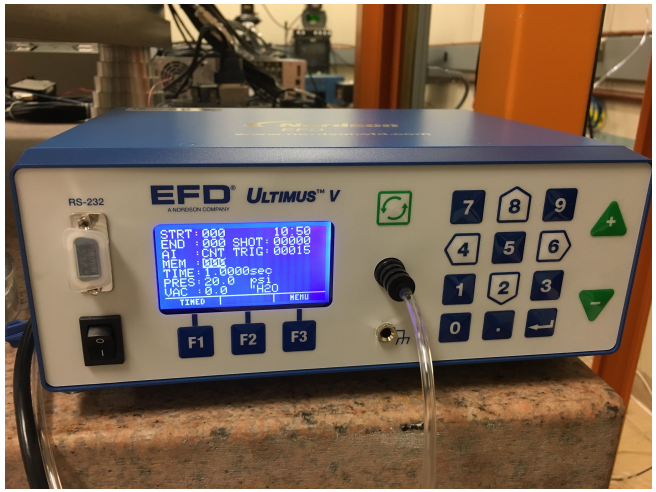
- Keyence laser metrology
  - Two University of Iowa students have developed a LabView program for scanning the edges of sensor pairs and determining the relative angle.
  - Although the laser spot size is about 30 microns, the dummy sensor-sensor combinations do not always lie flat on the fixture or have the sensors in repeatable vertical locations.
    - Add vertical scan to identify center points of sensors.

Sensor angle metrology

Measurements from M. Alhusseini and C. Rude



Hybrid gluing



- Follow the FPIX approach of adding a syringe holder and pressure multiplier to the gantry head.
  - Talking with Nordson about using vacuum to limit dripping of the epoxy.
  - May want to learn the position of the syringe tip for better accuracy.
- Dispensing is controlled by a Nordson EFD Ultimus V.
  - Can either enter a dispensing sequence at the EFD keypad or send start and stop commands through LabView.
  - Polytec TC 437.

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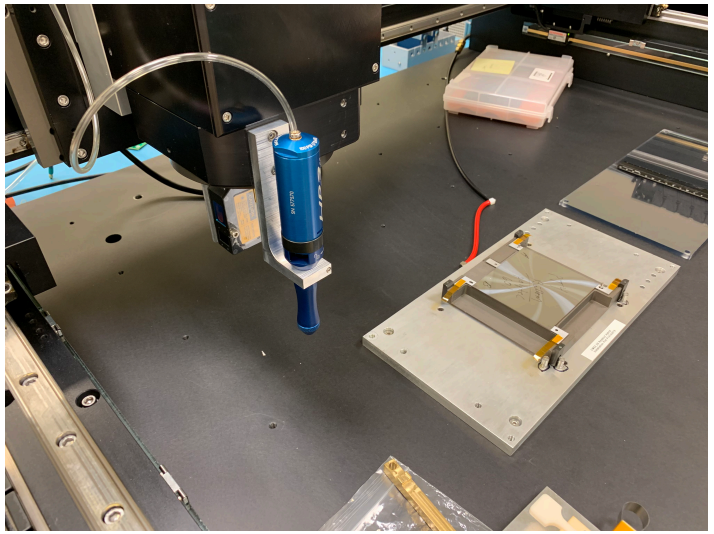
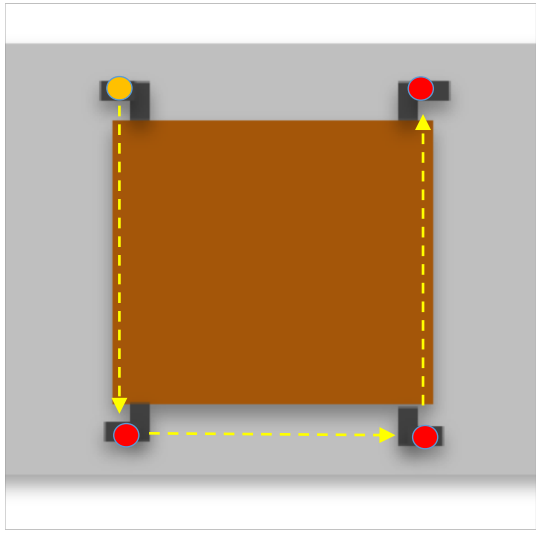
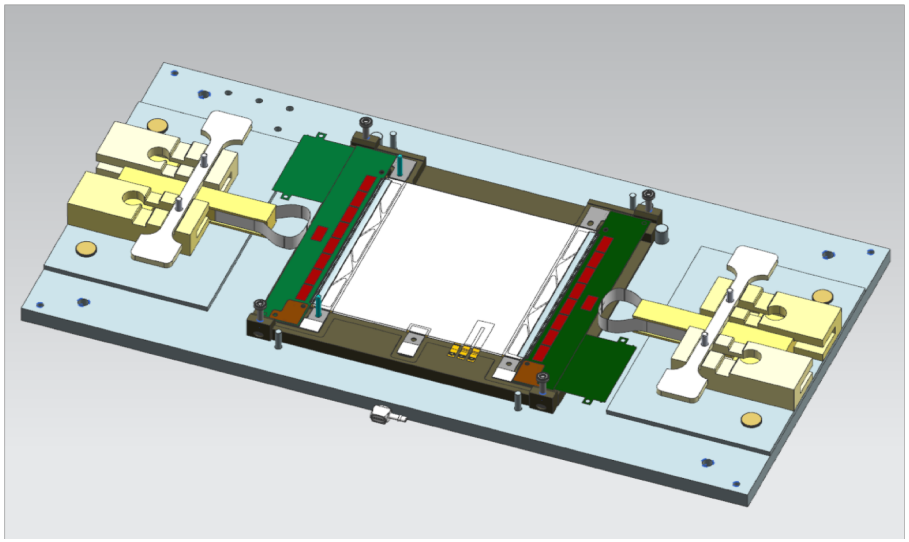
Hybrid gluing cont.

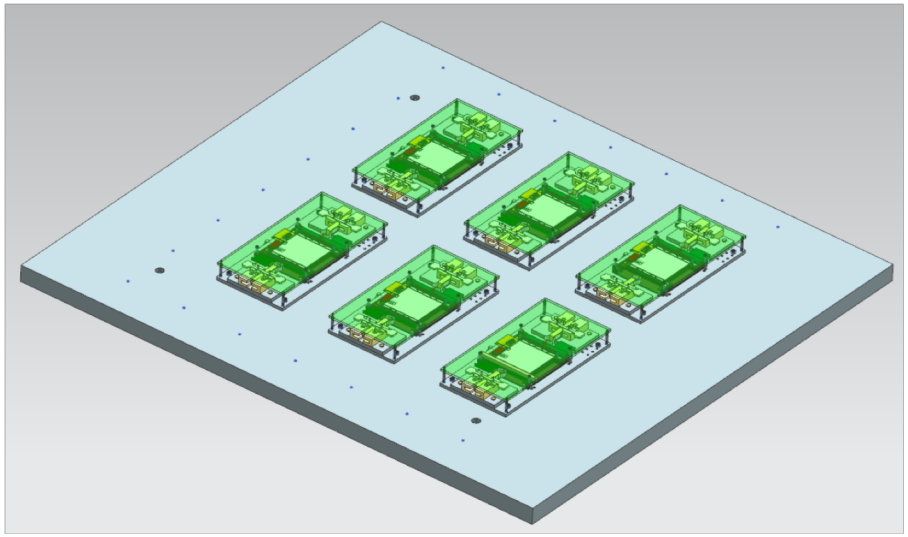
- Now have a LabView VI for dispensing epoxy at the 4 bridge points for adding 2S readout hybrids.
- As with the edge scanning the epoxy dispensing VI will be used as a subVI for N module positions on the gantry controlled through single line commands.





Replication





There is room on the gantry bed for up to 8 module position (6 shown in right side drawing). Our preference would be to let the epoxy harden over night while the modules remain on the gantry bed, but one could also imagine transferring fixtures off of the gantry if necessary.

Database support

- As modules are assembled it will be necessary to register the modules and their components in the construction database.
- At the same time one would like to preserve the sensor alignment information.
- This is naturally accomplished during the gantry robot assembly step, where the LabView xml file builder would have access to sensor-sensor relative angles and other metrology data.
  - And can be accomplished early on through contributed student labor.

R&D goals

- PS MaPSA-sensor assembly
  - At least duplicate the progress achieved by the DESY group in constructing a PS-s and MaPSA combination.
- Gantry metrology and hybrid gluing
  - Finalize 2S sensor-sensor laser edge scanning VI
  - Add air-activated insertion of 2S readout hybrids following bridge corner gluing.
  - Add visual scan of readout hybrid – sensor alignment.
  - Demonstrate wire bond encapsulation.
  - Implement a basic module registration xml file VI.

Quantifying automation opportunity

RO-402-2-03-D OT - Module assembly can be automated

Risk Rank:	3 (High) **Scores:** Probability : 5 (VH) ; Cost: 2 (M) Schedule: 1 (L))	**Risk Status:**	Open
Summary:	If automation in module assembly comes to fruition, then labor costs and schedule durations both decrease		
Risk Type:	Opportunity	**Owner:**	Leonard G Spiegel
WBS:	402.2 OT - Outer Tracker	**Risk Area:**	Management Risk / Experience or Capability
Probability (P):	66%	**Technical Impact:**	0 (N) - negligible technical impact
Cost Impact:	PDF = 1-point - single value Minimum = k$ Most likely = -1,000 k$ Maximum = k$ Mean = -1,000 k$ P * <Impact> = -660 k$	**Schedule Impact:**	PDF = 1-point - single value Minimum = months Most likely = -2 months Maximum = months Mean = -2 months P * <Impact> = -1.3 months
Basis of Estimate:	A reduction of $1.6M in fully burdened labor costs throughout the production period is determined assuming that 2 technicians per assembly site are replaced with 2 students (uncosted graduate students at FNAL and moderately costed undergraduates at Brown = $30/hr). The cost of two gantry robots ($150k each) and engineering+programming development costs ($300k) leads to a $1.0M opportunity. The impact on the schedule is expected to be 2 months of savings based on the current estimate of the labor required to carry our the steps being considered for automation.		
Cause or Trigger:		**Impacted Activities:**	All PS and 2S Module assembly activities in aggregate. Implemented as a risk hook between start and completion of production of 2S modules.
Start date:	1-Apr-2020	**End date:**	31-Dec-2024
Risk Mitigations:	In the R&D phase we will pro-actively explore automating certain steps in the module assembly process with the aim of realising the associated cost and schedule savings.		
Risk Responses:	Accept the risk , produce modules more efficiently		
More details:			

Summary

- Considerable progress has been made toward automating *some* of the assembly steps.
- There are potentially significant cost savings and the automation steps pan out and undergraduate and graduate student resources can be identified.
- The goal is to reach a decision point by the end of the summer for the Aerotech metrology and hybrid assembly, and a decision by the end of the year for the PS MaPSA-sensor assembly.