BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

LBNL Methods for Precision Assembly

LBNL Composites Workshop

February 29-March 3, 2016

Overview

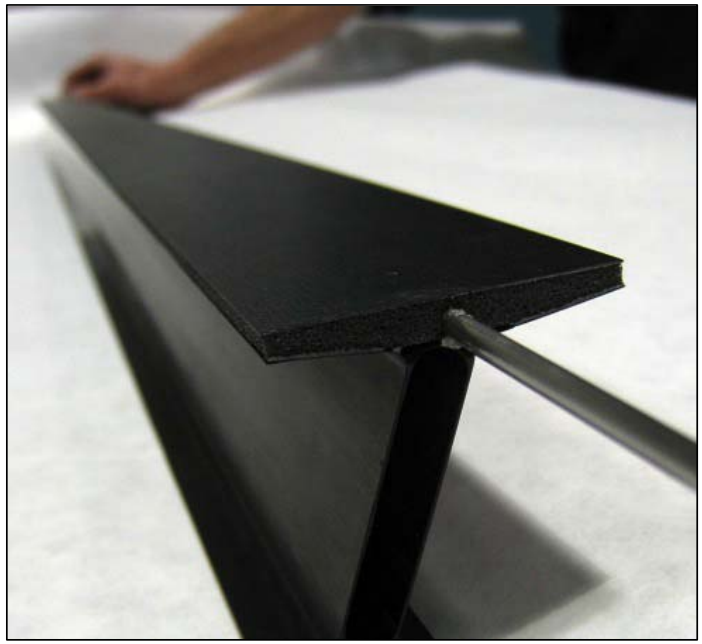
- LBNL Precision Assembly
  - Build loose
  - Bond precise
- Final Tolerances given through tooling
- Bond gaps make up uncertainties
- Accurate features machined where necessary
- Design for as few parts as possible
  - When bonding assembly is needed, make it as efficient as you can

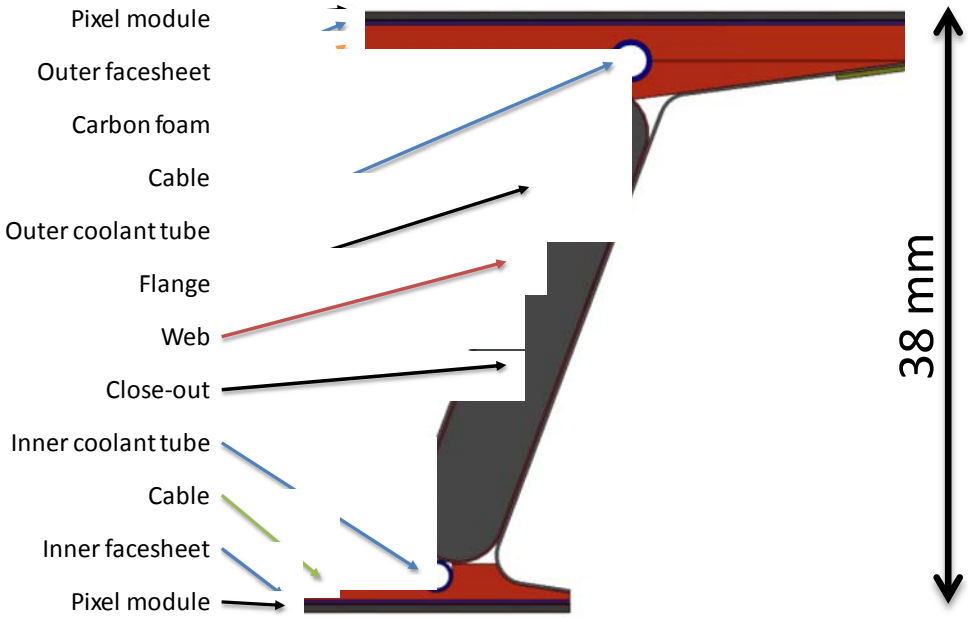
Tooling Approach

- Simple, modular components
- Single-sided machining where possible
- Hand assembly and alignment
- Isolate degrees of freedom
- Bond in place
- Simplify, simplify, simplify

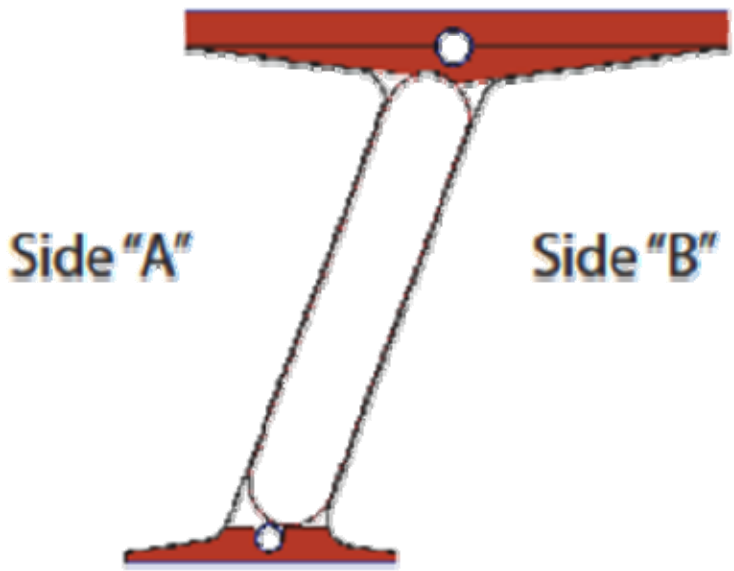
ATLAS Pixel I-beam

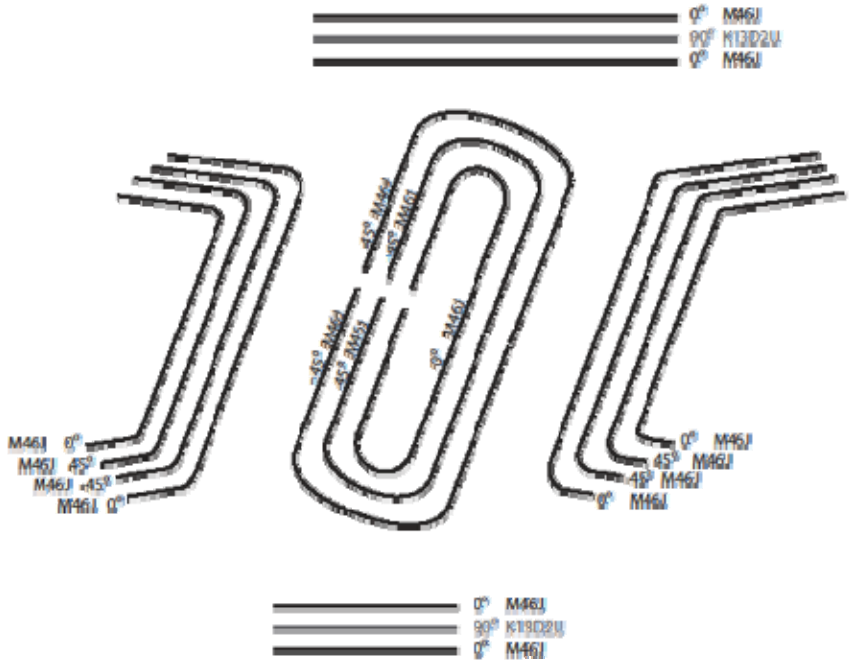
Pixel I-beam Construction



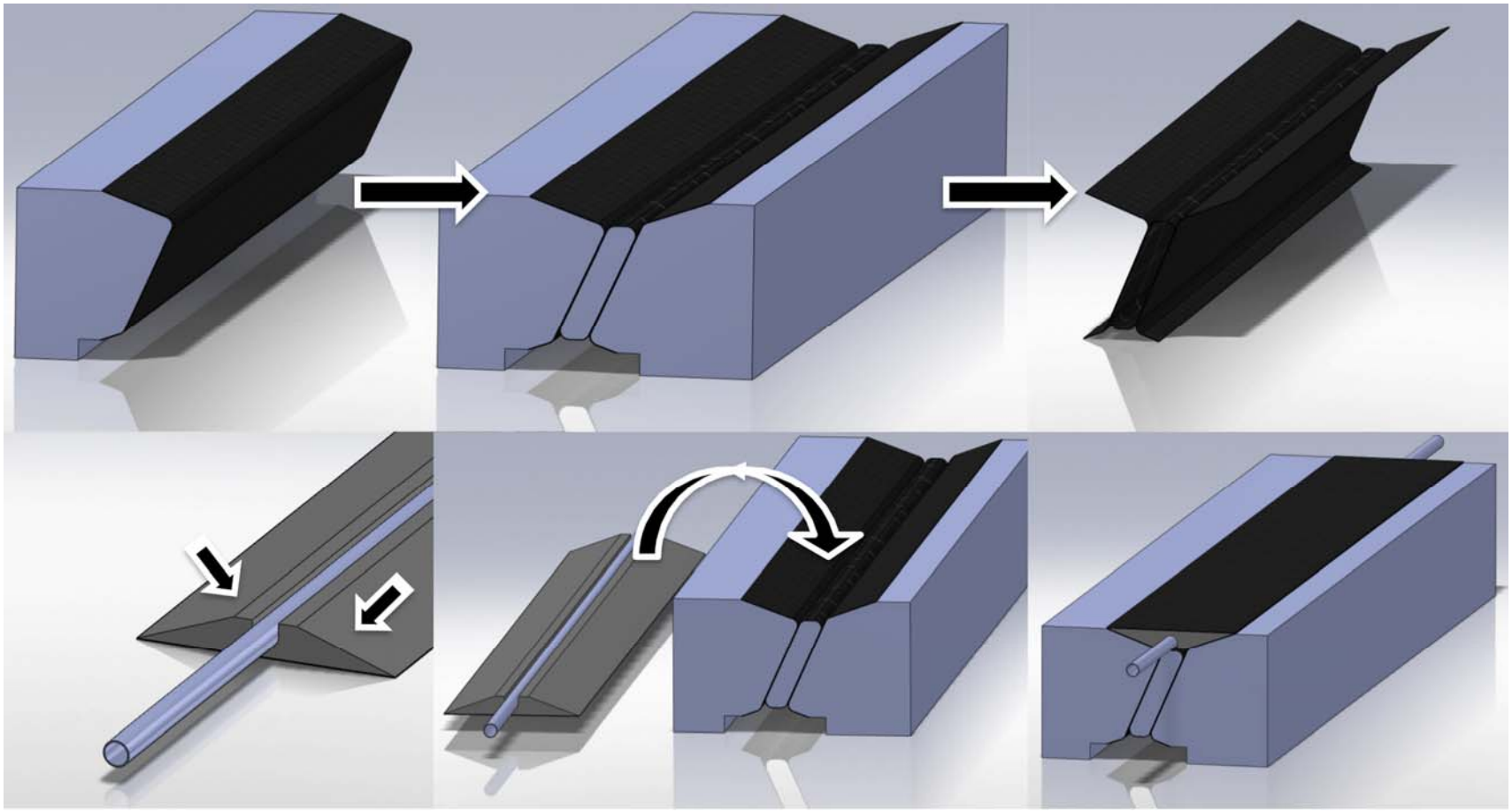


I-beam Laminate

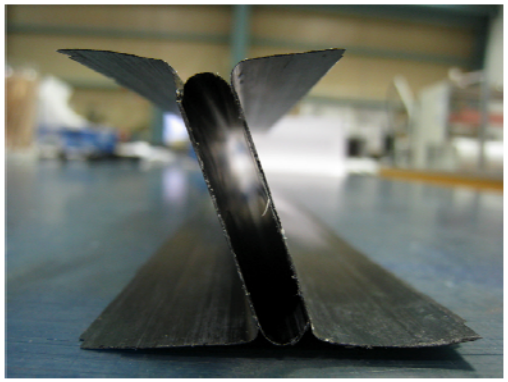


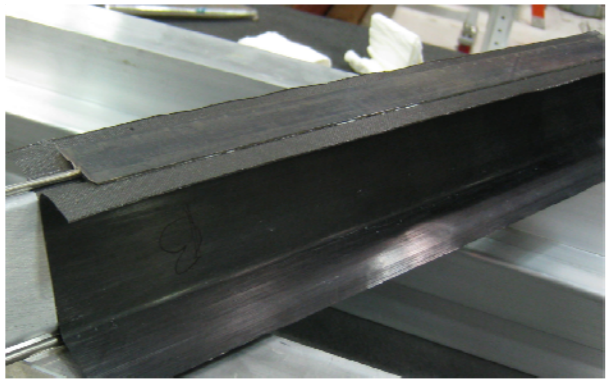


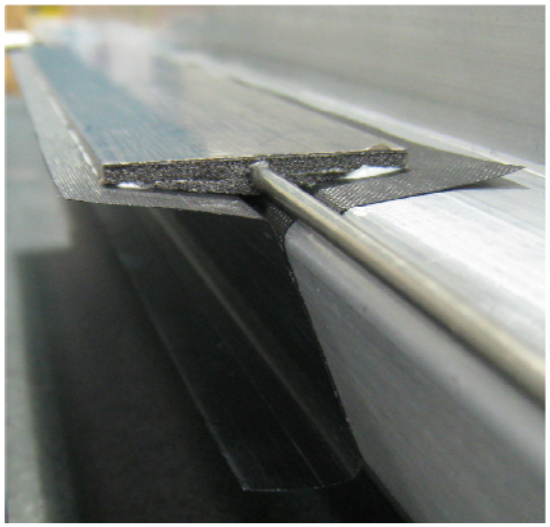
Manufacturing Process

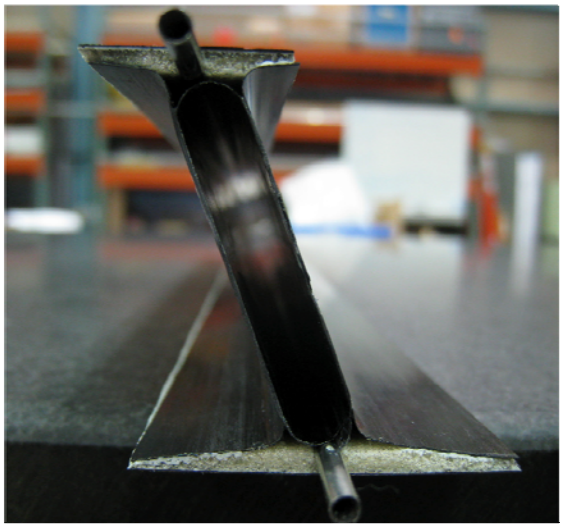


Stages of construction in photos

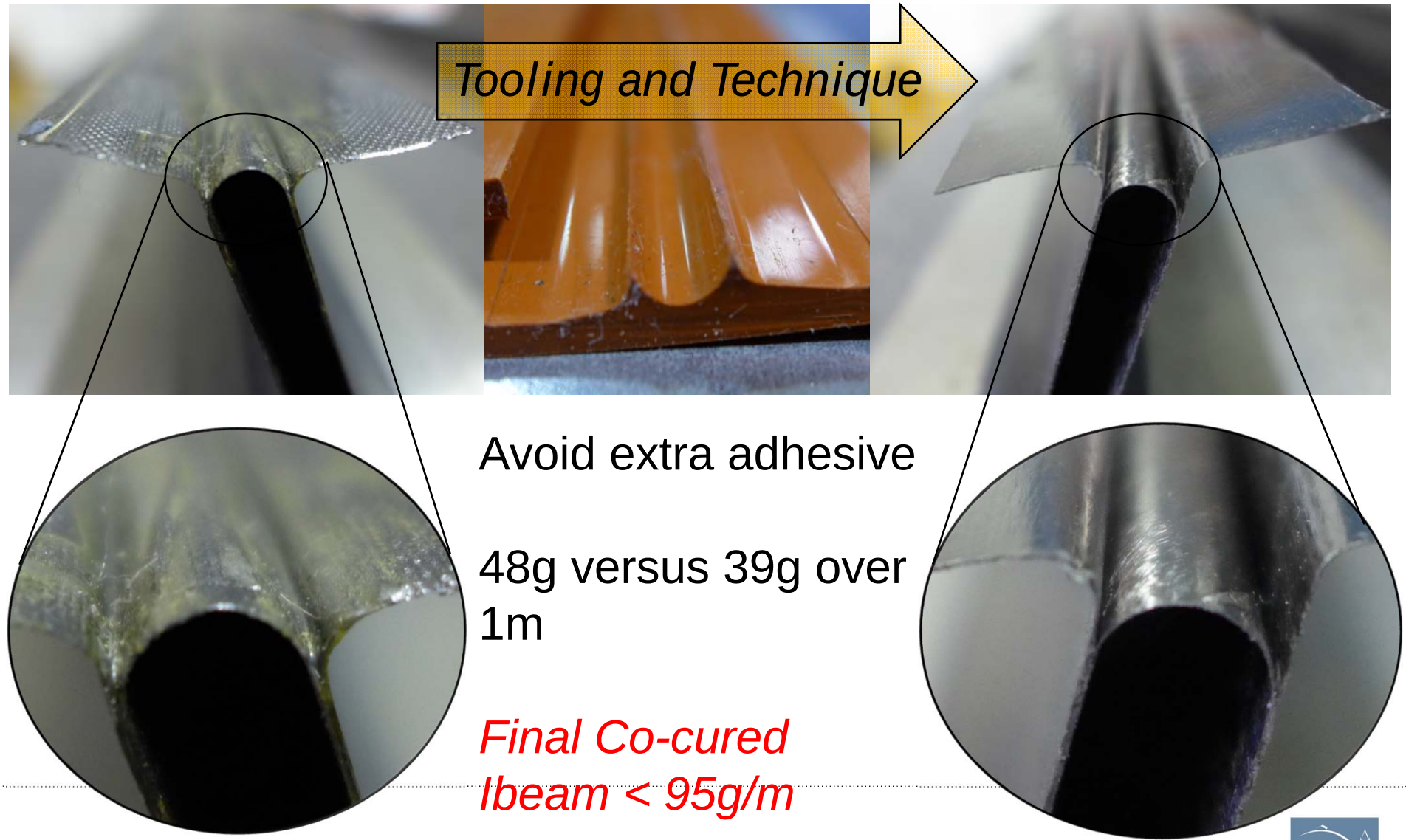








Co-Cured Assemblies

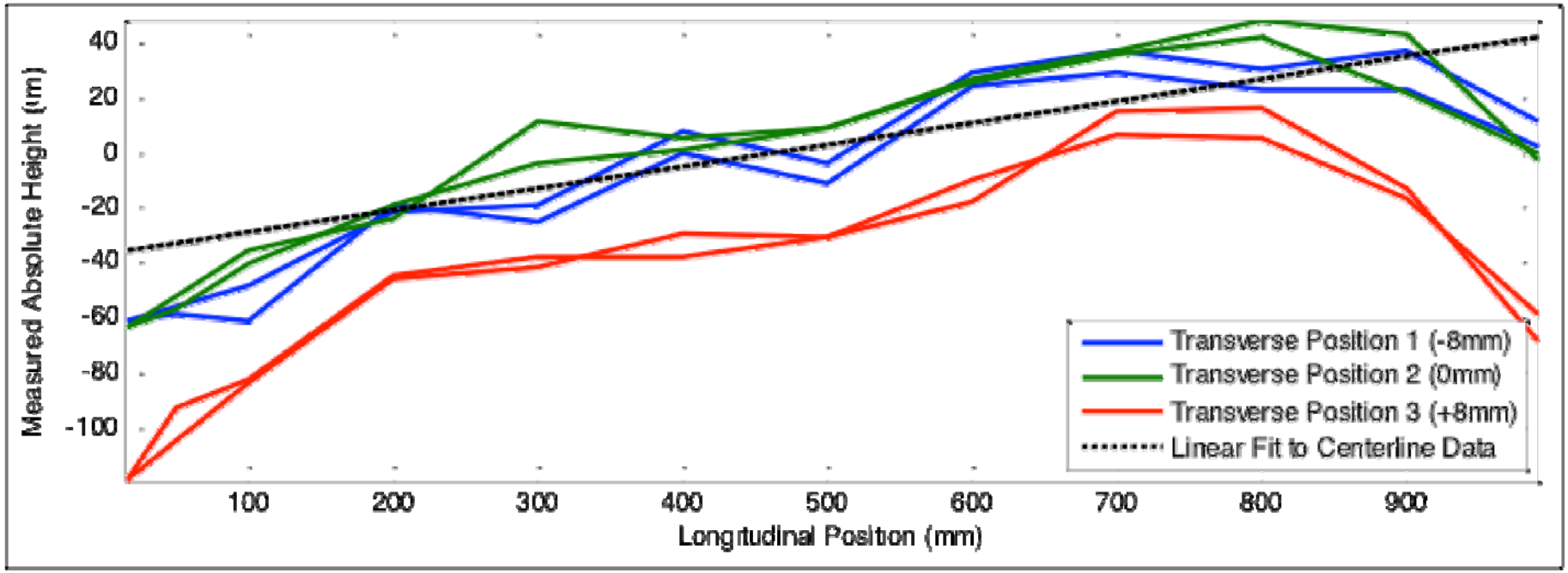


Avoid extra adhesive

48g versus 39g over 1m

Final Co-cured Ibeam < 95g/m

As built flatness on module mounting surface – first prototype



Star Tombstone Bonding Jig

Tombstone Shell Tool

- Classic example of LBL assembly approach
- In use since first Pixel Support Tube in 2003
- Used to bond flanges, mount pads, intermediate structures
- All-in-one approach

Tooling Assembly

- Simple alignment by pins and shimming
- Diagonal measurements with tube micrometer to tooling balls
- Features aligned in squares, identical measurements between all points – simplicity
- Tombstones are machined predominantly from one side
- All accurate features accessible in one (or max two) machining setups

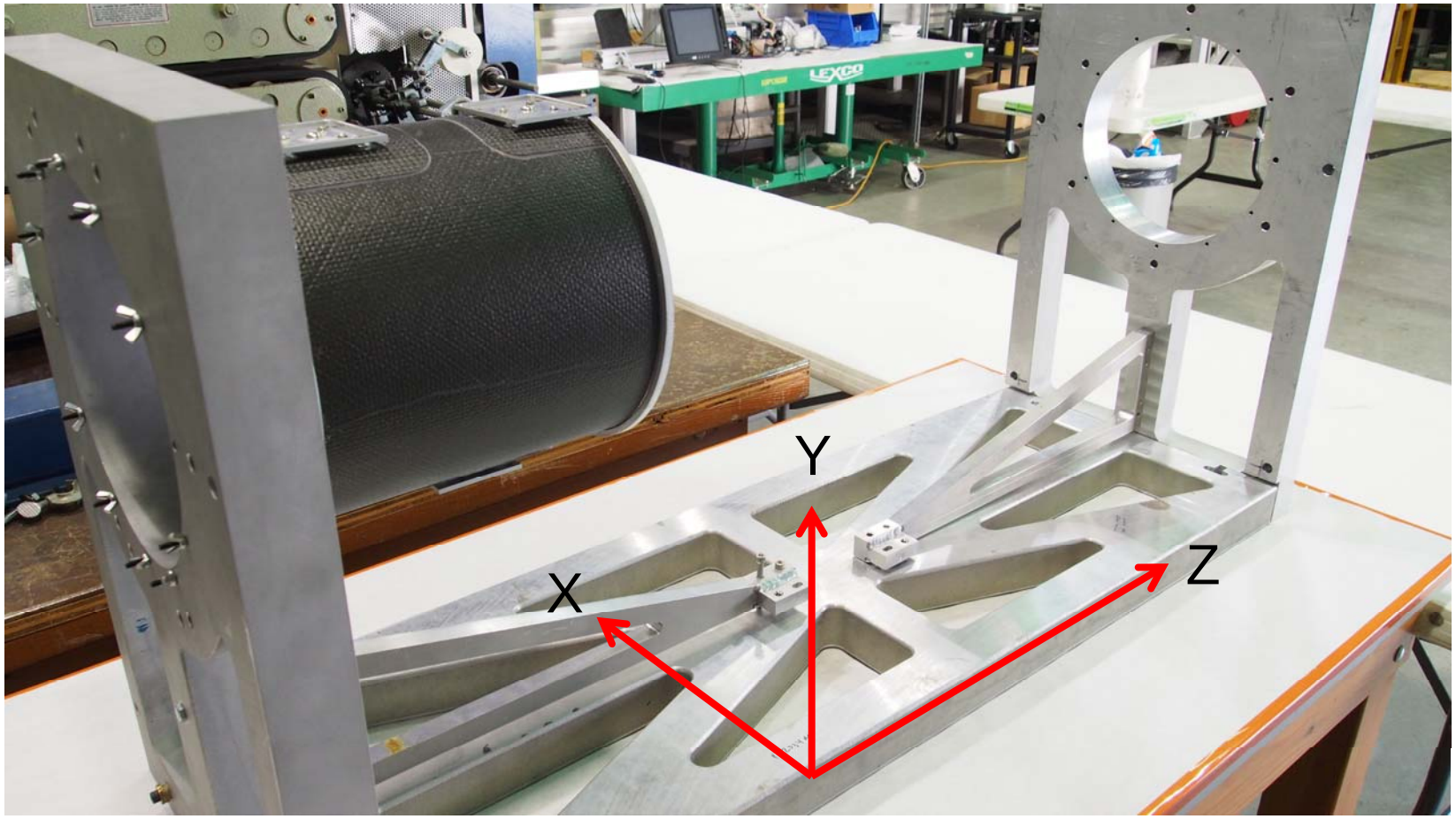
Tooling Assembly, Cont.

- Degrees of freedom are separated
  - X given by pin alignment
  - Z given by simple shimming
  - Y given by granite table
- Angles adjustable by simple shimming and adjustment of built-in angle bars
- Pins and Slots are not necessary. Machining is sufficiently accurate to use pins alone.

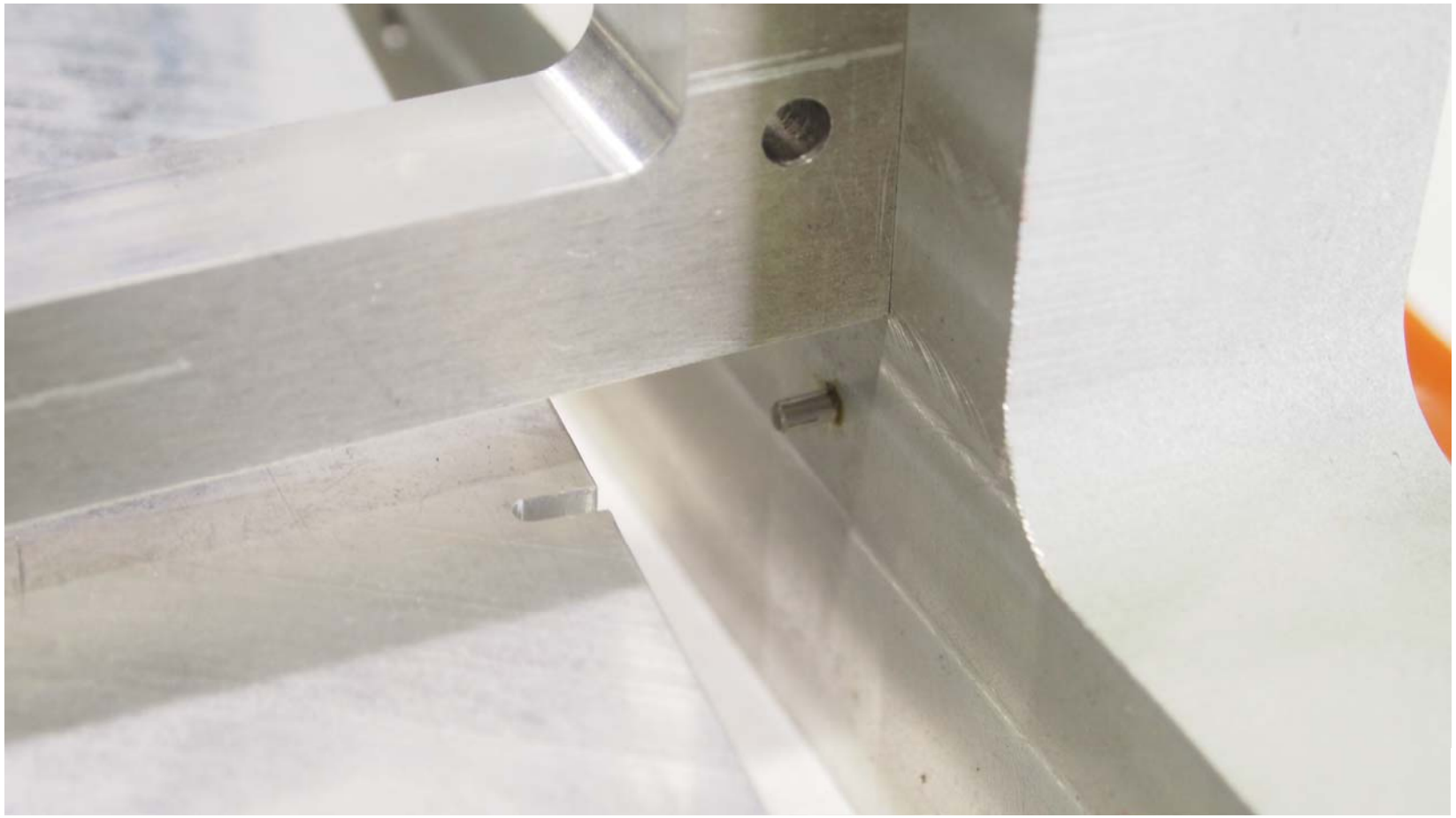
Bond in Place

- Key parts held at proper position and orientation
- Allow space for introduction of unfixtured parts (shell)
- Resin introduced after assembly
- At times vacuum applied with resin resevoir on opposite side – rudimentary resin infusion technique
- Always room temperature cure
- Liquid adhesive

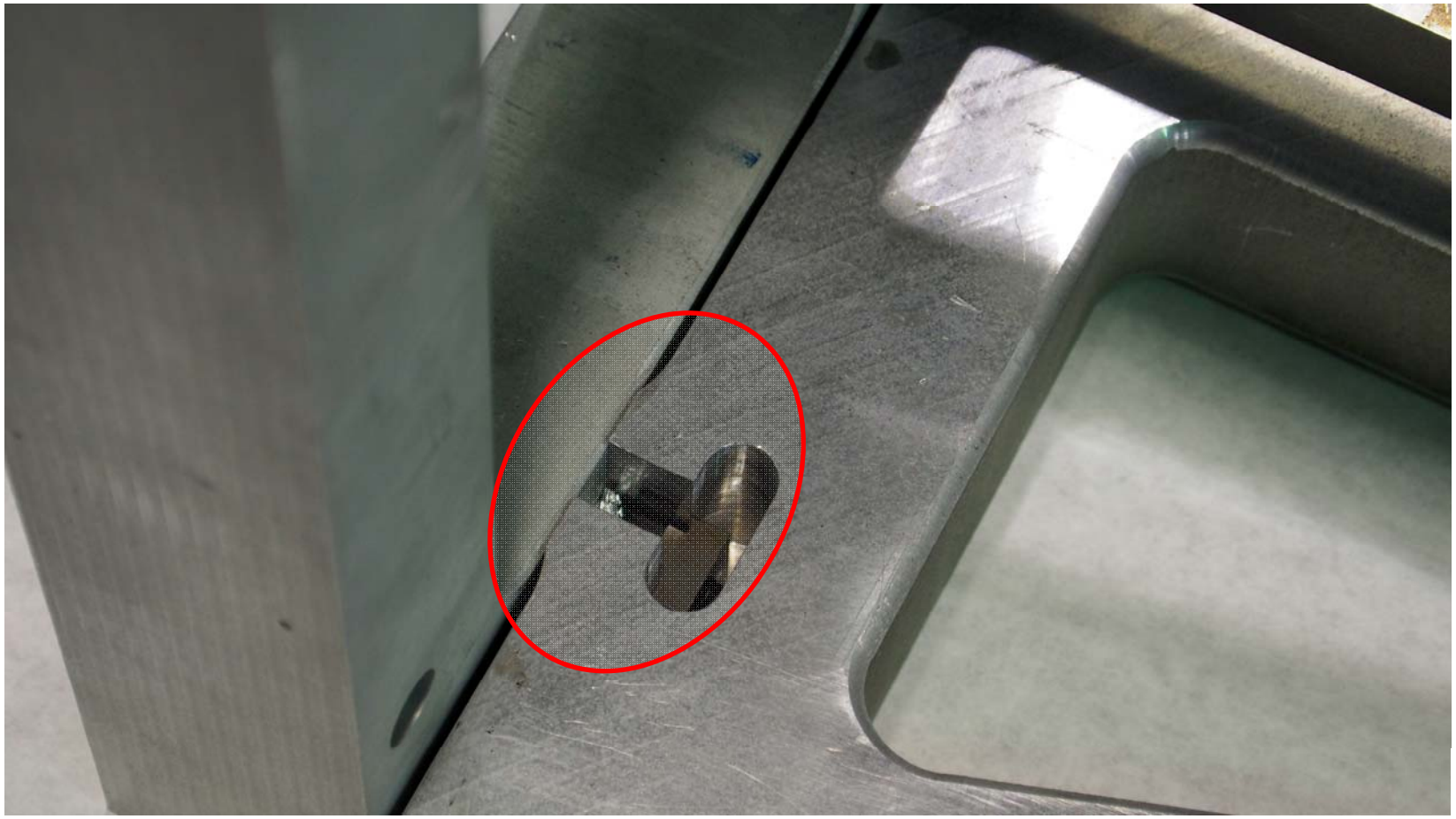
Jig Overview and CS, on Granite Table



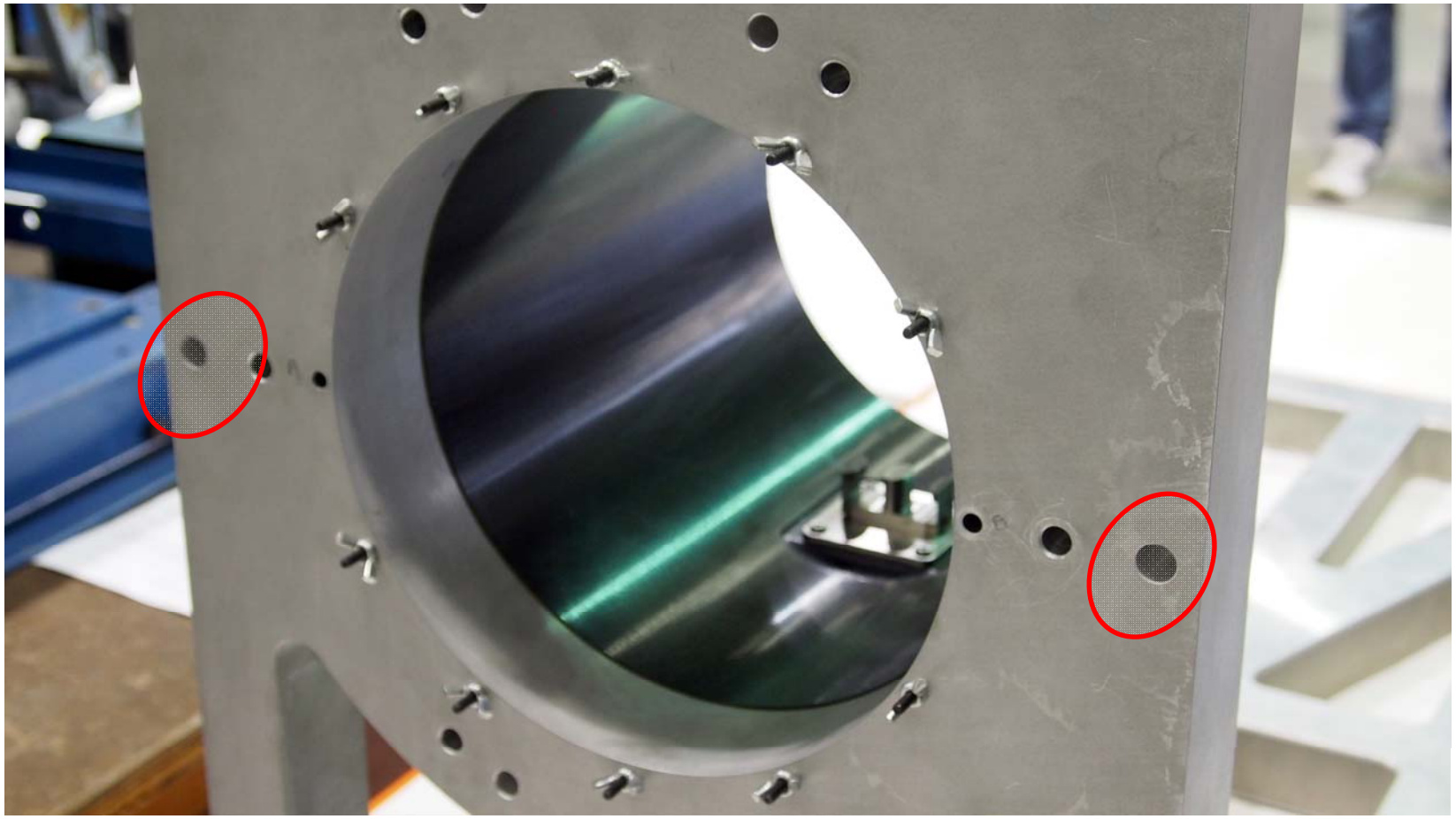
X Position Given by Center Pins



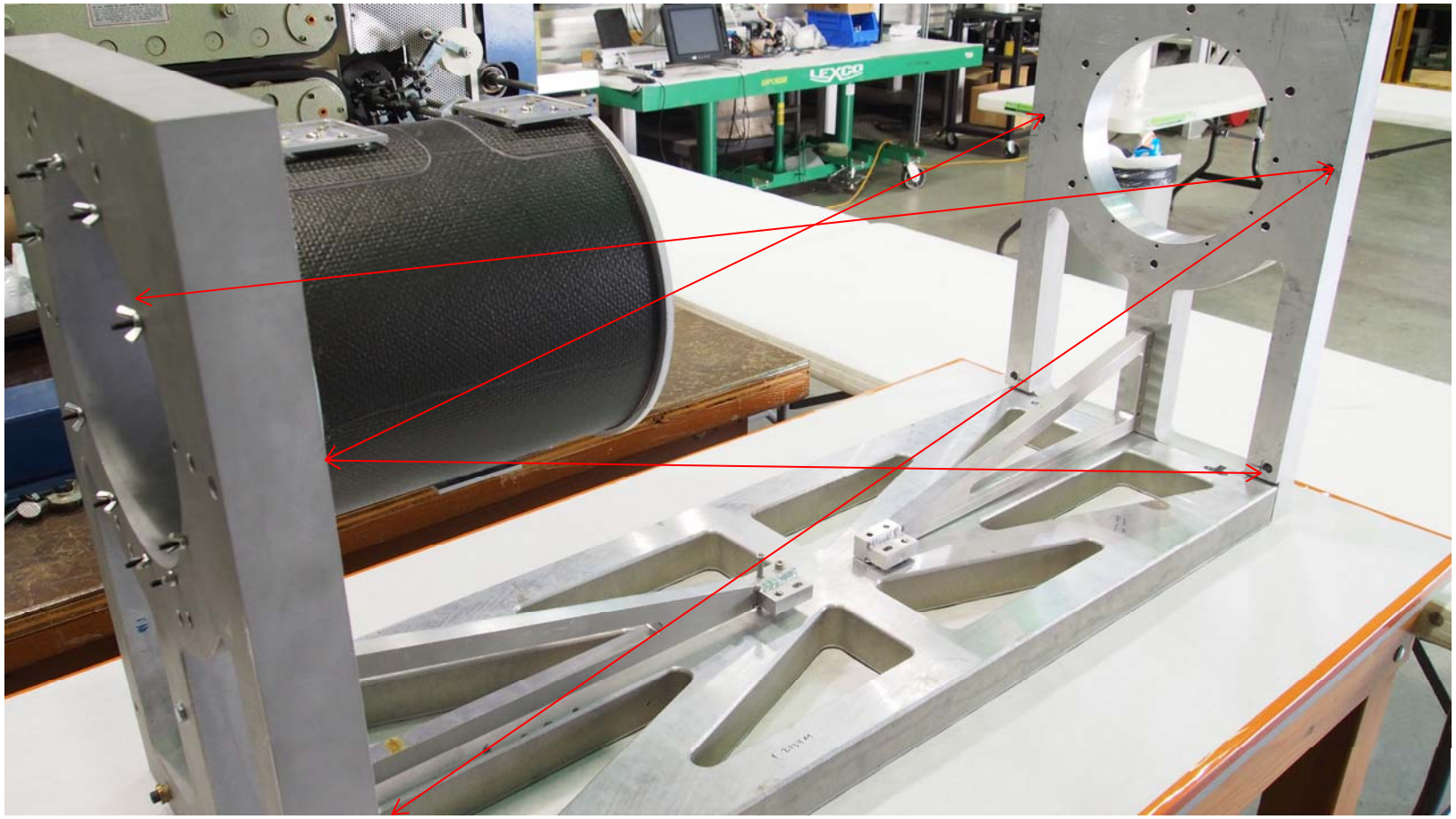
Insertable Hardware, Small Shim Areas



Accurate Holes for Tooling Balls

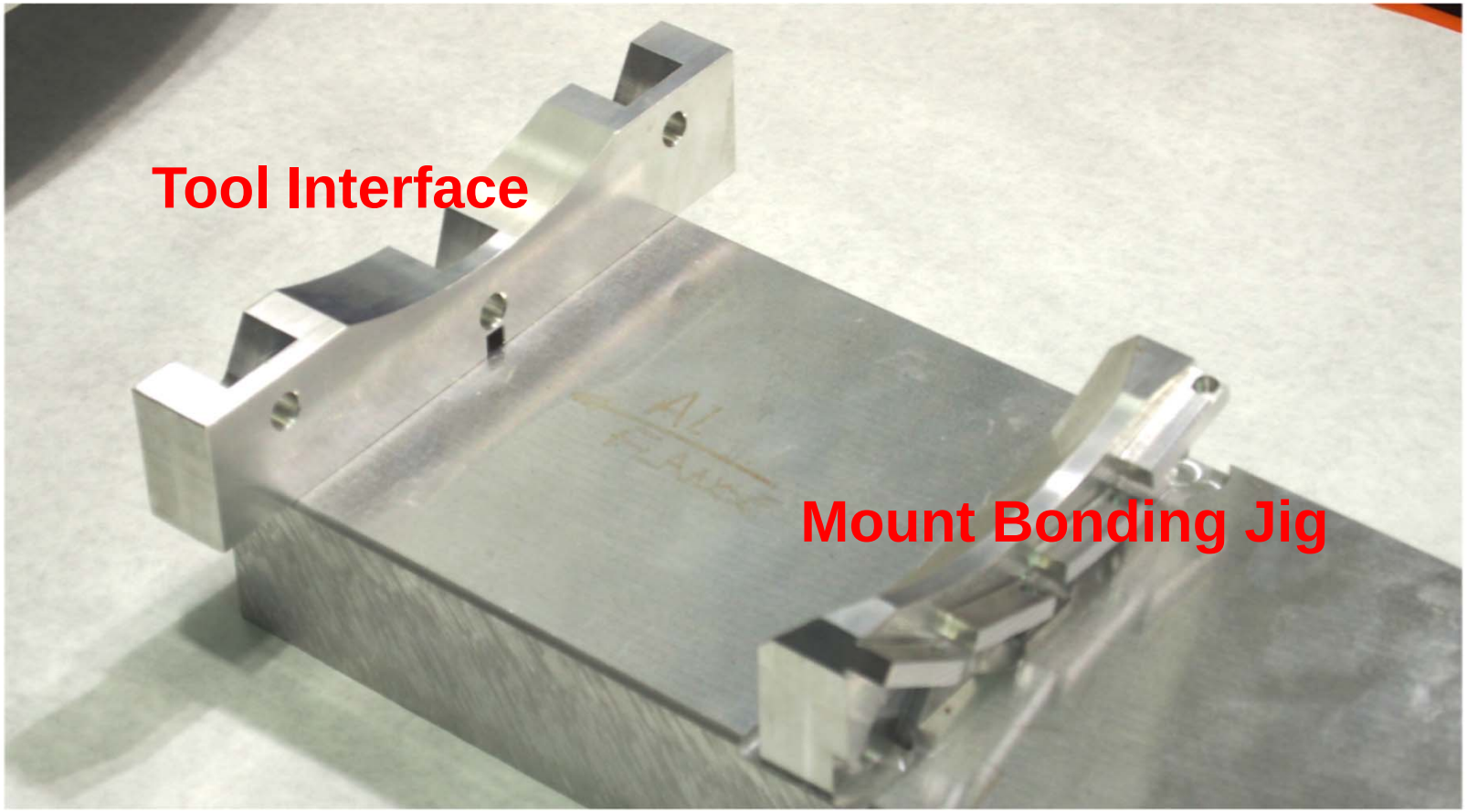


Diagonal Measurements with Tube Mic

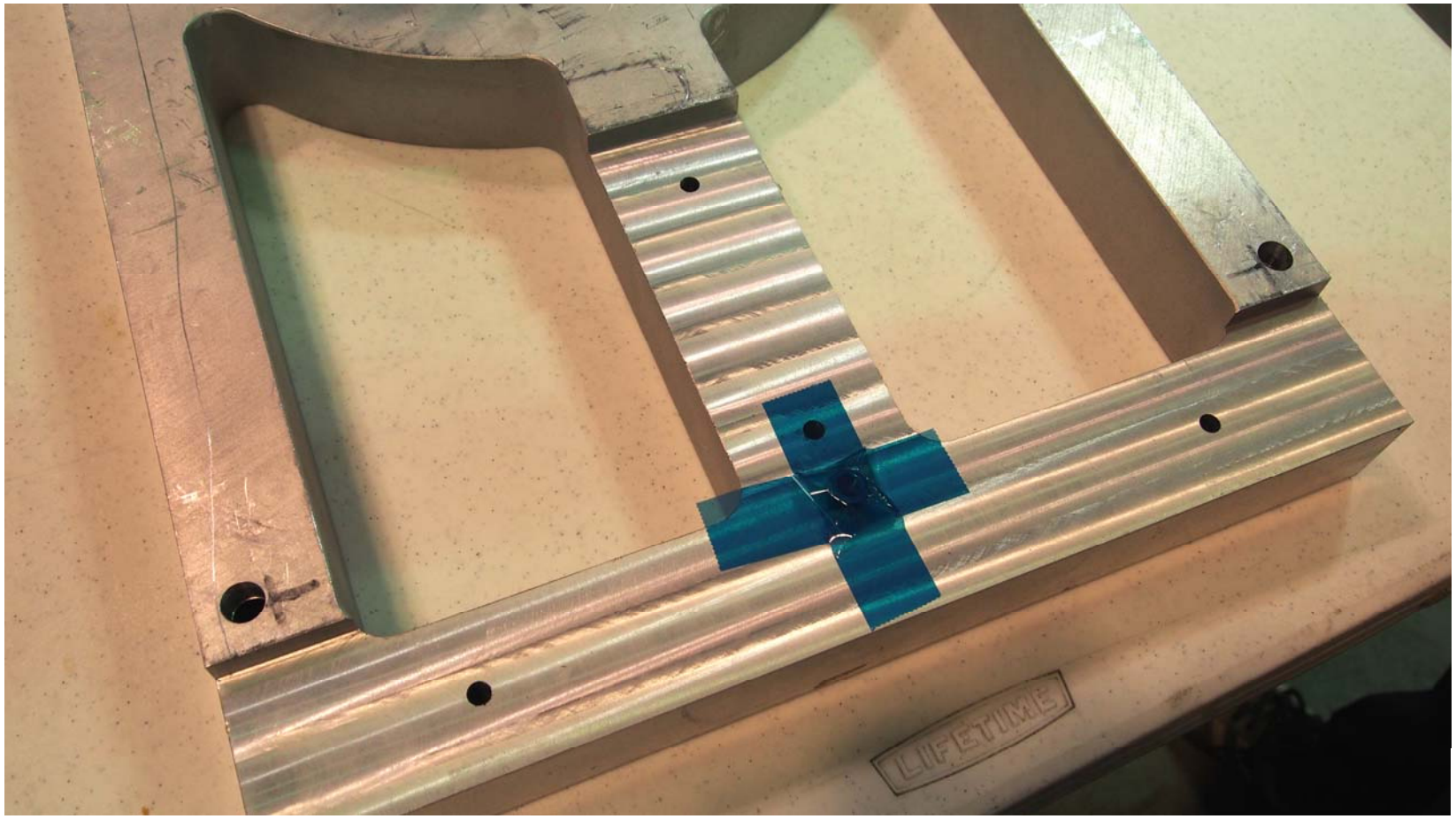


Clearance to Insert Shell from End

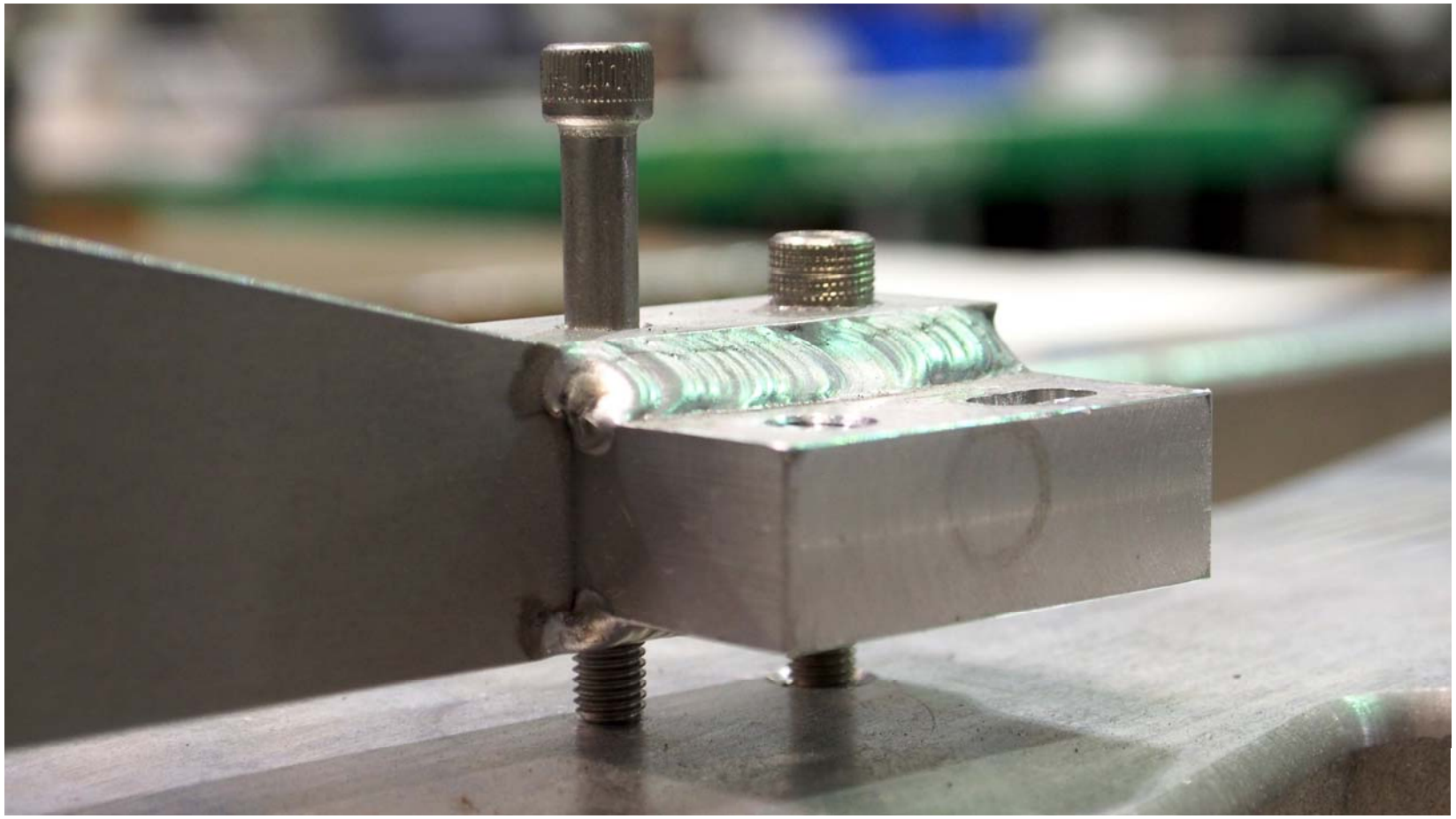
Mount Bonding Tool



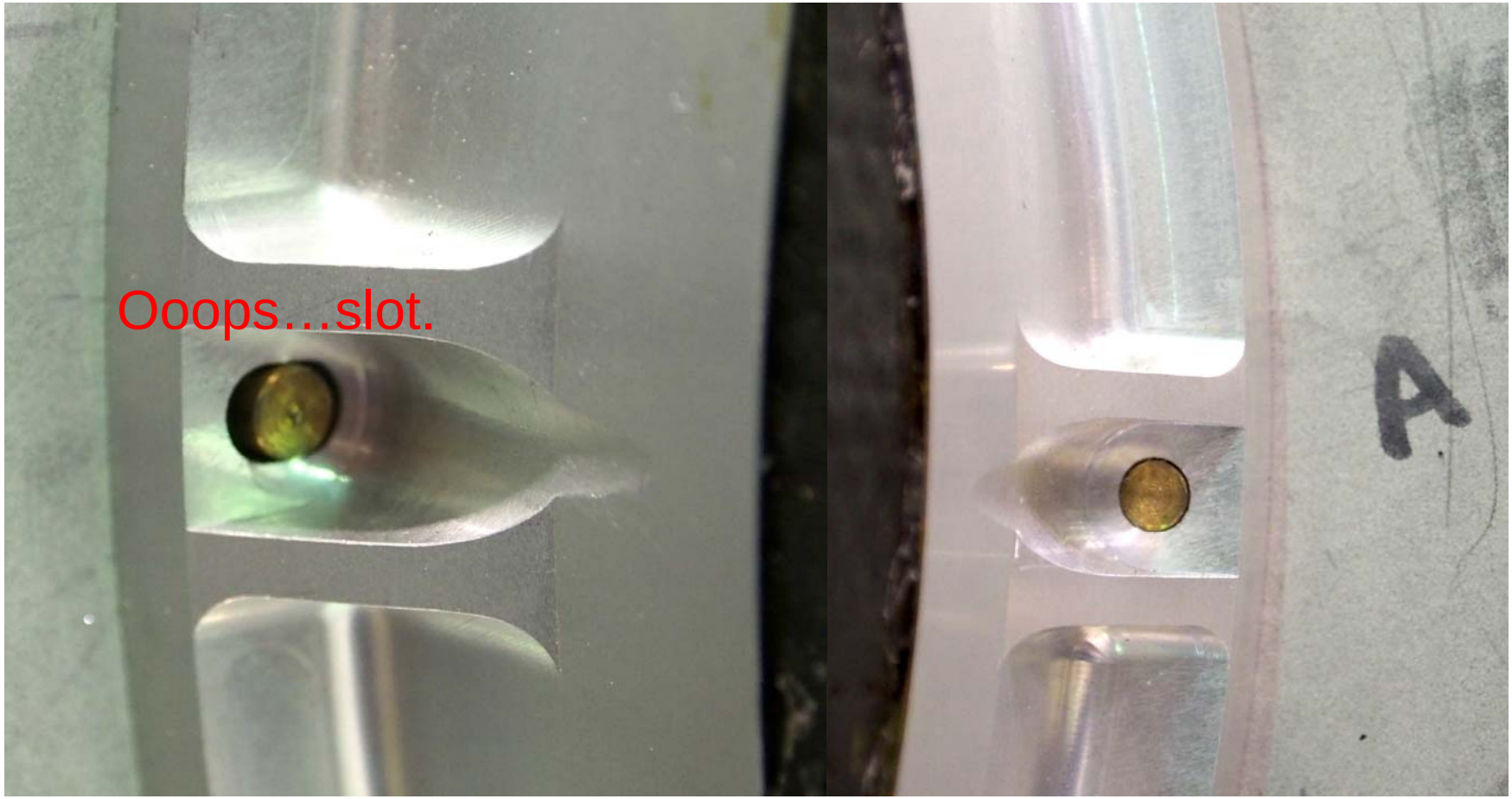
If length needs to be changed, simple machining can suffice



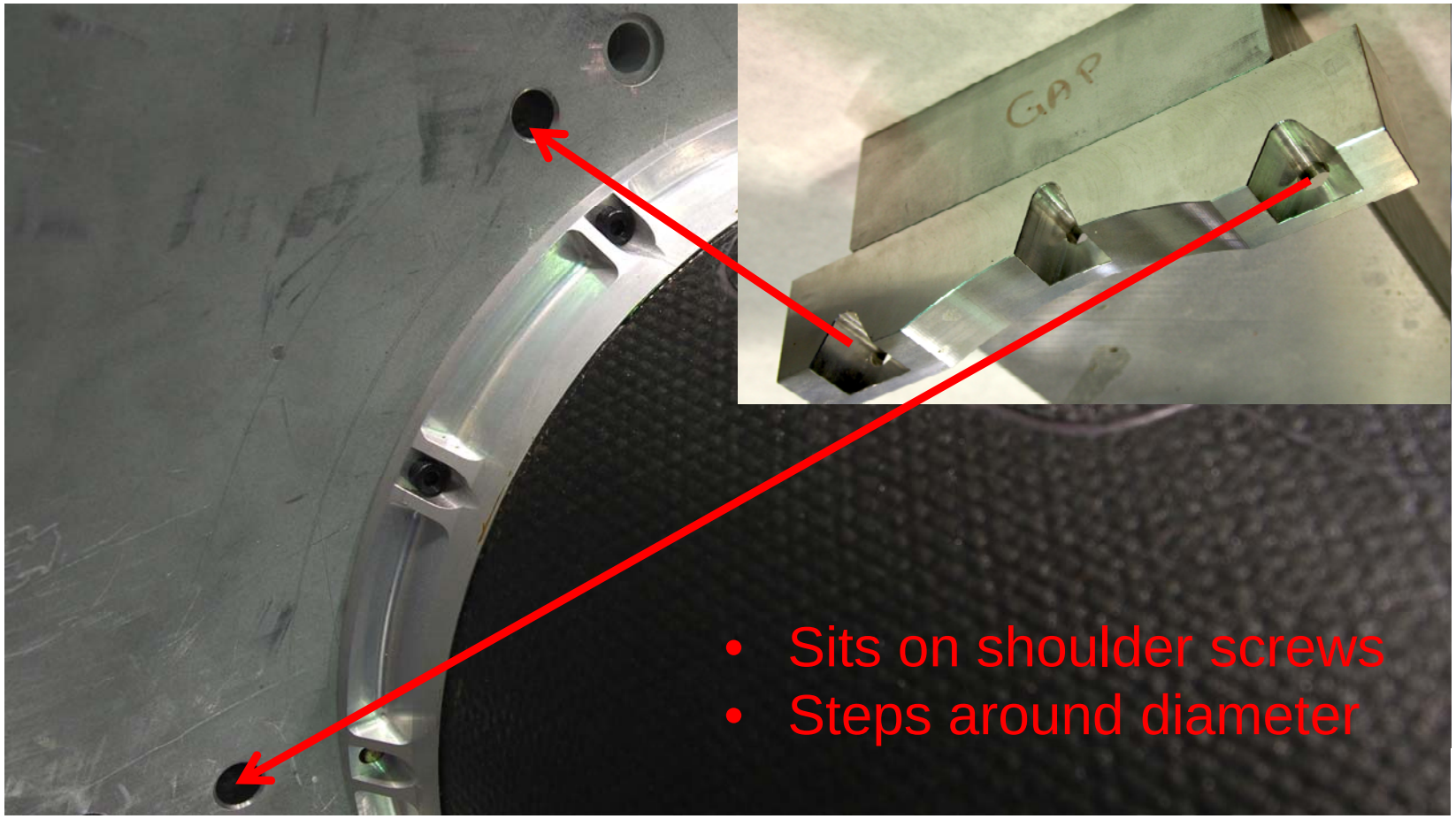
Angle Adjustment Bar – Jack/Lock Screws



Flange Alignment Pins



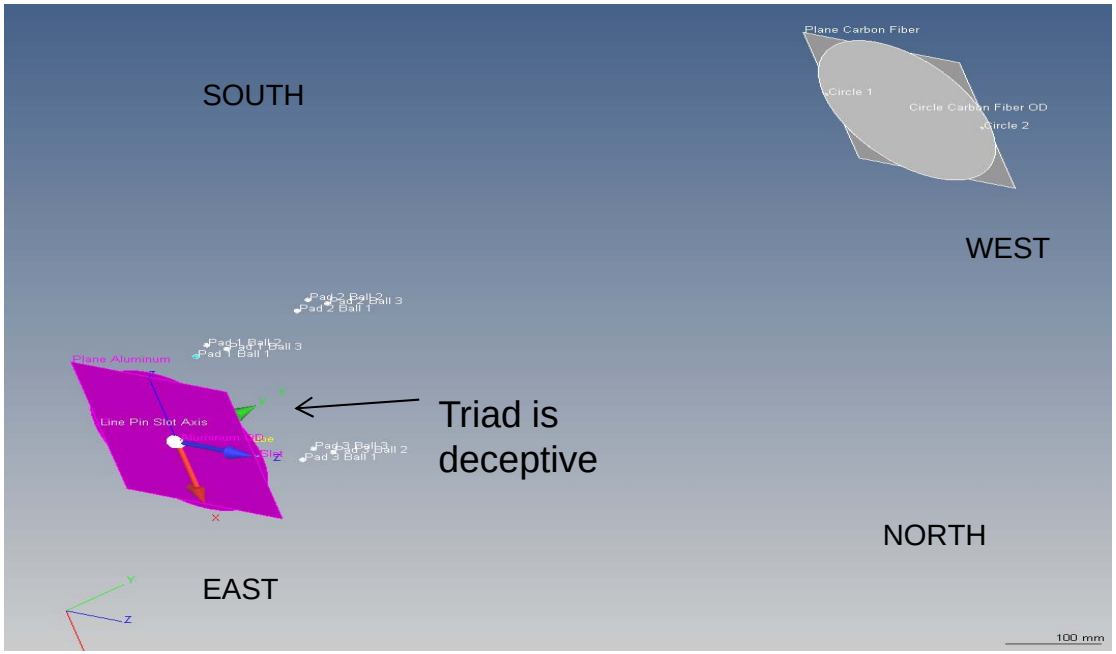
Interface Mounting Jig



Alignment Performance

SUMMARY OF KEY FINDNGS FOR KIN MOUNT POSITIONS (CAD COORD SYSTEM)

	OFFSET ERRORS…			ANGLE ERRORS ABOUT…		
	cone X	avg Y	cone Z	X axis	Y axis	Z axis
	mm	*mm*	*mm*	*deg*	*deg*	*deg*
top east	**-0.124**	**0.753**	**-0.150**	**0.10**	**-0.61**	**-0.07**
top west	**-0.019**	**0.540**	**-0.106**	**-0.16**	**-0.11**	**-0.10**
bottom	**0.090**	**0.362**	**-0.297**	**-0.15**	**0.09**	**0.21**



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- Bond precise
- Final Tolerances given through tooling