Final Design of the INTT Ladder and Production Readiness Review (PRR)

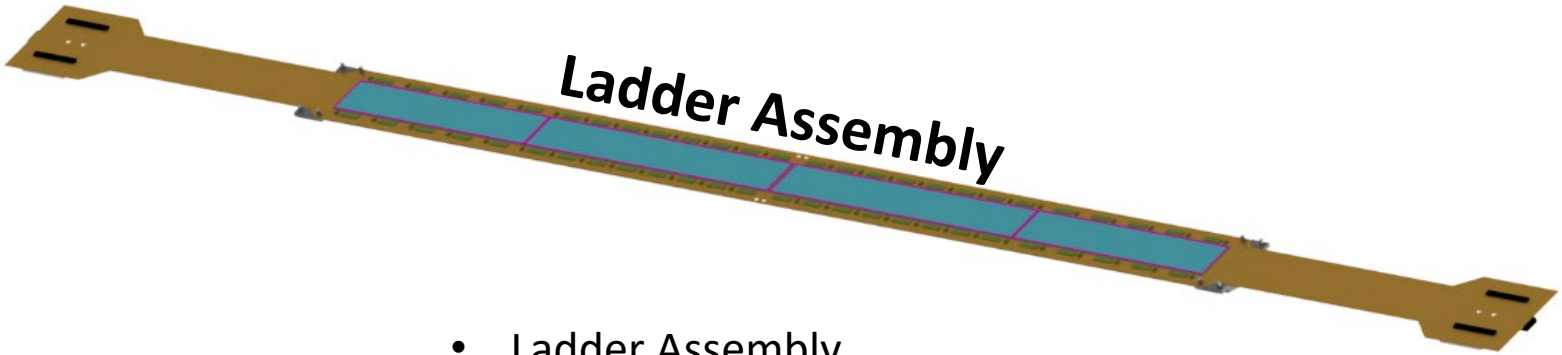
Ladder Assembly at BNL

WBS: 3.01

Connor Miraval, BNL

March 2nd , 2021

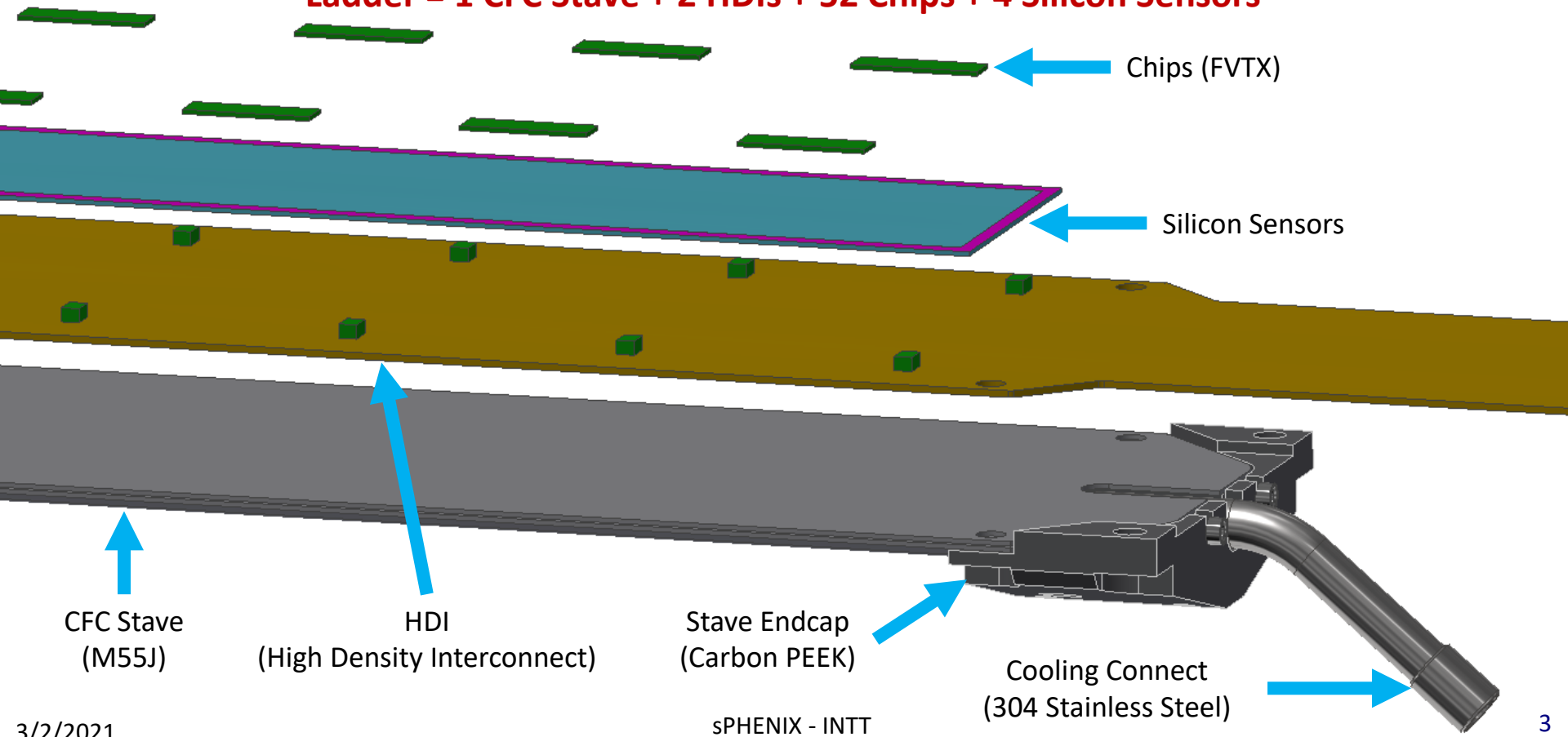
PRR Components



- Ladder Assembly
- Ladder Assembly Fixtures
- Ladder Assembly Procedure
- Prototype Assemblies
- Production Readiness

Ladder Components

Ladder = 1 CFC Stave + 2 HDIs + 52 Chips + 4 Silicon Sensors



Ladder Assembly Steps at BNL

Inspection → HDI Epoxy → Chips Epoxy → Chips Wire-Bond

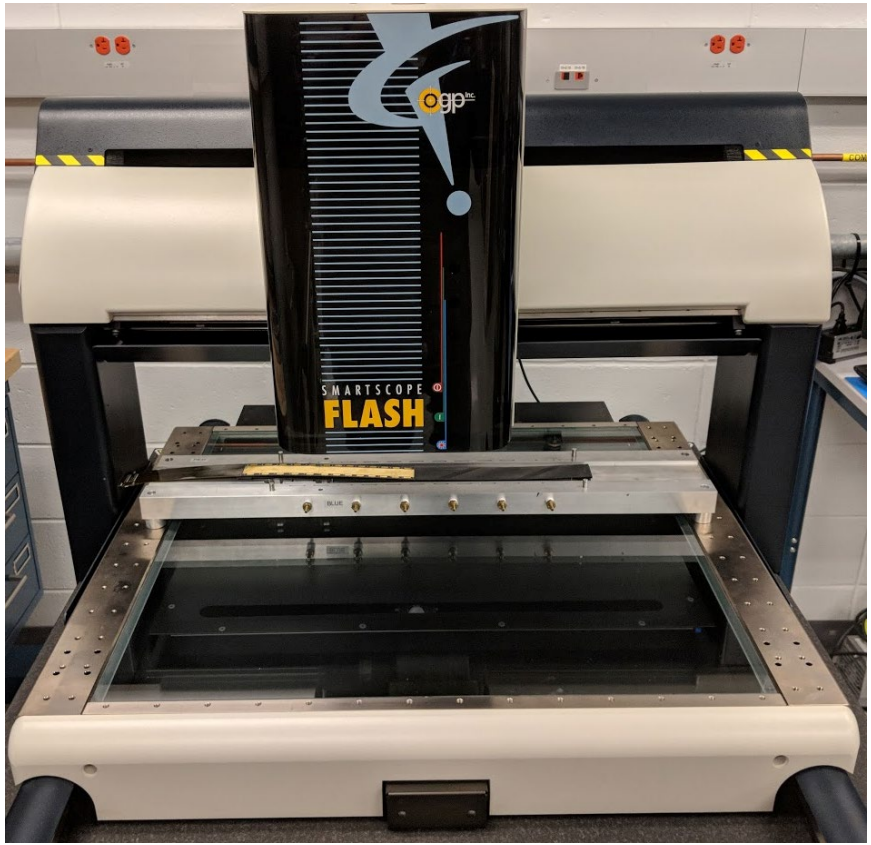
Chip/HDI Test → Sensor Epoxy → Sensor Wire-Bond → Full Assembly Test

1. Parts kitted and S/N's logged in database.
2. Laser scan CFC stave for flatness.
3. HDI's aligned and epoxied to CFC stave.
4. Set and epoxy chips to HDI.
5. Chips wire-bonding to HDI.
6. Chips/HDIs testing.
7. Set and epoxy silicon sensors to HDI.
8. Silicon sensor wire-bonding
9. Sensors/Chips/HDIs testing
10. Encapsulation wirebonding chips to HDI and sensors to chips.
11. Full ladder tests.

INTT Ladder Assembly Station
OGP Laser-Optical Measurement

Technical Overview – Laser OGP Machine 500

- With a wingspan of 31.5 inches, the staves require a large measurement system to survey the flatness throughout assembly.
- BNL's on-hand OGP Smartscope Flash 500 is the perfect tool for the job.
  - **Large travel bridge with a support span of 33.125 inches.**
  - **Measurement platen can accommodate multiple assembly fixtures at once.**
  - **Top-down laser optical measurement system with potential Z accuracy of 2 microns (calibrated by company every 6 months).**



Wirebonding/Encapsulation Expertise

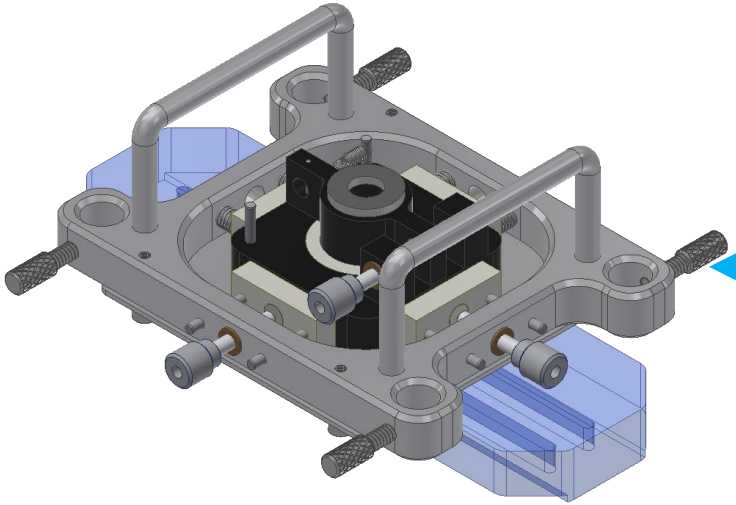
- The BNL group has experience in assembling silicon ladders/barrels (VTX/FVTX silicon trackers)
- Experienced wirebonding, bump bonding, encapsulation and debugging services are available on site.
  - **Multiple rounds of wirebonding is required at different stages of the stave assembly.**
  - **Following the final test, encapsulation is completed by the wirebonding group.**
- Users familiar with OGP measurement systems are available for metrology throughout the assembly process.

Thermal Recycling Chamber

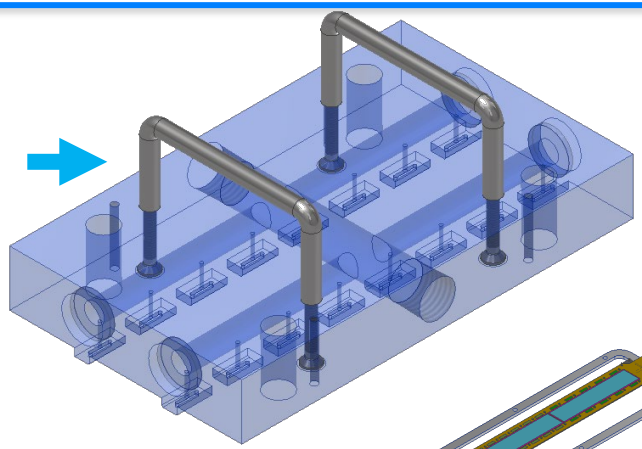
Automatic Encapsulation machine

Wire-bonding machines

Ladder Assembly Fixtures

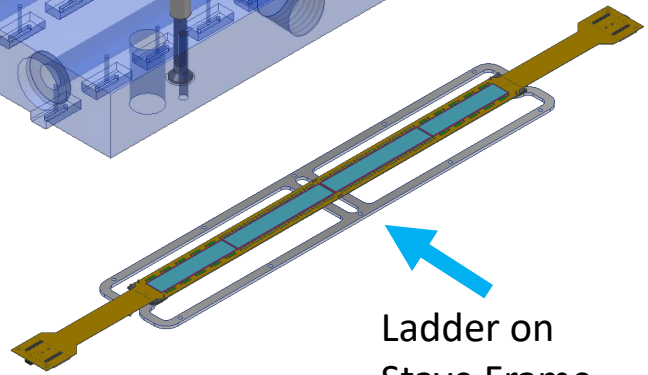


Chip Placement Tool

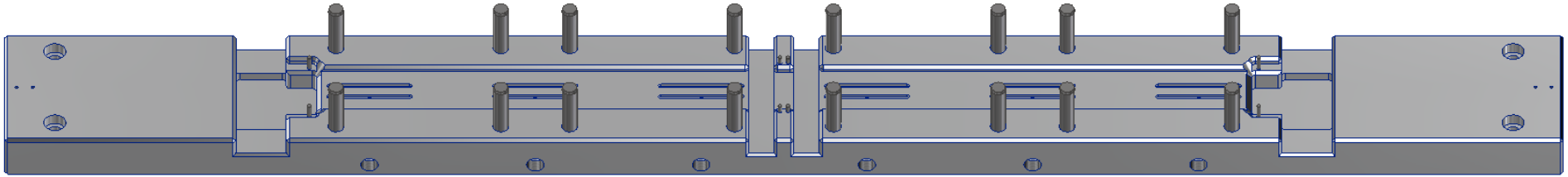


Sensor Placement Tool

Base Vacuum Fixture

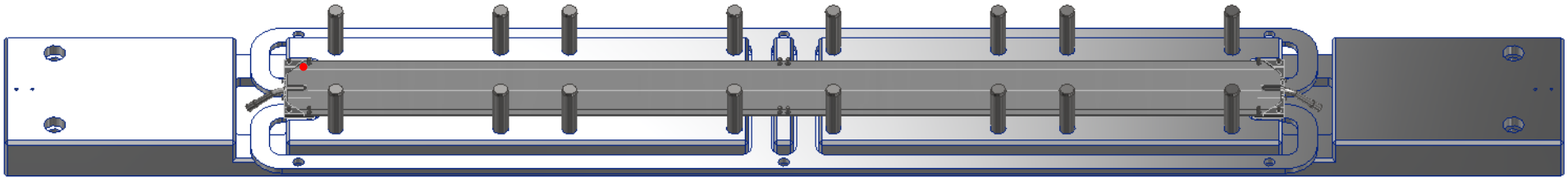


Ladder on Stave Frame

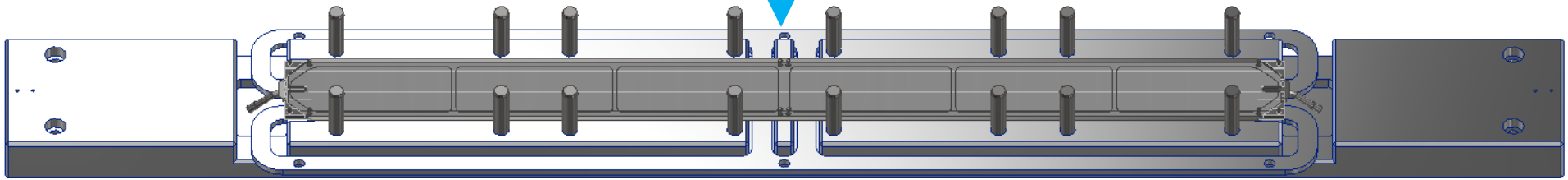


Technical Overview – HDI Placement

1. CFC stave is installed on the base fixture, and scanned by the OGP for flatness.



2. Glue mask is applied to prevent overspill of epoxy during and after application.



Technical Overview – HDI Placement Laser Scan

205-310-0100-01	0011	0.0948	0.0865	0.1190
205-310-0100-01	0013	0.1031	0.0845	0.0320
205-310-0100-01	0014	0.1535	0.1117	0.0580
205-310-0100-01	0016	0.0880	0.0820	0.0560
205-310-0100-01	0017	0.0759	0.0967	0.1030
205-310-0100-01	0019	0.1827	0.0993	0.0780
205-310-0100-01	0020	0.0723	0.1021	0.2560
205-310-0100-01	0022	0.1290	0.0761	0.0990
205-310-0100-01	0023	0.1055	0.1249	0.3890
205-310-0100-01	0025	0.1096	0.1149	0.1080
205-310-0100-01	0026	0.1360	0.1665	0.2090
205-310-0100-01	0028	0.1358	0.1150	0.1100
205-310-0100-01	0029	0.1278	0.1352	0.1240
205-310-0100-01	0031	0.0859	0.1479	0.0290
205-310-0100-01	0032	0.1106	0.1230	0.1270

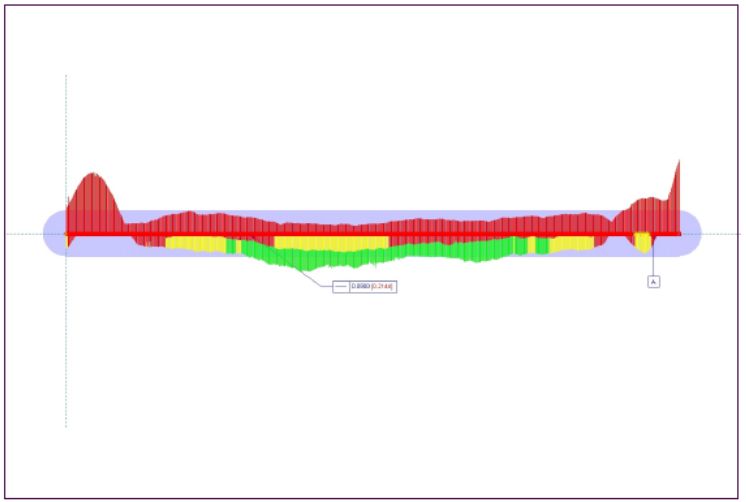
QVI MeasureFit Report

March 9, 2020
1:22:16 p

BROOKHAVEN NATIONAL LAB

Name INTT-CFStave-Flatness.mfp, INTT-

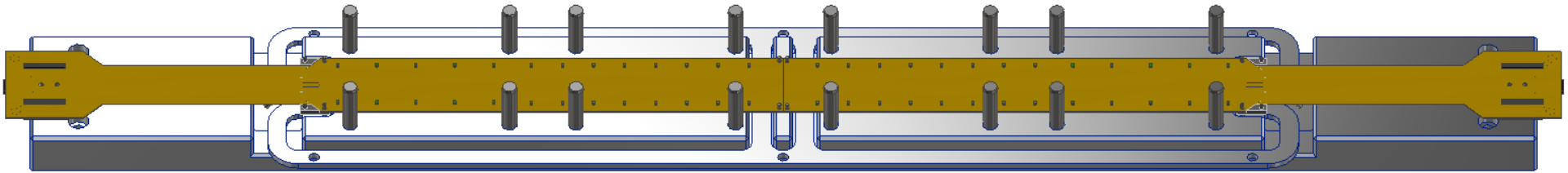
Date of Inspection: March 9, 2020



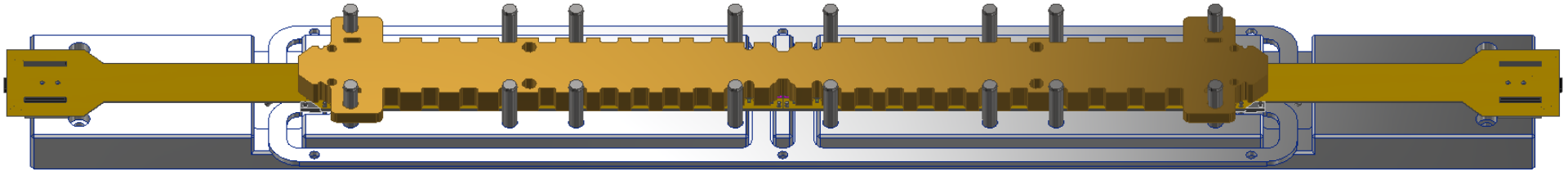
Dim	Dimension Label	Nominal	USL	LSL	Actual	Deviation	Status
1	Flatness	0.0000	0.0900		0.2144	0.2144	+ 0.1244

Technical Overview – HDI Placement

3. Glue mask is removed and both HDIs are installed on the stave, located by 2mm pins.

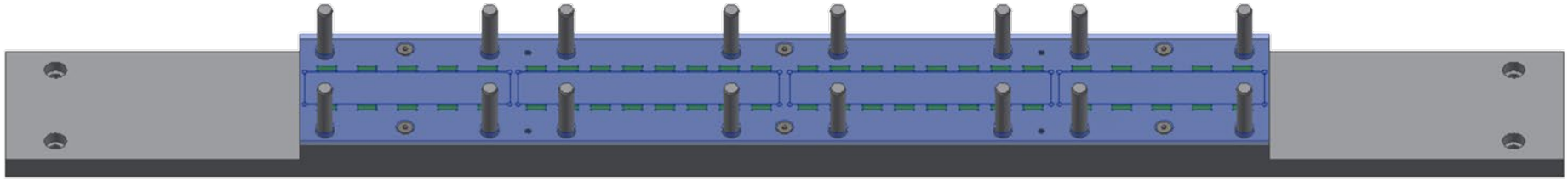


4. Glue weight is applied to the top surface of the HDIs and remains throughout curing.

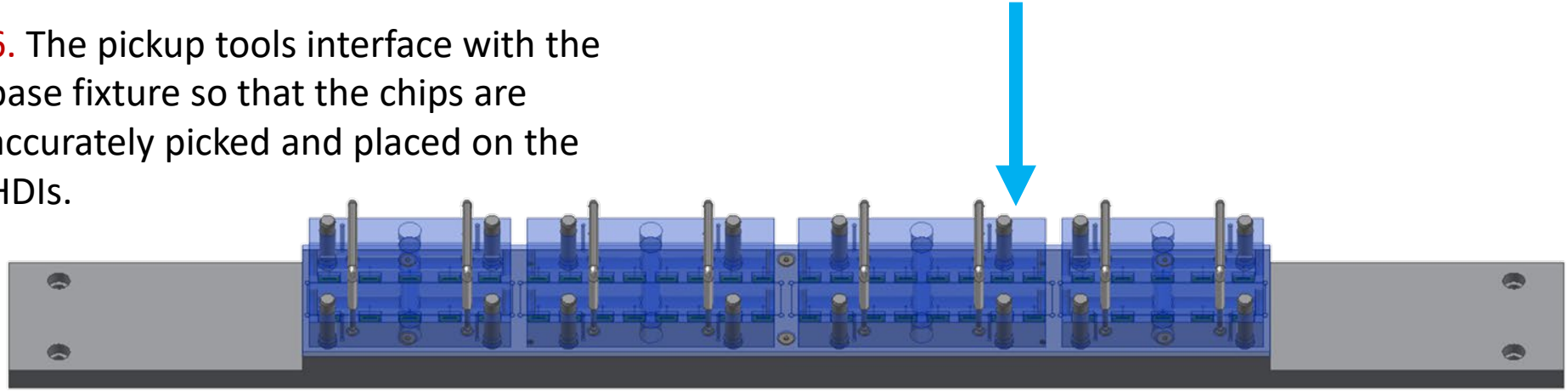


Technical Overview – Chip Placement

5. Chips are placed in the base pockets of the base fixture.

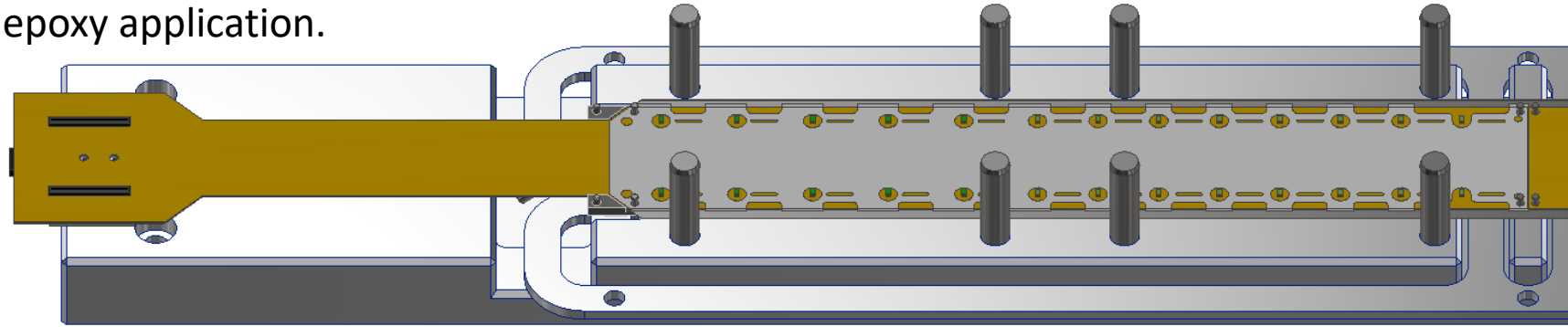


6. The pickup tools interface with the base fixture so that the chips are accurately picked and placed on the HDIs.

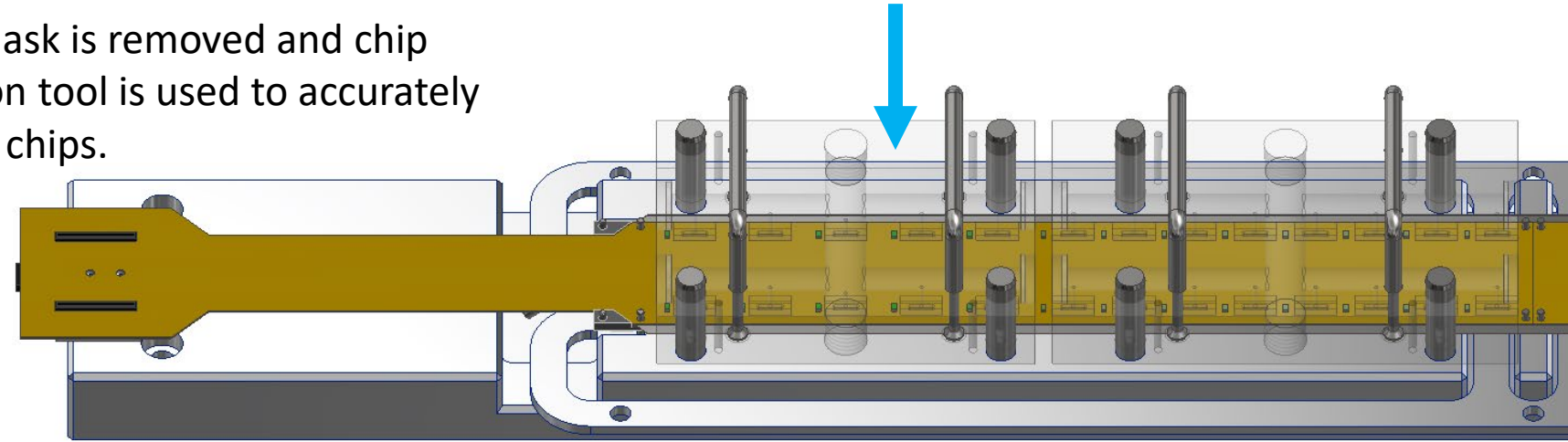


Technical Overview – Chip Placement

7. Chip glue mask is installed for precision epoxy application.

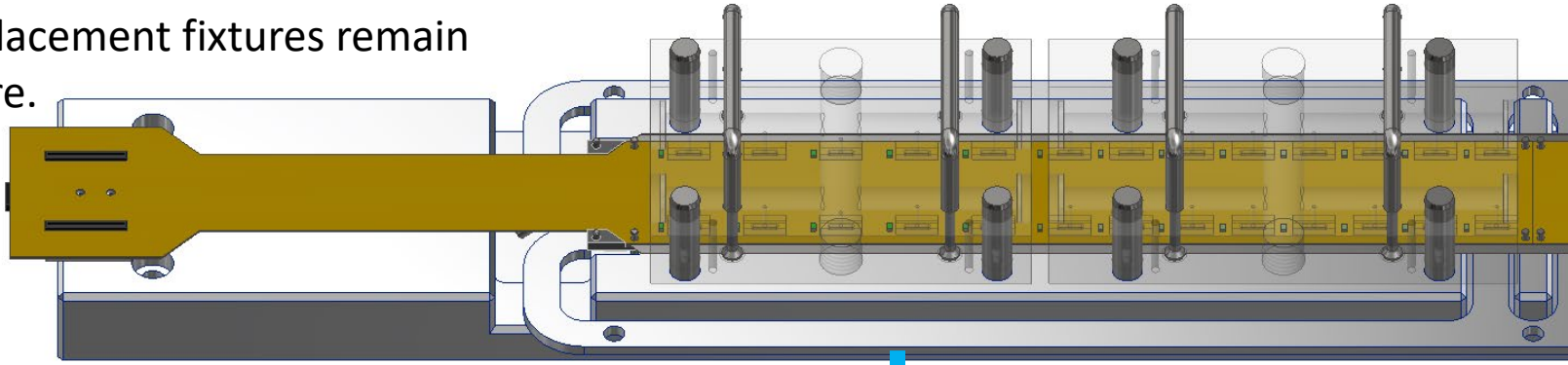


8. Glue mask is removed and chip installation tool is used to accurately place the chips.

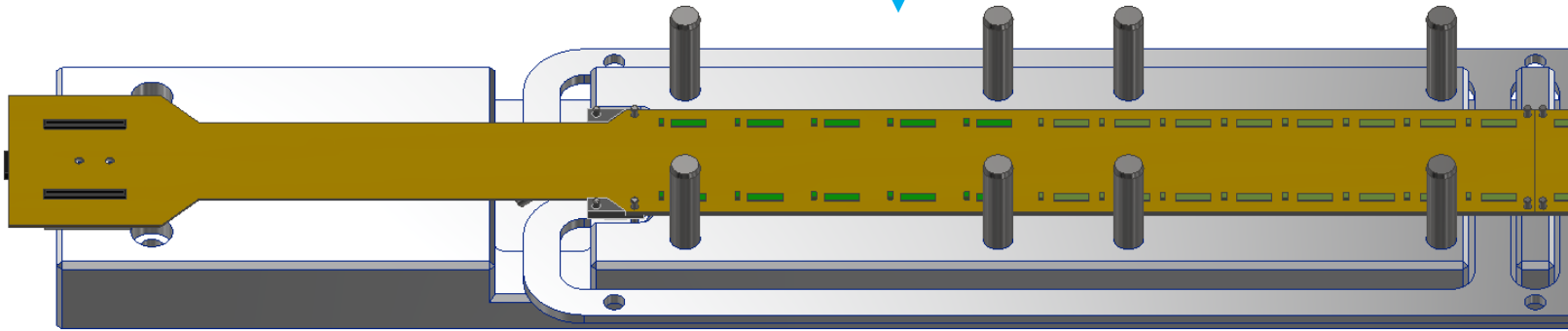


Technical Overview – Chip Placement/Metrology

9. All chips are installed at the same time and the placement fixtures remain throughout cure.

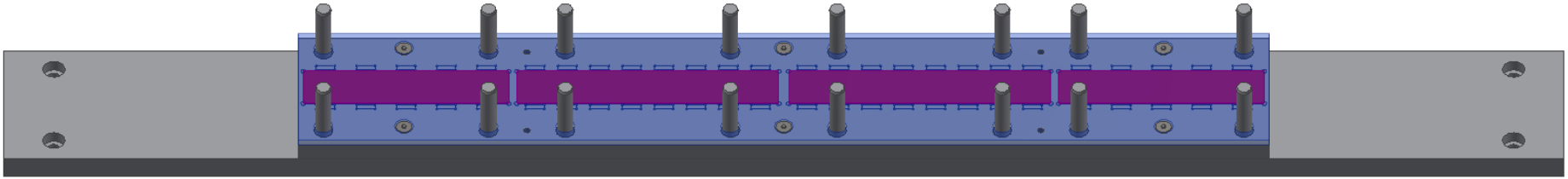


10. Once curing is complete, the fixtures are removed, OGP optical camera/metrology is used to verify accurate chips positioning on the HDI/ladder, and the ladder is sent for wire-bonding.

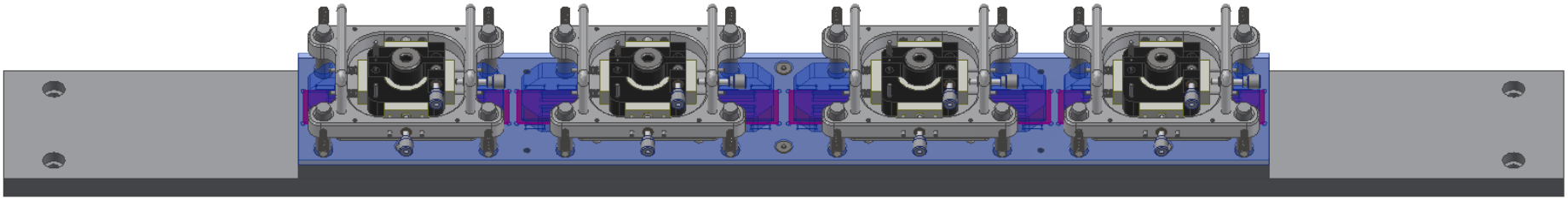


Technical Overview – Sensor Placement

11. Sensors are placed in the base pockets of the base fixture.



12. The pickup tools interface with the base fixture so that the sensors are accurately picked and placed on the HDIs.



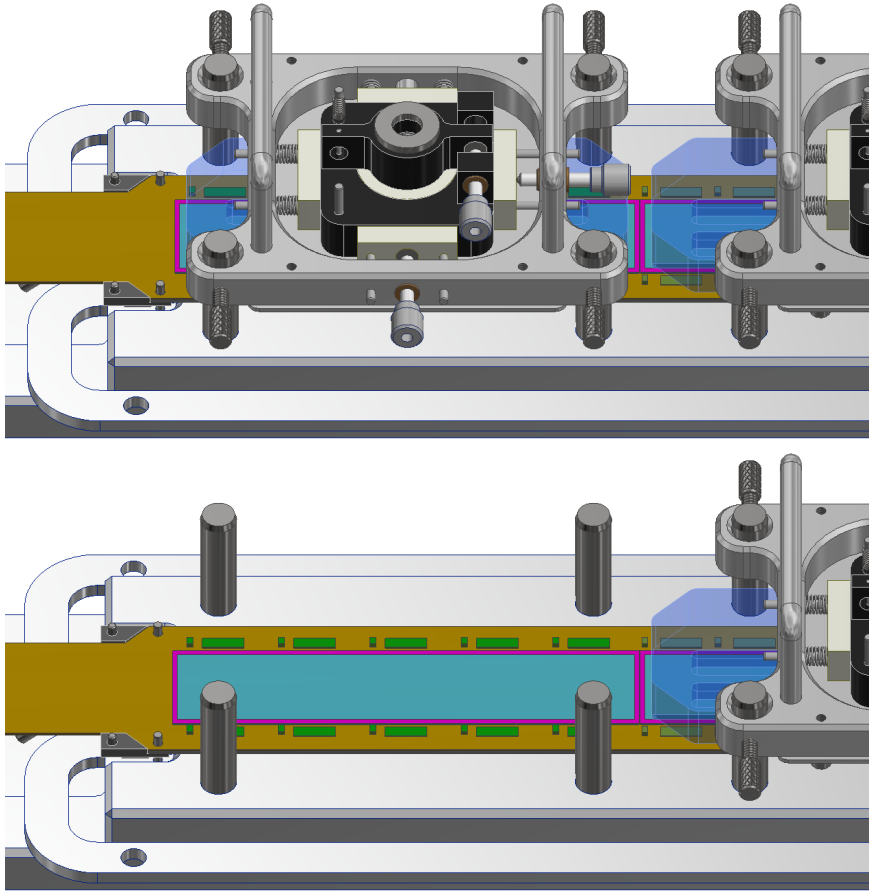
Technical Overview – Sensor Placement/Metrology

13. In the same manner as the chips, the silicon sensors are placed with a vacuum fixture.

14. The micrometer dials are adjusted to properly position the sensor on the epoxy.

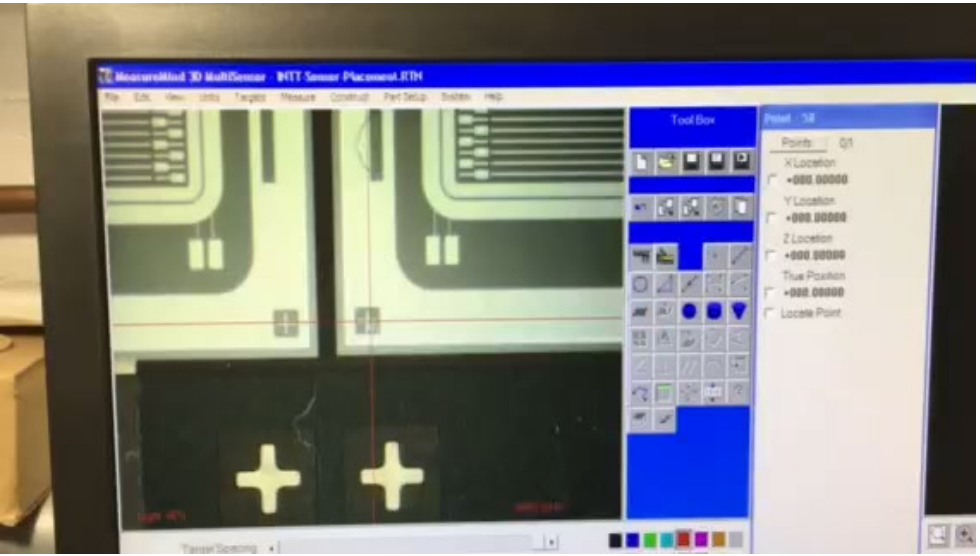
15. OGP optical camera/metrology is used to verify accurate sensor positioning on the HDI/ladder.

16. Once cured, the assembly is sent for additional wire-bonding.

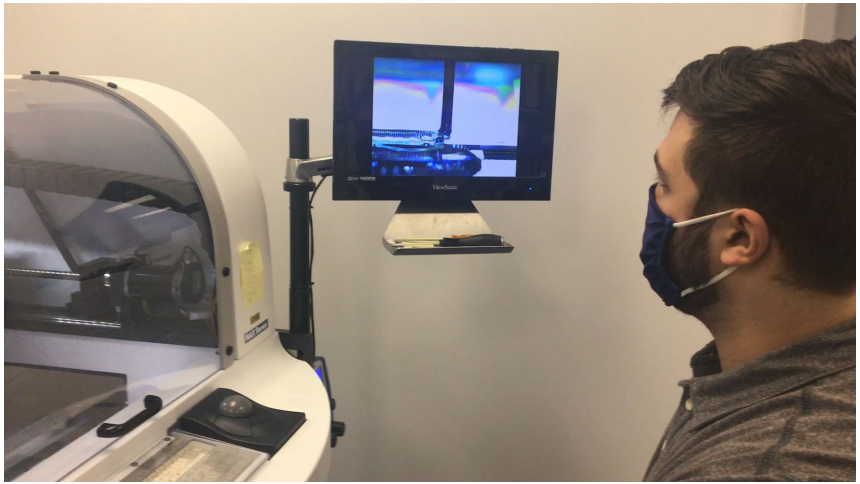


Sensors Placement and Wirebonding Encapsulation

Video: OGP optical camera/metrology is used to verify accurate sensor positioning on the HDI/ladder.



Video: Encapsulation wirebonding chips to HDI and sensors to chips.



BOM and Quotes

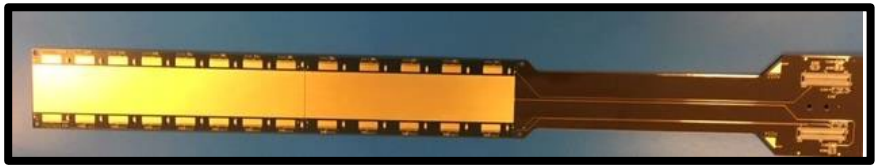
Description	Model Progress	DWG Progress	QTY	Material	Final Status
Ladder Base Fixture	100%	100%	1	MIC 6 Aluminum	Delivered
Stave Frame	100%	100%	1	Aluminum 6061-T6	Delivered
HDI Glue Mask	100%	100%	1	Stainless Steel	Delivered
HDI Glue Weight	100%	100%	1	Brass + Kapton Film	Delivered
HDI Glue Weight Adapter	100%	100%	1	Aluminum 6061-T6	Delivered
Chip Glue Mask	100%	100%	2	Stainless Steel	Delivered
Chip/Sensor Placement Base Assembly	100%	100%	1	Aluminum 6061-T6 + Plexiglass Assembly	Delivered
Chip/Sensor Base Acrylic	100%	100%	1	Acrylic	Delivered
Chip/Sensor Base Aluminum	100%	100%	1	MIC 6 Aluminum	Delivered
Chip/Sensor Base Mount	100%	100%	1	Aluminum 6061-T6	Delivered
Chip Pickup Tool Assembly - 10	100%	100%	2	Plexiglass	Delivered
Chip Pickup Tool - 10	100%	100%	2	Plexiglass	Delivered
Chip Pickup Tool Assembly - 16	100%	100%	2	Plexiglass	Delivered
Chip Pickup Tool - 16	100%	100%	2	Plexiglass	Delivered
Sensor Glue Mask	100%	100%	2	Stainless Steel	Delivered
Sensor Pickup Tool - 10	100%	100%	2	Aluminum 6061-T6 + Plexiglass Assembly	Delivered
Sensor Pickup Tool - Acrylic 10	100%	100%	2	Acrylic	Delivered
Sensor Pickup Tool - 16	100%	100%	2	Aluminum 6061-T6 + Plexiglass Assembly	Delivered
Sensor Pickup Tool - Acrylic 16	100%	100%	2	Acrylic	Delivered
Sensor Pickup Tool - Body	100%	100%	4	Aluminum 6061-T6	Delivered
Sensor Pickup Tool - Linear Drive	100%	100%	4	Delrin	Delivered
Sensor Pickup Tool - Flange	100%	100%	4	Delrin	Delivered
Sensor Pickup Tool - Plate	100%	100%	4	Aluminum 6061-T6	Delivered
Sensor Pickup Tool - Rotary Pin	100%	100%	4	4140 Alloy Steel - 97360A340	Delivered
Sensor Pickup Tool - Push Blocks	100%	100%	16	Teflon PTFE	Delivered
Sensor Pickup Tool - Insert	100%	100%	4	Stainless Steel	Delivered
Sensor Pickup Tool - Sheet	100%	100%	8	Stainless Steel	Delivered

Prototype/Pre-Production Assembly Components

FVTX Chips

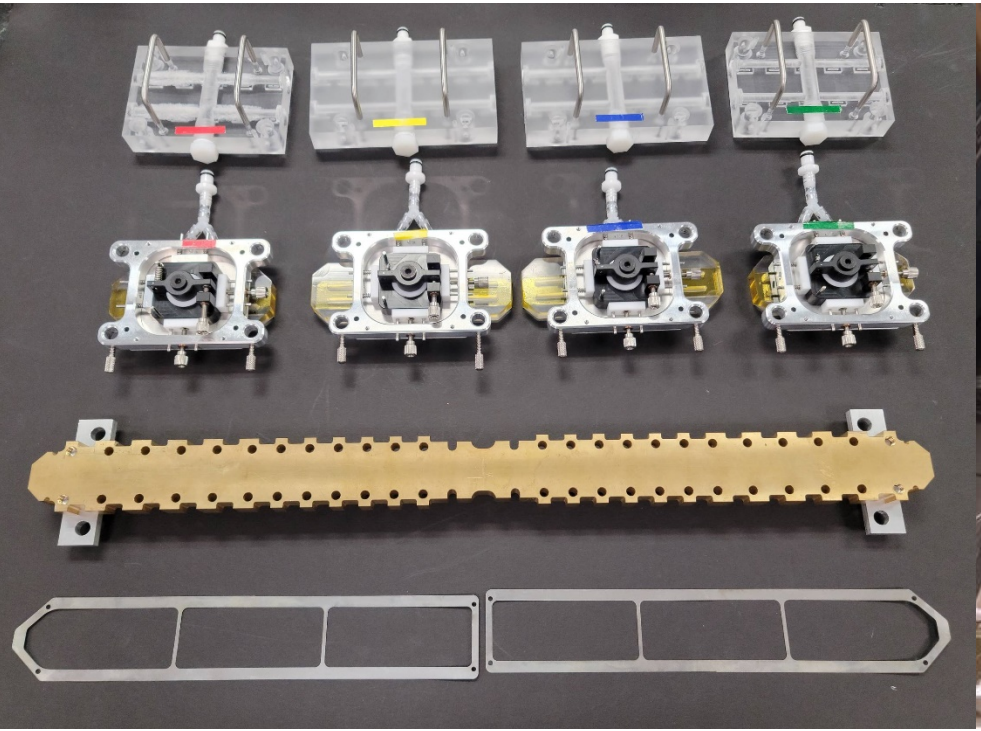
Silicone Sensors

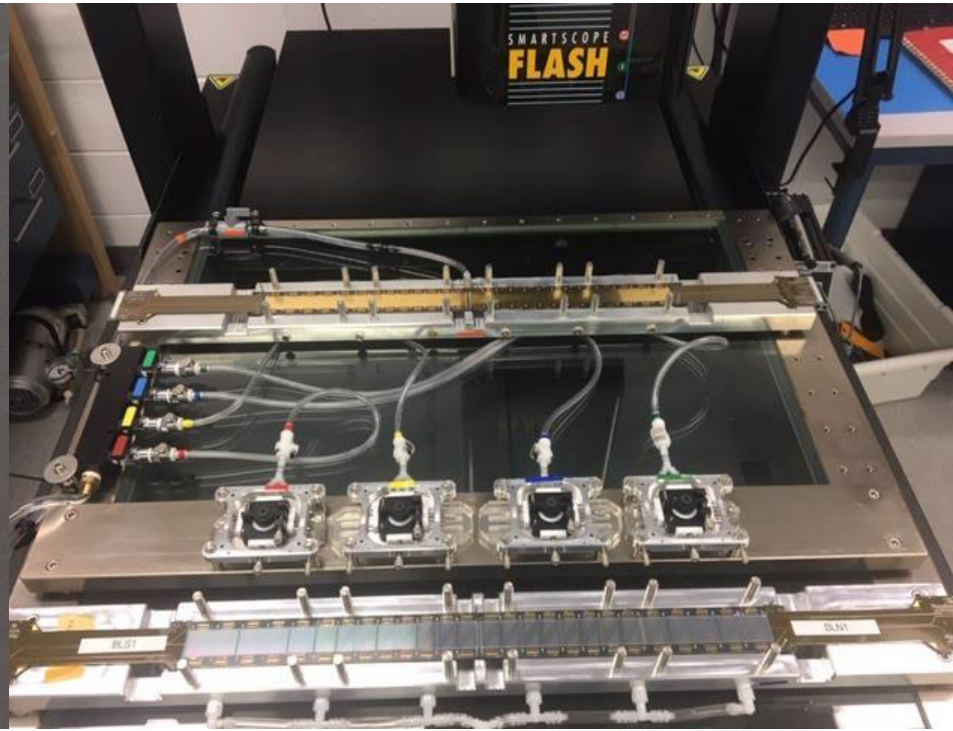
HDI



Carbon Fiber Stave

Procured Assembly Fixtures (cont.)





Ladder Assembly Procedure (first two pages)

Draft INTT Ladder Assembly Steps (ver. 12/16/2020)

A. Carbon Fiber Flatness Inspection Steps

1. Remove all fixtures from the OGP platen, except for the Base Fixtures and the Pickup Base Fixture.
2. Clean all debris from the OGP platen and base fixtures.
3. Power on the OGP system and open MeasureMind 3D Multisensor.
   a. Go through the OGP initialization process.
   b. File->Open: C:\INTT\Prod Routines\INTT-CF-Flatness.RTN
   c. Navigate to System - > Configuration -> Safe Zones and enable Safe Zones 1 and 2.
4. Open MeasureFit
5. Open SmartReport
   a. File->Open: C:\Prolink\QC-CALC 3.2\Data\INTT-CFStave-Flatness.mfp, INTT-CF-Flatness_Report.Qcc
   b. This file should already be open upon SmartReport startup. Check the top border to verify this.
6. Place Carbon Fiber Stave on Base Fixture (top fixture meaning located towards the wall) and remove the lower left (towards you), and lower right (towards you), pins to expose the small thru-holes in the fixture. (Pins closest to the operator when standing in front of the OGP machine).
7. Engage the vacuum pump.
8. Run the routine on the OGP.
   a. When prompted, save the output as C:\INTT\Prod Data\INTT-CF-Flatness.DAT
   b. After the OGP routine is completed, go to C:\INTT\Prod Data\ and save a time stamped copy of the DAT file in the Archive subfolder. (MeasureFit will delete the original when it generates the report).
9. In MeasureFit, play the INTT CF Flatness Inspection under the Macros tab.
10. Once the report file is generated, save the file under C:\INTT\Prod Reports\
    a. Save the file with the following timestamp format:
    INTT_SNXXXX_205-310-0100-XX_Report.pdf
    &
    INTT_SNXXXX_205-310-0100-XX_VAC_Report.pdf
11. Repeat these steps. Once with the Vacuum on and once with the vacuum off.

B. High Density Interconnect (HDI) Gluing Steps

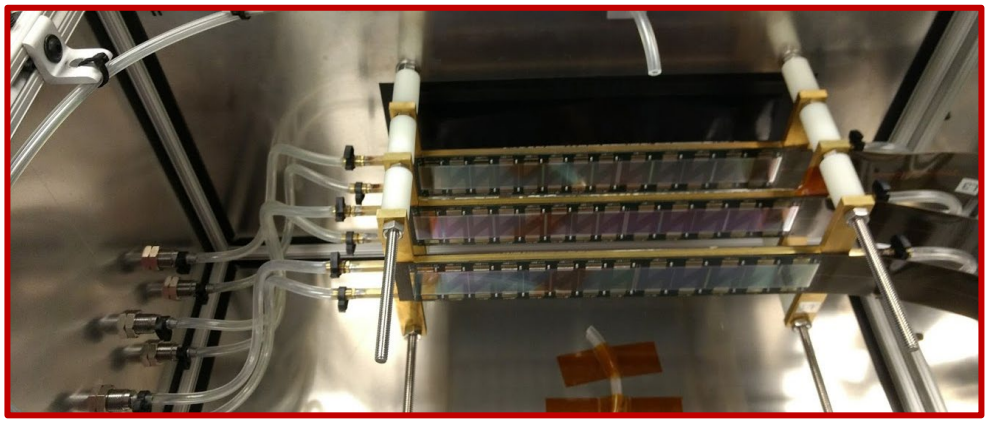
1. Install the Carbon Fiber Stave on the Base Fixture (mounted to the OGP platen located towards the wall) in the same fashion as [Section A | Step 6].
2. Verify that all 2mm locating pins are installed in the Base Fixture and are captured by the Carbon Fiber Stave.
3. Place the HDI Glue Mask on the Carbon Fiber Stave by engaging the 2mm locating pins on the Base Fixture.
4. Mix epoxy on the lab bench.
5. Apply a thick bead of epoxy (3M Epoxy Adhesive TC2810, 50 mL, /1.75 fl oz) along the center of the HDI Carbon Fiber Stave from left-to-right, within the area of the HDI Glue Mask using the pressure syringe.
6. Using an epoxy knife, spread the epoxy around the exposed Carbon Fiber Stave so that the epoxy is as thick as the HDI Glue Mask and does not run underneath the glue mask.
7. Remove the HDI Glue Mask by removing all 2mm locating pins and then peeling the glue mask from the left-most side to the right-most side.
8. With the HDI Glue Mask removed, re-install the eight 2mm locating pins. There should be no epoxy touching the pins.
9. Install the first HDI on the left side of the Carbon Fiber Stave by sliding the HDI down the locating pins (similarly to the glue mask).
10. Repeat step 9 for the second HDI to be installed on the right side of the Carbon Fiber Stave.
11. Gently place the HDI Glue Weight by installing it to the outer 8mm pins on the base fixture.
12. Let cure for overnight.

Chip Gluing Steps

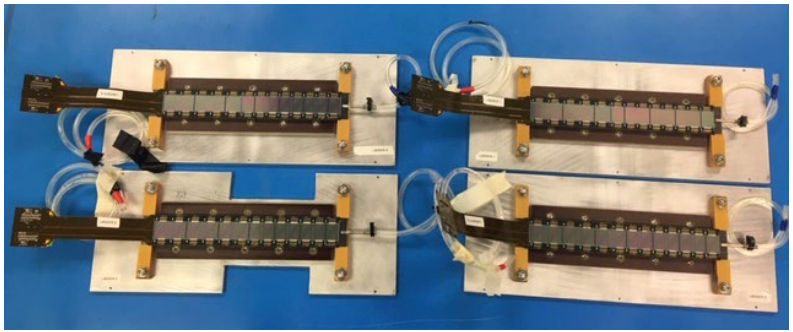
1. Install 52 chips into the chip pockets on the Chip-Sensor Assembly Fixture so that the bonding surfaces of the chips are facing upward.
2. Place the four Chip Pickup Tools on the fixture base so that they are mounted in their marked positions, engage the 8 mm pins (the four big pins), and make contact with the chips.
3. Be sure that all valves are closed.
4. Install the Carbon Fiber Stave on the Base Fixture (mounted to the OGP platen) in the same fashion as [Section A | Step 6].
5. Verify that all 2 mm locating pins are installed in the Base Fixture and are captured by the Carbon Fiber Stave.
6. Place one Chip Glue Mask (50 um thick) on the left side of the Carbon Fiber Stave by engaging the 2 mm locating pins on the Base Fixture.
7. Mix epoxy on the bench table.
8. Apply small beads of epoxy (silver epoxy Loctite Ablestik t2902 BIPAX) on each slot in the Chip Glue Mask for the chip positions.

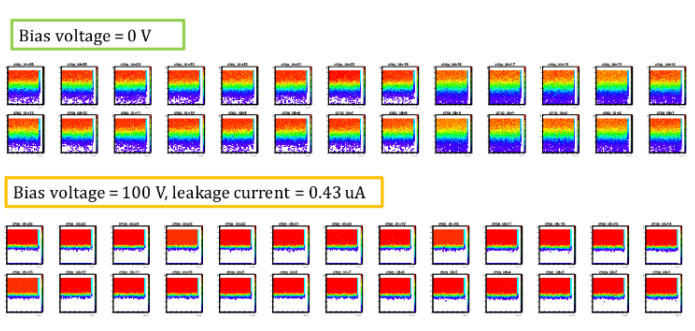
Learning Curve/Procedure Developed

Phase I: Half Ladders Prototypes:
FNAL Beam Test 2018



Phase II: Half Ladders Prototypes:
FNAL Beam Test 2019





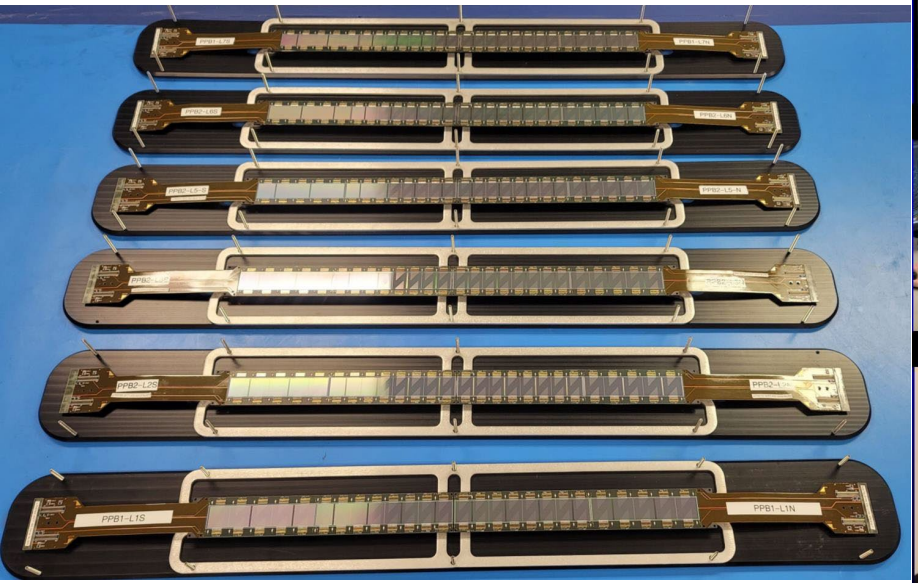
Assembly Parts Inspection

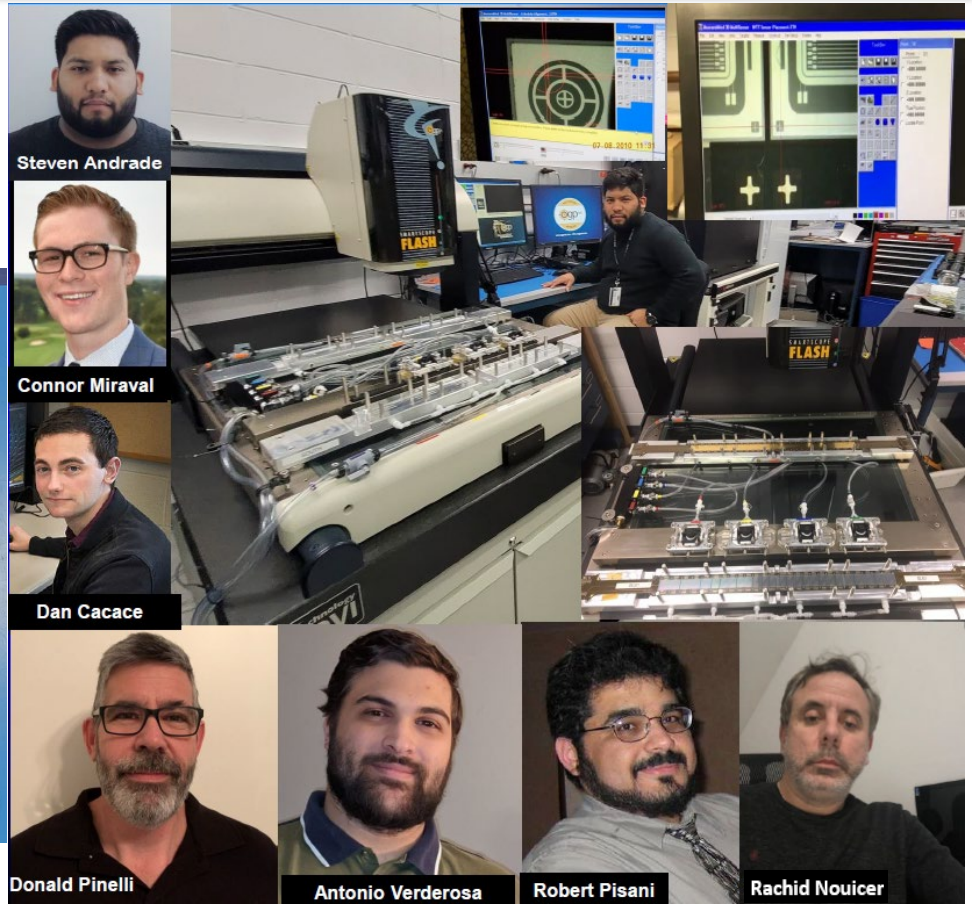
A	B	C	D	E	F	G	H	I	J	K	L	M	N	
	Barrel 2		Barrel 2		Excellen	Class 1	X < 0.15		Barrel 2		X <0.09 psi Goo	Range Good		
	Lot # -01 Layer 1				Fair	Class 3	0.150 < X < 0.200				0.75 < X < 1.25			
	Lot # -02 Layer 2				Poor	Class 5	X > 0.201	No Vacuum			>0.10 Poor			
	Lot Number	Serial Number	Stave Type		Flatness Operator	Date	Flatness no Vacuum mm	Vendor Flatness	Flow/Leak Opeer ator	Date	10 min leak in PSI start 20psi	Delta P of stave at 200 ccm (psi)	Vendor Flow #	
Count					Name				Name			PSI	PSI	
1	205-310-0100-02	0011	Batch 1	5	SA	12/16/2020	0.1037	0.0220	SA/RP	12/11/20	0.127	0.975	0.856	
2	205-310-0100-02	0012	Batch 1	1	SA	1/27/2021	0.0799	0.1140	SA	1/15/21	0.055	0.97	0.856	
3	205-310-0100-02	0014	Batch 1	1	SA	1/26/2021	0.1026	0.0670	SA	1/13/21	0.050	0.79	0.783	
4	205-310-0100-02	0015	Batch 1	4	SA	01/27/2021	0.1087	0.0340	SA	01/15/21	0.093	0.99	0.827	
5	205-310-0100-02	0017	Batch 1	1	RN	01/11/2021	0.1674	0.1450	SA	01/11/21	0.035	0.93	0.856	
6	205-310-0100-02	0020	Batch 1	1	SA	1/27/2021	0.0689	0.2560	SA	1/15/21	0.049	0.8	0.957	
7	205-310-0100-02	0021	Batch 1	5	SA	2/4/2021	0.0909	0.0660	SA	1/19/21	0.910	0.85	0.986	
8	205-310-0100-02	0023	Batch 1	5	RN	12/21/2020	0.0941	0.0820	SA	1/22/21	2.00	0.76	0.870	
9	205-310-0100-02	0024	Batch 1	4	RN	1/7/2021	0.1581	0.0980	SA/RP	12/23/20	0.103	1.18	0.812	
10	205-310-0100-02	0026	Batch 1	2	SA	1/27/2021	0.1698	0.0910	SA	1/15/21	0.065	1.005	0.740	
11	205-310-0100-02	0027	Batch 1	1	RN	1/11/2021	0.1584	0.2770	SA/RP	12/11/20	0.050	0.85	0.957	
12	205-310-0100-02	0029	Batch 1	1	RN	1/11/2021	0.1248	0.1450	SA	1/12/21	0.055	1.09	0.943	
13	205-310-0100-02	0030	Batch 1	1	RN	1/7/2021	0.0788	0.1330	SA/RP	12/23/20	0.043	1	1.044	
14	205-310-0100-02	0032	Batch 1	2	SA	1/26/2021	0.2212	0.0940	SA	1/13/21	0.070	0.975	0.783	
15	205-310-0100-02	0033	Batch 1	5	SA	2/4/2021	0.0679	0.1360	SA	1/28/21	0.190	0.59	0.841	
16	205-310-0100-02	0035	Batch 1	1	SA	1/25/2021	0.1328	0.2270	SA	1/14/21	0.047	0.925	0.928	
17	205-310-0100-02	0036	Batch 1	1	RN	12/21/2020	0.0906	0.1520	SA	02/04/21	0.055	0.575	0.812	
18	205-310-0100-02	0037	Batch 1	1	SA	1/27/2021	0.1090	0.2390	SA	1/15/21	0.065	1.025	0.740	
19	205-310-0100-02	0038	Batch 1	2	RN	1/7/2021	0.1768	0.0980	SA/SA	12/23/20	0.076	0.85	1.059	
20	205-310-0100-02	0041	Batch 1	5	SA	2/4/2021	0.1592	0.1210	SA	1/14/21	0.450	0.72	0.798	
21	205-310-0100-02	0042	Batch 1	1	SA	1/26/2021	0.1167	0.1450	SA	1/14/21	0.060	1.025	0.870	
22	205-310-0100-02	0044	Batch 1	2	SA	1/27/2021	0.1796	0.2240		1/13/21	0.055	0.8	0.754	
23	205-310-0100-02	0045	Batch 1	2	RN	1/7/2021	0.1838	0.2890	SA/SA	12/23/20	0.051	0.8	0.798	
24	205-310-0100-02	0047	Batch 1	2	SA	1/26/2021	0.1882	0.1380	SA	1/14/21	0.045	0.855	0.957	
25	205-310-0100-02	0048	Batch 1	1	RN	12/23/2020	0.1679	0.1720	SA	1/22/21	0.055	0.785	0.740	
26	205-310-0100-02	0050	Batch 1	2	SA	1/26/2021	0.2211	0.0910	SA	1/13/21	0.070	0.98	0.885	
27	205-310-0100-02	0051	Batch 1	5	RN	12/21/2020	0.1261	0.1760	SA	1/28/21	1.165	0.795	0.841	
28	205-310-0100-02	0053	Batch 1	1	SA	1/26/2021	0.1986	0.196	SA/RP	12/23/20	0.055	0.895	0.870	
29														

Production Team & Assembled Prototypes

Phase III: Full Ladders Preproduction

Ladder = 1 CFC Stave + 2 HDIs + 52 Chips + 4 Silicon Sensors

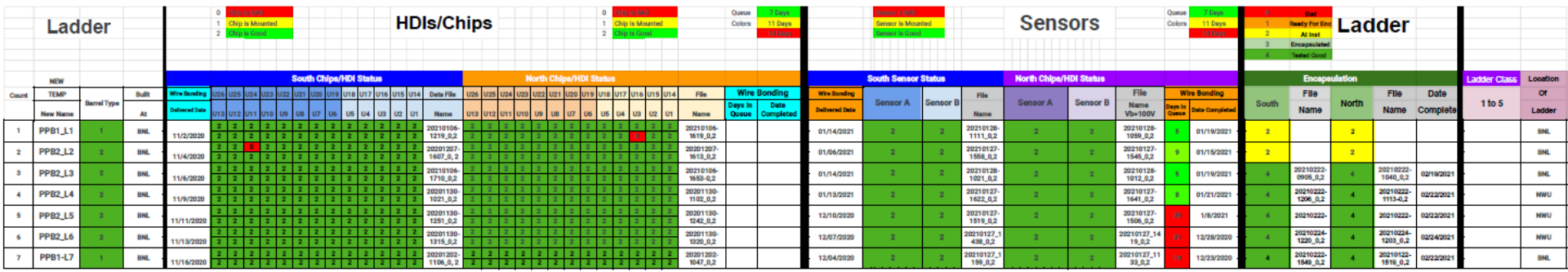




Production Tracking

Total	2	Barrel 1	PROJECT TITLE	INTT Ladder Assembly	Institution: Brookhaven National Lab		Institution: Brookhaven National Lab
Total	5	Barrel 2	PROJECT MANAGER	Rachid Nouicer	Deputy: Robert Pisani	B1 24	Deputy: Robert Pisani
						B2 32	

	NEW Ladder Number	Barrel Type	Build	START DATE	Ladder Class	Stave I.D.	HDI SOUTH Ladder / Chip Assembly: Name Initials	HDI I.D.	3M TC-2810 lot #	Chip I.D Wafer	Loctite 2902 lot #	HDI Flatness Wafer Type B Small (20x5)	HDI Flatness Waifer Type A Big (16x8)	HDI NORTH Ladder / Chip Assembly: Name Initials	HDI I.D.	3M TC-2810 Lot #	Chip I.D Wafer	Loctite 2902 Lot #	HDI Flatness Type A Big (16x8)	HDI Flatness Type B Small (20x5)	Chip Construction Notes	Bonding Chip to HDI North and South: HDI to CHIP START DATE	Name Initials	Bonding Notes	Sensors South Ladder START DATE	Name Initials	Waife
Count																											Small
1	PPB1_L1	1	BNL	10/6/2020		205-300-0100-0 S/N 0009	RP & RN	#003	936148	W6B752-09F3 #9	IDH:1402586 batch:049LAA4356			RP & RN	#004	936148	W6B752-09F3 #9 & #13	IDH:1402586 batch:049LAA4356				11/2/2020	DON&Anthony	none			
2	PPB2_L2	2	BNL	10/13/2020		205-300-0100-01 S/N 0008	RN & RP	#005	936148	W6b752-05a4 #19	IDH:1402586 batch:040EAA8855			RP & RN	#006	936148	W66752-05a4 #20	idh:1402586 Batch:040eaa8855				11/4/2020	DON&Anthony		1/4/2021	RP/RN	S14629-Yax303
3	PPB2_L3	2	BNL	10/21/2020		205-300-0100-02 S/N 0007	RN & RP	#007	936148	W6B752-05A4 #13	IDH:1402586 batch:040EAA8855			RN & RP	#008	936148	W6b752-05a4 #13 ,19, 22	IDH:1402586 batch:040EAA8855				11/6/2020	DON&Anthony				S14629-Yax303
4	PPB2_L4	2	BNL	10/24/2020		205-310-0100-02 S/N 0004	RN & RP	#009	936148	W6B752-05A4 #22	IDH:1402586 batch:049LAA4356			RN & RP	#010	936148	W6B752-05A4 #14 & 17 (U1-U13)	IDH:1402586 batch:040EAA8855			U1-u13+ Replaced	11/09/2020	DON&Anthony		1/11/2021	RP/RN	S14629-Yax303
5	PPB2_L5	2	BNL	10/29/2020		205-310-0100-02 S/N 0003	RN & RP	#011	936148	W6B752-05A4 #13 #15 #2	IDH:1402586 batch:040EAA8855			RN & RP	#012	936148	W6B752-05A4 #15	IDH:1402586 batch:040EAA8855			4 resistors broken on U12-N	11/11/2020	DON&Anthony		12/9/2020	Rp/RN	S14629-Yax303
6	PPB2_L6	2	BNL	11/4/2020		205-310-0100-02 S/N 0002	RN & RP	#013	936148	W6B752-05A4 #16	IDH:1402586 batch:049LAA0486			RN & RP	#014	936148	W6B752-05A4 #24 #18 #20 #19	IDH:1402586 batch:049LAA0486			one resistor 100 Ohm for U26-N replaced	11/13/2020	DON&Anthony		12/7/2020	Rp/RN	S14629-Yax303
7	PPB1_L7	1	BNL	11/09/2020		205-310-0100-01 S/N 001	RN & RP	#015	936148	W6B752-05A4 #18	IDH:1402586 batch:040EAA8855			RN & RP	#016	936148	W6B752-05A4 #18 #16	IDH:1402586 batch:040EAA8855				11/16/2020	DON&Anthony		12/4/2020	rp/rn	S14629-Yax303



Summary

- Assembly fixtures on hand ✓
- Parts testing procedure ✓
- Inspection procedure ✓
- Production tracking ✓
- Assembly inspection ✓
- Inspection report logs ✓
- Experienced production team ✓

Ready for full scale production.

Back Up